Towards a Latin America and Caribbean Knowledge Based Bio-Economy in Partnership with Europe

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Content

Introduction

The requirements to face the challenges that humankind is confronting have promoted the interest in technological developments towards the sustainable use of natural resources in order to reduce environmental impacts and, at the same time, promote social welfare and equity. One of the approaches for it is the Knowledge Based Bio-Economy (KBBE) which seeks to improve the efficiency of the processes; to promote environmental, social and economic sustainability; to encourage the replacement of fossil fuel and fuel-based materials and to develop closed cycles and recycling systems. All this makes it possible to transform residues into useful products.

The concept of bioeconomy is focused in production paradigms based in biological processes using natural materials, minimal non-renewable energy that do not produce residues or waste, since all the residues discarded in one process are used as raw material for the next one. Bioeconomy contributes therefore, to transform biological sciences knowledge into new, sustainable, eco-efficient and competitive products in order to improve life quality of the increasing world population. R&D activities with an innovator approach will provide alternative solutions to generate processes, products and to define remedial mechanisms in contaminating processes among others. In order to design more efficient processes "more with less", we must work in the development of systems focused to the integral and complete use of the biomass such as the bio-refineries, and to define biomass value chains which include the use of residues and by-products for the industry as well as the rural sector. Additional to the search for alternative materials, the study and application of microorganisms and enzymes and the improvement in bioprocesses efficiency are very promising approaches looking forward a better use of biodiversity and an important contribution for social and environmental sustainability, with the use diverse biotechnological tools..

This book gathers part of the documents produced by the FP7 Project "Towards a Latin America and Caribbean Knowledge Based Bio-Economy in Partnership with Europe" funded by the 7th Framework Programme for Research and Technological Development, in which Pontificia Universidad Javeriana was one of the strategic partners. This volume constitutes part of the collection "Prometeo: Tecnología y creatividad para la sostenibilidad" (Prometheus: Technology and creativity for sustainability) as a new contribution of the School of Sciences, Pontificia Universidad Javeriana to the international community, in its interest in promoting the development of technological innovations to confront the challenges facing mankind.

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Foreword

The Latin American and Caribbean (LAC) region, with its enormous biodiversity endowment, is particularly well placed to both contribute and benefit from the emerging bioeconomy. The region is already well on the way to exploiting the opportunities offered by the bioeconomy. It is among global leaders that exploit the benefits of the new biotechnologies. Three of the countries in the region are among the top five users of GM crops, and several more are included in the top 15 countries in terms of these technologies. Also, the region shows emerging eco-efficient agricultural practices, such as no-tillage, precision agriculture, integrated pest and nutrient managements, and organic agricultural approaches. Additionally, LAC is also a leader in bio-energy production and is home to several of the early and best known efforts to institutionalize biodiversity valorization activities. However, in spite of the importance of these activities, no established vision on the bio-economy exists in the region, nor so regarding the benefits that could be derived from these successful experiences. Building such a vision and, even more so, a roadmap and action plan to fill in the gaps and take advantage of the region's strengths, remains a major challenge for the future.

In moving towards this next level, several noteworthy steps have been taken. At the scientific level, a number of events specifically targeted at discussing and analyzing opportunities of the bioeconomy in the LAC region were organized in 2007 and 2008 with participation of LAC and EU experts, among others.

These events contributed to exposing both researchers and policy makers to the potential, and needs of the bioeconomy. They also provided the basis for the implementation since June 2011 of an FP7 project ALCUE-KBBE[1], aiming to construct a bi-regional platform of cooperation to accompany the introduction, validation and implementation of the LAC bioeconomy through the cooperation of key stakeholders, actors and experts from the LAC and EU regions.

The contents of the book in front of you are part of the results of this bi-regional project. The chapters draw heavily on the working papers that were especially produced during the first phase of the project. As such, the first chapter, towards bioeconomy development in Latin America and

1 For more detailed information of this project and its results, please consult www.bioeconomy-alcue.org

The Caribbean, gives an overview of the bioeconomy, relative to the LAC region. The second chapter analyzes Natural Resources in Latin America and the Caribbean. The third chapter discusses Policies and Institutional Framework for the Development of Bioeconomy in Latin America. The fourth chapter gives an overview of Socioeconomic and environmental impacts of the bioeconomy in LAC. The fifth chapter assesses the Current Status and Potential of Knowledge Based Bio-Economy Related Research & Innovation in LAC. The sixth chapter discusses an inventory of exciting and successful Bioeconomy related experiences in the region. The final chapter seeks to assess past Bioeconomy development by proposing lessons learnt and best practices.

At the political level, the LAC bioeconomy concept has found increasing recognition and active support through the ALCUE Bi-regional Summit on Science and Technology Cooperation (Madrid, May 2010) and subsequent Senior Officials Meetings (SOM) in 2011, 2012 and 2013, that have resulted in the adoption of the Bioeconomy as one of five proposed Joint Initiatives for Research & Innovation (JIRI), on which to implement the bi-regional S&T cooperation. To support the SOM strategic initiative, a bi-regional consortium, coordinated by the Argentine Ministry for Science & Technology, is participating in a new FP7 International Cooperation Network (INCO-Net) called ALCUE-NET[2]. The 4-year project, which started towards the end of 2012, aims to target bi-regional S&T cooperation to help alleviate climate change impacts, food security & safety, and environmental impacts by means of five sets of JIRI pilot activities, one of which includes the bioeconomy. Among its priority themes are (i) together with ERA-NET LAC, organizing a joint project call on specific research topics targeting biomass production and conversion, (ii) the construction of a bioeconomy observatory in LAC, closely linked to similar activities in the EU, and (iii) strengthening of capacity development through specialized training courses/modules and the formulation of a bi-regional Master in Bioeconomy.

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2 For further details please consult www.alcuenet.eu

Towards Bioeconomy Development in Latin America and the Caribbean

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Introduction: the Concept of Bioeconomy

Bioeconomy represents a vision of a future society much less dependent on fossil resources for its energy and raw materials' needs and where biomass produced in a sustainable way plays a critical role in the production of food, health products, feed, fibres, industrial products and energy. It is a response to at least four major emerging and converging global challenges: (i) the fact that over the next 20-30 years the world population will grow to nine billion people and consequently there will be the need to meet a global food demand, at least 50-70% higher than the present, (ii) there is mounting evidence of significant natural resource depletion and, in some cases, exhaustion, (iii) even though we cannot talk about "the end of oil", all available evidence points to the direction that cheap oil is a thing of the past or cheap energy (*e.g.* shale gas), having incalculable high risks for the

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environment and (iv) climate change impacts are starting to show at different levels around the world, and are increasingly accepted as major future constraints.

All of these trends are making evident that "business as usual" is no longer an option and major adjustments in social and economic behaviors are in order. Novel approaches are needed to make a chance of seriously addressing the Millennium Development Goals (MDGs) of eradicating hunger and poverty (MDG1) and assuring environmental sustainability (MDG7). The problems are global and certainly not new. They have been there for a long time now. What is new today is the coming together of a better understanding of the problems that need to be confronted, the maturity of national and international political processes, such as those of the United Nations Conferences on Sustainable Development (UNSDC) and the International Panel on Climate Change (IPCC), among others, which provide the basis for the needed minimum political commitment for actions that, given the global nature of the challenge need also to be global. At the same time there is a science and technology base that offers concrete hopes and possibilities of an effective change in the course of action.

In this context, the bioeconomy is increasingly seen as an opportunity —while challenging— to coherently address the complex situation and, at the same time, creating new sources for equitable economic and social growth. Its essence has been synthesized with subtle differences as "the application of knowledge in life sciences in new, sustainable, environmentally friendly, and competitive products" (EC, 2005), as "the aggregate set of economic operations in a society that uses the latent value incumbent in biological products and processes to capture new growth and welfare benefits for citizens and nations" (OECD, 2006), and more recently as encompassing "… the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy…" (EC, 2012).[9] Irrespective of the emphasis —use of biomass, or the role of the new biology— the common thread in all these concepts is the more efficient use of the natural resources base and the increase of the knowledge intensity of production processes to better capture solar energy and transform it in other forms of energy and products. The sectors and industries associated with the bioeconomy are seen as having a "… strong innovation potential due to their use of a wide range of sciences, enabling and industrial technologies, along with local and tacit knowledge …" (EC, 2012). Consequently, they show an important potential as a source of whole new value chains, with a reduced environmental impact, with promises for high and low-skilled jobs, helping

9 Along the same lines the German Bioeconomy Council, defined the bioeconomy as "… encompassing all those sectors and their related services which produce, process or use biological resources in whatever form …" (German Bioeconomy Council, 2010).

to reduce poverty and continuing to improve the quality of life for a growing world population. In this sense the bioeconomy is a concept also closely associated to that of the "green economy" (GE) that has been put forward by the United Nations Environment Program (UNEP) in an effort to further operationalize the MDGs and the long standing objective of building a global society that equitably meets the needs and aspirations of the present without sacrificing the rights and opportunities of future generations (UNEP, 2011).

Seen in this context, the bioeconomy is that segment (of the economy) building on improved uses of biomass and the opportunities emerging from the new biology and associated sciences. Previous cycles of modern economic organization and growth were dependent on the exploitation of non-renewable sources for the production of energy and chemical building blocks resulting from photosynthesis-based processes that took place millions of years ago. Today's bioeconomy value chains are evolving from renewable processes of what could be called "real time" photosynthesis. This process is already underway and showing impacts in a wide array of sectors, going from food and health to transportation, construction and, even, recreation. The greatest impact has been until now in the pharmaceutical industries, where modern biotechnology is already widely used (and accepted) both in diagnostics as well as in therapeutic applications generating a market that ranges in the tens of billions of US dollars a year (OECD, 2010). Since reaching commercial status 15 years ago, plant biotechnology has become one of the more rapidly adopted technologies in agricultural history, reaching more than 170 million ha of transgenic crops planted each year in more than 28 countries (James, 2012). In spite of the controversy and political discussions, agricultural biotechnology is sustainably evolving to become the standard of agricultural industry rather than the exception. In addition to transgenic approaches, plant biotechnology has gained wide application in non-GMO approaches accelerating breeding significantly. Today mainly by providing new and improved diagnostic tools for the detection of plant pests and pathogens, and in plant tissue culture for mass propagation or for the production of disease-free planting materials. In the future, more and more complex traits are required and will become available by improved methods. Industrial biotechnology, *i.e.* the use of micro-organisms or enzymes for the processing and production of chemicals, materials and energy, is one of the most promising approaches to produce goods and services with increased economic efficiency and environmental benefits (WWF, 2009). The application of biotechnological knowledge will probably gain even more strength as the idea of a much more diversified biomass-based energy and industrial matrix gets established, linking both current and second generation biofuels in the production of biomaterials including biopolymers and bioplastics for the chemical, construction and engineering sectors.

Moving towards an economy of new competitive bio-based industries and value chains will not only demand more carbon-efficient and sustainable primary production systems and more productive and resilient food chains, but also more effective innovation capacities and policies to mobilize the required knowledge base. Furthermore, the knowledge base for many urgent changes is already available and will continuously be expanded. The issue seems not to be whether science can deliver because the technical feasibility of the new concepts has been, in most cases, proven. Major limitations appear to be in the present level of understanding of the involved social and economic processes that accompany the emergence of the new sectors and ways of production, and questions regarding their implications, their costs and what the policies and institutions needed to facilitate a rapid and equitable transition are. A society less dependent on fossil fuels will be a very different society than the one we know today, more decentralized, less dependent on large scale for efficiency, with significant cyclic processes, with different inter-sector —rural/urban— networks, and with different international trade relations as a consequence of the changing balance in strategic resources. All this is leading to a new economic landscape (comparative advantages, countries, sectors, products' competitiveness), and it is demanding –as any new scenario–new policies, communication with and in societies and institutions to contain, explain and orient actors' behaviours, to optimize potential benefits and minimize transitional costs for all involved.

Framed in this emerging context, this paper aims to contribute to the discussion of (i) what should be the objectives of the bioeconomy given the resources and specific conditions, in the Latin American and Caribbean (LAC) region, and (ii) what could be the main items in the discussion agenda "towards a bioeconomy for LAC", with a particular emphasis on the agricultural sector.[10] In pursuing of these objectives, this document is organized in five sections additional to this introduction. The second section is a brief discussion on some existing bioeconomy experiences in the LAC region. This is followed by a discussion on food security issues and the connection/relation between the bioeconomy and rural development opportunities (section 3) and a presentation of the alternative pathways that could be part of the building-up of the bioeconomy in the LAC region (section 4). Section 5 discusses briefly the institutional and policy implications required for moving from conventional to bioeconomy approaches, and a summary of some of the constraints that would need to be faced for successful implementation of those strategies. The sixth and final section offers some concluding comments for the paper.

10 This focus by no means implies that health and other sectors using or based on biological processes are of less importance in terms of their share of the size of the emerging bioeconomy. Actually in many cases it is just the opposite. The selection of a focus on agriculture related issues is a reflection of both the need of somehow put boundaries to the discussion and also of the areas of expertise of the institutions participating in the ALCUE-KBBE project.

Comparative Advantages and Pertinent Experiences for Building LAC's Bioeconomy

The Latin American and Caribbean region is particularly well placed to both contribute and benefit from the emerging bioeconomy. Its extensive and diverse natural resource base —land, water, and biodiversity— paired with an emerging economy and growing human resources provide the region with an essential foundation for a solid bioeconomy. As a whole, the region is very well positioned in terms of agricultural land availability with over 50% of its lands classified as having agricultural potential (CEPAL, 2007), a situation only comparable in European dimensions, to East European countries, but more importantly, per capita land availability in the region is significantly above the world average of 0,2 ha/cap.[11] According to the International Institute for Applied Systems Analysis (IIASA, 2000), Latin America has more than 500 million ha in the "best suitability" categories and the largest expansion potential in the categories "very suitable" and "suitable", excluding forests. The projection for 2050 highlights that, even considering a significant population increase, more than 300 million ha could be brought into production without impinging on natural forests, with South and Central America representing about 25% of the land with "very suitable", "suitable" and "moderately suitable" cropping potential for cereals, more than 25% for the oil crops, about 30% for roots and tubers, and more than 35% for sugar crops (all cases for the intermediate and high input technological scenarios). All these figures highlight resource potential for the development of a bioeconomy contributing both to food security, supply of renewables and energy objectives, and with important income generation opportunities, as there are significant yield gaps across almost all product categories. In both sugar and oil crops current utilization vis-à-vis potential is very low and in most diagnostics a poor technological performance can be identified as the most relevant restriction to tackle for improving resource use efficiency (World Development Report, 2008). Beyond this, infrastructure limitations are also a big issue, as most of the new areas are not close to existing markets and this reduces their potential value.

A second set of key resources for the development of the bioeconomy in the LAC region, is its biodiversity endowment[12]. In this regard, Latin America is also very competitive, as it concentrates a number of the most important biodiversity hotspots of the world; seven of the nineteen LAC countries are considered to be "megadiverse" in terms of biodiversity resources pres-

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11 The main source of information for this section is the FAO/International Institute for Applied Systems Analysis —IIASA— study on Global Agroecological Zones (GAZ). For more information see http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm.

12 Understood as "the variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it" (http://cnx.org/content/m12151/latest/).

ent within their political-administrative frontiers (no other region of the world includes as many countries within this category). The countries of the region in the megadiverse group are Brazil, Colombia, México, Peru, Ecuador, Venezuela and Bolivia, but other three –Costa Rica, Panama, and Guatemala– have important National Biodiversity Indexes (NBI). Even Uruguay, which has the lowest NBI in the region —0,487— ranks over most European countries. [13] The region is also a centre of origin and diversity of a number of species that sustain current world food supply (*e.g.* potato, sweet potato, maize, tomato, beans, cassava, peanuts, pineapple, cacao, chili pepper, and papaya). The same applies for a great number of flowering plants with special compounds for food and agriculture, as well as for the biopharmaceutical, nutraceutical, cosmetic, and environmental industries (Roca *et al.* 2004). These resources offer substantial comparative advantage in terms of opportunities for value-adding and sustainable exploitation using new biotechnological tools, an opportunity which is underscored by the dynamism shown by the world market for natural products, which between 2002 and 2008 increased by more than 170% (Compes, 2011).

Regarding water, the LAC region is also a global asset, containing more than 30% of the planet's fresh water (UNEP, n. d.). This resource however, is somewhat unevenly distributed within the region, but less uneven than in other continents. Some extended areas such as the Pacific Central Plains in Central America, the coastal areas in Chile and Peru, the Patagonia in Argentina, and the Brazilian North East, among others, face either absolute or seasonal restrictions that substantially limit their agricultural production potential, in a context that is expected to evolve with climate change and needs to be monitored and anticipated.

The region's rich resource endowment has already served as a basis for significant developments towards a biobased economy in the region. Strengthening its traditional role in international agricultural and food markets through agricultural transformation processes which has not only touched traditional sectors, such as grains, oilseeds and tropical commodities. The region has made substantial in-roads in developing novel use for biomass *e.g.* in the biofuels sector as well as in key technologies such as biotechnological applications and eco-intensification practices.

At the present time, Brazil practically dominates the international ethanol trade market and countries like Argentina and others are becoming key players in the development of the biodiesel markets. Based on its strengths as sugar and oil crop producers, almost every country in the region has plans underway to increase its ethanol and/or biodiesel production in the immediate future. Brazil was expected to more than double its biodiesel production by 2011[14]. Argentina increased

13 Megadiverse countries are the nations that harbor the majority of living species on Earth (http://www.conservation.org).

14 www.biodieselmagazine.com/article.jsp?article_id=1064 - 35k

its production to more than 3.0 million tons in 2010 (Kerlakian, 2008, pp. 23-24), and Colombia has advanced plans for a 300,000 tons palm oil based refinery, which is expected to enter production during this decade. Biofuel projects are at different stages of completion in Costa Rica, Honduras, Peru and Paraguay, among other countries in the region (Ascher, Ganduglia, Vega, Abreu & Macedo, 2010). The importance of this potential and their tendencies are reflected in the projections of the role that bio-energy is expected to play in the future demand-supply equilibriums, where LAC appears as the only region in the world that would be able to meet its energy requirements based on "bio" alternatives. According to recent estimates (Gazzoni, 2009), this would require only a relatively minor increase in agricultural land being allocated to bio-energy uses; from 1,3% currently to about 2,4% by the year 2030. Additionally, there is large and growing number of initiatives to potentiate this situation through small scale energy production either aimed at production in marginal lands in association with food crops (black beans —castor oil beans in the north— eastern Brazilian drylands, *Programa Biodiesel Combustivel Social*, see http://www.mda.gov.br/portal/saf/programas/biodiesel/2286313) or based on different types of agricultural residues and waste (see for instance http://www.icidca.cu/Red/QueEs.htm).

The region is also a prominent player in the early stages of GM plants biotechnology exploitation. GMO technologies —herbicide tolerant soybeans and insect-resistant and herbicide-tolerant maize and cotton— were introduced in different countries of the region almost at the same time of their commercial availability in the international markets. Out of the more than 30 countries in the world that are using GM technologies at the present, ten are in Latin-America. Brazil, Argentina, Paraguay and Uruguay are currently planting more than a third of the total world area with GM crops, and are among the ten largest producers globally (James, 2012). The importance of these advances is not minor. Even though conventional breeding technologies are rapidly evolving, GM technologies are becoming a key component in pursuance of both economic and environmental objectives. From an environmental perspective, GM technologies are already showing significant impacts in terms of Greenhouse Gas (GHG) emission reduction (Brookes and Barefoot, 2010). Furthermore, it is estimated that due to the adoption of GM soybeans in Argentina international soybean prices are today 14% lower than they would have been if these technologies were not utilized (Trigo, 2011). Similar impacts have been estimated by Brookes and Barfoot (2012) for other GM crops.

Latin American countries can also boost internationally recognized experiences in some of the ecological intensification practices, especially "zero-tillage". This practice has been gaining force over the past 20 years and today it is widely adopted in Argentina, Paraguay, Uruguay and Brazil, making key contributions to the expansion of agricultural supplies under improved environmental performance standards (Trigo *et al.*, 2009). The net positive environmental impact of this practice has been in terms of retaining in the soil an amount of approximately 50 million ton of carbon dioxide, in the case of Argentina and about 0,85 million ton in Paraguay and Uruguay (Brookes and Barfoot, 2012).

These resources and experiences highlight the importance of bioeconomy pathways for the LAC region and the substantive nature of the contributions that they can make both to global equilibriums and to regional challenges. It is of particular importance to point out that all these aspects have evolved out of spontaneous, market-oriented processes and should be carefully monitored regarding their future evolution and how they can be optimized in terms of regional and global benefits. It is quite clear that whatever future scenario one anticipates for the global bioeconomy, LAC has a distinctive role to play in helping to achieve the global food/feed/fuel balances that will be needed. At the same time, the region has a challenge of its own. Hunger and poverty, although not as dramatic as in other parts of the developing world, are still important throughout the region, especially in the rural areas, making agriculture and biomass production an essential component of any hunger and poverty alleviation strategy. In this regard, the bioeconomy in LAC has a dual set of objectives. At the global level, the region has a critical role in contributing to global food, fiber and energy balances, while improving environmental sustainability. Within the region's boundaries, the emerging bioeconomy is a new source of opportunities for equitable growth through improved agricultural and biomass production and employment opportunities.

In a historical context the transition towards a LAC bioeconomy also offers the possibility of moving beyond the dichotomist's vision of agricultural *vs*. industrial development that has dominated regional development strategy discussions since the 1950s, as agriculture —industry linkages expand beyond the traditional views to include a much more complex and strategic set of input—output relationships. The next sections of this note look first at two aspects considered critical for the regional discussion. A first aspect deals with food security, rural development opportunities and the policy and institutional situation. Then, the discussion moves to presenting what the main pathways to consider would be in the development of the bioeconomy in the LAC region, and reviewing the main constraints that are needed to be addressed to make those pathways effective.

Food Security and Local Development Opportunities

The bioeconomy concept based on the diversification and sustainable intensification of natural resources use implies a potential competition between food and energy or other uses. This has been a source of concern ever since the concept started to be discussed, but it has intensified more in recent times as a consequence of rising food prices over the last few years and the emergence of social conflicts and food riots in a number of countries (Mittal, 2009). As oil prices have increased and bio-fuel alternatives have received increased attention throughout both the developed and developing world, the issue of the impact of bioeconomy on food security (access, availability, stability and resource utilisation) has moved to the forefront of the discussion. The importance of the issue is not being questioned. Clearly, food security is closely related to land use and if resources are taken out of food production and allocated to other uses, surely there is basis for the stated concerns.

This potential conflict, however, has to be put in context and there are several issues that need to be put forward for a meaningful discussion. Not all countries are, in this respect, in the same situation. The "land abundant countries", such as Ecuador, Surinam, Guyana, Paraguay, Uruguay, México, Peru, Venezuela, Colombia, Bolivia, Argentina and Brazil (Ascher et al., 2010), are certainly in a different position than smaller food import dependent countries, which are typically the most food insecure, given the high dependence on imports of primary staple foods and exports of primary tropical commodities (FAO, 2008). However, important biofuels are under demand-shifting parameters, they are not the only factor behind the recent evolution in the agricultural commodities markets, as the combination of a number of poor harvests, stagnant technological change and thus, small yield increases and a structural change in demand from a significant number of emerging countries' consumers, seem also to be playing an important role (Trostle 2008). Agriculture has been underrated as a source of growth and with regards to its role in poverty alleviation. This is reflected in a decline in investments across the board, including R&D, and also in the dynamics of crops' yield change which have decreased from more than 2% a year in the 1980s to less than 1% at present (CGIAR, 2011). The combination of all these factors should be explicitly brought into play before the final call of judgment in this matter can be made.

But even if the present tensions are to be related to the food *vs.* fuel/energy competition, in a longer-term perspective, the bioeconomy is most likely a positive rather than a negative item in the balance sheet. The essence of the concept —as we have indicated above— is about more efficient and effective use of natural resources (biomass, biological processes), through an increased knowledge intensity, leading, eventually, to significant diversification and increases in production levels, making room for both more food and biobased energy alternatives.

A first issue that should be considered is in relation to the income impacts of bioeconomy-based options. These will be double the poverty geography has significantly changed in the last decades, with urban areas concentrating now the largest numbers of poor and the rural areas still concentrating the worse cases of food insecurity and poverty. Bioeconomy development can help to improve both situations. Taking agricultural production to new levels of productivity and production will help to improve food supplies to the urban poor, while improving food security in rural areas, which is mainly a consequence of poverty and lack of opportunities. Thus, sustained progress in the agricultural business will also help to improve food security for the rural poor population through income and employment linkages (von Braun and Kennedy 1994; IICA 2010). Bioeconomy opportunities may be linked to nearly any kind of plant material. As such, bio-based industries are well suited for local production, as both work as engines for rural development and income generation. In developed countries, most of the available land is already being utilized, but in many of the poorer regions of the world, the proportion of unused land is still significant and that could potentially be used for the cultivation of energy crops (Ascher *et al.*, 2010).

