ISDA 2010 Agriculture and Food
Innovation and Sustainable Development
in Agriculture and Food
Montpellier – France
28 June – 1er July 2010
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THE KNOWLEDGE BASED BIO-ECONOMY AT WORK: FROM LARGE SCALE EXPERIENCES TO INSTRUMENTS FOR RURAL AND LOCAL DEVELOPMENT

Guy HENRY* and Eduardo J. TRIGO**

* CIRAD / ProsPER
Cerviño 3101, Planta Baja.
(1425) Buenos Aires, Argentina.
Email: guy.henry@cirad.fr

** Grupo CEO S.A.
Hipólito Yrigoyen 785
(1086) Buenos Aires, Argentina
Email: ejtrigo@gmail.com

Abstract - The new bio-economy is increasingly seen as a workable alternative to move today's economies in the direction of more sustainable natural resource use and economic growth. Most of existing experiences, both from science as well as from implementation of the Knowledge Based Bio-Economy (KBBE) concepts, refer to relatively strong science basis and relatively large scales of application. This paper proposes to review existing advances in the implementation of the KBBE in small scale situations and identify what the key research, institutional and policy issues that need to be taken into account to further promote KBBE approaches to rural and local development. As such, the analytical approach used includes an extensive literature review in the form of a desk study, followed by a comparative analysis and the formulation of recommendations regarding S&T and policy agendas.

Key words : *bio-economy, large vs. small scale, rural development, policy*

Résumé - La nouvelle bio-économie est de plus en plus considérée comme une alternative viable pour faire progresser les économies d'aujourd'hui vers une utilisation plus durable des ressources naturelles et la croissance économique. La plupart des expériences existantes, provenant de la science ainsi que de l'application du concept de la Bio-Economie Basée sur la Connaissance (*KBBE- Knowledge Based Bio-Economy*), se reporte à des bases scientifiques relativement fortes et à une échelle d'application relativement grande. Cet article propose d'examiner les progrès actuels dans la mise en œuvre du KBBE dans des situations à petite échelle et d'identifier quelles sont les principales questions de recherche, institutionnelles et politiques qui doivent être prises en compte pour promouvoir les approches KBBE au développement rural et local. À ce titre, l'approche analytique utilisée comprend une revue exhaustive de la littérature sous la forme d'une étude documentaire, suivie d'une analyse comparative et la formulation de recommandations concernant les S&T et les agendas politiques.

Mots clés: *bio-économie, grande échelle versus petite échelle, développement rural, politique*

1. INTRODUCTION

The new bio-economy, a concept synthesized by the OECD 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), is increasingly seen as a workable alternative to move today's economies in the direction of more sustainable natural resource use and economic growth. The transition to economies and societies based on this concept is already underway and there is clear evidence of its potential and impacts in a wide arch of application sectors, going from food and health to transportation, construction and, even, the recreational industry. Most of existing experiences, both from science as well as from implementation of the Knowledge Based Bio-Economy (KBBE) concepts, refer to relatively strong science basis and relatively large scales of application. The questions and challenge is whether the new concepts are of relevance for the small scale and what are the needed policies to promote and guide investments and the new institutions to ensure the safety of the new technologies and the equitable distribution of the benefits of the ensuing economic growth. Existing evidence, however, points in the direction that KBBE opportunities can be linked to nearly any kind of plant material and as such bio-based industries are well-suited for local production, at small and medium scales, and as engines for rural development and income generation (Trigo and Henry, 2009).

This paper proposes to review existing advances in the implementation of the KBBE in small scale situations and to identify what the key research, investment, institutional and policy issues are that need to be taken into account to further promote KBBE approaches to rural and local development. As such, it focuses on a desk study of the existing literature, as basis for a comparative analysis of on-going alternatives and the formulation of recommendations regarding S&T and policy agendas. It is expected that the discussion and findings in the paper will contribute to the growing literature on bio-economy and bio-energy aspects etc. but especially it is an attempt to fill in the gap regarding relevance/benefits/policies for the integration of small-scale farmers and processors with advanced knowledge/biotechnologies in LDC and emerging economies.