Bioeconomy alternatives may offer new ways out of the vicious circle of poverty in which many rural communities find themselves when their land base is not fit for high yield food crop production. The issue is to move the discussion of opportunities beyond the present generation of plant-based energy alternatives, towards strategies that explore more aggressively local biodiversity resources, and their relation not only to their direct income effects, but also their beneficial effects on the consolidation of non-agricultural rural employment opportunities. In this sense, Henry and Trigo (2010) and Bruins and Sanders (2012) discussed the potential of small-scale alternatives and found that there is an ample spectrum of relevant opportunities for adding value at the local or on-farm levels related to bioenergy or feed stock production. Lack of electricity, which, in many cases, is one of the critical restrictions for better market access and income generation in isolated rural situations, can be resolved through micro units fed with local biomass primary material, and/or subproducts (cassava, sweet sorghum, sweet potatoes, bananas and plantains, plant and animal residues and waste), thus creating better processing and conservation alternatives. Rural processing for "intermediate" product supply can resolve transportation and logistics restrictions, and facilitate local production linkages to large-scale factories (*i.e.* pre-processing of cassava for starch production factories).

Beyond the energy link, there are also the biodiversity valorisation opportunities in the form of identification of valuable functional components, as the basis for the development of "appellation of origin" systems that also represent income generation possibilities that should be factored in. These and other alternatives are being successfully explored in different parts of the world. However, they are still highly dependent on different types of "pro-poor (public) policies" (in the form of targeted subsidies, investments, training, information, advice), or "corporate social responsibility" policies by the private sector, for showing a high degree of insertion of small-scale actors (Henry & Trigo 2010). The road towards the emerging bioeconomy calls for the mainstreaming of these experiences into poverty reduction and rural development strategies and policies.

Linked to the above, but with an identity of its own, are the potential applications of biotechnology to increase global food supply. Until now, that potential has only been exploited in a very limited way and in relation, mostly, with its transgenesis applications and in a handful of crops and traits —soybeans, maize, cotton, canola— having herbicide tolerance, and insect resistance, among the most prominent. This is attributable to reasons more related to policy and institutional factors than to the actual lack of technological alternatives. Just as the bioeconomy is more than biofuels, biotechnology is more than transgenesis (Rocha, 2011). Over the last years, advances in genomics and other simpler, non-controversial, applications of the new biology, have been monumental (see for instance, Lusser *et al.*, 2011). However, they are still not fully incorporated into the toolkit to confront the global sustainability and food security challenges, and there are threads that even when such novel breeding technologies are clearly non-GM that unscientific applications of risk assessment cause significant hurdles to the application of these promising methods. Fully exploiting these advances in production and post-harvest applications could not only make many of the resource competition issues being discussed today irrelevant, but also to contribute to solve the poverty problem behind many of today's food insecurity situations.

Alternative Pathways for Bioeconomy Development in Latin America and the Caribbean

Given the diversity of natural resources, economic and social characteristics and even the nature of each individual country linked to the world economy, there will be not a common pattern for bioeconomy development fitting the whole of the region, but a number of different pathways each reflecting different aspects and comparative advantages. But they all share the same principles aimed at a more effective and efficient use of biological products and processes for achieving specific societal goals. Given the comparative advantages and pertinent experiences in the LAC region relevant to the bioeconomy, as described above, it is possible to identify six distinct pathways, each addressing the common issues and objectives from a different vantage point (remark: this distinction in 6 pathways seems rather arbitrary from my perspective but it does make sense from a LAC perspective, hence the adjusted sentence). These six pathways overlap in some aspects, but together offer a holistic approach for achieving the stated purposes in the LAC region. These six pathways include (i) biodiversity resources exploitation, (ii) eco-intensification of agriculture, (iii) biotechnology applications, (iv) biorefineries and bioproducts, (v) value chain efficiency improvement and (vi) ecosystem services.

The potential importance of the bioeconomy for the region becomes evident from some of the benefits associated to the already identified pathways. Biotechnology products have transformed commodity production in many countries of the region and generated billions in increased economic activities as well as significant contributions in terms of employment and other benefits. Bioenergy is a growing sector in most countries of the region, providing a solid basis for the diversification of the local energy portfolio and also contributing significantly in terms of employment generation –mostly in the rural areas–. Eco-intensification has made important contributions to agricultural productivity increases as well as proved a relevant component for climate change mitigation strategies. The levels mentioned above potentiate loss reduction within existing biomass based on value chains and they make more than evident the need for working at preventing waste and not just focusing in the re-use, or recycling of waste materials. Eco-systems services are, by definition, essential components of the types of social and economic behavior that will make the new bioeconomy successful, and the importance of biodiversity valorization is beyond argument once the nature of the region's resources is brought to bear.

The remaining of this section presents a brief discussion of each of these pathways as an introduction and guidance for the discussion of the institutional, policy and knowledge generation gaps that need to be addressed for them to effectively contribute to bioeconomy development. These aspects are currently under analysis in other project activities.

1. Biodiversity resources utilization covers all scenarios where the differentiating element is the valorization (domestication, transformation, linking to market, etc.) of distinctive biodiversity (discovery of functional traits related to specific uses and sectors, development of new products through innovative transformation, market development for local products, etc.). In Latin America, there are many crops that have never been exploited because they were toxic, had low yields, they were hard to get to markets, or just because they were not well known. But certainly, given the nature of their components and the kind of scientific tools and infrastructure available today, they can contribute a lot to the biobased economy such as new industrial feedstocks or be a basis for new value chains in the phytotherapeutics, cosmetics or tropical fruits and other areas.

2. Eco-intensification relates to agronomic practices directed to improving environmental performance of agricultural activities without sacrificing existing production/productivity levels. Eco-intensification covers a broad and evolving set of concepts having in common their departure from "business as usual" behavior usually over-focusing on maximizing yields. Eco-intensification aims to achieve a balance of agricultural, environmental, economic and social benefits, seeking more efficient use of energy resources and targeting at reduced use of fossil fuels, pesticides and other pollutants. Examples of specific eco-intensification strategies include no-till agricultural practices, precision agriculture strategies, integrated pest and nutrient management, at the more "production oriented" end of the spectrum, and more socially oriented concepts such as that of sustainable land management where a greater emphasis on environmental functions is made. Beyond primary production the eco-intensification pathway is associated to the early concept of the clean technologies, particularly those aspects related to the use of biological processes in support of industrial and other activities (waste waters treatments), although the mere use of biological resources or processes is *per se* insufficient, and effective environmental "goods" should be associated to deserve the link.

3. Biotechnology applications (products, tools and processes), including industrial tissue culture, marker assisted selection in crops and husbandry, GMO seeds/plants, molecular-based diagnostics, animal reproduction improvement through molecular techniques, modified enzymes, microorganisms and yeasts, etc. These are applied throughout the whole spectrum of agricultural applications and extending both, upstream into natural resources managements, and downstream into the food, fibre and chemical industries and in bioenergy supply. Given the magnitude of the demands, modern biotechnology, is called to play a key role in solving emerging conflicts. [15] [16] Through the opportunities they offer in terms of new options to manage biotic as well as abiotic limitations to production and productivity, biotechnology is re-setting the "limits" within which biological processes interact with natural resources –soil, water, solar energy– and opening up a whole new range of opportunities not only in food, fibre and energy production, but in almost every sector of the economy, including pharmaceutics and industry in general, triggering both changes in the production function in a number of sectors and products, and also affecting the production function of technology itself, by improving the efficiency and effectiveness of R&D processes. The fields of application are vast, though it is becoming evident that substantial investments and institutional adjustments –including an enabling global regulatory environment– are needed to benefit from this potential[17].

Although there is mounting evidence that biotechnology will be one of the major elements shaping future technological trajectories, both in agriculture and manufacturing industries (Katz *et al*., 2004), in the more immediate future, however, it is quite unlikely that we can rely only on biotechnology. Thus production and productivity increases will continue to come from conventional animal and plant breeding and improved chemical technologies, with more efficient

15 Biotechnology is understood here as "the array of techniques using living organisms or substances derived from these organisms to make or modify a product, improve plants or animals or develop microorganisms for specific uses" (Cohen 1994).

16 For an extensive discussion of the role of biotechnology in breaking-up genetic ceiling and improving food security through crop diversification see Gressel, 2008a.

17 Trade disputes related to GM soybean for feed imports to the EU from GMO exporting countries, are a good example of the problems that will need to be dealt with if the full benefit potential of the technologies realizes.

resource use and agro-ecological considerations becoming increasingly important concerns. Rather than going from a "green" to a "gene" revolution, the more likely situation is one of technological "hybridization" and "blending", with a shift from present day energy-intensive technologies to win-win alternatives that increase productivity while at the same time generating benefits in terms of natural resources management, or conservation technologies that integrally contribute to gain agricultural productivity, with biotechnology having a much more important role in the tool-kit of research and technology development ("omics" and other molecular techniques), than at the product level. The difference between "traditional" (or conventional) and "modern" technological environments becomes also less relevant as information and management technologies "blend" with biotechnological tools and traditional knowledge on the basis on location-specific requirements. Advances in this direction are already underway with ecological and environmental paradigms being incorporated in the eco-intensification efforts.

4. Biorefineries and bio-products include the bioenergy sector and processes aimed at the substitution of fossil fuel industrial inputs. Examples are plant ethanol, biodiesel, biogas, and different green chemistry oriented activities. Biorefineries and bio-products are one of the key components in the bioeconomy concept and, in their essence, they are alike the oil refineries, facilities aimed at transforming biomass into a broad spectrum of marketable products and energy. Their importance is related to the improvement of the efficiency and the spectrum of bio-based products. Efficiency mainly results from the possibility of decomposing the raw materials into different product chains, and from lowering the cost of the primary products. Biorefineries open up value adding possibilities of agricultural activities and transforming the nature of its links to the rest of the economy, particularly with the industrial sector. In this sense, biorefineries are the cornerstones of the bioeconomy response to high prices of oil and need for capital. Through the better life cycle performance of their products they are also critical in the environmental performance of a number of industrial and consumer products industries. Biorefineries also offer the possibility of a more diversified linkage structure between agriculture and the rest of the economy, and consequently a much more efficient use of biomass resources. A good example of this kind of relations is with animal feed: by biorefining the raw materials for animal feed, one can get a higher quality feed and many by-products not useful for the animal, but useful in other value chains (Matthews and MacDonell 2009 and Feedipedia 2012). Additionally, small-scale biorefinery technologies are able to function with different crops feed stocks and require low investment per unit of product and speed-up and multiply impacts at a local level. However, current developments in the region are essentially restricted to biofuel production with little further exploitation of the wider potentials, particularly in regards to value adding and local development opportunities. Issues to address in this sense, include a better understanding of the biorefinery concept and the alternative biomass production strategies that lower restricting factors. These concepts need to include the nature of the linkages between novel bio-based raw materials and inputs and existing value chains, and the explicit actions that would assure that agricultural producers –particularly the small-scale– and rural communities not only create but also retain bioeconomy value.

5. *Value chain improved efficiencies* include activities that (i) reduce postharvest losses at whatever level they are occurring, and (ii) aim at developing the needed market links for innovative bio-based products. There is a common mistake in equating the bioeconomy with sustainability concepts. It must be made clear that bio-based options are not *per se* more sustainable. Resource overuse is always a latent issue and resource use efficiency has no less importance in the bioeconomy than in conventional approaches. But the most important issue is related to the potential conflict in achieving the objectives of the bioeconomy to meet increased global food/ feed/fuel demands (50-70% over present levels) without further encroachment of forest and marginal lands and at the same time using part of the biomass production efforts to replace present use of fossil resources. How to reconcile these seemingly conflicting tendencies is one of the key challenges in the transition to the bioeconomy, for which there are neither unique nor simple solutions. The final equilibriums will certainly be a complex mix of many new strategies. These will involve, among others, aspects such as the diversifications and expansion of sources of biomass, and more efficient use and processing strategies. Within the latter an immediate challenge in the transition is a more efficient value chain. At present, over 40% of what is actually produced is wasted before it reaches its final use (UNEP, 2011). This represents a huge opportunity to start moving into bioeconomy strategies without creating additional conflicts and pressures on the natural resources base. What are the technological, logistical and policy options to improve chain efficiency are questions that need to be addressed. In addition, an aspect which is often neglected, is the recycling and reuse of nutrients and other resources in agricultural production that have to be regenerated during processing as well as from the bio-based products in the end.

6. *Ecosystem services* include the processes by which the environment produces resources utilized by humans such as clean air, water, food and materials.[18] Given the special nature of the

18 According to the the Millenium Ecosystems Assesment (http://www.maweb.org/), ecosystems services can be of the following four types: **Supporting services:** The services that are necessary for the production of all other ecosystem services including soil formation, photosynthesis, primary production, nutrient cycling and water cycling. **Provisioning services:** The products obtained from ecosystems, including food, fiber, fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, ornamental resources and fresh water; **Regulating services:** The benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination, natural

relationship and interactions between natural resources and economic and social activities in a bioeconomy approach, an ecosystem perspective becomes a strategic component of any sustainable bioeconomy strategy. The bioeconomy is a response to a long period of resource overutilization and an attempt to readapt behaviors in the light of anticipated global challenges. Accordingly, implementation strategies can only succeed if the integrity of the natural environment is recognized throughout the decision-making processes and if the values of the different flows are appropriately accounted for. Within this general context, the development of carbon credit systems, eco-tourism strategies and water management pricing and management mechanisms, are three specific entry points that should be considered in relation to ecosystems services in the framework of a bioeconomy approach.

Promoting the Transition to a Bioeconomy Model

Existing experiences in Europe, the USA and several Asian countries, and also in some of the region's countries such as Brazil in the case of biofuels development, and Costa Rica in biodiversity valorization, highlight that policy and institutional dimensions are key elements in the transition from a conventional to a bioeconomy-based perspective.

A more extensive and efficient utilization of biomass based alternatives opens up a wide scope of potential benefits. At the same time new issues that need to be clearly incorporated into the policy and institutional environments for those benefits to materialize are raised. Many of these issues are related to the particular characteristics of biotechnological applications and how they are perceived, and differ from conventional technology systems. In addition, they arise from the new and different ways in which the output of biomass production processes develop and are integrated into the new value chains. They include aspects related to the comprehensiveness of the policies involved and the role played by them in the necessary processes, the kind of science on which technology development is based and the type of institutions that are leading the process, the proprietary nature and investment requirements of the new technologies and the new regulatory systems, among other aspects.

The common denominator of the emerging system is the increasing complexity of the new environment when compared to that of existing conventional food/fiber agricultural systems. Table 1 summarizes the main contrasts that need to be considered (for a more comprehensive discussion of these aspects see Trigo, 2002, and Trigo, & Henry, 2009).

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hazard regulation; **Cultural services:** The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences, thereby taking account of landscape values.

Table 1: Conventional *vs.* "Bioeconomy" oriented agricultural systems

Conventional food and fiber oriented agricultural systems	Bioeconomy oriented agricultural systems
- Predominance of agricultural and food security policies - Predominance of public good strong participation and leadership from public institutions as drivers of new technological concepts - Agronomic and applied sciences - R&D most oriented to food production-productivity-quality related issues - Relatively low investment requirements - "Weak" intellectual property systems - Low regulatory intensity - Predominance of bulk marketing and logistical infrastructure, low product differentiation except for quality standards	- Policy environment integrating natural resources, food and agriculture, energy and industrial development dimensions - Strong participations and leadership from the private sector in technology development - Technological applications closely linked to basic research - Horizontal R&D systems ("beyond food" —natural resources use— value chain issues) - High investment requirements - "Strong" intellectual property protection systems - High regulatory intensity - Biosafety - Consumer protection - Increasing importance of value chain integration, product differentiation and standards, and market segmentation issues

Source: the authors; and on the basis of Trigo (2002).

The main contrast that should be highlighted is with respect to the policy focus and the type of instruments involved. Policy objectives and instruments need to be adapted to the different life cycles implied in the bioeconomy. Conventional policies evolve from "mature" stage situations. In the bioeconomy, most cases are in their early stages of development and in need of, on the one hand, incentive policies to attract and guide investments into the sector. On the other, sustainability instruments to assure best practices in natural resources management and preserve food – energy/other uses balances are needed. A bioeconomy policy environment needs to explicitly consider the natural resources/environment, energy, agricultural, industrial and trade policy domains. The experiences of Brazil, the EU and the US with regulations, taxes and market incentives aimed at the development of modern biofuels, are clear examples of how important the structure of these and other policies are to shape the direction of the new industries and their markets (EU example: Lead Market Initiative). However there are also warning examples, where policy intervention caused serious misconceptions with long-term consequences due to wrongly guided investments. Thus, a bioeconomy approach requires a more complex and evidence-based policy mix, for central issues, including feedstock, input diversification, land use planning and industrial and consumer level —fair trade, sustainability and "green" certification, etc— policies, reaching beyond the energy/transportation sector. In this sense, policies need to consider and promote socially acceptable land use and steer bioenergy development in a sustainable direction to avoid environmental and social damages.

At the primary sector level, agricultural policy, including the availability of rural infrastructure, credit and land tenure will determine the scale and distribution of economic benefits. All these policies need to have a regional as well as a global component, as bioeconomy markets will develop in a globalised economy. Beyond the change in focus and scope of the policy environment, there are several areas that need to be specifically highlighted for action. These include the science and innovation base, human resources development and social participation, and a number of specific regulations and promotion instruments that become essential for assuring a safe and sustainable bioeconomy development pattern.

Science and Innovation

Two dimensions need to be clearly identified and promoted. There is no doubt that, science and new knowledge are needed to solve the values of the equation of producing "more with less", implied in the concept of the bioeconomy. But new knowledge alone will not do the trick if it is not effectively put to work in transforming existing production patterns. There is also the need to assure appropriate levels of innovative behavior by the relevant economic actors.

In spite of the relatively good performance on key components of the bioeconomy as biotechnology applications and eco-intensification practices, the region's science and technology infrastructure in the LAC region is relatively weak. The high intensity of use of biotechnological applications in the region's agricultural sector is, indeed, a great advantage, with respect to the logistical and field experience in effective handling of one of the strategic components of the new production strategies. However, a closer look at the situation shows that regional science and technology systems have had little contribution and link to this, as most of the innovations involved have come from outside the region and domestic investments both in science and technology, in general, and in the biotech related fields, in particular, are dismally low (Trigo, Falck-Zepeda & Falconi, 2010). Up to 2007, more than 80% of the field trials of GM crops and 100% of the GM varieties in the field were technologies generated outside the region. This reflects not only the low levels of investment in biotechnology research –about USD 130 million for the whole region[19] [20], corresponding to a fourth of the investments of the largest multinational corporation–. In addition, significant underinvestment in conventional agricultural research is present in the region, for which the average research intensity index is a little over 1%, but with a large number of countries (8 in a 15 countries sample, showing negative growth rates during the first part of this decade —2001-2009—, Stads & Beintema, 2009). The extent of the knowledge gaps resulting from this situation emerges from the poor level of scientific production in the region. According to a recent study (Trigo, 2012), the total number of scientific papers published by researchers and institutions from the region in refereed sources during the period 2006-2011, is of the same order as that of countries like Canada or Spain, and only a fraction of Chinese publications in the same field. Furthermore there are large differences within the region, with only Brazil, Mexico, Argentina, Colombia and Chile showing significant figures (Trigo, 2012). A similar situation exists in regards to patenting activity in relevant fields related, including the areas of bioenergy crops and processes (Cepal, 2011).

The relative weakness in conventional agricultural research investments is probably more damaging, in terms of an immediate strategy for the development of the bioeconomy, than the low levels of investments in biotechnology. It is true that weaknesses in biotechnology capacities lower the potential value of biodiversity resources. But experiences around the world clearly show that a country does not need to have the capacity to develop the new technologies in order to benefit from them. Actually, in very few cases the whole cycle is domestic. Most of the successes in GM varieties have strong and significant international technology transfer linkages (Trigo *et al.*, 2002). What is essential is the conventional research capacity to backcross new genes into the commercial genetic pool well adapted to local conditions. Conventional research is also essential as the source of knowledge on soils, pest, and other agronomic information. This provides the basis for novel eco-intensification practices. In fact, in the short/medium term the most likely scenario is the technological "hybridization", where eco-intensification practices and biotechnological approaches share the stage to move production pathways to higher sustainable productivity levels. In the long term, the latter, will however be essential to meet the dual food security-environmental sustainability standards implicit in the bioeconomy concept (Trigo *et al.*, 2009).

19 According to the OECD (2009) the seven largest multinational companies in the field were investing in biotechnology related R&D over USD 1.85 billion, with the largest of them —Syngenta— investing an estimated USD 510 million a year.

20 The situation is even worse if disaggregated by country. In both cases about 50% of total investments are in Brazil and the five largest countries (Brazil, Argentina, Mexico, Colombia and Chile) account for more than 85-90% of total investments (Trigo, Falck –Zepeda and Falconi 2010; ASTI).

In the context above, a key set of questions for moving towards a sustainable bioeconomy concerns the priority research areas that should be strengthened in the future (disciplines, type of resources, types of technologies, etc.), and the appropriate investment criteria that should be pursued. A closer integration of basic science with technology development and delivery systems, and effective incentive mechanisms for productive actors to assume the risks of mainstreaming the new, is also essential and, in most cases, not well attuned. Science and technology investment levels, inter-institutional collaboration, including public-private joint ventures, among others, become key elements that need to be recognized and directly addressed if an appropriate environment for an effective research and innovation system is to be set in place.

Human Resources and Social Participation

A successful transition to the bioeconomy will require both an intensive effort at human resources development and improved mechanisms for social participation. Bio-based processes require not only a new technological base, which in turns reflects in a rearrangement of the scientific skills base for research and development. They do also need changes at the production and management levels as bio-based strategies are usually much more knowledge intensive than conventional approaches. A good example of these tendencies are eco-efficient agricultural approaches, in which successful technological innovation is highly dependent both on sophisticated biological sciences capacities and production level human resources (farmers and extension services) able to understand and manage the intrinsic dynamics of biological processes. At a more aggregate level, bio-based strategies also change the established balances within a given society (local, regional, national, international). Access and resource use patterns, benefit distribution and many other aspects of the existing *status quo* are changed, creating the need for better understanding of the issues involved for decision making processes at the community level to evolve in a proper direction. There is need for identifying and managing the emerging trade-offs among the old and the new activities, between the different scales of application, between the short and the long run. At the same time the emerging ideas and processes have to deal to the fact that available knowledge about biological systems is usually low, while mythical, ideological and even religious aspects are intrinsically linked to biological systems. Improved training at all levels, from primary education upwards, extension programs, the promotion of entrepreneurial capacities, and social communication and decision-making processes are key strategies in this sense.

Supporting New Markets Development

Future events are already starting to show in current situations, but they are still not fully reflected in present market signals. In this context public policy and regulations have a critical role to play in triggering the needed new responses. Topics in need of action include the development of the appropriate metrics for the new processes —so that they can be adequately monitored—, the already mentioned integration of policy domains (natural resources, agriculture, rural development, education, science and technology), the reorientation of public investments in infrastructure, education, science and technology together with new incentives to redirect private decision making toward the new areas of economic activity, improved IPR frameworks capable of effectively reflecting the nature of the new scientific and technological parameters as well as the changing role on natural resources in economic processes. All these must go hand in hand with other aspects such as biosafety regulatory frameworks and the development of market standards for bio-based products, among others. Actions regarding incentives and regulations for the bioeconomy should aim beyond traditional economic and science and technology policy instruments. Increased investments and better science focused on appropriate priorities are necessary conditions, but they should go hand in hand with other instruments that address the human resources issues, IPR and biosafety regulatory systems and other actions directed to promote innovation and the development of the new markets for bio-based products.

1. *The IPR issues* are of particular relevance for LAC. At the general level, the growing relevance of knowledge intensity in production systems and the emergence of biotechnology bring about a noticeable displacement of the "technological space" in the direction of the private sector. Proprietary technologies grow in importance *vis a vis* the public goods dominance in conventionally oriented agriculture. This demands an in-depth and continuous review of technology research, development policies and organizational systems, to recognize the more complex management requirements of R&D processes, and to establish adequate conditions for promoting investments and access technologies originally developed for other environments. An indicator of the importance of IP, in general, and of patents, in particular, is what has been occurring in the area of biofuels.

Until 2007, 2796 biofuel-related patents had been filed worldwide, 1047 of them in 2006-2007[21]. At a more specific level, IPR issues are a key aspect for effectively realizing the region's genetic and biodiversity resources potential, especially since to date the framework to regulate access and benefit sharing is still mostly under development. While many countries in LAC are active in the Convention of Biological Diversity and the International Treaty on Plant Genetic

21 www.bakerdaniels.com. The term "Patents" refers to US patent applications, PCT international applications and granted US patents published up to November 2007.