The paper is structured in three sections additional to this introduction. The second section focuses on the review of the KBBE concepts and general applications, emphasizing, in particular, those dimensions that are of greater relevance for improved natural resources use, rural and local development, and poverty alleviation. The third section reports on a number of actual experiences of small-scale applications with emphasis on Latin America. The fourth and final section, builds up on the lessons learnt both in Europe as well as in the experiences reported for LDCs. It also proposes and discusses the main components of a research and policy agenda for the better use of KBBE concepts and opportunities in small scale situations in general, and those linked to rural and local development in particular.

2. REVIEW OF KBBE CONCEPTS AND APPLICATIONS

The bioeconomy, as indicated above, is defined as the utilization of biology – and biological processes – in economic activities. There is nothing new about this, since human societies have been not only utilizing, but have been dependent on biological processes going back to the beginning of time. Actually, if we associate food with mankind survival, the bioeconomy is at the centre of historical processes and societies, as we know them today. Even the idea of added knowledge as a differentiating issue, is not adding anything new, as there are countless examples of progress been associated to processes based on different forms of life getting to be more complex and effective. But somehow, until now, we have been essentially working within species or "sector" issues, with advances constrained to given species or process improvement, essentially related to food and medicine, while engineering and chemistry provided the materials for economic evolution and wellbeing. The essence of the new bioeconomy, is the increasing scope of applications and the rapid disappearance of those relatively "clean" frontiers.

In the last fifty years since the discovery of the DNA structure, the rapid emergence of biotechnology and the new biology and, in more recent times, their interface with advances in information and communications technologies and the nano-sciences, are already creating a new scientific and technological environment within which input-output relationships can be rearranged, existing products and processes redesigned and even whole new products and processes can be developed. Through the possibility of changing the "limits" within which biological processes interact with natural resources –soil, water, solar energy – the new technologies are opening up a whole new range of opportunities not only in food and fibre, but in almost every sector of the economy, including pharmaceuticals, energy production and industry in general. What is new in the "new bioeconomy" is not its conceptual basis; it is the scope of its reach. The consolidation of biotechnology as one of the key components of the technological substratum of today's and future societies, making it pervasive to all sectors of the economy, is probably a key strategy for an effective response to the challenge of building a more equitable society, while reducing humankind environmental footprint.

In its essence it's the coming together of biology, chemistry, materials sciences, genomics and information technology to better exploit natural resources both in agriculture and industry. As such, it implies to capture solar energy and transform it in energy and products, and eventually whole new value chains, with a reduced environmental impact, without sacrificing job creation, helping reduce poverty and continuing to improve the quality of life for a growing world population. In this context, the KBBE is about new ways of linking natural resources and processes to goods and services through increased knowledge intensity as a common denominator of the new value chains.

The transition to economies and societies based on this concept is already underway and there is clear evidence of its potential and impacts in a wide arch of application in different sectors, going from food and health to environment, transportation, construction and every sector of industry. Plant biotechnology – "green" biotech – through GMOs is rapidly becoming the standard rather than the exception – in the international agricultural commodities markets, but the applications are hardly confined to his controversial field. Biotech is today a strategic input into the breeding and propagation of crops, livestock and fish, through the use of genetic markers, and other techniques, such as embryo transfer, and they also play a key role in the development of more effective methods for veterinary and food safety - e.g. veterinary vaccines (pseudo-rabies or foot and mouth disease), detection of salmonella and BSE8 - and more efficient food production processes through enzyme design and engineering, and feed additives.

Applications in the health sector – "red" biotechnology – are probably the most developed ones, with biopharmaceuticals already representing a major share of turnover from all pharmaceuticals, with recombinant vaccines – e.g. hepatitis B - insulin and monoclonal antibodies for cancer treatment, and *in vitro* diagnostics (IVD), representing the main products but with other applications, such as genomic based diagnostics – e.g. diagnostic assays for detecting biomarkers associated with different diseases – rapidly gaining ground (Zilka et al, 2007).