Resources for Food and Agriculture, at the national level there still is little in terms of concrete mechanisms needed for the effective transformation of potential into actual benefits. Policies in this respect do not only need to consider the promotion of private involvement in research and development activities. They must also include more global issues related to the creation of the appropriate environment for greater direct domestic and foreign investment in biodiversity valorisation and business development activities.

2. *Biosafety regulations* present a similar picture than IPRs. From the point of view of the development of the bioeconomy, biosafety is a key issue, not only linked to present day biotech applications. Future bioeconomy applications of many plant materials —*i.e.* for biofuel production— are highly dependent on genetic engineering and the application of knowledge from modern plant biotechnology for their full exploitation in new uses, or production environments. In addition, one should expect a greater move towards developing, testing, distributing, and cultivating crop species in environments where their potential economic and, particularly, social and environmental benefits are still largely unknown. Working in this field is of particular importance for the smaller countries as it impinges on their ability to free ride on external R&D and capture spill-in benefits. Existing systems also discriminate against national public research institutions and national firms and their ability to become active players in product development —for instance, in biodiversity value adding initiatives—. Having, usually, a weaker financial position than large multinational corporations, it is more difficult for them to bear the additional costs involved. An in-depth review and the analysis of alternatives are key issues for the future impact of bioeconomy strategies on the region's social and economic development opportunities.

3. *The development of new product and process standards* is also a key issue for the development of the bio-based products market. Standards are essential elements in aggregating initial demand and allowing effective communication among agents within a given market and across connected markets. They are the basis for market transparency by providing common reference methods and requirements in order to verify claims about these products (*e.g.* bio-degradability, bio-based content, recyclability, sustainability). They provide guidance to investment and other related economic decision-making. The experiences of the European countries with the Lead Market Initiative and of the US with USDA's Certified Biobased Product label, together with the minimum blend regulations for biofuels in many of the LAC countries clearly prove the importance and effectiveness of this type of incentive/regulatory mechanisms.

Concluding Comments

The aspects discussed in this note highlight that even though there may not be yet an explicit discussion and effort directed to explicitly promoting a bioeconomy for LAC, the processes are already present and evolving according to market conditions based on the characteristics of the region's resources and modes of insertion in the international markets. This should not come as a surprise. The bioeconomy is far from an ideal model to be induced in the pursuit of desired objectives. It is rather a needed response to perceived global challenges; it is a process emerging from the need to confront the challenge of dwindling resources, climate change and growing global demand being built on the basis of the extensive and growing knowledge base accumulated over the last decades that make departure from previous behavior, not only desirable but possible.

In this context, the LAC region has a critical dual role to play. Because of the weight of its natural resources and in global markets, under any possible scenario, its evolution is a critical component for the needed global food security and environmental equilibriums. At the same time, bioeconomy development can be anticipated to make a significant contribution to domestic food security and poverty alleviation objectives at the national and regional levels. In line with this, we have identified a set of six pathways representing potential entry points for the promotion and implementation of the needed changes and we also discussed some of the common constraints that need to be confronted for moving forward. The ideas presented do not pretend to be neither exclusive regarding options, nor extensive in the depth of the analysis. Far from this, they are only a first approximation conceived to stir further discussion. Nevertheless, we hope to highlight two aspects, which to us are by no means of minor importance. One is that the transition to new situations where biomass and biological processes play a greater and more effective role in meeting the identified challenges will not evolve from a "business and usual" environment. The second one, directly related to the former is that for taking advantage of the new opportunities significant policy and institutional changes will have to be set in motion.

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Natural Resources in Latin America and the Caribbean: a Bioeconomy Perspective

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Introduction

Several concurrent crises during the last decade: in climate, biodiversity, fuel, food, water, and simultaneously in the financial system and the economy as a whole, have promoted developments in the sustainable use of natural resources (NNRR) as a means to reduce environmental risks and to improve human well-being and social equity (UNEP, 2011). The world population is expected to be over 8.2 billion people by 2030, and the world economy is expected to nearly double. Rising income and aspirations for better living standards will increase the pressure on the planet's natural resources (OECD, 2010). Meeting growing global demands for food and other agricultural products is an important economic opportunity for Latin America and the Caribbean for which strategic innovation is required.

The concept of Knowledge Based Bio-Economy —KBBE— is an answer to these challenges. Bioeconomy developments are directed to contribute to the conservation and sustainable use of biodiversity through the promotion of trade and investment in products and services, and to reduce the dependency on fossil fuels and non-renewable resources. It is directed towards the transformation of life sciences knowledge into new, sustainable, eco-efficient and competitive products. In general terms, the basis of KBBE is the fact that NNRR can be transformed into biomass and useful products.

Bioeconomy includes the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. It comprises agriculture, forestry, fishery, food, pulp and paper production, as well as parts of the chemical, biotechnological and energy industries. These sectors have a strong innovation potential due to their use of a wide range of sciences (life sciences, agronomy, ecology, food science and social sciences), activating industrial

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technologies (biotechnology, nanotechnology, information and communication technologies —ICT—, and engineering), as well as local and tacit knowledge (EC, 2012). The term BioTrade —a component of bio-economy— is understood as activities related to the collection or production, transformation, and commercialization of goods and services derived from native biodiversity (genetic resources, species and ecosystems) according to the environmental, social and economic sustainability criteria (UNCTAD, 2007). Additional considerations for bio-trade are prospective markets, supply chains and distribution networks.

Natural resources (NNRR) are substances/materials present in nature, considered useful and valuable for the humankind. Their significance for bioeconomy lies in their availability (supply) and their possible demand, related to their usefulness for productive systems. Mining, petroleum extraction and purification, forestry, fishing, hunting and similar activities are considered natural resource industries while agriculture is not. In general, NNRR are classified in renewable (living resources like fauna, flora and microflora), and non-renewable resources (non-living such as minerals). Natural resources extracted from the earth's biosphere are categorized as biotic. Petroleum is a resource included in the category of biotic natural resources because of its organic origin. Land, water, air, minerals, metals and other such materials (non-living) fall into the category of abiotic natural resources.

NNRR are of paramount importance for the social, cultural and economic development of humankind, being part of the national patrimony of each country and representing enormous environmental, cultural and economic values. Technologies and the way in which we should use them are a growing challenge for KBBE promotion, and problems related to governability, social organization and human rights are of increasing importance for achieving sustainable development (Hodson, 2009). Biodiversity and ecosystems offer ecosystem services —ES— and provide inputs directly into the production of key sectors of the economy such as water, air quality, soil fertility, pollination, pest and disease control, growth and reproduction of food species, recycling nutrients, providing fertile soils and prevention of erosion, and additionally regulating services such as climate regulation, water purification, storm mitigation, waste assimilation, among many other functions (Schuler *et al*., 2011). CBD (2010) describes the importance of biodiversity: "[…] It provides for food security, human health, the provision of clean air and water; it contributes to local livelihoods, and economic development, and is essential for the achievement of the Millennium Development Goals, including poverty reduction".

In the framework of the FP7 ALCUE-KBBE project "Towards a Latin America and Caribbean Knowledge Based Bio-Economy in partnership with Europe", the first step, in terms of promoting the development of the bioeconomy in Latin America and the Caribbean (LAC), is to establish the information base and to identify potential future developments and constraints (benchmarking). The assessment of the existing natural resources (NNRR) in Latin America and the Caribbean (LAC) is one of the elements of this analysis. In its context, this document identifies some alternatives that can be followed to take advantage of the region's potential. A transformative SWOT analysis was made for three thematic groups in order to establish the main opportunities, limitations and requirements for KBBE development in LAC. The objective of this document is to identify opportunities emerging from the NNRR base with respect to bioeconomy developments in the LAC region as well as the main limitations that exist to realize the potential, and tentatively propose possible policy alternatives to overcome them.

The Importance of Natural Resources in LAC

The LAC region has one of the greatest endowments of natural capital in the world with an immense wealth of natural resources, in terms of land, water and biodiversity. It also has a variety of cultures, which are of increasing strategic value for a bio-based world. This is a source of economic growth, and gives LAC the potential of becoming the world leader in offering the services that its ecosystems and biodiversity provide, and in return receiving new benefits from this conservation and sustainable management. The LAC region is among the global leaders exploiting the benefits of the new biotechnologies (Trigo & Henry, 2011). It is also notable for being a leading region in the production and export of soybean, sugar, coffee, fruits, poultry, beef, and —more recently— ethanol (IDB, 2012).

The NNRR abundance in Latin America and the Caribbean —including biodiversity and geodiversity— places the region in privileged position in terms of potential for the development of KBBE. Throughout history, this wealth has been critical for LAC economies. The production of precious metals, sugar, rubber, grains, coffee, copper, and oil have made countries in LAC —and their colonial powers—, at various historical periods, some of the most prosperous in the world. Properly managed NNRR constitute a crucial source of growth and development. Commodity exports have always powered the economies of the region. LAC's agro-industry has experienced a strong growth as a result of increased global demand and international prices for agro-foods as well as raw materials for biofuel production. Approximately 54% of the region's exports are commodities (UNEP, 2010).

The region is a biodiversity superpower. It includes five of the world's ten most bio-diverse countries —Brazil, Colombia, Ecuador, Mexico, and Peru— as well as the world's single most biologically-diverse area: the Amazon rainforest. South America alone has more than 40 % of the Earth's biodiversity, and more than one-quarter of its forests. The Meso-American Reef is the largest coral barrier reef in the Western Hemisphere. Central America, with only 0.5% of the world's land mass, has 10% of all of LAC's biodiversity (Bovarnick *et al*, 2010).

Brazil —one of the mega diverse countries— has the greatest biodiversity in the world and it stands second in number of endemic species. It houses approximately 60% of the Amazon rainforest, with nearly 10% of all the species in the world. In addition to the existing biodiversity wealth in Brazil, the Tropical Andes (Bolivia, Colombia, Ecuador, Perú and Venezuela) is the richest and most diverse region on Earth in terms of biodiversity. It is one of the major centres of species domestication, according to Vavilov —far exceeding the diversity of any other hotspot in the world—. It contains about a sixth of all plant life in less than one percent (0.8%) of the world's land area, in an extension of 1,542,644 km^2, from western Venezuela to northern Chile and Argentina, including large portions of Colombia, Ecuador, Peru and Bolivia.

The Tropical Andes holds the first place in the world in diversity and endemism of vascular plants, birds, amphibians, and total vertebrates (excluding fish). The sub-region is also the center of origin of important Andean-Amazon plant genetic resources which supply approximately 35% of the world's agricultural food and industrial production (Schuler *et al*., 2011). Many rural and indigenous populations depend on biodiversity for their livelihoods, including fishing, non-timber forest products and agriculture. The region's immense array of natural resources offers a unique laboratory for products and processes that could provide medical solutions for current and future generations (Bovarnick *et al*., 2010; UNDP, 2010). The sustainable use of natural resources and specific biological diversity is one of the cornerstones for development in many countries with high biodiversity. This should be associated with the implementation of diversified markets that favor the quality and add value to the products obtained directly, as well as the services arising from their use.

The LAC region has only about 16% of the global land surface and 10% of the world's population. It comprises 28% of the world's arable land, 33% of its renewable water, and the highest rate of land area per inhabitant. LAC is estimated to have 31% of the planet's 35 million km^3 of freshwater resources. Some of the world's largest rivers are in Latin America —the Amazon, Parana-Paraguay, Orinoco, Uruguay, Magdalena-Cauca and Usumacinta— (UNEP, 2010). In general terms, most of the LAC region has moderate to high annual precipitation (800-2000 mm) with a small percentage of zones with low precipitation. Most of the land in LAC has not shown severe climate constraints excepting some zones —about 17% of the total area— with moisture constraints, and scarce zones of seasonal wetness constraints (GAEZ, 2000). Nevertheless, among other effects, global climate change has increased the intensity and frequency of hurricanes in the Caribbean and it has caused changes in the distribution and intensity patterns of precipitation and temperatures as well as a rise in droughts, and some other effects are anticipated (UNEP, 2010).

In relation to land, LAC has an advantage for sustainable development, economic growth and bioeconomy promotion. According to the International Institute for Applied Systems Analysis (http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm), South and Central America's extension is 2049 million hectares of land, of which 853 million is land with cultivation potential. A total of 346 million are forests, 16 in housing and infrastructure and 1048 are not suitable for cultivation (Tables 1 and 2).

Table 1. Land with rain-fed cultivation potential for major food and fiber crops (million ha)

Región	Total Land	Land with cultivation potential		Housing, Infra-structure	Not suitable
		Total	Under Forest		
South and Central America	2049	858	346	16	1.048

Source: GAEZ, 2000

Table 2. Rain-fed cultivated land in 1994-96, and rain-fed cultivation potential for major food and fiber crops (million ha).

Región	Rain-fed Cultivated Land 1994-96	Land with good cultivation potential		Land with moderate cultivation potential	
		Total	Under forest	Total	Under forest
South and Central America	141	698	281	161	65

Sources: GAEZ, 2000 - FAOSTAT

To alleviate hunger and poverty within the context of environmental sustainability, while creating new sources for equitable economic and social growth, it is essential to link NNRR and livelihoods with the important role of biodiversity and natural systems in meeting other sustainability challenges such as climate change, water scarcity and agriculture. Sustainable use of biodiversity benefits people in several ways improving health, increasing food security and reducing poverty as well as safeguarding the variety of nature (SCBD, 2010). The main requirements are to strengthen the management of ecosystems, to take into account biodiversity and ecosystem service values, to improve technical and institutional capacity, particularly in the areas of agriculture, tourism, fisheries and forestry (IDB, 2012).

Natural resource production shows considerable heterogeneity across LAC countries along a number of dimensions. Much of LAC's gross domestic product (GDP) is also generated in countries that rely heavily on fiscal revenues from commodity production and export. Of the seven economies LAC-7[3], which make up approximately 85 % of regional GDP, six have a substantial commodity revenue share in overall revenues, ranging from 10 to 49% on average over 2004-08. These six are Argentina —export of agricultural commodities—, Chile —copper—, Colombia —oil—, Mexico —hydrocarbons—, Peru —mining—, and the República Bolivariana de Venezuela —hydrocarbons—.

The wide and diverse forest types in Latin America and the Caribbean generates a series of goods and services that range from wood, lumber, bio-based products and/or medicinal plants, to services such as erosion control, flood and climate regulation and recycling of nutrients. The opportunities for local populations to incorporate new technologies along with alternative and sustainable land uses need to continue expanding, including opportunities for income generating non-agricultural activities able to ease the pressures on the environment (UNEP, 2010). Plants and microorganisms are the most representative groups of the biodiversity being used as a source of industrial developments, food, fiber, fuel, medicines and raw materials. The most important sector in which plants are used for producing medicines and drugs is the pharmaceutical industry and the manufacture of glue, soaps, cosmetics, dyes, lubricants and polishes, among many other products. Plant biomass also provides an important source of renewable energy and a new opportunity to take advantage of the biotechnology potential (Schuler *et al.*, 2011; Ruane *et al.*, 2010). Additionally, industrial and environmental biotechnology is a broad category of technologies that employ microorganisms and enzymes in a wide range of industrial and pollution control processes such as bioleaching and bioremediation.

Research and innovation aim to increase the adaptive capacity of plants, animals and production systems to cope with rapidly changing climate conditions and environments, as well as increasingly scarce resources. This includes dealing with diversification and specific adaptation, mixed farming systems and land use practices, adaptation of plants, animals and cropping systems to biotic and abiotic stresses, conservation and use of biodiversity, as well as specific climate change mitigation and stress adaptation measures at farm. In addition, research will promote the sustainable management of soils, exploit advances in conservation agriculture and reduce greenhouse gas emissions from agriculture and forestry activities, while enhancing sequestration of carbon in soils (EC, 2012). The dependence on 15 crop species which provide more than 80% of the food of the world —after 10.000 years of agriculture, and the discovery of 50.000 varieties of edible plants— and only a few of the numerous animal species being used for food has been one

3 LAC-7: the largest seven countries in the region: Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela

of the factors to increase the vulnerability of agriculture and impoverishment of the human diet. As a result, many regional and local crops that have traditionally been important for feeding the poorest sectors of society are nowadays underutilized or neglected. Those are valuable resources requiring efforts in R&D, and with great potential for activities related with KBBE (FAO, 2011).

Biodiversity management plays a significant role in the development of sustainable agricultural development practices and strategies against malnutrition. The integration of biodiversity into food security and anti-hunger policies is likely to generate more socio-economic benefits —including supporting poverty alleviation efforts— than in any other sector (Toledo & Burlingame, 2006). In this context, one of the greatest technical challenges is to accelerate the development and introduction of new suites of productivity-increasing bio-based technologies (for crops, animals, algae, fish, forestry and food), that are sustainable as far as that they do not inflict damage on the soil, water and ecological resources as well as on the atmospheric conditions in which future food output depends (FAO, 2011):

Agricultural biotechnology is an important tool for increasing and improving food production capacity and promoting sustainability, including the genetic improvement of plant varieties and animal populations to increase their yields or the genetic characterization and conservation of genetic resources (Ruane *et al.*, 2010). In traditional agricultural areas, modern biotechnology offers an opportunity not only to increase productivity and significantly reduce the use of off-farm chemical inputs, but also to enhance natural agro-biological systems (Roca *et al.*, 2004). Biotechnology developments include: identification of genes of interest for crop production (*i.e.* pest and disease resistance/tolerance, abiotic stress tolerance), improvement of nutritional value, obtaining compounds of interest, improvement of industrial or processing qualities. The production of biofertilizers and biopesticides, which reduces the use of contaminant chemicals, an environmentally friendly and sustainable practice is a very promising industry with high potential in LAC. Metagenomics —for soil microorganisms—, functional genomics and plant genomics have a critical role to play in the 21st-century agriculture, energy, and environmental stewardship. The economic value of the reservoir of genetic traits present in wild varieties and traditionally grown landraces is extremely important for bioeconomy development. Plant genomics has significant cross-disciplinary applications and has already encouraged advances in medicine, chemistry, and engineering, in addition to basic biology (The Academies of Sciences, 2007).

Bio-refineries and bio-products are some of the key concepts in the bioeconomy. Bio-refineries, in essence, are like oil refineries —facilities aimed at transforming biomass into a broad spectrum of marketable products and energy (Trigo & Henry, 2011)—. Of great global interest is the development of second-generation fuels, which are generally those made from non-edible lignocellulosic (LC) biomass, either residues of forest management or food crop production (*e.g.* corn stalks or rice husks) or whole plant biomass (*e.g.* grasses or trees grown specifically for biofuel purposes). OECD (2010) considers that if second generation biofuel technology —based on biomass waste— becomes widely available by 2030, the projected expansion of agricultural lands to supply biofuels production, the increased use of pesticides, fertilizers and water, and the impacts on biodiversity and ecosystems associated with this land use, could be avoided.

Scope, Approach, Methods

The immeasurable diversity in Latin America and the Caribbean region makes it very difficult to evaluate in a single analysis all its potential and vast possibilities for developments in bioeconomy. The analysis presented is a first approach to be complemented and articulated with the other tasks within the activities of the project.

Based on the four previously defined areas in the framework of the Project ALCUE–KBBE namely Biofuels, Biotechnology, Biodiversity and Ecological intensification (Trigo, 2011), potential productive chains were defined, prioritized and analyzed. Within the framework of biodiversity based activities, value chain analysis is an approach that makes sector support possible. It starts by establishing a collaborative mindset, then it identifies needs, limitations, and strengths, and goes on developing strategies that promote the sustainable trade of products derived from the use of biodiversity. The implementation of these strategies helps to increase competitiveness in the sector, facilitate coordination between the different actors, and bring about environmental, social and economic benefits (UNCTAD, 2009).

The SWOT analysis is one of the tools used in strategic planning. It helps to identify the critical and the key factors involved in a given development, and to formulate strategies to overcome the unfavorable conditions and make the best use of the favorable ones in order to achieve the planned objectives. It evaluates the Strengths, Weaknesses/Limitations, Opportunities, and Threats of a given project. Confronting strengths/opportunities is possible to find competitive advantages, and weaknesses/threats to define activities in order to minimize or reduce them. It helps to visualize resources and capabilities to formulate specific projects. With the traditional SWOT analysis the main strengths, weaknesses, opportunities and threats related to the use of NNRR in the context of KBBE were determined. The inputs from the conventional SWOT were used for a transformative SWOT analysis, which facilitates the identification of strategic actions to be adopted in the strategic plan and to define concrete actions.

The steps involved in the preparation and development process of the SWOT analysis included:

- General identification of products/services with good potential. Information of relevant potential products was gathered and compared in a first matrix trying to categorize the product/service according to defined issues. This first selection considered "screening" criteria based on significant attributes of the actual potential of the resources such as availability and possible supply, use of native species, potential for sustainable use management, experience with the product, objective or purpose of the development and uses, developments in R&D (as well as requirements), potential value chain, institutions involved, infrastructure, potential geographic coverage, possible demand and market familiarity, capacity to generate exports, existing information, and generation of socio-economic benefits, among other issues criteria.

The lists are not exhaustive; they just give a broad idea of the possibilities. Not all aspects of NNRR possibilities can be included in this first approach. Lessons will be learnt and further adjustments will be needed. It is an enormous challenge to establish a common base and define the most relevant possibilities for LAC covering adequately the full range of NNRR in terms of goods and/or services.

Preselecting extensive topics and definition of priority groups focusing in strategic productive (value) chains with potential and of common interest for the partners (considering possible scenarios, requirements, limitations and solutions), according to the general objectives. This selection was made considering issues in environment and biodiversity, technology (R&D) and socio-economic considerations. Three "Thematic axes" were defined: 1. New products / processes; 2. Bioenergy; 3. Ecointensification–Bioinoculants. These "Thematic axes" were delimited during the identification and establishment of priorities and they are representative of different applications and stages of R&D in LAC.

- Characterization of the components in the value chain; identifying critical and key issues and recommending solutions to the main problems. Strategic analyses of the groups through a SWOT analysis. In a first instance, the conventional SWOT and subsequently the Transformative SWOT Analysis (for each of the three thematic axes) allowed formulating concrete actions to face the limiting aspects and take advantage of the opportunities.

Analysis–Results

It is clear that the LAC region constitutes an important, rich and diversified portfolio of a bioeconomy based on agro-industrial activities that have been generating significant economic value. In the future these activities will increase, both in terms of their economic importance and geographical coverage. There are many species of native plants with high potential for economic exploitation in the food, feed, pharmaceutical and chemical sectors, biomass, including non-timber forest products (NTFP), novel sources for biomass and bioproducts, novel high added-value bioproducts and bioprocesses for industrial biotechnology, and the use of residues/waste and by-products of biomass-based industrial sectors. Given the high diversification and specific conditions, there will be not a common pattern for bioeconomy development fitting the whole LAC region, but a number of different pathways, each reflecting different aspects and comparative advantages.

In all the countries of LAC, agriculture is a key sector, fundamental to the economy and growth, a pillar business, engine of social and economic development. A comparative advantage in terms of innovation is that the use of biotechnology in the LAC countries is quite extended and biotechnological applications are generally accepted. As an example, 10 of the 29 countries using GM crops in the world (2011) are in Latin-America. The biofuels sector is probably the strongest area in LAC, basically because many governments in the region support this sector, such as Argentina, Brazil and Colombia. LAC region counts on the longest track-record (40+ yrs) of a bio-ethanol sugarcane based- industry experience.

There are also a number of successful experiences in developing novel use for biomass based in R&D (biofuels sector, biotechnological applications and eco-intensification practices). Biomass raw material (woody materials, sorghum, castor beans, *Jathropha*, cassava, bananas and plantains and different grasses, among others) to produce non-fossil fuel energy sources and bio-based renewable material constitute a key entrance point of the Bioeconomy model. This alternative feedstock is offering interesting on-farm opportunities for small-scale agriculture either by generating intermediate products for larger factories, or through small on-farm processing units for ethanol and subsequent electrical power generation. However, there are continued concerns regarding the possible cropland expansion trends linked to biofuel production alternatives, and the unfinished food/fuel debate.

The SWOT analysis carried out showed a large coincidence among the results obtained for the three thematic axes —New products/processes; Bioenergy; Ecointensification–Bioinoculants— (Table 3). This suggests that the identified factors are determinant for KBBE developments in LAC. Moreover, they also indicate that there are several challenges for the sustainable use of NNRR in the development of bioeconomy activities in the region. The region has S&T

Table 3. Main factors identified in the SWOT analysis

Strengths	Weaknesses
- Large endowment of NNRR, species, water, land, day length for biomass production. - Normative framework for sustainable use of NNRR in place, including IPR. - Investments in LAC for KBBE developments are considered attractive and trustworthy. - Rapidly growing economies in several countries of LAC. - High availability of arable land, biodiversity and water (including rainfall) in the LAC region. - Agricultural and environmental country policies encouraging and supporting sustainable development in most of LAC countries. - Strong scientific & technological capacity, infrastructure and researchers as well as funding possibilities, which varies among countries. - Participation of research groups in scientific & technological international networks. - Competitive costs and environmental benefits for many of the developments related with NNRR.	- Insufficient capacity for turning existing NNRR endowment into profitable products and/or services. - Limited training/skills in market planning and design. - Genetic basis of biodiversity are not completely understood. - Frequently access to NNRR is limited and complicated by governmental policies and rules. - Insufficient infrastructure for advanced high-tech, basic research. - The concept of NNRR is too wide; it is convenient to define more specific targets. - Low use of waste from ethanol production (bagasse and vinasse) can impact negatively on natural resources. - High water requirement for processing in biofuel industries. - Land quality degradation due to agricultural practices such as burning. - Current low use of the available biodiversity (sustainably) is a limitation for an efficient use of natural resources.
Opportunities	**Threats**
- Abundance of potentially useful resources and species including useful genes -many unexplored and unemployed- and increasing worldwide interest for their commercial exploitation. - Increasing awareness of the importance of supporting technological developments in a context of sustainability and therefore, growing markets (demand) for bioeconomy developments (products and services). - High availability of potentially useful land with adequate water, and the potential of some species to grow in degraded soils and/or semi-arid conditions. - Need to develop new organizational governance forms to create competitive advantages for developments in KBBE.	- Inequitable sharing of benefits derived from the use of NNRR, which discourages local developments and involvement of communities. - In some countries of LAC there is political instability, specific political situations or political/social and armed conflicts which could interfere with developments and access to NNRR. - Difficulty to obtain access / permissions to NNRR. - There is no reinforcement of laws, or stable and substantial incentives for sustainable exploitation of NNRR - In some cases there is overexploitation of NNRR (non sustainable).

- Growing demand for ecologically friendly agricultural inputs and promotion of sustainable practices. - Underutilization of several native species for food and feed. - Increased industrial investments to reduce inputs and to preserve NNRR. - Existence of basic technical capability and infrastructure for profitable development of LAC resources. - Many biotechnological developments are being used in LAC with good acceptance of the society and favorable perception for new developments. - Propensity to increase bioelectricity production from ethanol production waste, which supports biodiversity conservation. - Need to improve the methods of collecting and transporting plant residues generating less waste and reducing the pressure on NNRR. - High potential for using alternative feedstock (jatropha, palm oil, native palms and others) to produce bioenergy. - High interest and demand for 2nd generation biofuels leading to positive impacts on biodiversity, where technological developments are needed.	- Impacts of bio-piracy on developments of KBBE and weakness to protect ancient knowledge. - Climate change impacts and employment of REDD (selling land rights including biodiversity) on the availability of natural resources. - Legislations in developed countries (ex. 2009/28/EC) related to the indirect land use that might restrict the employment of this resource in the LAC region. - Competition between food energy and implications for natural resources. - Disadvantages of local communities to negotiate with researchers & industry.

capacities for developments in Bioeconomy and significant infrastructures and human resources, with high concentration of scientific and research capacities in few countries. There are great differences in innovation potential among different countries.

Several comparative advantages as well as constraints for the development of Bioeconomy in LAC were defined in the study.

The main comparative advantages include:

- High potential (Immense wealth of natural resources —land, water, biodiversity and cultural variety— as well as emerging economy and growing human resources, which provides the region with an essential foundation for a solid bioeconomy.
- Policy and institutional environments favorable to BE in most countries in LAC.
- Long tradition in food, feed and biomass production. Food, fiber and energy supplier.

- Leaderships in bioenergy: Brazil, Argentina, Colombia (longest track-record -+40 yrs). Alternatives —woody materials, sorghum, castor beans, jathropha, cassava, bananas, plantains and different grasses— are under development (farm scale). Second generation biofuels (residues/waste and by-products).
- The region is among global leaders in exploiting the benefits of the new biotechnologies in agriculture, health, industry and environment. Agrobiotech in LAC countries is quite extended in agriculture (more than GM), ecological intensification.
- Skills in bio-activities.
- Increasing global requirements and demand.
- Regulatory systems placed in most countries.
- Investment is attractive.

Among the constraints:

- Bioeconomy development depends not only on resources quality and availability but also on social, economic and cultural factors.
- Weak capacity for turning developments into profitable products and/or services and for marketing.
- BE development requires innovation power, change in attitude and strong defined policies —incentives and rules—, leadership for sustainable social changes.
- There is a lack of adequate mechanisms for integrating private and public R&I efforts in a sustained way.
- Access to NNRR often limited by tough policies in some countries.

The major factors analyzed show that there is great interest in developing higher degrees of sustainability and economic productivity which in turn, can help to alleviate poverty levels, increase food safety levels and reduce income inequity. As the main components of KBBE are generating employment, economic growth, promotion of innovation, and the protection of natural resources, it is required as a priority to focus and stimulate policies aimed at higher efficiency in the use of NNRR and consequent benefits. It is evident that innovation and supporting innovation policies are fundamental for the development of sustainable and highly competitive ventures in KBBE. It also requires incentives, appropriate and accessible regulations, funding and international S&T cooperation. Multidisciplinary programmes have to be decided with investment in relevant research areas, involving different sectors aligned with the specific needs of the sector and their customers are the way to encourage innovation for sustainable and competitive bioeconomy.

Though there are significant differences among the LAC countries in terms of S&D capacities and productive structures, the common fact is that external market growth is in great extent reliant on NNRR. Consequently impacts of agriculture in environment, biodiversity, water and land use are crucial considerations when planning developments and use of NNRR. The present productive systems need to be replaced by more sustainable ones with higher social improvements. Based in the results of the conventional SWOT and transformative SWOT analyses, and considering the stakeholders consultations, specific topics were defined to have the higher potential for KBBE developments in LAC (Table 4).

Table 4. Particular topics for KBBE development in LAC defined by the SWOT Analysis and Stakeholder consultations

Key topics found with greatest potential for ALCUE-KBBE
- Bioenergy Bio-refineries and bio-products as basic concepts in the bioeconomy. A priority is the development of second-generation fuels, from non-edible lignocellulosic (LC) biomass (residues of forest management or food crop production or whole plant biomass grown specifically for biofuel purposes). - Eco-intensification Reduced or non-tillage; Integrated crop management; Bioinoculants: biofertilizers, biopesticides; Precision agriculture. Clean technologies; residues & waste microbial treatment (bioremediation, recycling). - Valorization of Biodiversity Food and feed from native species; pharmaceuticals; flowers; specific traits - Biotechnology products and processes. Biomaterials: enzyme production for industrial uses, biopolymers, nutraceutics, biosensors.

Source: own work

There is an urgent need to stimulate greater efficiencies in parallel with environmental protection looking forward to socio-economic welfare. This constitutes a great challenge to develop scientific, economic and social policies in new organizational systems of governance to encourage local research and R&D on local natural resources. In order to define concrete actions and establish the best options to take full advantage of LAC's NNRR potential, it is fundamental that all stakeholders —academic, productive, institutional, civil society and all the sectors— get involved in a cooperative process, in order to analyze technological, environmental, social and economic objectives. Economic analyses, specifically cost-benefit studies should be performed in order to determine the feasibility of the particular activities.

Principal Conclusions and Policy Recommendations

A main worldwide concern is to develop cleaner, consistent and affordable new energy sources to promote sustainable growth. Governments are supporting research, fostering innovation and the application of new technologies in productive and industrial activities, and encouraging the adoption of "green technologies" (OECD, 2011). Reduction of environmental impacts with new systems and innovative technologies requires adequate policies and conditions. The challenge is to reduce energy-related CO_2 emissions and mitigate greenhouse gas effect, and to reduce the dependency of current economies on fossil fuels and non-renewable resources, which need decisive actions and solid policies. High food prices and water scarcity are other important issues for both developed and developing countries. Innovation is increasingly perceived as essential to undertake such challenges. Meeting them depends crucially on the speed of innovation in new technologies, for example in the areas of renewable energy, carbon capture and storage, lower emissions, bioremediation, smart grids, synthetic biology, bio-informatics and personalised medicine (OECD & T&I, 2011).

The concept of the KBBE implies environmental sustainability that can be promoted through the development and application of modern biotechnology. R&D activities well focused will provide solutions for sustainable processes and products as well as for preventing and cleaning-up pollution. In order to accomplish sustainable development, emphasis should be focused in the development of systems for an integrated and complete use of the biomass, and to define biomass chains including the use of residues and by products of rural and industrial sectors. Additional to the use of alternative feedstock material, it is crucial the study and use of microorganisms and novel enzymes with enhanced biocatalyst activities for the improvement of the bio-processes with higher efficiency, increased yield and environmentally benign products.

For KBBE convenient and efficient development in LAC it is recommended:

- To replace present productive systems with more sustainable long-term practices for more permanent social improvements and to develop appropriate and feasible technologies for increasing the productivity of food and energy production
- To implement policies with incentives encouraging bio-trade and sustainability: increase investments on new sustainable technologies enabling the use of the rich biodiversity. An urgent need is to enhance the negotiating capacity of countries including the identification of market opportunities. Economic analyses, specifically cost-benefit studies are needed to determine the feasibility of the particular activities.
- To encourage policies offering incentives to second generation technologies, for a better waste conversion —recycling—, those to recover degraded areas through techno-

logical developments and to develop technologies for adapting and/or mitigate climate change (This means new plant varieties with less water and chemical fertilizer requirements).

- To encourage the development of ecologically benign bioproducts —genes, enzymes, metabolites— for crop sustainable management (biopesticides for phytosanitary purposes, bioinoculants for biofertilization and plant growth promoters).
- To promote R&D in microorganisms and their processes in order to increase efficiency in agricultural and agro industrial waste processing and reduce pollution in a sustainable context.
- To strengthen technical capacities in order to meet international market quality requirements and to develop skills in order to detect possible market demand.
- Appropriate, accessible and applicable regulations in place are needed. Funding and international S&T cooperation are required.
- In order to define concrete actions, and establish the best options, all stakeholders must be involved in a cooperative process.
- To adopt new organizational governance forms between university, industry and State (clear and transparent modes to negotiate, orientation and coordination of R&D networks, promotion of entrepreneurship and the fair trade in the international markets).
- To develop collaborative competitive bio-business strategies allowing the participation of small and medium entrepreneurs, based on the definition of those products or processes generating the higher market added value.

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Policies and Institutional Framework for the Development of Bioeconomy In Latin America

Pedro Rocha[1]

Introduction

Bioeconomy is a vision of a society that is less dependent on fossil fuels to meet their energy and raw materials needs (Trigo & Henry, 2011) in response to challenges related to increase in world population, demand for food and non-food products, depletion of natural resources and biodiversity use, provision and supply of energy, and impact of climate change (Barrera, 2011).

In order to know the basis that would support the development of the bio-economy in Latin America and the Caribbean (LAC) and explore the possibilities of their relationship with European countries, the project "Towards a Latin America and Caribbean Knowledge Based Bio-Economy in Partnership with Europe" (ALCUE-KBBE) has been developed. Among the activities of this project, methodological exercises (including electronic consultation, survey, SWOT analysis and discussions with various sectors) have been carried out. Several possible routes were established for the development of the bioeconomy in LAC: biotechnology, bio-energy and sustainable use of biodiversity, among others. To transit these routes, the bioeconomy should consider scientific, technical, economic, political, institutional and social scopes.

This paper presents a brief analysis of the institutional dimensions, in particular related to policies and institutions of the proposed routes.

Policies and Institutions for the Development of Products and Processes of Biotechnology

Under the definition of biotechnology of the Convention of Biological Diversity (UN, 1992), it is recognized as a powerful and varied toolbox that includes *in vitro* animal and plant cell and tissue culture, generation of bioreactors, fermentation (lactic and alcoholic), biological control of pests

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and diseases, plant breeding, molecular markers, the "omics" and, of great importance, transgenesis or genetic modification, among others (Rocha, 2011).

For bioeconomy, biotech route is certainly more than transgenesis and it recognizes in the other techniques tremendous opportunities for increasing efficiency of multiple processes and, consequently for linking commercial activities in a real way. Some areas that could be enhanced by the introduction of biotechnological tools include generation of bioinputs (nutrients, growth regulators); recovery, processing and use of waste (organic, industrial, toxic); identification, isolation, purification, characterization and use of enzymes in industrial processes; development of industries that make virus cleaning, clonal propagation and cryopreservation of plant materials for commercial and conservation purpose; generation of disease diagnostic kits; services for germplasm characterization and genotyping; generation of new crops or animals with desired characteristics; production of third and fourth generation of biofuels, etc.

It is noteworthy that, in LAC countries, most biotechnology tools supporting such developments with commercial potential have been introduced, and are being used, mostly for research purposes and to a lesser extent for commercial ones (Table 1).

Because of the importance of the genetic modification and the impact that its use has on certain regions of LAC, it is worth mentioning that in 2011, genetically modified (GM) crop production was reported mainly for soybean, corn and cotton in the Southern Cone countries (Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay). GM crops were also planted in Colombia, Costa Rica, Honduras and Mexico (James, 2011).

An important consequence of the production of genetically modified organisms (GMOs) using biotechnology techniques is that biosafety regulatory frameworks have been generated. Overall, biosafety is the range of measures, policies and procedures for preserving the biological integrity and minimizing potential negative effects or risks that biotechnology could eventually pose on the environment or human health (SCDB, 2003; IICA, 2013). Despite its breadth, the issue of biosafety in LAC countries has focused on the introduction and management of GMOs into the environment and how to ensure the biological integrity of ecosystems and living creatures (animals, plants and humans) (CAS & IICA, 2010).

1. Three strengths could be considered for the development of biotechnology in LAC:
2. Most countries have recognized it as a strategic area (IICA, 2011).
3. Several countries have created policies for development (Table 2), although a few have implemented them.

There is an institutional body represented by universities, agricultural research and livestock disease control agencies and national agencies to promote science and technology, among others (Table 2).

Similarly, from the point of view of biosafety, a strength is the availability of a supranational regulatory framework represented by the Convention of Biological Diversity (UN, 1992) and the Cartagena Protocol on Biosafety (SCBD, 2000), where several countries in LAC have in place National Biosafety Technical Commissions (CTNBio), for example, Brazil, Colombia, Costa Rica, Honduras, Mexico, Paraguay, among others.

Table 1. Biotechnological techniques and examples of some countries reporting their use for research and commercial purposes

Technique	Examples of countries reporting its use	Purpose
In vitro plant cell and tissue culture	All LAC countries	Research Commercial
Criopreservation	Colombia	Research
Plant transgenesis (generation of novel events or crops)	Brasil, Argentina, Colombia, Costa Rica, México	Research Field trials
Plant transgenesis (growing GM crops)	Argentina, Bolivia, Brasil, Chile, Colombia, Costa Rica, Honduras, México, Paraguay, Uruguay	Commercial
DNA sequencing and genomics	Brasil, Colombia, Argentina, Chile, México	Research
Bioinformatics	Argentina, Brasil, Colombia, Costa Rica, México	Research
In vitro animal reproduction	Argentina	Research Commercial
Animal cloning	Argentina	Research Field trials

Source: based on information obtained by IICA in e-interviews and field visits in various countries

Table 2. Example of some of the institutions and policies related to biotechnology in selected LAC countries

Country	Institutions	Policies
Argentina	- Instituto Nacional de Tecnología Agropecuaria (INTA, research) - Cámara Argentina de Biotecnología de la Reproducción e Inseminación Artificial, (Cabia, private management) - Centro Argentino-Brasileño de Biotecnología (Cabbio, research)	- Resolución 124 de 1991 de la Secretaría de Agricultura, Ganadería y Pesca (SAGyP) para la creación de la Comisión Nacional Asesora de Biotecnología Agropecuaria (Conabia) - Resolución 413 de 1993 de la Dirección de la Administración Nacional de Medicamentos, Alimentos y Tecnología Médica (Anmat) para la creación de la Comisión Nacional de Biotecnología y Salud (Conbysa)
Brasil	- Empresa Brasileira de Pesquisa Agropecuária (Embrapa, research)	- Política Nacional de C&T e o Programa de Biotecnologia do MCT (Mota, 2000)
Colombia	- Centros Nacionales de Investigación (Cenis: Cenicafé, Cenicaña, Cenipalma, Ceniacua; private sector, research and extensión) - Instituto Colombiano Agopecuario (ICA, control). - Corpoica (research) - Colciencias (S&T promotion) - CTNBio (regulation)	- Política Nacional de Diversidad - Conpes 3697 del 2011 Política nacional para el desarrollo comercial de la biotecnología a partir del uso sostenible de la biodiversidad - Ley 740 del 2002 ratificación del Protocolo de Cartagena sobre Bioseguridad (PCB) - Decreto 4525 del 2005 que reglamenta PCB (tema Organismos Vivos Modificados -OVM). y establece los Comités Técnicos Nacionales en Bioseguridad - CTNBio

Country	Institutions	Policies
Costa Rica	- Instituto de Innovación y Transferencia de Tecnología Agropecuaria (INTA, research) - CTNBio (regulation)	- Ley 7664 (creación de CTNBio), 7788 (ratificación de funciones) - Ley 8537 de 2006 (ratificación del Protocolo de Cartagena)
México	- Consejo Nacional de Ciencia y Tecnología (Conacyt, management) - SSA, Instituto Nacional de Medicina Genómica (Inmegen, research) - Comisión Intersecretarial de Bioseguridad de los Organismos Genéticamente Modificados (Cibiogem, regulation) - Cinvestav (research)	- Revisión exhaustiva en Álvarez (2009)
Uruguay	- Gabinete Nacional de Bioseguridad (GNBio) - Asociación Uruguaya de Empresas de Biotecnología	- Plan Sectorial de Biotecnología 2011-2020 - Consejo Sectorial Tripartito de Bio y Nanotecnología

Sources: Institutions mentioned in the table (2013)

One of weaknesses of LAC countries in biotechnology is the misunderstanding of technology represented, for instance, in believing that biotechnology is only the development of transgenics or that a biosafety framework implies acceptance of any GMOs, all of which is totally wrong (Rocha, 2011). This situation has negative consequences for the scientific development of certain countries. For example, it has caused confusion and led to the approval of laws, or even constitutional articles, that prohibit the development or commercialization of this technology.

Some countries have implemented moratoriums to prevent entry, production, and cultivation of GMOs thereby discouraging private investment and affecting negatively technological development of different sectors (agriculture, medical, industrial, etc). These facts, added to the disinformation campaigns of some nongovernmental organizations (NGOs), cause in some sectors of the population confusion, distrust and fear (SIMAS, 2009) of a technological option that has shown to be a technically feasible, environmentally friendly, and economically profitable alternative in other LAC countries (MAGP & IICA, 2012).

Other notable weaknesses include the absence of biotechnology profitable companies, which is represented by the minimal participation of this sector in the gross domestic product (GDP) of countries, and low public and private investment in biotechnology (Zepeda *et al.*, 2009). The weak —and sometimes contentious— relationship between governmental institutions (*e.g.* environmental *vs*. agricultural) as a consequence of competencies crossings, political heterogeneity, lack of clarity in regulation, weak technical capacity and high staff turnover, among others, is also damaging the development of biotechnology in the countries.

From the contrast between the strengths and weaknesses presented so far, it is clear that there are opportunities for consolidate biotechnology as a pillar of bioeconomy in LAC, for example:

1. Encouraging the creation of regional institutions of biotechnology and biosafety to complement the current ones: North American Biotechnology Initiative (NABI) and Group 5 of the *Consejo Agropecuario del Sur* (G5-CAS). Steps in this direction are occurring in Central America with the creation of Central-American Initiative for Biotechnology and Biosafety (Icabb; IICA, 2012).
2. Using the South-South Cooperation. Considering the remarkable growth of Brazilian agrobiotechnology, represented by Embrapa, a huge opportunity is open to strengthen South-South cooperation between this and the other National Institutes for Agricultural Research (INIA) hemisphere. These steps have already been taken and the Embrapa-America program is already defining nature, guidelines and actions of Embrapa and cooperation between countries.
3. Forming research and innovation consortia within and between countries.

4. Taking advantage of the current funding sources for the implementation of biosafety regulatory frameworks.
5. Implementing actions of capacity building and training for regulators and policy makers from various government institutions.

To achieve the above, in some cases it will be needed to create, to strengthen, and in others just to use the policies related to:

1. Intellectual property rights
2. Regulatory frameworks that strengthen national innovation systems
3. Biosafety regulatory frameworks. It should be noted that the issue of development of modern biotechnology based on GMOs is primarily a political-economic-philosophical rather than a technical one.
4. Synchronization or harmonization of biosafety regulation at a regional level.
5. Promoting the creation of biotechnology-based businesses. The true relationship between universities and business and investment attraction mechanisms (private).
6. Strengthening of qualified human resources and their incorporation into national institutions.

Policies and Institutions in Biodiversity

Biodiversity is an almost endless supply of products and services (Figure 1) and this has been recognized by several LAC countries as a foundation on which they could support part of their development. Brazil, Colombia, Ecuador, Mexico, Peru and Venezuela are megabiodiverse countries and Costa Rica and Panama are highly biodiverse.

Some of the strengths for the development of biodiversity in LAC include:

1. Recognition as a strategic area by the governments of the countries (IICA, 2011).
2. There is a binding international regulatory framework based on the "Convention Biological Diversity" –CBD– (UN, 1992), that all the countries of the hemisphere have signed. It is also discussed the implementation of the "Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity" (SCBD, 2011).
3. As part of the commitment to the CBD, countries have generated policies and institutions for implementation and development (Table 3).
4. Public-, private-, national- and international-funding have been established (*e.g.* UNDP-GEF, http://web.undp.org/gef/aboutus.shtml) for promoting conservation of biological diversity, particularly in high-risk regions as a result of the effects of climate change (IAI & Scope, 2011).

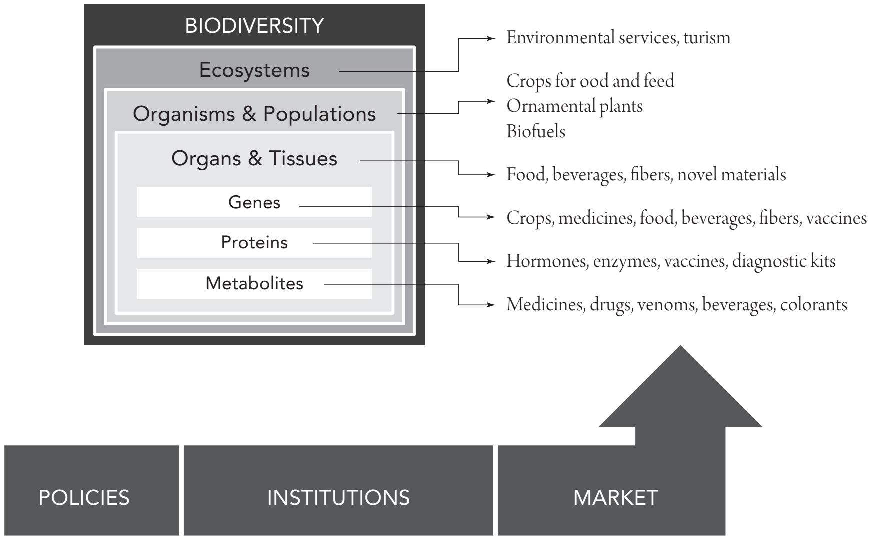

Figure 1. Biodiversity elements and some of their uses

However, the potential of the rich biodiversity contrasts with the reality of poor management, a situation clearly appreciated in countries of the Andean Region. For example, from the institutional point of view, most of the public institutions involved in the management and control of biodiversity have small and insufficient budgets for their actions and a high staff turnover. Often, there are clashes and disagreements between environmental institutions (based on conservation) and the productive sectors (focused on the use). In addition to the confrontation of the views, the discussion involves the difficulties in quantifying the actual value of those elements of biodiversity and lack of clarity on the application of intellectual property rights.

The institutional isolation of biodiversity with the productive sector of the countries has made private investment very low. In addition, opportunities for generation of profit enterprises, based on the use of components of biodiversity, are undetected. Although biodiversity of the Andean countries is enormous, really few companies are consolidated, profitable and successful based on the systematic use of biological diversity. Moreover, the conditions for the creation and maintenance of these few companies are considered more as quaint curiosities than as routes to emulate commercial development in order to create more business.