Besides these applications for human medicine, there is also a rapidly growing interphase between human health and plant biotechnology, through the engineering of plants for the productions of pharmaceutical molecules or vaccines and also the development of new crops for food/feed markets with safer and more-healthful products. This is a major opportunity for positive impact of agriculture on human health, with strong potential to contribute significantly to containment of escalating diseases such as obesity, diabetes, cardiovascular ailments, some cancers and possibly some neurodegenerative diseases. Although still in the early stages this field already has some concrete examples including oil-crops with more healthful oils – Omega 3 – functional foods – yogurt with high phytosterols – and Golden Rice with high vitamin A content for decreased blindness in developing countries, among others (NABC, 2007).

In industry and the environment – “white” and “blue” biotechnology – coverage is also expanding. The production of the new energy feedstocks, as well as in the design of new, more efficient, biofuel production processes, is a development that is just in its early stages, but which has already had a significant impact on the structure of the energy sector and it will probably continue to do so, as technologies evolve from the present generation – competitive with food production – into second and third generation applications aimed at the engineering of enzymes and micro-organisms to convert cellulose crops and waste into more advanced biofuels. Associated with this the production of biomaterials including biopolymers and bioplastics for the construction and engineering sectors is also rapidly developing, although it is still represents a very small fraction of the market. However, it is to be expected that this will change in the not so distant future as the combination of what has become to be known as “green” (plant) and “white” (industrial) biotechnology bringing together conventional plant breeding with genomics and genetic engineering tools allows the production of “high tech” plants designed to better perform under stress conditions, or with properties well suited for industrial processing and the biosynthetic production of specialty chemicals and more complex molecules.

Other examples of this emerging world can be found in mining and environmental remediation, where bioengineering bacteria to facilitate the liberation of valuable metals from mineral ore – e.g. copper from sulphite ore – or to capture and recycle metals form the waste produced from primary extraction processes, is already been used, not only increasing the efficiency of mining operations, but also significantly reducing its environmental impact – reducing by 10 fold or more the concentration of heavy metals in refinery waste waters.

Beyond this there are already advanced experiences with the use of engineered “extremophyl” microorganisms to deal with different types of pollutants or fast growing plants and trees that could extract heavy metals and other contaminants form degraded soils (CBAC, 2006).

The above examples – by no means exhaustive – are clear cases of how KBBE processes work at integrating “green”, “red” and “white” biotechnology, agricultural production, conversion technologies, materials sciences and other areas, to create new and more sustainable value chains.

Even though these developments are, in most cases, still at an early stage, and market wise they represent only small fractions of the different sectors, their feasibility is in most cases proven. The issues to be confronted are not whether the new concepts are feasible or not, but whether they represent a workable instrument to advance the situation in the developing world and can help improve poverty conditions and their insertion in the world economy. Most of existing experiences, both from science as well as from implementation of the KBBE concepts, refer to a relatively strong science basis and relatively complex applications (both in terms of process and scale). The questions and challenge is whether the new concepts are of relevance for the simpler and small-scale situations and what are the necessary policies to promote and guide capacity development and investments, as well as to ensure the safety of the new technologies and the equitable distribution of the benefits of the ensuing economic growth.

3. ASSESSMENT OF PAST SMALL SCALE EXPERIENCES

So far, a macro picture was drawn on the concepts, aspects and general applications of the KBBE. This was principally driven by the KBBE diversity of possible products and processes, with the underlying notion of existing or potential demands and markets. In this section we will slice the KBBE cake from a user and/or actor perspective and within this realm especially look at the notions of scale, and foremost small scale. The latter notion first needs further specification. Since, while a developed country – be it US, Europe or Japan - definition of small scale or Micro, Small and Medium Enterprise (SME) has one specific definition[1], this not necessarily coincides with small scale in Developing Countries or Emerging Economies. The Very Small Enterprises (VSE) in Europe could still be classified as medium enterprises in countries like Colombia or Vietnam. For example, Blank (2008) analyzing relations of SMEs in biotechnology (as part of OECD's KBBE analyses) notes that the average OECD countries' SME had an asset value of 40 million USD. Hence, caution is required on the correctness of terminology when comparisons are made between Less and Developed countries….