With regard to the regulatory framework, it is considered that the legislation on access to genetic resources is the main barrier for research and economic development and trade of biodiversity, particularly in the countries of the Andean Region, which are ruled by the Decision

Table 3. Institutions and legislation related to biodiversity in some LAC countries

Country	Institutions	Rules
Colombia	- Ministerio de Ambiente - Instituto Alexander von Humboldt - Instituto Sinchi - Invemar - Colciencias - Dirección Nacional de Planeación (DNP)	- Decisión 391/1996 del Acuerdo de Cartagena - Ley 165 de 1994 aprobación CDB - Ley 740 de 2002 aprobación PCB - Decreto 309 de 2000 reglamenta estudio de la biodiversidad - Decreto 1337 de 1978 Educación ambiental - Decreto 0620 de 1995 Explotación, control y vigilancia de recursos naturales - Conpes 3697/2011 Política Nacional para el desarrollo comercial de la biotecnología a partir del uso sostenible de la biodiversidad
Costa Rica	- Comisión Nacional de Gestión de la Biodiversidad (Conagebio) - Ministerio del Ambiente, Energía y telecomunicaciones (Minaet) - Sistema Nacional de Áreas de Conservación (Sinac), - Instituto Nacional de Biodiversidad (Inbio)	- Ley de Biodiversidad (1998)
Ecuador	- Dirección Nacional de Biodiversidad - Min. Ambiente	- Decisión 391/1996 del Acuerdo de Cartagena - Ley 26839/1997 conservación y aprovechamiento sostenible de la diversidad biológica
México	- Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (Conabio)	- Ley General del Equilibrio Ecológico y la Protección Ambiental (Lgeepa Art. 80 fracción V)
Perú	- Servicio Nacional de Áreas Naturales Protegidas por el Estado (Sernanp)	- Decisión 391/1996 del Acuerdo de Cartagena - Decreto Legislativo 1013/2008 creación del Min Ambiente

Sources: Institutions mentioned in the table (2013)

391/1996 of the Andean Community of Nations (former Cartagena Agreement). Policy implementation has tended to encourage conservation without the economical use of biodiversity.

Although some of the LAC countries are very rich in biodiversity, which is not reflected in their GDP, this wealth is declining at a rapid rate because of water, soil, and air pollution, among other reasons that include the widespread environmental mismanagement that occurs in certain productive activities (mining, agricultural, industrial), bio-piracy, and global climate change.

There are policies and institutional bodies in the countries that support the rational use of biodiversity (Table 3). In addition, global funds are available to which LAC countries can access to (*e.g.* the Global Environment Facility http://www.thegef.org). However, the disarticulation between different visions and institutions, and the absence of profitable businesses based on biodiversity are leading the countries to lose the present opportunities offered by new and heterogeneous markets, and worse, to watch passively the extinction of their natural resources.

Opportunities for the use of existing biodiversity for LAC countries are manifold. The many components of biodiversity (genes, metabolites, organisms, ecosystems) will generate novel products and services, or improve the existing ones. Regarding biodiversity products, the potential is almost unlimited for diverse industries such as pharmaceuticals, cosmetics, food, agricultural inputs and livestock, bio-energy, new materials, etc. (Figure 1).

Conservation is an application that can be exploited, which has been successfully demonstrated by Costa Rica, a country based on a policy of promoting environmental education. This has made possible the articulation of biodiversity with tourism, and it has found and developed new and profitable applications and services, thus making this relationship a major socio-economic pillar.

Institutions and Policies in Bioenergy

The development of nations is closely related to energy use. The countries energy consumption increases progressively (http://yearbook.enerdata.net) and the predominant energy sources face problems associated with their availability, environmental impact (emission of greenhouse gases and contamination by use of coal and petrol) and safety (*e.g.* nuclear power risks). In this scenario, alternative energy sources have taken relevance. One of them is based on biomass, which is of great interest to LAC countries for its potential to make new uses of already consolidated agricultural products. Thus, the production of biofuels (biodiesel and ethanol) has been used for Argentina, Brazil and Colombia, and it has awaken great interest in other nations (IICA & Arpel, 2009).

Based on the behavior of the leading countries in biofuel production in LAC, it can be stated that the strengths to develop this bioeconomy route include at least the following:

1. Presence of strong and consolidated public institutions (involving a close interaction between the ministries of agriculture, finance and energy) and private agro-subsectors such as oil palm (Colombia), sugar cane (Brazil) and soybean (Argentina).
2. Generation of national policies for promoting production and use of biofuels (Table 4).
3. Presence of international standards for the quality of the final product.
4. Intensive-capital private investment motivated by market opportunities and promotion policies.
5. Tradition and experience of raw material production and efficient coordination with agro-industrial processes of extraction and processing to obtain sufficient quantities of product which will cover food and energy demands.

Table 4. Main features of the policies of first-generation biofuels

	Economic agent or activity affected directly by the policy				
	Biomass production	Biofuel production	Biofuel use	Biofuel trade	
Form of policy	Quantitative requirements			Blending obligation	Import quota
Form of policy	Qualitative requirements	Land set-aside obligations with permission to produce energy crops	Fuel standards (*e.g.* oxygen content)		Fuel standards
Form of policy	Financial incentives	Energy crop payment	Investment/ ais tax credits for production plants	Fuel tax concessions	Import tariffs
Form of policy		General agricultural support measures	Loan subsidies Public research in conversion processes	Sales tax concessions for biofuel compatible vehicles Public research in engine development	

Source: OECD (2007)

But the clear achievements of the biofuel sector in Argentina, Brazil and Colombia contrast with the situation in most other countries of LAC, where policies are absent or are emerging regulatory frameworks for the use of biofuels, there is no promotion schemes for production or raw material productive systems are not yet consolidated.

But other than first-generation biofuels (derived from oil palm crops, corn, soybeans, sugar cane and beet), other items (such as jatropha, sweet sorghum, castor oil, etc.) are explored in what some known as the "1.5 generation biofuels" (IICA & Arpel, 2009). The second-generation biofuels are based on the use of various forms of biomass by different methods of extraction. Finally, biofuels of third and fourth generation are based on genetically modified microorganisms (algae, yeasts, etc.) or engineered by synthetic biology with the potential to be used in bioreactors, thus bypassing some of the limitations and problems of current production systems. However, these are still under investigation and institutional policies are encouraging development of such energy sources and they do not exist for the vast majority of LAC countries. Special cases are Argentina and mainly Brazil, which through Embrapa has infrastructure for research and innovation in biofuels (Teixera Manoel Souza, Director General Agroenergia Embrapa, 2012, personal communication).

Final Considerations

Within the framework of the Alcue KBBE, there have been various diagnostic activities and discussions, in which several routes have been defined for the development of bioeconomy in LAC: biotechnology, biofuels, and biodiversity, among others. For the development of each route, it is necessary to deepen the scientific-technical, economic, political, institutional, and social levels, so each country determines the best way to develop its bioeconomy.

In this paper, we have presented a brief analysis related to the strengths, weaknesses and opportunities for each of the bioeconomy routes from the perspective of policy and institutions using some countries as examples.

Not all routes of the bioeconomy will be replicated in all LAC countries or in the same way. The high degree of heterogeneity between and within countries for each route makes necessary to analyze the situation in each country or region to identify potential areas, specific business actors and institutions which will build on the development of a route. Similarly, these analyses will identify the institutional gaps related to poor articulation and unclear definition and distribution of roles and responsibilities. It will also assess the strengthening of existing policies or creating new ones, so the governments can be able to envision and realize their bioeconomy development.

It is clearly understood that for the development of the bioeconomy, policies should be clear, streamlined, simplified and stable. And if a policy is not complete or good enough, it should be changed, but in the case this happens it will be necessary to comply with the initial one. *Dura* *lex sed lex* and the bioeconomy with all routes must meet this assumption, particularly in aspects of access to genetic resources and other biodiversity elements.

On the other hand, for the development of bioeconomy, public institutions should make things work by generating good policies. On its side, the private sector is responsible for: taking risks, act responsibly, accurately and efficiently respond, and certainly generate wealth.

Some of the necessary policies should focus on attracting investment through legal stability, for example, related to access to genetic resources and the promotion of investment in science, technology and innovation, allowing the development of profitable business based on biotechnology and biodiversity. Specific policies are essential regarding, for instance, water and land use, access to genetic resources for commercial purposes, promoting the use of clean technologies and implementation of biosafety regulatory frameworks, among others. Meanwhile, biofuel policies that encourage investment (*e.g.* tax incentives) and use (*e.g.* use of fuel mixtures) have shown to be efficient for industry consolidation. It will also be important to focus policies leading to building of human resources capacity and the incorporation of such trained-personnel in public and private institutions.

For any of the bioeconomy routes developed and supported by the LAC countries it is essential to define the role to be played by small producers who hope that bioeconomy is not a simple training program for providers (primary resource owners) that allows selling raw materials to potential buyers ("owners" of knowledge). The viability and success of the knowledge-based bioeconomy for LAC will depend on schemes that demonstrate a real application of knowledge, enabling the generation of added value by supporting small producers and their incorporation into profitable markets. In order to reach these goals, working hard, specially on the policy side, will be essential, because for the vast majority of countries small farmers have not been subject to the current policies that promote the bioeconomy routes.

Finally, it is clear that bioeconomy will not develop spontaneously and it will require that institutions and policies can stimulate investment, generate knowledge and articulate with profitable markets. Examples presented here reflect an overview, but each country will need to perform a timely exercise in order to determine the actual institutions and policy instruments available to each.

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Social, Economic and Environmental Impacts of Bioeconomy in Latin America and the Caribbean

Guillermo Alfonso Valbuena[1]

Introduction

Prospective analysis of regional trends in the economy places Bioeconomy as one of the key strategies for the future, which significantly will influence the economic growth of several Latin American economies.

The challenges for the implementation of bioeconomy will focus on applying innovative strategies and processes that will enhance the adaptation of the current business models to new market trends; integrating the value chain from a sustainability perspective; generating collaborative business models favoring the shared production of knowledge (knowledge brokers); encouraging greater participation of Small-to-Medium size Entreprises (SMEs) in the market, due to reduced costs in research and development; strengthening regulations and regulatory processes in relation to biodiversity, minimizing uncertainty for access to genetic resources and improvement of intellectual property guidelines to ensure the ownership of products generated from biomass; developing new technology to boost bioeconomy; developing investment and integration policies between government, industry, and universities; and public acceptance of bioeconomy.

The benefits generated by biodiversity should be equitable and fair, encourage economic, social and environmental development as well as the transfer of the technologies necessary for the valuation, analysis and sustainable use of biodiversity (Andrade *et al.*, 2012)[2] in the region.

Biotechnology will generate competitive and sustainable advantages for the development of bioeconomy, if applied to primary production, health, energy, pharmaceutical processes, materials and industry in general. The application of biotechnology will increase productivity, yields

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2 An invaluable biological source is the unknown potential of genes, species and ecosystems.

and efficiency of the processes of production and marketing of bio-products, generating positive impacts on the economy, society and environment.

The United Nations Conference on Trade and Development (UNCTAD), considers, among its efforts to develop fair bio-trade, the contribution to conservation and sustainable use of biological diversity in the provision of services and investment, and compliance to regulations on intellectual property rights.

The biodiversity index of the World Bank shows the relative biodiversity potential for each country, where zero corresponds to a country with no biodiversity potential, up to 100 to a country that has the greatest biodiversity potential. In 2008, some biodiversity indexes for Latin America and the Caribbean (LAC) were: Brazil (100.0), Mexico (68.7), Colombia (51.5), Peru (33.4), Ecuador (29.3), Venezuela RB (25.3), Argentina (17.7), Chile (15.3), Bolivia (12.5), Panama (10.9), Costa Rica (9.7), Guatemala (8.0), Honduras (7.2), Dominican Republic (6.0), Haiti (5.2), Jamaica (4.4), Puerto Rico (4.4), Nicaragua (3.3) and El Salvador (0.9) (World Bank, 2012).

The socioeconomic impact of the bioeconomy in LAC will depend on the levels of investment in research and development, policies and regulatory measures, the implementation of emerging business models for biotechnology, social acceptance and strengthening synergies between the different actors involved, among others.

The development of a sustainable bioeconomy in LAC will have positive environmental impacts, keeping in mind that there are still many challenges to ensure sustainability, such as the decline of economic activities that cause biodiversity loss.

Social and Economic Impact

The bioeconomy policy agenda for 2030, developed by the Organization for Economic Cooperation and Development (OECD), provided for the application of biotechnology to improve crops for human consumption, therapeutics, functional products, pharmaceuticals, as well as for the development of bioprocesses with enzymes, chemicals and biosensors, among others, all of which will promote the development of biotechnology research with commercial applications.

This should be supported by research and innovation policies that enable the creation of synergies and development of strategic skills in order to support the expansion of existing markets and the development of new ones, with standards of sustainability and valuation of biodiversity.

The opportunities for bioeconomy development in LAC are countless due to the richness of biodiversity in the region, allowing the generation of strategic and added-value applications of biotechnology to generate new products, processes and strengthening value chains.

The conservation and sustainable use of biodiversity is a pillar for the implementation of bioeconomy, which stands on biotrade development, and is defined as the production, processing and marketing of goods and services derived from genetic resources, species and ecosystems, under the criteria of economic, social and environmental sustainability.

Technological innovations should emphasize the combination and/or adaptation of existing and newer technologies, having the former a key role in finding new applications, while the latter ones correspond to advances in the conversion of biomass into products or processes. The implementation of technological innovations influences favorably an economic growth in the region, increasing revenues derived from the biotechnology industry in its multiple fields of application.

The advantages of the new applications include new options for rural and regional development. Brazil is one of the biggest drivers in the region. In this country the development of bioengineering is a fundamental part of the regional development programs. Another advantage is the diversification of energy products from renewable energy utilization. In addition to Brazil, other countries in the region such as Mexico and Colombia have great development potential. On the other hand, new applications will contribute to reducing greenhouse gas emissions.

As for crop improvement, it is expected that new applications will help to create a wide range of bioproducts economically viable that will support the sustainable production of raw materials, thus mitigating the impacts of high-rocketing prices, which are influenced mainly by the behavior of oil. This should lead to reduced use of fossil materials in the elaboration of products and services. This is an important policy issue for LAC, because many countries in the region depend on the exports of raw materials, and therefore they are exposed to the risky global fluctuation of their prices.

The increased use of biomass offers development opportunities for rural areas of LAC, support for increasing employment and income, bioproduction at a lower cost and more efficient energy processes. Technology adaptation is a highly dynamic process, because the innovative technologies must gradually adapt to industry and consumers.

The strategy of development of biotechnology in the region should be based on significant investment on research and development. In 2009, worldwide it was spent on both 2.21% as a percentage of gross domestic products (GDP). In countries like Israel and Finland it was 4.49% and 3.38%, respectively; while for LAC such as Argentina, Bolivia, Brazil and Colombia, spending on research and development reached only 0.60; 0, 16; 1.17 and 0.16%, respectively (World Bank, 2012).

The transfer of net flows of foreign, direct investment for 2012, in the following countries was (in USD millions): Argentina (12.551), Brazil (76.111), Chile (30.323), Colombia (15.823), Mexico (12.659) and Venezuela (2.199). Comparatively, China's level of foreign, direct investment flows was 253.475 million (World Bank, 2012).

In this process it is necessary to increase public and private spending on research and development, and a greater participation of foreign, direct investment in economic activities that boost biotechnology development.

On the other hand, regulation must allow necessary and sufficient conditions for the efficient development of biotechnological applications, for example, ensuring a predictable regulatory environment. Higher regulatory costs only provide competitive advantages to large companies, discouraging innovation processes in smaller ones. Regulation that prohibits the use of generic technology can have detrimental effects on the development of bioeconomy and innovation.

In the case of Colombia, the regulations on Contracts to Access Genetic Resources (CARGs)[3], are one of the main concerns of small businesses, universities, etc., that use them as input in their research programs. Not having adequate CARGs limits their ability to participate in the progress and development of bioeconomy. Regulatory processes should encourage innovation, research and development, public-private partnerships or joint ventures (Chavarriaga & Valbuena, 2013).

For the development of bioeconomy it is also required the strengthening of skills needed to increase the interdisciplinary nature of biotechnology, including experts in computer science, chemistry, engineering, physics, law, social sciences and business, working together in the development of product innovation.

The social attitude in relation to the biotechnology market is an important factor, since the acceptance of biotechnology varies according to applications and the beliefs and experiences of society. For example, regarding the application of biotechnology for the development of vaccines, it does not present a broad range of views, while for biotechnology applications in cells and genetic testing in humans, opinion diverges more.

To minimize the social cost that the biomass use could produce on local populations and for the protection of traditional knowledge of the region, there must be an adequate framework which ensures conservation and sustainable use of biodiversity.

The latest publication of biodiversity status (biodiversity barometer) by the Union for Ethical Bio-Trade (2013), provides relevant information about the consumer awareness regarding biodiversity. In the case of LAC, the status was determined only in Brazil and Peru. One result is that 90% of consumers interviewed had heard about the preservation of ecosystems, fair trade, etc., highlighting Brazil and China that have a significant awareness regarding the preservation of

3 Aditionally, topics related with intellectual property rights such as registered brand, patents, trade secret and copyright.

biodiversity. Additionally, 98% of Brazilian consumers demand products that use, for its preparation, natural ingredients.

The ethical vision of society favorably influences the development of bioeconomy, for its impact on the creation of laws and regulations regarding biotechnology research, application of new business models and potential biomarkets.

The emerging business models in biotechnology that will play an important role in the development of the bioeconomy in LAC, are the integrated and collaborative ones. The first refers to maintaining and adapting existing market models, coordinating the different actors along the value chain. The other model focus on reducing the costs of research and shared knowledge generation, allowing the development of a collaborative networking to reduce transaction costs to acquire new knowledge, and reducing costs in the acquisition of licenses, among others. A concrete result of these models is to reduce research and development costs, increasing technological progress and innovation, and the creation of markets or shared knowledge brokers that increase the participation of buyers and sellers of specialized knowledge, due to reduced transaction costs (OECD, 2009).

At a company level, a strategy for the implementation of sustainable practices is the collaboration for innovation. A case in point is the collaboration to improve information flows, where together the companies and providers administer the company to ensure broad flow, ensuring collaboration and sharing of relevant information on sustainability.

The implementation of emerging models will be reflected in increasing revenue through the creation of new business models, innovation to develop new services and products, decreasing costs due to improved energy efficiency and integration of production chains and also in increasing transparency of businesses.

In the information from the World Bank's Doing Business (World Bank, 2013), it is determined that many countries in LAC must strengthen the ease of doing businesses. In 2013, Chile (37), Peru (43), Colombia (45) and Mexico (48) were the Latin American countries where it was easier to conduct business, occupying the top positions in the region; while Nicaragua (125), Honduras (130), Brazil (130) and Ecuador (139), do not have such favorable positions. Singapore (1) Hong Kong (2), New Zealand (3) and the United States (4) are the countries with the best positions in the rating scale[4].

In order to achieve a positive economic impact, the development of bioeconomy must ensure an advantageous business environment that allows significant investment levels.

4 The analysis focuses on small and medium enterprises. The sample corresponds to 185 countries.

Environmental Impact

In Latin America and the Caribbean, the most megadiverse countries are Brazil and Colombia followed by Mexico, Venezuela and Ecuador. One of the challenges of environmental policy in this region is to strengthen systems and mechanisms to reduce the impact of activities that are detrimental to the conservation of biological diversity.

Among the causes of biodiversity loss are: the transformation of ecosystems, overexploitation, habitat transformation, policies that overstimulate land use and excessive development of infrastructure projects (Andrade, 2011).

Among the main challenges for policy makers to take advantage of the potential of the bioeconomy in LAC, are reducing carbon dependency, improve energy efficiency and conservation, mitigating the effects of climate change, reduce ecosystems degradation and consumable water scarcity, and increase investment levels to ensure environment's and biodiversity's sustainability.

Climate change has adverse effects on biodiversity, for example, changes in the composition of the atmosphere by greenhouse gas effects that impact the distribution of species.

Greenhouse gas emission[5] by the year 2009 were 4.7 tmpc globally, while LAC and East Asia & Pacific emissions produced were 2.6 and 4.6 tmpc, respectively, much lower than those recorded by OECD countries (10.0 tmpc) (World Bank, 2012).

The vast majority of LAC economies are highly dependent on commodity exports, being them highly exposed to climate risk caused by the uncertainty in climate change, thus affecting food policy decisions at the regional and local levels. Therefore, to reduce such risk, LAC should implement investment strategies, innovations in the rural sector, increase access to financial instruments, develop better economic practices, strategic communication channels and adaptation of production systems, ensuring sustainability and climate change adaptation.

The development of a bioeconomy in a sustainable manner will have positive environmental impacts in the region, because it will generate conditions that mitigate the causes of biodiversity loss.

Final Thoughts

Threats must be transformed into chances to develop bioeconomy in the region. Therefore, climate change and technological, financial and regulatory uncertainty, among other threats, must be managed to turn them into opportunities. It requires an integrated and collaborative structure that includes:

5 Expressed as per capita metric tons.

- The interaction between the public and private sector to promote research, development and innovation (R & D & I), with skills training on new applications of knowledge.
- The competitiveness of markets for developing a sustainability assessment, to ensure the availability of biomass, the strengthening of integration of supply chains, and the supply of relevant information for the consumers, for example, product's properties.
- The integration of policies including the international, national, regional and local communities. The international community should play an important role in the transfer of knowledge, provide financing mechanisms, climate investment funds, etc..

Emerging business models for biotechnology must have a good adaptation to the social, economic and environmental conditions of the region.

More investment is needed in sciences since it is a necessary though not sufficient condition for the development of bioeconomy, requiring the strengthening of partnerships between the academia, the government and the private sector.

Summarizing, there are high expectations and a broadly and favorable landscape for the development of the bioeconomy in Latin America and the Caribbean.

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Current Status and Potential of Knowledge Based Bio-Economy Related with Research & Innovation in LAC

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Introduction

In the last decade the Bioeconomy (BE) concept has gained importance not only for European countries, but for the entire world. To a large extent this is caused by climate changes consequences and future food security, poverty and energy challenges, among other topics. However, its relevance and implications are quite different depending on the countries' strategies (policies, economic and environmental). In this context, this paper pretends to analyze the Research & Innovation (R&I) capacities of Latin America and the Caribbean (LAC) countries toward the Bioeconomy and develop some recommendations to support the adoption of this concept in the region. The first part of this document provides a background about LAC capacities in R&I, especially regarding agriculture and environment. Following, a description of relevant topics related to BE. The third part includes the analysis, conclusions and recommendations.

History and Current Importance of Bioeconomy (BE) Related with R&I in LAC

Latin America is a highly heterogeneous region. Each country implements its regulatory frameworks, policies and strategies in different ways. Nevertheless, countries have common characteristics, such as their high inequity levels or their dependence on commodity exports. In the agricultural sector the situation is similar. In general, the region has a common objective: to increase

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production and yields, with the purpose of achieving better living standards and food sovereignty, preserving the environment and retrieving local knowledge (Bin *et al.,* 2009; Echeverria and Trigo, 2008). However, strategies to achieve those goals vary among countries.

Currently, LAC societies need to increase agricultural production and technology as a powerful tool although it is a partial response. Nevertheless, with the current conventional techniques, environmental costs could be too high. For this reason, the intensive use of modern technologies is proposed as a strategy for production increase, while reducing the environmental impacts. Bioeconomy is based on the intensive implementation of the knowledge on the conversion of natural resources to produce goods and services, as well as create new value chains (Trigo, 2011a). For developing and implementing this concept, it is necessary to have agricultural research systems with qualified human resources, a modern infrastructure, a regulatory framework and policy tools that integrate them with the new trends. Actually, the resources assigned to R&I continue to be significantly different between developed and developing countries. However, the latter ones exhibit a change in their strategies on the agricultural sector. The same happens in China and India, and some LAC countries. In the following paragraphs a brief description will be given on the R&I potential in the region.

In general, the structure of the agricultural research system in LAC is similar among countries, but its implementation varies depending, in many cases, on government policies. During the 60's and 70's the region adopted a model focused on the creation of National Agricultural Research Institutes (NARs) for developing the agricultural research sector. The initial idea was to respond to the demands for increasing agricultural production and productivity. NARs had a strong support from the public and international sector. However, during the last decades, the economic models and goals in the region have changed, and agricultural sectors were affected, and therefore the whole system. NARs in many cases lost their principal focus (research) and became in development institutes and also in some cases (mainly in Central America and the Andean Region) have been politicized and weakened. By contrast, in other countries they have been significantly strengthened, like Brazil. Currently, agricultural research systems include a new range of actors, such as universities, institutes, research centers, NGOs and, to a lesser degree, the private sector. The exceptions to this system are Chile, Argentina and Brazil, where the private sector has acquired importance. Furthermore, the research topics have changed mainly focusing on breeding improved varieties to increase productivity and have an impact on a socioeconomic (poverty and food security) and environmental level.

Some countries have developed initiatives to design and implement coordinated and efficient systems. This would be reflected in the capacity to adopt and distribute the technologies inside and outside of the frontiers. Ardila and Sain (2009) (Trigo 2011b) evaluate the LAC countries based on a *scientific capacity index* (number of researchers and publications), *capital innovation index* (The percentage of research resources as part of the GDP and number of researchers per a geographical unit) and *imitation index* (education and number of extensionists per geographic unit). The results grouped countries into three categories (see Table 1), which can be the equivalent of local/external offers, a local and external client offers respectively. These patterns will be reflected, in general, in the different areas related to R&I in the LAC region.

Table 1. Capacity of technological diffusion and adoption in the LAC countries

Generation capacity/use	Description	Countries
High	Countries with high capacity to diffuse and adopt technologies both, inside or outside	Brazil, Argentina, Mexico, Chile
Medium	Countries with high local capacity of adopting technologies, but low external influence	Venezuela, Cuba, Colombia, Uruguay, Costa Rica, Peru, Panama, Jamaica, Ecuador
Low	Low capacity of technological diffusion and adoption both, national and international	Bolivia, Honduras, Guatemala, El Salvador, Nicaragua, Paraguay, Dominican Rep., Haiti, Belize, Rest of Caribbean

Source: Sain and Ardila (2009) in Trigo (2011b)

International markets demand new agricultural products based on sustainable and efficient processes. To allow a competitive position in this scenario, LAC countries have to create integral and coordinated research systems.

Investments in Agricultural Research

The capacities of the agricultural research systems differ among the countries of the region. The policies and tools that coordinate the systems could be an explanation for the differences. Another point is the institutions capacities (availability of infrastructure, financial and human resources). There are important differences from countries such as Brazil and Mexico, compared to Paraguay or Panama. In the former case, Brazilian governments during the last decades have transformed support on agriculture research into a state policy. This explains the current increase of the R&I

capacities in the country. Stads y Beintema (2009) gathered figures on public agriculture capacities and investment in 15 LAC countries. The results reflected Brazil's position and showed that 60% from the resources invested on R&I in the region are only in two countries (Table 2). In addition, most of the agricultural R&I is executed and financed by the public sector. According to the mentioned study, in 2006 there were 19,000 agricultural researchers (full time equivalent researchers) in LAC; Brazil, Mexico and Argentina employed 70% of all LAC researchers. From all agricultural research staff hired in 15 LAC countries, 33% hold a PhD, 32% a Master's degree and 34% a Bachelor degree. In the last decade, Argentina and Uruguay have been the countries showing the highest growth rates in qualified staff, compared to the lowest growth rates by countries in Central America. In a global context, the LAC invests in agricultural R&I was 2,800 million USD in 2000, equivalent to 12% of the world (23,000 million USD). This percentage was 14% in 1981. The decrease over time can be explained by increased investments in agricultural R&I in China and India.

Other highlighted information that illustrates the situation of LAC in research and innovation are the number of patents and publications. Considerate as a whole, LAC has a fifth of all USA publications and only three countries (Brazil, Argentina and Mexico) hold 80% of the scientific articles production in the region. On the issue of patents, the difference is even greater: All patents LAC produces are 20 times less than those of Germany (Table 3).

Innovation and Agricultural Research Funding

To stimulate the adoption of technologies (innovation) some governments in the region established national funds for promoting innovation. Brazil, followed by Argentina, Chile and Mexico are the most relevant cases of the S&T funds implementation.

In Chile, during the 90's, it was created the first Science and Technology Program, the government aimed to increase economic growth and sustain it through improved productivity. This program was operated initially with three competitive funds: Fontec, Fondef and Fondecyt. In 1996 the Science and Technology of the National Innovation System was consolidated, as a part of the Technology Innovation Program (PIT), which constituted a basic component of the policy of scientific and technological development government. The PIT through the introduction of competitive funds sought to ensure the relevance of S&T projects, catalyze a rapid development of technological innovation, encourage private sector participation, modernize public institutions and contribute to the formation of high quality human resources. Many funds required the private sector to fund research projects. This participation has resulted, in general, in a contribution in kind. The participation of private sector is still low compared with developed countries. The funds, aware of this situation, in recent years have developed various strategies to strengthen private

Table 2. Public Investment in Agricultural Research in LAC (millions of PPP dollars 2005)

Country	Total Investment				Annual growth rate (%)		
	1981	1991	2001	2006	1981 1991	1991-2001	2001 2006
Brazil	1.005,4	1.432,5	1.194,9	1.224,1	2.99	1.36	0.66
Mexico	517,6	369,2	437,0	517,6	-3.2	0.85	2.98
Argentina	202,7	199,0	221,9	448,6	2.57	1.33	16.01
Colombia	104,0	135	176,3	152,4	3.73	3.92	3.75
Chile	58,2	65,6	124,3	98,1	5.554	6.71	4.63
Uruguay	17,6	28,5	41,0	59,8	8.3	0.8	9.71
Costa Rica	13,4	20,9	26,7	29,9	-0.49	1.07	2.82
Nicaragua	11,6	14,6	22,5	24,1	1.28	4.03	-2.27
Dominican R	14,8	12,2	14,6	17,4	-1.99	1.83	4.17
Honduras	5,5	15,8	13,0	11,0	14.6	0.68	2.94
Panama	10,1	12,6	10,5	10,0	1.35	-0.68	-0.98
Guatemala	21,4	11,4	9	8,3	-1.43	-4.7	-2.04
El Salvador	13,5	10,5	6	5,7	-2.227	-5.48	-3.32
Paraguay	2,8	3,4	2,6	3,1	-6.53	-3.41	1.24
Belize	1,0	2,3	2,3	2,6	2.5	1.33	2.38
Total sample (15)	1.999,7	2.333,6	2.303,5	2.614,5	1.79	-0.12	2.56
Total (26)	2.274,7	2.697,5	2.072,9	2.983,4	1.86	0.02	2.14

Source: Stads y Beintema (2009)

Table 3. National Patent Applications

Country	2010	Country	2010
Argentina	801	Panama	-
Bolivia	-	Peru	39
Brazil	2.705	Uruguay	23
Chile	328	Venezuela, RB	-
Colombia	133	China	293.066
Costa Rica	-	Germany	47.047
Ecuador	4	India (2009)	7.262
Guatemala	7	Israel	1.450
Honduras	-	Spain	3.566
Jamaica	-	United Kingdom	15.490
Mexico	951	United States	241.977
Nicaragua	-		

Source: //data.worldbank.org/indicator/IP.PAT.RESD/countries

participation and diffusion of results. For example, Corfo (through Innova) has created a fund for financing 12 months of negotiation and consolidation in projects that involved public and private partnerships. Fondef (Conicyt financing line) has launched a line of technology diffusion for projects that have successfully completed the research phase. In addition, the grant fund is becoming more demanding in seeking private sector to provide new resources to research rather than in a contribution in kind, in order to generate greater commitment to their participation in the alliance (Engler-Palma, Johnson and Gonzalez, 2006).

There are 14 funds promoting strategic sectors in Brazil. The idea is to support the R&I activities but also to encourage the adoption and diffusion of results. The same idea is being implemented in Argentina: the Fondo Tecnológico Argentino (Fontar) financed by public resources, seeks to generate clusters, alliances, support enterprises through public grants (Trigo, 2011b). Other countries such as Colombia are trying to develop these types of mechanisms (innovation funds) complemented with additional strategies as the parafiscal incentives. A distinctive feature of Colombian agricultural research is the significant private sector contributions channeled through sub-sector industry associations. Since the 1940s, the Colombian government has enabled social and economic groups to establish parafiscal associations that raise funds for use by specific agricultural sub-sectors. As the national government began to abandon support to producers in the 1990s, these associations have assumed increasing responsibilities. The administration of the producer associations manages the allocation of funds among various initiatives. Investments address themes of research and extension, sanitary controls, marketing, export and consumption promotions, price stabilization, and general activities and infrastructure for the socio-economic benefit of the sub-sector. Parafiscal funds, raised through mandatory or voluntary levies on production or exports, are not part of the national budget and they are considered private resources.

In Mexico, the Secretary of Agriculture, Livestock, Rural Development, Fisheries and Food (Sagarpa) have a program budget called "National Agricultural Research System" (SNIA) to stimulate the adoption of technologies. This program allocates resources to three policy instruments: Sectorial Fund of Research in Agriculture, Livestock, Aquaculture, Agricultural Biotechnology and Plant Genetic Resources (Sagarpa-Conacyt Sector Fund), National System of Research and Technology Transfer for Sustainable Rural Development (Snitt) and scientific cooperation agreements. Sectorial Funds are trusts that the agencies and entities of Federal Public Administration in conjunction with the National Council for Science and Technology (Conacyt) can constitute to assign resources to scientific research and technological development at the sector concerned. For its part Snitt aims to coordinate and schedule the actions of public, private and social organizations that promote and conduct scientific research, technological development, validation and transfer of knowledge in the agricultural sector (Conacyt, 2010).

Scope, Approach and Methods

Based on the Project ALCUE–KBBE framework and considering the document's guidelines of "Concept Note on inclusive rural and economic development KBBE opportunities in LAC" (2011a) four broad Bioeconomy areas were defined: (a) Biofuels, (b) Biotechnology, (c) Biodiversity and (d) Ecological intensification. A brief discussion on these topics will be reported in some key LAC countries, which have a technological proposal in the defined areas (human resources and infrastructure):

Biofuels

In LAC, the biofuels sector is probably one of the areas with more strength, basically because many governments in the region support this sector. An assessment on the biofuels R&I will be conducted based on a literature review and experts' opinion. Regional capacities have been distributed in three country groups, taking into account their human and financial resources and public policies on which these countries rely on.

The first group includes Argentina, Brazil and Colombia: they are provided with a critical mass of researchers in several areas related to biofuels, such as agricultural, chemistry, and engineering research. The first two countries have an established market with enormous economic potential; meanwhile Colombia has programs that seek to produce capital in the biofuels sector. Moreover, the country has currently established research institutions and commercial organizations looking for new business opportunities (Cepal, 2011).

Mexico, Chile and Peru form a second group: Chile begins to venture in this area, based on its capacities of high profile universities, agriculture research centers and a potential production of biofuels. Peru also has an established research system but this is less competitive. However, the country is making efforts to increase the potential of the agricultural system in the near future. Mexico has a high-level research sector and a potential production in biomass and algae, but its energy sector is highly regulated and there is no favorable environment for massive initiatives in the biofuel sector (Cepal, 2011).

Countries with production potential and different energy demands form the third country group, but a common factor is not having a solid R&I national platform on the biofuel sector (e.g. Paraguay).

In order to obtain an estimate of the quality of research in the region, we conducted a search of the number of articles published in each of the areas that integrate the bioeconomy, described in this project, between which biofuel is. This study allowed knowing, additionally, the outstanding institutions for each of the areas (Table 4). This could guide the potential partners to present and develop future proposals.

In the case of biofuels, since 2000, around 65 LAC organizations have published articles in refereed journals. 41 of them are universities and 22 are research institutes. The 11.3% of the total number of articles published in this decade (2,750) were developed in LAC. The following table presents the first five universities and research centers in the LAC countries with publications in this area.

During the last 30 years new biotechnologies have been developed and used as a solution for agricultural and environmental problems. The three mentioned areas (biotechnology, biodiversity and eco intensification) are connected/overlapped in many cases. In the following paragraphs a more detailed description of the three areas is developed.

Biotechnology

The biotechnology techniques have been widely adopted and used in LAC agriculture. However, only few countries integrate and use them as an aggregate value for the agricultural sector. Since

Table 4. LAC leading Organizations that have published about biofuels, since 2000

Brazil	Argentina	Mexico	Chile	Colombia
Universida de Sao Paulo (1)*	Universidad de Buenos Aires	Univ. Nacional Autónoma de México (5) Unam	University of Concepcion Chile	Universidad de Antioquia
Universidade Estadual de Campinas (2)	Universidad Nacional de Córdoba	Colegio de Postgraduados	Universidad Austral de Chile	Universidad de Caldas
Universidade Federal do Rio de Janeiro (5)	Universidad Nacional de San Luis		Universidad de Talca	Univ. Nacional de Colombia Medellín
UNESP-Universidade Estadual Paulista (6)	Universidad Nacional de San Juan		Pontificia Universidad Católica de Chile	Universidad Nacional de Colombia
Univ. Federal do Rio Grande do Sul (7)				
Empresa Brasileira de Pesquisa Agropecuária - Embrapa (3)	Instituto Nacional de Tecnología Agropecuaria Buenos Aires	CIAD-Centros Públicos de Investigación Conacyt		Centro Internacional de Agricultura Tropical- CIAT
Petrobras	Instituto de Investigaciones en Fisicoquímica de Cordoba	Instituto Politécnico Nacional		
Centro de Análises Proteômicas e Bioquímicas		Ipicyt-Centros Públicos de Investigación Conacyt		
Fundacao Oswaldo Cruz		Centro Internacional de Mejoramiento de Maíz y Trigo Cimmyt		
Instituto Nacional de Ciência e Tecnologia INCT do Bioetanol		Centro de Investigación y de Estudios Avanzados		

Source: ISI Web of Knowledge and Scopus; *( ) Ranking

the 80's, biotechnology has played an important role in the development of the region, especially for agriculture and food sectors. Nevertheless, only few countries have high scientific potential, that is, they possess a critical mass of high quality researchers with innovation ability and advanced research centers with experience in biotechnology applied to agricultural activities. Countries with an average capacity, represented by Colombia, have better potential resources (natural, physical and human) for biotechnological use. They also have relative solid institutional and regulatory frameworks, and an active but incipient participation from the private sector, even though the investments in R&I are small with a low level of integration. A third group of countries (as Paraguay or Bolivia) are characterized for having restricted qualified personnel for developments in biotechnology areas.

In general in LAC, the most frequently used techniques in biotechnological research are the conventional ones, and the infrastructure is scarce and dependent from the public sector (Trigo *et al*., 2010; Roca, 2004; IICA, 2008). Around 115 organizations in LAC involved in R&I activities have been reported in this area, 87 of which are universities. The top five are described in the table 5, complemented with the most relevant research centers in terms of publications.

Using the same methodology described above to determine the impact of research in the area of biotechnology, the following was found:

Biodiversity

Six mega-biodiverse countries in the world are in the LAC region (Brazil, Colombia, Ecuador, Mexico, Venezuela and Peru) and others are centers of diversity and the origin of many species (Costa Rica and Bolivia). Therefore, biodiversity constitutes an essential axis for the development of LAC countries BE. However there are not many examples to demonstrate it. In the next paragraphs, some aspects of this subject will be developed.

There is a limited use of genetic plant resources in the LAC countries in spite of the enormous native genetic diversity richness, even with important species worldwide, such as potato, corn, cassava and forage crops species, among others. This limited use of genetic agro-resources is generated by a series of factors such as: the absence of information about the description and evaluation of the natural resources and the limited documentation of existing genetic heritage; in addition to the deficiency of basic knowledge, especially about native species. In the same way, the lack of national programs for genetic modification of plants for some key species and, finally, the lack of financial resources as a result of the lack of interest of the governments in this area (IICA 2007; Quezada *et al*., 2009).

Whit respect to human resources, in the literature in general, there is not specific information about personnel working in biodiversity in LAC. The data are presented together with biotechnology because of the affinity of the areas. Some studies (Roca, 2004; Quezada *et al.*, 2009) reflect that structure: for example Bolivia (2004) had 30 research groups, 23 of them were working in agricultural and forest products, 4 in environmental and 3 in biopharmaceutical and cosmetics. Some of the projects are based on genetic resources use, mainly those related to the latter topics. However, it was not possible to extract information about the level or number of researchers or the infrastructure dedicated only to biodiversity studies.

In order to take full advantage of the biodiversity in the LAC countries it is important to (a) identify and exploit potential functions, and (b) conserve them for future purposes. In terms of conservation *in situ*, most countries in LAC have little support in activities of this nature. Nevertheless, some of them already declared their forests reserves. In LAC there are a particularly high number of protected areas: for example, in Brazil there are 1,297 areas (95 million acres are for native people/tribes) meanwhile the rest of South America (without Brazil) currently has 1,507 protected land areas that cover 22% of the subcontinent's terrestrial surface and 114 marine reserves. In 2006, the conservation *in situ* status in South America was critical in most of the countries. It is important to know that there are legal and institutional frameworks established in many countries of the region, although in fact there are missing more efforts to preserve fragile ecosystems highly intervened (IICA, 2006; Unesco, 2010). The same situation occurs in Mexico and some countries in Central America.

With respect to quality of research conducted in the LAC region: since 2000, 91 organizations have published 2,910 articles related to Biodiversity. This represents 8.5% of the total world publications. Table 6 describes first ten organizations per country. Again, universities represent more than 70%.

Eco-Intensification

The Eco-Intensification refers to an agronomic practice to improve the environmental performance of agricultural activity without sacrificing existing production/productivity levels. This concept includes: no-till agricultural practices, precision agriculture strategies, integrated nutrient management, organic production and clean technology. As in the case of biodiversity, there is very little regional literature available regarding human resources and infrastructure in regards to eco-intensification. The literature that exists is fragmented or derived from biotechnological studies. However, there is a tendency to develop this sector. Many of the institutes/organizations listed in above paragraphs have research groups working in the field of eco-intensification, without being

Table 5. LAC leading Organizations that have published about biotechnology since 2000.

Brazil	Mexico	Argentina	Chile	Colombia	Cuba	Venezuela
Universidade de Sao Paulo(1)	UNAM (6)	Universidad Nacional de La Plata	Universidad de Chile	Universidad de Los Andes	Universidad de La Habana	Universidad Central de Venezuela
Univ. Estadual de Campinas (2)	Univ. Autónoma Metropolitana	Universidad Nacional del Litoral	Univ. Nacional de Tucuman	Universidad Nacional de Colombia	University of Matanzas	Costa Rica
Univ. Federal do Rio de Janeiro(3)	Tecnológico de Monterrey	Universidad Nacional de Rosario	Pontificia Univ Católica de Chile	Universidad Industrial de Santander		Universidad de Costa Rica
Univ. Federal do Parana (5)	Universidad de Guadalajara	Universidad Nacional de Mar del Plata	Univ.of Concepcion Chile	Pontificia Universidad Javeriana		Bolivia
Universidade Federal do Rio Grande do Su (10)			Pontificia Universidad Católica de Valparaíso	Universidad de Antioquia		Universidad Mayor de San Simon Bolivia
Embrapa	Centro de Investigación y de Estudios Avanzados	Consejo de Investigaciones Científicas y Técnicas	Centro de Referencia Para Lactobacilos	Colombian Centre Genom Bioinformat Extreme Environmental	Center for Genetic Engineering Biotech. Havana (7)	

Brazil	Mexico	Argentina	Chile	Colombia	Cuba	Venezuela
Fundacao Oswaldo Cruz	Instituto Mexicano del Petróleo	Instituto Nac. de Tecnologia Agropecuaria Buenos Aires		CIAT	Cuban Institute for Research on Sugar Cane	
Instituto Butantan	CICY-Centros Públicos de Investigación Conacyt	Planta Piloto de Procesos Industriales Microbiologia				
Centro de Análises Proteômica Bioquímica	Ipicyt Centros Públicos de Investig. Conacyt					
Petrobras	Cimmyt					

Source: ISI Web of Knowledge and Scopus; *( ) Ranking

Table 6. LAC leading Organizations that have published on biodiversity, since 2000.

Brazil	Mexico	Argentina	Chile	Colombia	Costa Rica
Universidade de Sao Paulo (1)	Universidad Nacional Autónoma de México (2)	Universidad de Buenos Aires (5)	Universidad Nacional de Tucuman UNT	Universidad Nacional de Colombia	Universidad de Costa Rica
Universidade Federal do Rio de Janeiro (3)	El Colegio de la Frontera Sur	Centro Regional Universitario Bariloche	Universidad de Chile	Universidad de los Andes	
UNESP-Universidade Estadual Paulista (4)	Universidad Veracruzana	Universidad Nacional de Córdoba	Pontificia Universidad Católica de Chile	Universidad del Valle	
Universidade Federal de Minas Gerais (8)	Universidad de Guadalajara	Universidad Nacional de La Plata	Universidad de Concepción		
Universidade Federal de Goias (9)		Universidad Nacional de Mar del Plata	Universidad Santiago de Chile		
Instituto Nacional de Pesquisas Da Amazonia (7)	Instituto de Ecología, A. C.	Consejo de Investigaciones Científicas y Técnica (6)		CIAT	Catie
Empresa Brasileira de Pesquisa Agropecuária – Embrapa	Centro de Investigaciones Biológicas Del Noroeste	Instituto Nacional de Tecnología Agropecuaria Buenos Aires			

Brazil	Mexico	Argentina	Chile	Colombia	Costa Rica
Instituto de Botânica de Sao Paulo	Cinvestav Unidad Merida	Museo Argentino de Ciencias Naturales Bernardino Rivadavia			
Museu Paraense Emilio Goeldi	Centro de Investigación Científica y de Educación Superior de Ensenada	Museo de La Plata			
Instituto Agronômico	Centro Internacional de Mejoramiento de Maíz y Trigo	Comisión de Investigaciones Científicas - La Plata			

Source: ISI Web of Knowledge and Scopus; *( ) Ranking

designated as such. Additionally, in the field of Integrated Pest Management (IPM) there are some relevant existing programs and networks, such as the Farmer Field School (FFS-project developed by the FAO), which seek to help farmers tailor their IPM practices to diverse and dynamic ecological conditions. In Bolivia and Peru, this program has been adapted for the potato. Results indicate that FFS graduates acquired the knowledge necessary for the management of late blight, which led in substantial income increases (www.fao.org). Other examples include the Sicta net (http://www.redsicta.org/), focused on the sustainable production of beans and maize in Central America, and various successful programs run by NARs such as INTA (Argentina) and Embrapa (Brazil).

Other case to highlight is the organic agriculture in Brazil: during the last years, developing countries are beginning to see these crops as a new market opportunity. Regarding the Brazilian case, at the end of the last decade, the country regulated this activity and started to finance the agro-industry development in this sector as well as research projects (in 2001 the state government of Parana trained more than 100 professionals on this area). It is expected that there are at least three universities that offer graduate courses and PhD's with organic agriculture as the major field, and five institutes dedicated to this subject development. The associations that join organic producers, also provide technical assistance. There are two NGOs: Cepagri and AS–PTA (FAO 2001).

Both Brazil and Argentina show important technological advances in the area of zero-tillage. In the last 30 years, Brazil has experimented with and adopted systems for improving soil conditions. In 1969 the Federal University of Rio Grande do Sul developed the first scientific zero-till trial. Following this line of research, other universities, Federal research institutes, and Embrapa have been developing breeding programs to enhance various crops' suitability to zero-till conditions. In the past ten years, also farmer and multinational organizations have joined the research in this area (Bolliger *et al.*, 2006).

In Argentina, during the 90's, the adoptions of zero-tillage together with the GM soybean were the key factors to position the country as a leader in international markets. This transformation process was based on innovative alliances involving researchers, farmers, public and private sector. Stakeholders are members of the important (thematic) entity Apreesid. Currently, the National Institute of Agricultural Technology (Instituto Nacional de Tecnología Agropecuaria, INTA) has a critical mass of experts working in soils, degradation, and friendly technologies with the environment. This work is supplemented with extension staff, private technical assistance providers, farmers, input suppliers, and other related institutions, generating a successful innovation process (Trigo *et al.*, 2009). On-farm experiments are also conducted through the network Crea.

Regulatory efforts in Mexico for organic agriculture began in 1995 and in February 2006 the Law of Organic Products was published in the Official Journal of the Federation. It seeks to

Table 7. LAC leading Organizations that have published about Eco-intensification (no tillage) since 2000.

Brazil	Mexico	Argentina	Chile	Colombia
UNESP-Universidade Estadual Paulista (1)	Colegio de Postgraduados	Universidad de Buenos Aires	Universidad de la Frontera	
Univ. Federal do Rio Grande do Sul (3)		Univ. Nacional de Mar del Plata	Universidad de Chile	
Universidade Federal de Santa Maria (4)		Univ. Nacional de Rio Cuarto	Univ.Concepción Chile	
Universidade de Sao Paulo (5)		Univ. Nacional de Rosario	Universidad Austral de Chile	
Universidade Federal de Vicosa (7)		Universidad Nacional de La Plata	Universidad Nacional de Tucuman UNT	
Empresa Brasileira de Pesquisa Agropecuária - Embrapa (2)	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias	Instituto Nacional de Tecnología Agropecuaria Buenos Aires (6)		CIAT
Instituto Agronomico do Parana	Cimmyt	Consejo de Investigaciones Científicas y Técnicas		
Instituto Agronômico	Centro de Investigación y de Estudios Avanzados	Instituto de Botánica Carlos Spegazzini		
Epagri-Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina S. A.		Comisión de Investigaciones Científicas-La Plata		
Empresa de Pesquisa Agropecuária de Minas Gerais		Comisión Nacional de Energía Atómica Argentina		

Source: ISI Web of Knowledge and Scopus; *( ) Ranking

promote, among other things, to access to alternative income and employment, to conserve natural resources and produce healthier foods. The regulations of this law were published in 2010. The National Organic Production Council (CNPO) was also created, which acts as a promoter of organic agriculture in Mexico and as advisor to the Secretary of Agriculture (Sagarpa) in terms of technical and regulatory matters. In Mexico more than 45 organic products are cultivated. The organic sector is the most dynamic agricultural sub-sector in Mexico, having increased its organically cultivated area from 23,000 hectares in 1996 to 400,000 hectares in 2008. During 2011, there were 128,000 producers and 394 million dollars in foreign exchange.