For our analysis and discussion, relevant small scale KBBE experiences are grouped in three principal classes: (i) Biotechnology crops, (ii) Bio-refineries value chain insertion, and (iii) Biodiversity prospecting and development.

3.1 – Biotechnology crops

The latest report[2] on global commercialized biotech/GM crops, collected by the International Service for the Acquisition of Agri-Biotech Applications (James, 2010) states that global area of biotech crops continued to grow in 2009 and reached 134 million hectares, or 180 million "trait or virtual hectares". This translates to an "apparent growth" of 9 million hectares or 7% measured in hectares, whereas the "actual growth", measured in "trait or virtual hectares", was 14 million hectares or 8% year-on-year growth. Global growth in "trait or virtual hectares" increased from 166 million "trait or virtual hectares" in 2008 to approximately 180 million "trait or virtual hectares" in 2009. Recent growth over the last few years in the early-adopting countries has come largely from the deployment of "stacked traits" (as opposed to single traits in one variety or hybrid), as adoption rates measured in hectares reach optimal levels in the principal biotech crops of maize and cotton of the major biotech crop countries.

In 2009, the number of farmers benefiting from biotech crops globally in 25 countries reached 14.0 million, an increase of 0.7 million over 2008. Of the global total of 14.0 million beneficiary biotech farmers in 2009, (up from 13.3 million in 2008), over 90% or 13.0 million (up from 12.3 million in 2008) were small and resource-poor farmers from developing countries; the balance of 1 million were large farmers from both industrial countries such as the USA and Canada, and emerging economies such as Argentina and Brazil. During the second decade of commercialization, 2006 to 2015, biotech crops have an enormous potential for contributing to the Millennium Development Goals (MDG) of reducing poverty by

[1] See: http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/sme-definition/index_en.htm
[2] The following section is borrowed from James (2010)

50% by 2015. Initial research in China indicates that up to 10 million more small and resource-poor farmers may be secondary beneficiaries of Bt cotton in China (James, 2009).

It has to be also noted that together with this evidence that so far biotech crops not only have not excluded small producers, but actually significantly benefited them (Tripp, 2009). It is also true, however, that when looking into the future that there is little in the research pipelines that could be of benefit for the small scale producer and the field is clearly dominated by the activity of the large multinational seed corporations. Furthermore there is also little evidence that developing countries – outside China, India and Brazil – are important players in today's biotechnology scene, an issue with important implications not only in relation to the GM crops, but with respect to many other applications of modern biotechnology which could be of significant impact for the welfare of the rural areas (Stein and Rodriguez-Cerezo, 2009; Trigo et al., 2010).

In the same vein as GMOs, a biotech product example is noted by Jongerden (2008), that in Southern India, small scale farmers apply a Bt-based insecticide against infestations of their Castor bean plantations. The Bt component in powder form is fabricated in the same region and as such enables farmers to have easy and direct access. This is an example of a biotech product for which the farmer is the direct client and beneficiary.

A final note relates to the application of biotechnology tools to improve the levels of nutrients in grain crops. While for example, the research conducted in HarvestPlus or in GoldenRice (Falck-Zepeda et al, 2009) to a large extent still rely on conventional plant breeding, the technological advances enable these kind of projects, that impact directly on poor (nutrient deficient) consumers in LDCs.

3.2 - Bio-refineries value chain insertion

KBBE is often (erroneously) interpreted as principally involving bio-based activities targeting the research and development of bio-fuel products and processes… Indeed, the latter do represent a large share of current KBBE activities. However, this study aims to look beyond the extensively published successes of large scale bio-refineries i.e. Brazil, US, Argentina…, and to identify tools and activities that are small scale, but also result in bio-energy and/or feed stocks. Furthermore, the objective is to look at cases where small scale farmers are not mere suppliers of raw materials for large scale bio-refineries, but rather to identify the opportunities for small scale farmers to add value on-farm. The documented experiences (mainly from LAC countries) fall into two groups:

3.2.1 Micro units fed with local biomass primary material and/or sub products:

- In Colombia, ethanol prepared from cassava by a pilot plant, has the capacity to produce an average of 300 liters of hydrated ethanol (containing 4%-5% water) per day. The processing plant is part of a major project to develop rural social bio-refineries—low-cost fuel production plants that use cassava, sugar sorghum, or sweet potato as feedstock. As well as powering vehicles, cassava biofuel can also be used to generate electricity—a lifeline for rural communities in developing countries lacking access to the national grid. Waste products from fuel production can be used to make fertilizers and nutritional blocks for livestock. Any rural community that is not yet connected to electricity power can set aside 3-5 hectares to grow cassava as an energy crop and what they would produce would be sufficient to provide electric power for 6 hours a day, all year round. The biofuel requires the use of inedible high-starch cassava varieties, developed by CIAT researchers for industrial use, meaning there is no direct trade-off between fuel and food. The stems of sugar sorghum and sweet potato can also be used (CIAT, 2009).

- The same principal can also be applied to waste and by products, not only of cassava but also for example of banana. Besides plant waste products, the small-scale applications for on-farm biogas based on animal waste (pig, cattle) have been around for decades in both developed and developing regions. With current further advanced technologies, these applications can be further modified to become more cost-effective and applicable to additional biomass waste feed stocks (UNIDO, 2007a).

3.2.2 Rural processing for "intermediate" product supply to large scale factory

The logic of this small-scale actor model is based on the objective of reducing transportation costs for delivery to the principal refinery, which as a secondary objective generates added value to the raw material, by introducing a pre-processing step on-farm. Sanders (2008) argues for such "forward integration" model which, although not designed for the purpose of value adding at the farm,? offers the small scale farmer the following potential benefits :

- Pre-processing step generating additional demand for (family) labor and economic return,
- Possibility of spreading income stream beyond the principal harvest seasons,
- Adds further value through the on-farm utilization of the byproducts generated during the preprocessing step,
- Shortens commercialization channels and hence improves/stabilizes prices,
- Reduces transport costs.

A concrete application of Sanders' forward integration model is offered by DADTCO (2009) in Nigeria and further discussed by Sanders et al (2008): cassava is on farm processed by Autonomous Mobile Processing Units (AMPU), that are constructed in containers and driven to regions with a high concentration of cassava production. These units process the cassava into an intermediate product that significantly reduces its perishability, leaves by products on the fields, reduces farm-factory transport costs and increases farmers' bargaining power with starch factories. Currently there are 14 units operating together pre-processing 40 000 MT. A salient detail is that in 2009, the Bill and Melinda Gates Foundation, together with the Dutch DGIS, co-funded further replication of this model in African countries (Sanders, 2010).

3.3 - Biodiversity prospection and development

Conventionally, biodiversity has been seen in the context of the conservation of the natural resources base, assuming that it deals with a public good and that no immediate economic value is attached to it. However, the KBBE paradigm turns the concept around from a defensive "conservation" strategy, to a pro-active "exploitation" strategy. Hence, the KBBE aims to fully target biodiversity to explore and capture the full economic potential by means of suitable economic, political and technological interventions. As stated by UNIDO (2010) "The recent phenomenal scientific and technological advances imbedded in biotechnologies, are enabling the construction of "win-win" scenarios. Today a wide range of technologies exist allowing to tap into the economic value of hitherto under-utilized or unexplored biological resources".

Cutting through the expanding literature on this subject with a small scale actor knife, suggests that perhaps an appropriate classification would be the following: (i) "known" biodiversity that needs further full exploitation and development, and (ii) "unknown" biodiversity that needs to pass the full cycle of exploration, discovery and development.

3.3.1 - Already prospected, hence "known" but not yet (fully) exploited nor domesticated nor developed plant based feed-stocks typically targeting biofuel production i.e. Castor bean (*Ricinis comunis*), Purging nut tree (*Jatropha curcas)*, Switch grass, ….