In terms of quality publications, the Table 7 includes the top 10 organizations per country. It is important to mention that around 30% of the publications in the world have been developed in LAC, different from the other topics. However, 90% of the institutions are from the South cone. This represents an opportunity for the sub-region to export knowledge not only in LAC but also for the entire world.

Analysis and Results

Some of the key aspects are analyzed in the following paragraphs:

- *High concentration of scientific and research capacities in few countries of the region.* In general, the Southern Cone (Brazil, Argentina and Chile) and Mexico are the countries that present the greatest institutional R&I capacity in LAC. In comparison to others in the region these countries have high quality institutions and better-trained researchers.

Regarding the biofuels sector, the Southern Cone, specifically Brazil and Argentina, have significant research development relying on qualified staff and a regulatory framework that promotes this. However, they do not have yet the developed-countries level, mainly in terms of researcher's critical mass, patents and scientific papers production. There is a second group of countries that are trying to consolidate the biofuels sector: Chile, Colombia, Mexico and Peru, relying on government support but they do not have achieved so far an articulated R&I system in this sector. These countries have human capacities, but the projects are not linked as part of the country's strategy. A third group of countries that are interested in developing this sector, are potential customers for technology transfer.

In the biotechnology area, as a result of the R&I activities and the private sector alliances, biotechnology applications have evolved towards production and marketing products in the agro area in the Southern Cone. In countries such as Argentina and Brazil, and to a lesser degree in Chile, the progress has been constant for the last ten years and there is a tendency to keep growing.

The sub-region relies on a clear and evolving regulatory framework and it is a leader in genetically modified crops production in LAC, with more than 55 million of harvest hectares for 2011 (James, 2011). According to these features, it could be assumed that this group of countries will play a significant role in leading support to others in the region for the development of technological capacities.

- *Providers and Buyers:* There are great differences in innovation potential among the different countries in the region: Brazil, Mexico and Argentina are industry leaders; Bolivia, Ecuador, Paraguay and the Central American countries trail significantly behind. Brazil, the unquestionable leader of the region, has the advantage of substantial financial resources and the potential to act as a catalyst for continent-wide initiatives. Regional actors with fewer resources profit indirectly from the initiatives and the technologies of their larger neighbors. This suggests two country profiles: buyers of technology and creators/producers of technology. This dual profile situation can be fostered through measures of international cooperation.
- *"Brain Drain"*: Many countries in LAC have supported programs to increase the quantity of qualified regional researchers. However, very few of this countries have developed strategies to include these researchers in the R&I or production/industry sector.

Most of the LAC countries have significant infrastructure and human resources. They also have a good base of academic education programs and established groups with qualified scientists working in areas as biotechnology or biofuels. However, talent migration is an important issue in a competitive area as biotechnology, because the best job opportunities come from economically better-developed countries. Therefore, the management potential of research and development is relatively weak, as well as the institutional environment that holds it.

- *Public and Private Mechanism for Integration:* In recent decades, with the exception of a few countries, public expenditure for R&I in Latin America has declined substantially. In some cases this has resulted in low levels of technological innovation and a loss of competitiveness in the agricultural sector. In other countries, such as Colombia, Uruguay and Peru, the weakening of the public sector research has been simultaneously accompanied by a growth in private sector investment in science and technology. In Colombia, for example, although the number of biotechnological companies is relatively small, the private sector has compensated, investing in production and marketing of derivative products from conventional natural resources (Zurbriggen *et al.,* 2010). However, in LAC in general, the lack of an adequate mechanism for integrating R&I into the research system has been the main obstacle to achieving the full integration of private sector efforts. New areas related to bioeconomy have the potential to generate tools for facilitating the integration of both sectors.

LAC relies on an important number of capacities, although these tend to focus to a reduced number of countries and institutions. Specifically in the case of biodiversity and eco-intensification there is not enough information about human capacity specialized in these sectors. Generally, it is included with the biotechnology capacity. This is coherent because of the nature of the activities, but it is also important to create a specialized critical mass for having long-term strategies in both areas. Clearly, there is a predominance of universities performing these activities as well as some research centers. With the exception of Embrapa and INTA, practically the NARs are not the reference points for the agricultural research.

Conclusions and Emerging Policy Issues

Latin America and the Caribbean is a heterogeneous region in many aspects. Regarding R&I systems in agriculture related to Bioeconomy, it represents a challenge, because it involves planning strategies for such different countries as Brazil and Bolivia (for example). However, this can be also an opportunity given the complements between different strengths and capacities in each one of the countries. Likewise, what stands out is the presence of an established research system and a regulatory framework in almost all the regions. Nevertheless, in many cases it is hard to implement and consolidate these. It is a region with extraordinary diversity of natural resources, but still with a reduced capacity to appreciate or safe-keep them.

Moreover, the need for additional financial funds, infrastructure and qualified staff training is existent in the whole region. To consolidate R&I processes it is required to increase and consolidate the critical mass and develop novelty processes/techniques to go beyond just to be technology adopters. The region's research volume, although significant, is relatively low compared with other developed or developing countries such as China and India. This is reflected in low number of patents and published scientific papers. The innovation capacity is still dependent on the external supplies that come from developed countries. LAC does not require self-sufficiency *per se*, but it is important that local technology production can be competitive in the global market.

Some recommendations that may support the research in the sectors related to the Bioeconomy are described in the following paragraphs:

- In general, it is required to support technology research systems and their links inside and outside the region. In order to do this, the established institutions in LAC should be directed to create technological cooperation agreements, and support their integration with the research global system, as well as taking advantages of externalities.

- Increase public investments in each country. It is important to guarantee financial resources and a constant flow to give continuance to already existent R&I programs in all areas described in this document.
- For the biofuels sector it is important to create cooperation networks around common programs of innovation and development on basic topics demanded at a regional level. The idea is to have an articulated regional system that achieves enough critical mass and research density.
- Training researchers in the use of biodiversity and biotechnology. These areas can resolve the industry demands and country's needs. This implies exploring the international universities exchange, as well as producing enough and qualified local courses, seminars, degree courses and specializations in the different areas.
- As in the biofuels sector, it is necessary to reinforce relationships in the region. There is still a low integration, and there are many cross topics for several countries. Activities must be rationalized, in order to increase efficiency and reduce efforts redundancy.
- Exploit the advantage in the eco-intensification topic (mainly no tillage). The region has developed research and tools applicable in other regions.
- Support the regional and sub regional financial resources funds.

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Bioeconomy Successful Experiences in Latin America and the Caribbean[1] [2]

Ana Clara Pisón[3] and Maria Alejandra Bentancur[4]

Introduction

Given the diversity of natural resources, the economic and social characteristics and even the nature of each one of the Latin American countries, there is no common model for the development of the bioeconomy in the region. It is indeed recognised the existence of different pathways that reflect the aspects and the comparative advantages of each country. However, all share the same principles that lead to a more effective and efficient use of biological products and processes to achieve social objectives. In this context, the aim of this chapter is to present successful bioeconomy experiences in countries of the region that account for its potential.

For their selection and inclusion various sources were considered, among which the experiences disclosed by the IICA Office in Uruguay[5] and another developed by Fontagro along with IDB and IICA stand out for specific cases.[6]

1 The authors appreciate the contributions made by Federico Villarreal and Eduardo Trigo in structuring the chapter.

2 The source of all the pictures in this chapter is a publication by IICA about successful experiences: Experiencias exitosas en Bioeconomia (IICA & ALCUE-KBBE project, 2013). For further information, please go to: http://www.iica.int/Esp/regiones/sur/uruguay/Documentos%20de%20la%20Oficina/experiencias_exitosas_bioeconomia_iica_2013.pdf

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6 Henriquez, Priscila, ed., Li Pun, Hugo, ed. (2013) Impact Innovations: Lessons from family farms in Latin America and the Caribbean. Edition: San Jose de Costa Rica: IICA, IDB, 2013 [243 p].

For their description they were organized and addressed according to four out of the six routes of bioeconomy intensification proposed by the project "Towards a knowledge based bioeconomy in Latin America and the Caribbean in partnership with Europe", outlined in Chapter 1. The four pathways considered are: (i) the exploitation of biodiversity resources, (ii) the eco-intensification of agriculture, (iii) biotechnology applications, and (iv) biorefineries and bioproducts. The other two pathways that have not been considered in the experiences grouping are (v) improving the efficiency of value chains and (vi) ecosystem services. The choice of emphasizing the four mentioned pathways does not necessarily reflect a judgment about the importance of the other routes, but expository issues and the fact that these alternatives are still underdeveloped in the region and therefore there is little information about them.

Biodiversity Resources

Biodiversity is an almost inexhaustible supply of products and services, which has been recognized by several countries in the region as a base on which they could support part of their development. There are often clashes and disagreements between environmental institutions (based on conservation) and the productive sectors (focused on the use). In addition to the confrontation of opinions, the debate involves the difficulties to quantify the real value of the components of biodiversity and the lack of clarity in the application of the intellectual property rights.

Although some of the countries in the region are rich in biodiversity (as in the case of Brazil, Costa Rica, Colombia and Panama, among others), this is not adequately reflected in their GDP. This wealth would decline at an accelerated pace because of: water, soil and air pollution, widespread mismanagement of the environment that occurs in certain productive activities (mining, agriculture, industry); biopiracy and global climate change, among other causes.

As for biodiversity products, the potential is almost unlimited for various industries such as the pharmaceutical, cosmetic, food, agriculture and bioenergy ones. Conservation is also an application that can be exploited, as it has been successfully demonstrated in Costa Rica, where based on a policy of environmental education, the articulation of biodiversity with tourism has been possible, and new and profitable applications and services have been discovered and developed.

INBio[7]

INBio is a research and biodiversity management center, established in 1989 to support the efforts of knowing the country's biodiversity and promote its sustainable use. INBio is a public-private partnership that carries out its tasks in close collaboration with government agencies and the private sector as well as with universities and both national and international scientific institutions. The institute works under the premise that the best way to conserve biodiversity is to study it, appreciate it and take advantage of the opportunities it offers to improve the quality of human life.

Its mission is to promote greater awareness of the value of biodiversity to achieve its conservation and improve the quality of human life. And its vision is to turn nature into a central hub for culture, the educational process and the competitive strengths of the country; to constitute a core of scientific development that guides the use of the natural capital of Costa Rica and to be the most recognized institution in Latin America in its field. Its work is mainly developed around: inventory and monitoring of species, conservation, communication and education; bioinformatics and bioprospecting.

Although INBio is a national initiative given its scope of action, it has become an international effort aimed at integrating conservation and development. The application of scientific knowledge of biodiversity in economic activities such as ecotourism, medicine, agriculture, or the development of mechanisms for the collection and payment of environmental services, exemplifies that integration effort and these activities are part of the actions that attract the attention of the international community.

Ecoflora[8]

Ecoflora is a company that focuses its business strategies in the care of the environment and biodiversity. It was founded in 1998 by a group of entrepreneurs with experience in the agriculture, forestry, biotechnology and biocommerce industries. Its mission is to create value and welfare through innovation in technology business and products with high added value, derived sustainably from plant biodiversity to provide: toxic-free food, cosmetics without guilt, reliable personal care and cleaning without pollutants.

7 This section has been elaborated based on the information from the website www.inbio.ac.cr (25/11/2013).

8 This section has been elaborated based on the information from the website www.ecoflora.com (25/11/2013).

Currently it has 42 highly skilled employees and 12 patent applications for dyes, fungicides, insecticides, surfactants and elicitors (4 approved and 8 in process). In 2011 it was divided into two companies named Agro and Cares. Ecoflora Agro is responsible for developing agricultural biopesticides, such as insecticides, repellents, fungicides, miticides, nematicides and molluscicides.Ecoflora Cares, on the other hand, focuses on the development and commercialization of natural ingredients for cosmetics and food (dyes, waxes, oils and functional ingredients) and bioproducts for home care (cleaners, disinfectants and insecticides).

Among their differentiation strategies are: (i) the emphasis on native and endemic biodiversity, (ii) the strengthening of sustainable supply chains; (iii) open and disruptive innovation, (iv) the development of patents and other intellectual property mechanisms; (v) the development of inclusive business models, and (vi) the use of certifications in fair, sustainable and equitable biocommerce. These strategies together with the strengthening of the link with universities and other research and development centers, make this innovative experience a true example of the application of the bioeconomy of biodiversity.

Agave Cocui Program: RSIP[9]

9 The information comes from the actual actors and it is further developed in the publication "Experiencias exitosas en Bioeconomia", carried out by IICA and the ALCUE-KBBE Project (2013, 80-83).

The development of the cocui spirituous liquor and the crafts made with Agave cocui fiber are typical activities of the semi-arid areas of the Sierra de Falcón in Venezuela, particularly in the Pecaya parish located in the Sucre municipality. In order to establish the historical and cultural value of the crop, several institutions are responsible of the Agave cocui program that promotes and supports the sustainable development of products derived from *Agave cocui* in these depressed areas.

Productive Projects in Indigenous Communities for in situ Conservation and Application of Agrobiodiversity[10]

Among the Mexico's greatest assets are its biodiversity and agrobiodiversity. The latter is the result of the knowledge and work that the indigenous communities have preserved for centuries. These can provide expertise and knowledge on *in situ* conservation practices. To prevent this knowledge from being lost, a multidisciplinary group works with communities on identifying opportunities for productive projects that allow them to increase the added value of the products they produce out of their agrobiodiversity.

The Agriculture Eco-Intensification

The agriculture eco-intensification is related to agronomic practices aimed at improving the environmental performance of agricultural activities, maintaining the levels of production and productivity achieved until today. With the eco-intensification it is sought to reach a balance between

10 The information was obtained from the publication "Impact Innovations: Lessons from Family Agriculture in Latin America and the Caribbean", developed jointly by Fontagro, IDB and IICA.

the agricultural, environmental, economic and social benefits, with a more efficient use of energy resources and focusing on reducing the use of fossil fuels, pesticides, and other pollutants derived from non-renewable natural resources.

This way of intensifying the bioeconomy is associated with the concept of clean technologies, particularly with the aspects related to the use of biological processes to support industrial activities and others (waste water treatment). It should be noted, however, that the mere use of biological resources or processes is not enough, and the consideration of effective environmental benefits should be associated with the use of these kind of products to be included in this path.

No-till Farming in Argentina and Brazil

The expansion of agriculture during the first half of the twentieth century had consequences including a marked increase in erosion and soil degradation. These issues were recognized in various areas of international research, and they were the main stimulus for the development of environmentally friendly techniques. More precisely, from the recognition of the consequences of improper land management, a strong interest arises in developing less aggressive cultural techniques for the preparation of the seedbed that reduce erosion and consequently the potential deterioration of farming. This process of awareness of the implications of soil erosion, along with the incorporation of technical advice on the piece of land, promoted the circulation of information about the experiences that took place in the United States and elsewhere, with the purpose of moderating this problem with the reduction in the impact of cultural works. This was how, with the advance of soybean crops and genetically modified varieties that allow a more efficient weed control stage, it was established the scene that started the development of techniques (and machinery) of minimum tillage and later zero-tillage or direct drilling.

The R&D institutions played an important role in the introduction of this technological innovation, as together with the agriculture actors (producers, suppliers of agricultural inputs and technical advisors, among others) formed the network that made possible the adaptation and introduction of direct drilling. In Argentina, the National Institute of Agricultural Technology —INTA— began to participate in programs related to the creation of local technical teams trained in the subject since 1968. This was in line mainly with the situation in Brazil, where during the 1970s a strengthening of the linkages between the productive sector (and input provider) and the research centers began to develop in order to adapt this technology to the national reality. That was how the State, through IPEA (subsequently renamed, Embrapa), became a major promoter of the direct drilling, establishing a real network innovation as in the USA.

Once strengthened the innovation network between the industry actors and the public R&D institutions, the rate of increase of the area under direct drilling in Latin America increased significantly. In 1987 the Mercosur member countries (Brazil, Argentina, Paraguay and Uruguay) used direct drilling in 670,000 ha (Less than the current surface with direct drilling in Paraguay). In 2009, according to estimates by Rolf Derpsch and Theodor Friedrich (2009), the tillage system was used on more than 106 million hectares worldwide. Approximately 46% of this technology is practiced in Latin America, 38% in the United States and Canada, 11% in Australia, and 5% in the rest of the world, including Europe, Africa and Asia. In Brazil, direct drilling represents approximately 70% of the cultivated area, and in Argentina and Paraguay it is near 80-90% respectively, being the latter two countries the ones that lead the percentage of adoption in the world. It is interesting also to note that over 90% of the area cultivated with direct drilling in Brazil, Argentina, Bolivia and Paraguay, is worked on an ongoing basis, *i.e.*, without the occasional presence of crops.

The main factors that promoted such an impressive change in Latin America can be identified:

- Efficient and economical erosion control under conditions with high potential for erosion and land degradation.
- Appropiate knowledge available in the region through research and development and also through the experiences of leading farmers.
- Extensive use of green manures to reduce weed infestation especially in Brazil and Paraguay (reduced use of herbicides), increased organic matter content in soil and biological pest control, among others.
- In general, the same message, consistent and positive, towards direct drilling has been expressed by all the sectors involved (public and private) without contradictions;
- There has been an aggressive and efficient farmer to farmer extension through direct drilling organizations.
- Publications with appropriate, useful and practical information have been produced and placed in the hands of farmers and extensionists.
- Economic evaluations with a farming system approach have shown a high economic income when practicing direct drilling. The profit improved with the use of green manures and crop rotations.

All these matters locate direct drilling as a successful experience that, in addition of promoting a more environmentally friendly agriculture, also favors the economic equation of both producers and State as well as other actors in the agricultural sector. Undoubtedly, this has been a successful experience related to bioeconomy and it has transcended national boundaries.

Biofertilizer for Silvopastoral Systems in the Colombian Caribbean Region

In the dry Colombian Caribbean, the fodder supply for feeding dairy cattle has been affected by weather conditions and soil deterioration. The search for a sustainable development of dairy farming is the beginning of the project that aims to increase the sustainability and profitability of land use, through the production of a mixed organic fertilizer based on nitrogen fixing bacteria for silvopastoral systems in the region.

Pedasi Silvopastoril Intensive System

Although farming has stimulated the development and economic progress of the community of Pedasi, in the province of Los Santos located in Panama, it has had negative consequences on local ecosystems and the environment. The yield of the soil has been affected because of conventional extensive cattle grazing which has removed trees and shrubs in order to grow a monoculture of better nourishment. In order to implement a less environmentally harmful activity to benefit grazing supply, relieve soil compaction and control erosion, the Association of Livestock and Agro-Silvopastoral Producers of Pedasí (Apaspe) launched an Intensive Silvopastoral System (ISPS) in the region.

Improved Organic Potato Production in the Andean Region of Peru

The native organic potato has emerged as a new gourmet product highly demanded in the world and this has been a catalyst for organic production in Peru. However, Andean potato weevil and moth infestations are a threat to the crop in a growing market, affecting the profitability and viability of native potato. With the intention of linking smallholders to these new markets, several national and international institutions encouraged farmers to adopt an Integrated Pest Management, to counteract the damage of pests and achieve certified organic potatoes for sale.

Intercropping: Corn with Guama

The Ixcán region in the department of Quiché, Guatemala, has very low indicators of human development and therefore environmental problems due to poor agricultural practices. Agriculture is a subsistence activity and maize constitutes 75 to 80% of the families diet. To condition the soil for planting, stubbles are burned resulting in a loss of nutrients in the soil that is counteracted by the application of agrochemicals. In 2008, seeking solutions to these problems, a NGO and municipal authorities started up the Agroforestry Project, which associates the corn crop with Inga tree *(Inga edulis),* a legume capable of restoring soil fertility.

Biotechnology Applications

In relation to biotechnology the outlook has been dominated so far by genetically modified crops (GMOs) and the fact that, in practice, it has been identified with these innovations. This is undoubtedly a reflection of what the technological cycle has been up to today and of the indisputable fact that these innovations are the ones that have had more "press" and visibility, either for their potential impact on agriculture —which have already become evident, not only from the standpoint of coverage, but also for their economic and social benefits— or because of the controversy that they have arisen. Beyond this, during all this time the scientific background has continued expanding along with the progress of molecular biology in general, and genomics and bioinformatics in particular. The expansion also extends to a number of other areas that have open the spectrum of independent applications of transgenesis and they allow to glimpse an even greater impact than the one achieved with the GMOs, because they do not only cover agricultural production, but livestock and forestry, and they include new areas of interest, such as bioenergy. All these closely related to the bioeconomy.

The application of molecular markers, genomics and bioinformatics in general (to increase the efficiency and effectiveness of traditional breeding, and the conservation and application of plant genetic resources), nutrigenomics (the use of information about how the genes and other chemicals in food affect the genes and metabolic processes in humans), new vaccines and new diagnostic methods, the application of molecular biology to improve reproductive management in animal production, the new applications designed to take advantage of the efficiency of plant sources and of biomass in general for the production of biofuels, as well as other innovations related to improvements in the quality and effectiveness of the ingredients and processes in the food industry, are becoming gradually a dense tissue of components for the new technological environment. Which makes us think about technology scenarios independent of a technique or a particular set of techniques (transgenesis in this case). But beyond this that represents a scenario that is beginning to envisage around biotechnology, specific cases of the successful application of these technologies for the benefit of society are described below.

Genetically Modified Organisms in Latin American Agriculture

Since the introduction of transgenic varieties on the market, the area cultivated with Genetically Modified Organisms (GMOs) has increased in a progressive and steady way,

The GMO cultivated area in the region has a more than relevant participation on the world stage of these technologies. Indeed, 7 out of the 14 countries that cultivate more than 50 million hectares in these crops belong to the region, and not only that, because Brazil, Argentina, Paraguay and Uruguay are among the top 10 in the world in this regard (James, 2012).

Brazil ranks second, after the USA., in hectares of biotech crops in the world, with 40.3 million hectares and it is emerging as a world leader in biotech crops (Celeres, 2013). For the fourth consecutive year, Brazil was the engine of global growth in 2012, increasing its hectares of biotech crops more than any other country: a record 6.3 million hectares increase, equivalent to an impressive growth of 21% (James, 2012). Brazil grows 21% of the worldwide 170 million hectares and it consolidates its position consistently narrowing the gap with the USA. A fast regulatory approval system allows this country to approve events easily and timely. Brazil has already approved the first stacked insect-resistant and herbicide tolerant soybean to be commercialized in 2013. Notably Embrapa, a public institution with an annual budget of US$ 1.000 million was authorized to market biotech virus resistant local beans (rice and beans are staples in Latin America), fully developed with its own resources, thus demonstrating its impressive technical capacity to develop, produce and implement a new cutting-edge biotech crop (James, 2013).

Several studies in Latin America and the world account for the benefits that biotech crops contribute, mainly to mitigate the enormous challenges associated with climate change and global warming. They show, in turn, their potential associated with the opportunities for significantly increase productivity and income and thus contribute to economic growth in rural areas.

Bio-Innovation Network for the Americas (Bionna)

Innovation in biotechnology requires constant adaptation and interaction between entrepreneurs, researchers, the public and private sectors and the civil society. Therefore, networking is essential for innovation to happen. In this context, in September 2010 the Bio-Innovation Network for the Americas (Bionna) was founded with the objective of promoting competitiveness and local innovation capacity in the Latin America and the Caribbean biotechnology, with the participation of Canada.

PhasIbeAm (A Cyted-Sponsored Genome Project)

Latin America is the largest producer of beans in the world, representing nearly half of the global production. However, low yields are reported in some regions as a result of a number of physiological factors (drought and water shortage, low soil fertility, etc.) caused by phytotoxicity, diseases and pests. Seeking alternatives for a crop that defends food security in the region, 21 Latin American countries approved in October 2009 the Cyted Genome Project. It aimed at obtaining the complete genome of beans so to enhance their breeding, leading varieties better adapted to the Latin American needs.

Soybean improvement against biotic and abiotic stress

Soybean is one of the most important crops in the agricultural sector of the Southern Cone and Mercosur produces 50% of soy consumed in the world. Seeking the environmental, economic and social sustainability of the crop, a public-private space of Mercosur agents is consolidated in order to provide an added value to soybean crops under water and health stress through genetic improvement. In November 2008 the project Biotecsojasur called "Integrated approach on genomics in Mercosur for the exploration of useful genes for improving soybean against biotic and abiotic stresses" was born.

Bioceres: Bio-business & Innovation

After the release of the glyphosate-resistant soybean and its rapid adoption by the Argentine producer, a group of farmers shared the dream of having Argentina as a benchmark for Agricultural Biotechnology. Bioceres was founded for this purpose on December 12, 2001 by 23 shareholders, with the aim of managing and funding research and development projects on Agricultural Biotechnology. Implementing a strategy of public-private partnership, the initiative allowed to merge the Argentine scientists' competitiveness with the entrepreneurial skills of farmers.

CorpoGen Corporation

In Colombia, an adequate and continuous funding of the Autonomous Research Centers, based solely on government funds, could be extremely difficult to achieve for long periods of time. Thus CorpoGen was born in July 1995 as a nonprofit corporation, governed by private law. Its mission is to promote science and technology through the implementation of research projects, collaborate to other scientific groups, develop and market products and services, and train qualified scientists. Research is a central area of the CorpoGen activities and it takes place in the fields of human, animal, plant and environment health.

Biorefineries and Bioproducts

In this pathway of bioeconomy intensification, there are included the sectors and processes aimed at replacing fossil fuels and industrial supplies. Examples of these are the vegetable ethanol, biodiesel, biogas, and different activities oriented to green chemistry.

Biorefineries, in essence, are the same oil refineries in that they are facilities for the processing of biomass into a spectrum of marketable products and energy. Its importance is related to improving the efficiency and range of biobased products: increasing efficiency through the possibility of breaking down the raw materials into different product chains and also reducing the cost of commodities. Biorefineries generate value adding new and innovative opportunities for agriculture by transforming nature and enabling new linkages with the rest of the economy, particularly the industrial sector.

Biorefineries and bioproducts have the ability to enhance the links between the new biobased materials, the raw materials and the supplies, with the existing value chains. Generating, in turn, explicit and concrete actions to ensure producers —particularly the small-scale ones— and rural communities, the creation, maintenance and enhancement of bioeconomy.

Social-rural biorefineries[11]

The Clayuca Corporation has been implementing since 2006 a research and development project with the aim of establishing a technology platform for processing hydrous bioethanol. This initiative is developed at the level of small rural communities, using as raw material the cassava, sweet potato and sweet sorghum crops.

This initiative has been named Rural Social Biorefineries (Rusbi) and it seeks to promote rural development in low-income communities. To do this, it proposes the production and use of hydrous ethanol. It is considered that Rusbi will have a social impact in the regions, and that they will help producers to boost their economies, create jobs and improve energy, food and agriculture security.

The operational prototype of the Rusbis that has been developed by Clayuca to process hydrous ethanol is a small-scale one, with low cost of construction, operation and maintenance. It is based on the use of saccharine (sweet sorghum) and/or starchy (cassava, sweet potato) bioenergy crops.

Clayuca started the spread of the developed model in rural communities with limited access to electricity and high dependence on fossil fuels and that, in general, are maintained solely on agriculture. The facilities of the existing pilot plant have been used as a center for demonstrations and training of groups of farmers and technicians from various regions of Colombia and other countries in the region facing similar problems. They find an alternative in this innovation able to generate rural development in important parts of the most disadvantaged communities in Latin America.

Babethanol

11 This section has been prepared based on the information found in the website www.clayuca.org (11/25/2013).

Rising fuel prices and the concerns about global warming have moved biofuels towards innovation. However, producing the raw material for the creation of biofuel uses a lot of energy and it competes with food production. Babethanol is a project funded by the EU and an international multidisciplinary team of specialists from different institutions and private industries of LAC coordinates it. It seeks the innovation of new processes for more a sustainable use of the lignocellulosic waste that is applicable to a wide range of biomass as an alternative to the biofuel production processes that are currently used.

Pine Oil Production for the Pilot Plan on Power Generation in Galapagos

The Galapagos Islands, recognized by the Unesco as a natural heritage site, have a fragile and vulnerable system of energy supply, as it depends on fossil fuels shipped from the mainland. Looking for cleaner and sustainable alternatives to reduce greenhouse gas, it was launched a project to produce biofuel from the Jatropha Pure Plant Oil coming from the province of Manabi, in the Ecuador mainland.

Biodiesel from Palm Oil

Colombia is the largest producer of palm oil in Latin America and the fourth largest producer in the world. This product is the second most consumed oil in the world and, in recent times, its use as biofuel raw material has been catching on. Besides the diesel it is transformed into biodiesel, which is consumed both by vehicles and industries. This biodiesel has many advantages that benefit the environment and the human health, reducing significantly the greenhouse gases emission. The National Federation of Oil Palm Growers (Fedepalma) was commissioned to develop this new technology.

Construction of Small Biogas Stoves in Digesters

Dairy farms and piggeries of the Bugaba district in the province of Chiriqui, in Panama, faced the problem of not knowing what to do with the organic waste they produced. Taking into account this situation, coupled with the adverse effect of organic wastes on the environment, the Dairy

Farmers Multiple Services Union (Cooleche R. L.) launched a program in 2011 to build small biogas stoves in the digesters settled in farms.

Microbial Exploration and Development of Bioproducts in Bolivian Peasant Communities

Bolivia is currently undergoing a process of desertification as a result of the erosion of soils, the scarce precipitations in the highlands, and pests and diseases that affect food crops. To counteract this problem, farmers use agrochemicals. This becomes a vicious circle, as the indiscriminate use of these chemicals has a negative impact on the environment. In this context, The Foundation for the Promotion and Research of Andean Products (Proinpa) and various strategic partners, developed alternative technologies to reduce the negative impact of agrochemicals through the evaluation and dissemination of bioproducts that enhance the ecological balance, the soil fertility, the crops productivity and the income of small farmers.

Wheat Seed Yampara: Reducing Bolivia's Food Dependency

Bolivia depends on the importation of wheat and wheat flour for its domestic consumption because its production barely covers 27% of its domestic demand. It could be said that about 70% of the bread that is consumed comes from abroad. In 2006, the Foundation for the Promotion and Research of Andean Products (Proinpa), international cooperation agencies, government agencies, NGOs and farmer organizations, agreed to promote the gradual shift from traditional long cycle wheat varieties to short cycle ones resistant to droughts. The process of generating, validating and disseminating new varieties of high-yielding and drought-resistant wheat, took about 14 years.

Ecuador's Fine Cocoas

Cocoa is the third largest export item of the agriculture in Ecuador, achieving 5% of the national exports. The country has a very fine cocoa species characterized by its flavor and aroma. In this context, the Ecuatorian government has decided to capitalize on the product potential and work to create a "national brand" for the fine Ecuadorian cacao flavor. Organizations committed with the agricultural development implemented in the Ecuadorian coast the Rehabilitation Program for mature and unproductive Cacao Fino de Aroma plantations, through the production and use of a Biofertilizer locally developed by producers.

To Conclude

This chapter aimed to present successful experiences of bioeconomy in countries of the region that account for its potential. In this regard, examples with different impacts on regional, national and local levels were included. All these experiences represent just one example of the bioeconomy scope in the region and in this regard, they express concrete possibilities of bioeconomy for the generation of economic, social and environmental benefits.

Precisely both, the intensification pathways that organized the presentation of the successful cases, which are reviewed in detail in other chapters of this book, and the success stories that have been synthetically presented, shared principles related to an effective and efficient use of the biological products and processes. They also include innovation, technological and scientific as well as public-private joints, and the need for public policies that encourage their development and expansion in the territories that constitute Latin America.

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LAC Bioeconomies: Different Pathways, Preliminary Results and First Best Practices

Guy Henry[1], Eduardo J. Trigo[2] and Elizabeth Hodson de Jaramillo[3]

Different Conditions, Bioeconomy Pathways and Preliminary Results

As was discussed earlier, important bioeconomy developments are evident across the LAC continent, some of which are already mature, while others are in their infancy. The dialogue of the bioeconomy model has been most opportune, especially in countries like Brazil, Colombia, Argentina and Costa Rica. Construction of bioeconomy models so far has been mostly implicit and reflecting the countries natural resources base as well as some of its main institutional characteristics and insertions in the international markets. The following paragraphs highlight some of these.

The bioeconomy development in Brazil is generally labeled as green economy especially preceding and following the RIO+20 Earth Summit, or bioenergy development. While the former is the result of a geopolitical, institutional discussion, the latter has its undisputed right given the 45+ year trajectory of the sugarcane ethanol sector in Brazil. As such bioeconomy focused dialogues in Brazil automatically tend to result in bioenergy discussions where the sugar cane to ethanol experience serves as a baseline to which other feedstock based bioenergies are compared *i.e.* jatropha, ricinus, switchgrass, sorghum, etc. Furthermore, Brazil is betting (investing) heavily on a much more important palm oil contribution to its energy matrix, programming massive expansion of its palm oil acreage over the next decade.

Brazil has also gained important experience of in zero-tillage as an ecological intensification practice. Similar to Argentina, Brazil has applied a powerful combination of GM soybean varieties

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with zero-tillage practices. The latter country has also been one of the pioneers in payments for ecosystem services, while at the same time it has championed the valorization and sustainable management of biodiversity. As such, Brazil, due to his very specific natural resources and institutional conditions has been forging ahead along 3 major and 2 minor bioeconomy development paths: bioenergy, biotechnology products and ecological intensification on the one hand, and biodiversity and ecosystems services, on the other.

Argentina has readily embraced the bioeconomy principles, given the opportunities offered by a BE model *vis-à-vis* its natural resources base and institutional and political arrangements. Its long tradition and importance as a principal producer and processor of biomass lent itself well to becoming one of the world's largest producers of GM crops in combination with zero tillage. The heavily invested bioenergy development path was sugar cane based initially and shifted towards soybeans and, more recently maize. In Argentina, besides the widely adopted biotech products *i.e.* GM crops, other biotechnology products and processes based companies have also been growing in the last two decades (these include a strong presence in seeds, biologicals, food ingredients, and animal health, among other sectors). Hence, the Argentine bioeconomy is largely being developed along 3 pathways: bioenergy, biotech products and processes and ecological intensification. The timing for dialogues on the bioeconomy has been very advantageous for Argentine institutions. Several high-profile bioeconomy events were staged during 2013 (see http://www.bioeconomia.mincyt.gob.ar/).

Colombia is strongly advancing its bioenergy sector, that is currently split between sugarcane based ethanol and oil palm based diesel. As such it currently occupies third place in the LAC ranking. This aside, bioeconomy activities in Colombia seem to be scattered along several different pathways. Biodiversity exploitation and biotech products and processes (mostly non GM) may be the most dynamic of possible bioeconomy development pathways. For example, several startups and young companies are focusing on mining functional properties from the large and highly diverse Colombian biodiversity to target niche markets in the food, cosmetics, agricultural, therapeutic and pharmaceutical sectors, both nationally and internationally. In addition, GM-crops (cotton, maize, flowers) are being planted with mixed success. The last few years have seen several private sector induced dialogues in Colombia, mostly around biotechnology and biodiversity valorization topics, their potential and the current obstacles and opportunities. At the public level, ad-hoc discussions are limited within institutional mandate limits (Ministries). The organization of a national platform for bioeconomy stakeholders would therefore be a necessary next step.

In the case of Costa Rica, the emphasis has been on biodiversity and ecosystems services based developments. Costa Rica was one of the first countries in the world to develop an initiative to valorize biodiversity and in 1989 created the National Biodiversity Institute (INBio) as a private research and biodiversity management center, aiming to support efforts to gather knowledge on the country's biological diversity and promote its sustainable use. These efforts were later on complemented with significant developments to take advantage of ecosystems services through the creation of probably one of the most important networks of eco-tourism alternatives in the world and, more recently, a number of bioeconergy initiatives utilizing not only traditional feedstock, such as sugar cane, but also non-traditional ones such as coffee and rice production residues. Further on, the country is also looking at alternatives emerging from its growing palm oil industry.

Lessons Learnt

The introduction of the KBBE model in the LAC region was principally based on a series of bi-regional stakeholder consultations that were conducted during 2012-13 in Cali, Buenos Aires, Brasilia and Costa Rica. These consultations had as primary objective to establish, on the one hand, a dialogue regarding the different roles and opportunities for the Bioeconomy in the region and individual countries. On the other hand, the events advanced the formulation of research and policy agendas, in addition to arriving at a preliminary consensus of a bi-regional LAC-UE cooperation strategy for the bioeconomy development in the LAC region.

The stakeholder consultations proved excellent opportunities to jointly analyze and debate the ongoing developments of bioeconomy models in the EU and member countries, in addition to the adoption of BE principles in countries like US, Canada, New Zealand, Russian Federation, India. These ongoing experiences, as evidenced from secondary and primary information sources, together with the advancements in several countries of the LAC region, have generated a series of useful lessons. The principal ones include the following:

1. The fact that there is not one definition of the BE but that each region, country, or sub-region needs to establish its own definition and parameters, based on the relevant conditions, policies and socio-economic, environmental and institutional priorities and objectives. This includes the prioritization of which development pathway(s) to select.
2. Co-existence of several similar models. This has been generating confusion for both stakeholders and the public at large. There are very obvious and less evident overlaps with green economy, blue economy, eco-efficiency, sustainable agriculture. It would be very useful to detail and compare these, and then to disseminate this information widely.
3. Probably the most important drivers of the bioeconomy are (i) appropriate policies in the public sector, and (ii) private sector economic incentives at the industry level. Contrary to the UN sponsored Green Economy model that is largely an institution driven model, the cham-

pions of the Bioeconomy is the private sector. Its success in taking advantage of BE based opportunities is directly related to the public policies in place, which ranges from very constraining to very supportive.

4. In order to awaken the interest of the private sector à detailed information (sector analyses) on the economic potential needs to be carried out in order to show where the different potential markets exist and what the comparative advantages of bio-products and value chains (*vis-à-vis*) traditional chains, are to be found.
5. In order for any country, region, or area, in order to start constructing a Bioeconomy activity, perhaps the first two steps that are crucial and perhaps conditional, are: (i) organizing a group of private and public principal stakeholders and together (ii) engage in a strategic thinking process towards the formulation of a common acceptable strategy, and subsequent action agenda. Very powerful examples can be seen in Germany, the Netherlands, Flanders, etc. where inclusive national council on the bioeconomy have been established that include the representation of several ministries, industry, academia. In contrast, there are other countries were efforts for a bioeconomy organization have gotten bogged down due to turf-fighting between different ministries and/or private sector lobby groups.
6. One notion that has mostly remained implicit but which deserves to be underlined here is: that the basic principles of the Bioeconomy do NOT per-se guarantee environmental sustainability (in all activities), NOR do they assure social equitability. If these issues prove to be important (objective) for a given region or country, they need to be explicitly built into the future bioeconomy model. These specific objectives will then directly influence the choice of selected bioeconomy development path(s) and related value chains.

Towards Best Practices for Bioeconomy Enhancing Policies

Practices for policies of bioeconomy in LAC have to consider four general components. The first component is to *install bioeconomy in the public and private Latin-American decision actors*. This is fundamental because is the base of the strategy. This component introduces the following five fields necessary for establishing the bioeconomy (see figure 1). These are:

1. *Enhancing the knowledge base* considering different areas and the interaction between them.
2. *Reinforcement of the implementation in companies.* This is a critical field of actions because it is the base of the innovation system and the component that generates the participation of private sector in the development of bioeconomy in the Region. As such, this field has to include

action that promote cooperation between science and industries through projects that articulate public and private interaction and the implementation of a information system that divulgate results of this interaction.

3. *Promote organization among Latin-American actors that work in bioeconomy.* This field is closely in line with the previous and reinforces it. In fact, in relation with the general goal of the step, this field stimulates the building of network with actors, organization and discussion between institutions of different countries, both public and private.
4. *Communication* is the fourth field and it is fundamental into delivering and promoting bioeconomy between actors involved in this sector and the rest of society. In fact, public knowledge and acceptation of bioeconomy is critical for its consolidation.
5. *Framework condition* is the last field and it represents a consolidation of the aforementioned. Additionally, this field is the beginning of a new journey through the circle (figure 1).

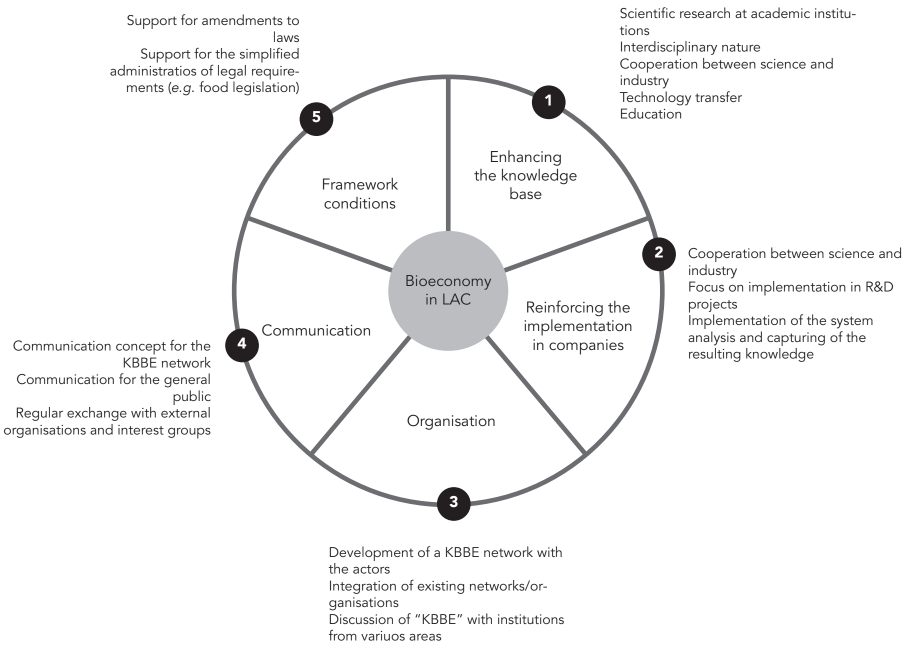


Figure 1. The five fields of action for establishing Bioeconomy in LAC.
Source: MINCYT – CEO. 2013[4]

4 MINCYT-CEO. 2013. FP7 Project No. 264266. D6 Document: Framework, good practices and policy guidelines for the exploitation of the potential of the KBBE for promotion of inclusive social and economic development opportunities at the local, national regional and international levels in LAC. Work document ALCUE-KBBE.

The second component of the mentioned list of best practices consists of *identifying opportunities to reinforce the use of natural resources in the context of the bioeconomy*. The information and analysis presented in chapters one and two of this paper introduce the principal component of the Latin-American scenario. The region is very rich in natural resources and it is at the forefront of a strategic opportunity to play a central role in the context of global bioeconomy. For these reasons is crucial to identify opportunities and work on them considering the elements and actors of the preceding component.

The third component includes *what work, which actors and which strategic sectors*. What work implies the identification and a prioritizing of a field of action and this is the result of deeper analysis of the opportunities. In conjunction with this, which actors participate in the identification of opportunities that in the first component is the work of the institutions that lead the overall process. What work and which actors define what is the strategic sector linked to natural resources that will be central in the strategy.

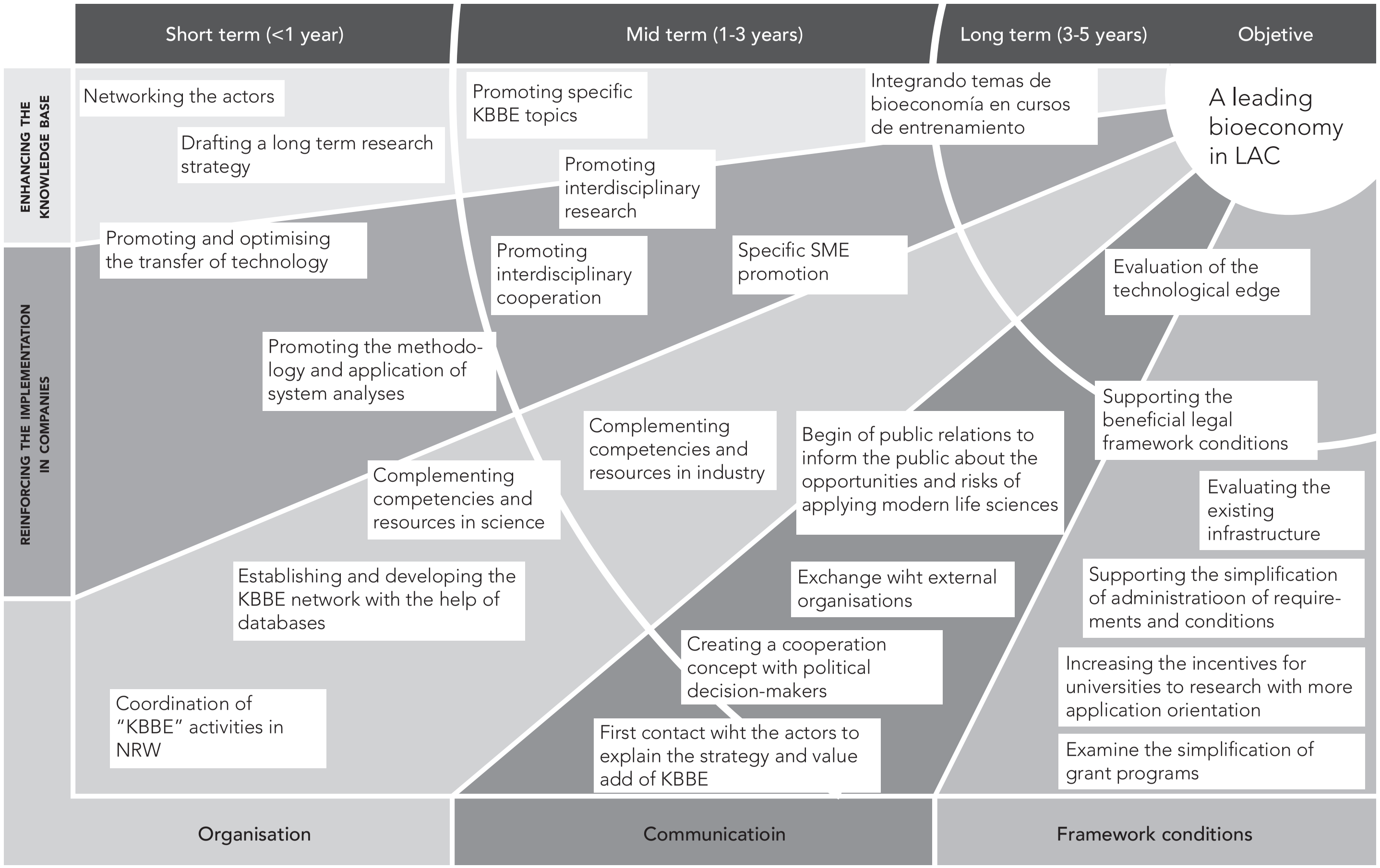
Finally, the fourth component involves the *building up of an action plan for three different periods or stages (short, medium and long terms)*. This will have to consider the information systematized in the other components and it has to involve the participation of the actors and organizations linked to bioeconomy in LAC. A schematic example of this process is shown in figure 2, in which the component of best practices and the field of the first component are included.

Some Forward Looking Final Comments

The information and experiences summarized in the preceding chapters and sections highlight both the importance of bioeconomy alternatives in the region and also the fact that in-spite of the lack of specific policies and strategies, in LAC the bioeconomy is a reality already underway, with many strong platforms on which to build upon. The region's extended experiences and leadership in areas such as GMO crops (Brasil, Argentina, Paraguay, Uruguay, Colombia, Honduras, Mexico, Bolivia), bioenergy development and emerging biodiversity utilization and ecosystems services industries (biologicals, carbon credits) clearly attest to the strengths of the existing comparative advantages. It is also encouraging that developments are taking place not only in the countries that participated in the ALCUE-KBBE project, but also in almost every other country in the region; such developments may be smaller or incipient, but they are, nonetheless, clear indications of how diversified and extended those strengths are.

From the discussions and experiences emerging from the project, some high priority issues for future R&D efforts in bioeconomy include: (i) Biorefineries and bioproducts including green biorefinery, lignocellulose biorefinery and production of high value bio-based products and oil

Figure 2. Schematic example of action plan for bioeconomy development in LAC



Source: MINCYT – CEO. 2013

based biorefinery. (ii) Sustainable commercial use of prioritized native plant species and microorganisms as well as screening for new bioactive metabolites/enzymes and standardization of valuable functional components in food, cosmetic and pharmaceutical ingredients. (iii) Bioreactors for the production of health promoting compounds and development of innovative production of bioplastics. (iv) In terms of ecological intensification the development of bio-inoculants and bio-products for plant nutrition and phytosanitary management using metagenomics as a valuable tool. (v) Agricultural and agroindustrial waste treatments are also considered a high priority in the LAC region.

However encouraging the above situation may be, there is also a downside that needs to be built into the equation of the future strategies. It is important to emphasize strongly that in most cases we are talking about relatively "short" value chains and there is very little exploitation of the "cascade" potential implicit in biomass, and there is still a long way to go yet in terms of R&D and market development investments before these potentialities can be fully taken advantage of. The good news is that many of the countries have already begun to travel this road, and there is also a long standing cooperation experience with countries of Europe and from other developed and developing regions which can provide strategic support on this journey. The challenge now is to start moving these processes, which until now have mostly been market led, to wider processes of more strategic reach that can start to serve as basis for wider sustainable social and economic development experiences. We hope that the information and ideas presented in this book serve as a modest but useful contribution to these processes.

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