- Probably the most frequently referenced “new” biodiesel feedstock is the purging nut tree (*Jathropha c.*). While not new, since experiments have been recorded for 80+ years, *Jathropha c.* needs much additional research, “domestication” and development. In the mean time, on the 3 continents, sizeable public and private investments are fast increasing planted areas. Current production systems range from large scale plantations to small family farms. So far production and processing costs remain relatively high and several research challenges remain regarding oil quality and detoxification. An expert consultation in Brazil (UNIDO, 2007b), concluded that *Jatropha* cultivation for biofuel, be it in Brazil or other parts of the world, can only be socio-economically beneficial to the rural poor and marginalized communities if done on small scale, retaining the small holder and family farm land use and ownership. However, recent data from pilot projects in Namibia (Bruntrup et al, 2009) show that economic and social benefits are positive and only vary according to different models (plantation, community, …).
- Castor bean (*Ricinis comunis*) has traditionally been cultivated in Brazil and India. Castor bean meal is internationally traded animal feed ingredient. The crop is tolerant to the marginal climatic and soil conditions like the semi-arid Northeast of Brazil and as such it represents one of the few cropping options in the region (besides extensive cattle production, cassava and cashew). In NE Brazil virtually all production is done by small scale farmers. Current yields in this region are low (629 KH/ha), compared to those on the more fertile land in Minas Gerais or Sao Paulo state, that are double or triple (UNIDO, 2007b). Subsequent higher production costs in the semi-arid regions need to be offset by strong market demand from chemical industries. Nonetheless, principal bottlenecks are identified and could be resolved through RDT interventions.
- Non Timber Forest Products (NTFP) like *andiroba, buriti, guarana, copaiba, unha de gato* etc have been traditionally locally exploited for perhaps centuries. However, increased prospective research continually generates new (functional properties) opportunities for additional potential uses and markets (Henry et al, 2001). Small farmers and forest dwellers play an essential role in the collection, pre-processing and delivery of the raw materials. Subsequent economic returns are important. The construction of the value chain originating in native tropical forests and delivering to high-tech European or Asian based (cosmetic, pharmaceutical) laboratories has many challenges. Nonetheless, these traditional products that are inserted in new high-value international markets are an important part of the bio-based economy portfolio for small scale actors. Some of the well known examples are *guarana* for Brazilian soft drinks, and NTFP essential oils for NATURA cosmetics product line (Henry et al, 2001).

An important point in the aforementioned 3 experiences is that the basic relevance to small scale farmers is evident. However, the small scale actor model here of basic raw material supplier needs to evolve by introducing pre-processing steps on site (on farm), hence value adding and increasing economic returns. This is already the case for NTFPs.

3.3.2 - Unknown biodiversity needing prospection, domestication and development.

- Corporation Biotech in Colombia is advancing a program to indentify, explore and value add bioactive products in traditional tropical fruits produced by small scale farmers, for nutrition and industry uses incl. cosmetics (UNIDO, 2010).
- In Peru a government funded project PNCC advances the prospection of camu-camu (*Myrciaria dubia* (HBK) Mc Vaugh), which is a native tree that grows in flooded areas in the Amazon region. The tree is an important component of riparian vegetation in Peru and Brazil, and is especially abundant in Peruvian black water river systems. It produces a fruit with the same name extremely rich in ascorbic acid (an average of 2.7–2.8g of AA and up to 4000mg AA per 100g of pulp). The tree is also highly productive, with some studies of wild populations estimating fruit production at 9000 to 12,000kg per hectare,

with the potential to generate exceptional economic returns for small local farmers and forest dwellers. Besides ascorbic acid, the camu camu fruits contain small quantities of calcium, iron, niacin, tiamin, riboflavin and other phytochemicals that gives to the fruit powerful oxidative, anti-inflammatory and anti-depressive properties. This, combined to the agreeable flavour, makes the camu-camu a good alternative to the nutraceutical industry (UNIDO, 2010).

- The Industrial Biotechnology Center at INTI in Argentina is advancing a program to improve the nutraceutical properties of blueberries. The programme includes research for the determination and quantification of fisetin in blueberries and the process to obtain rich extracts of fisetin. In addition, fisetin rich varieties and blueberry appropriate agronomics characteristics are being studied. Results serve the pharmaceutical industry. Future blueberry varieties can be directly adopted by small and medium local producers (Diaz, 2009).
- At the Pontificia Universidad Javeriana in Colombia research is well advanced in the identification of functional properties of *Aloe barbadensis* waste products that are subsequently being converted into lactic acids using thermophylic strains, producing feedstock for biofuels. This process is applicable to small and medium enterprises (Hodson, 2009).
- Kew Gardens in the UK is among other research, focusing on the functional properties of oil seeds from annual and perennial crops and trees in moderate as well as tropical climates. One of its successful projects, in collaboration with Unilever, regards the *Allanblackia floribunda* which thrives in native African rain forest. Its seeds contain 70% oil for edible and cosmetic uses. In 2008 in Tanzania and Ghana, 100 000 seedlings were commercially planted. The technology is scale neutral and small farmers will be the principal beneficiaries (Prittchard & Seal, 2009).

Mateo (2009) analyzed the lessons learnt and future prospects of biodiversity utilization in Latin America. He documents an experience in Costa Rica where the National Biodiversity Information System – CRBio (part of the Global Biodiversity Information Facility), has placed through electronic means, a total of 30,000 species of its principal taxonomic groups in the public domain. He also points out that bioprospecting not only is of principal interest to upmarket transnational companies, but also for national and regional markets. He further concludes that given the complexities attached to environmental policies, commercial use and IPRs, considerable additional discussion, analysis and agreement is needed between the principal (private and public) actors in the various sectors of society. In this discussion, small-scale actors and ethnic groups will deserve further intention to safeguard their appropriate share of potential future benefits.

3.4 – Relevance and bottlenecks for LDC small scale users and actors

The small-scale experiences so far discussed have been analyzed regarding their appropriateness for small scale farmers, benefits to rural development, bottlenecks and future R&D and policy needs (Table 1). What can be observed first of all is that there actually exists an interesting range of different options to connect small scale actors to the KBBE. As such, local small actor socio-economic, policy-institutional and agro-ecological conditions pre-destine the most viable options that could best intervene (once adapted appropriately). However, the issue of the lack – or not sufficiently developed – capacities in the biotech area, is a common limitations appearing in each case. Secondly, there seems to be a group of on farm (pre)processing technologies that offers a very wide variety of different applications using raw material ranging from traditional crops (cassava, banana, plantain, sorghum, maize, …), their by and/or waste products, and other materials such as grasses, wood products etc. Livestock can play an additional role in these scenarios. Thirdly, timelines are varying. Certain bio-based applications suitable to small scale actors are already (or close to) transfer/adoption i.e. biotechnology crops, small pre-processing units and some of the "newer" feed stocks. Other applications at the earliest are "in the pipe" or need additional basic and/or applied research, i.e. biodiversity prospecting. This time aspect again is important to take into account when analyzing KBBE related innovations and their potential for small scale actors. Fourthly, while we argue that the discussed KBBE applications for small scale actors have varying degrees of suitability, they will all need additional RDT and policy interventions to become KBBE small scale champion examples for wider diffusion and adoption.

Table 1 – Relevance and bottlenecks of small scale KBBE experiences and future needs

KBBE type of activity	Applicability for small scale user	Beneficial for rural development	Current principal bottlenecks	Necessary policy intervention	Necessary RDT needs
Group 1 - Biotechnology crops					
	Dependent on the crop. Maize and soybean applications not clear. But majority of benefits in cotton have been to small producers	Important through multiplier effects of increased activity in the non-farm sector (estimated to be 50%-100% of increases in the farm sector)	Low levels of investments in non-commodity crops, by both the public and private sector. Reduced capacities and regulatory complexities limiting involvement from public research institutions	Regulatory systems harmonization to facilitate extension of available innovations to small producers crops	Applications emphasis on small farmers and "orphan" crops.
Group 2 - Biorefinery value chain insertion					
On-farm micro units i.e. CASSAVA IN COLOMBIA	Pilot experiences with high potential for small scale, with feedstock not competing with food production	Impacts are through improved rural communities wellbeing through more reliable sources of energy to support other social and economic activities	Lack of biotech capacities for exploring options and scaling up pilot experiences in terms of equipment availability and diversity of sources of feedstock	Investment support both at farm level and for integrating surplus energy production into the regional /national energy supply	Feedstock diversification avoiding competition with food use
Intermediate products pre-processed on-farm i.e. CASSAVA IN AFRICA	Pilot experiences have proven viability at the small scale level	Potentially high benefits from expanded possibilities of added value on local production	Lack of biotech capacities to explore / develop options and product standardization and limited experiences and small local markets	Market integrations policies to connect local and national markets	Post harvest and value adding technologies Impacts of norms and standards
Group 3 - Biodiversity prospection, domestication and development					
"Known" but yet unexploited biodiversity i.e. JATHROPHA	New crops have proven competitive and improved alternatives over traditional, particularly in poor resources areas	Potentially important through expanded income opportunities for farmers and other activities at the local level	Not enough knowledge on many aspects of the new crops and their production systems and value chains are not fully developed	Funding mechanisms for projects integrating on farm production with value chain development	Breeding and agronomy for productivity improvement Market potential and information for value chain development.

"Unknown" and unexploited biodiversity i.e. REALLY NEW	Not important in short run although small producers usually in high diversity areas can integrate traditional knowledge to prospecting efforts	High through the identification of new opportunities and valorization of local resources	Lack of biotech capacities in national institutions Financing is also difficult because long maturation time of investment and market risks, also complex IPR management	Facilitating benefit sharing mechanisms and risk capital for specific project development	Genomic capacities for compounds identification, breeding for domestications and commercial exploitation

Source: Authors' analyses.

A recent paper by Langeveld et al. (2010) assesses the main development perspectives of bio-based products (for LDCs). While discussing bio-fuels, bio-refineries and bio-materials, they analyze in more depth the bio-products such as pharmaceuticals, chemicals, solvents, polymers, etc. Their results show that these mostly high value bio-products have only a low to moderate prospect of impact for local producers. This may serve as an additional set of information regarding KBBE prospects for development (though not *per se* small scale).

4. CONCLUSIONS AND RECOMMENDATIONS

In this paper the line of argument was that so far, typically the larger scale KBBE applications have driven and proven the model, thus raising the question regarding the possible benefits of the KBBE model, its concepts and applications for small-scale actors and rural / local development. The previous sections have shown evidence, that there exists a wide range of KBBE related innovations that can benefit small scale actors directly or indirectly through lower operational costs, improved markets, better product prices, expanded demand for labor, etc. It was also shown that most applications still need varying levels of RDT and/or policy interventions to optimize their suitability and subsequent diffusion, and the capacities to do so is lacking in many of the developing countries where the benefits of such work would be the greatest.

KBBE applications without policy interventions typically seek to increase scale economies for improved cost effectiveness and competitiveness. Equity considerations in the form of "pro-poor (public) policies" (in the form of targeted subsidies, investments, training, information, advice….) on the one side and "corporate social responsibility" as internal policies with the private sector, on the other side, will be needed to increase the probability of the degree of insertion of small-scale actors in the KBBE model. Furthermore, research and technology delivery agendas need to be adapted to include the wide array of (new topics and/or already existing) small-scale technologies, applications, systems etc that are part of the KBBE concepts and that target their benefit streams to small scale actors and/or rural development. This is in line with Langeveld et al. (2010) who argues that "one pathway to household food security and poverty reduction comprises household entitlements (income) associated with high value added products from biomass, through small scale local bio-refineries producing bio-energy or bio-products in poor, marginal and remote areas. Incentives for such decentralized investment in bio-refineries would require pro-poor institutional and policy environment".

Besides appropriate equity considerate policies, improved regulatory policies (IPR, bio safety) are needed to create the institutional and market conditions that allow for small actors to benefit from the KBBE RDT opportunities. As Louwaars (2008) argues "Opportunities exist to tailor intellectual property rights (IPR) to development objectives, and where policy space is reduced due to strong demands from trade negotiations, openings are forged through private and NGO initiatives. It appears that such openings are not being developed in developing countries in the field of genetic resources rights".

In moving forwards towards a more proactive environment in terms of taking advantage of the opportunities identified there is the need to increasing awareness among institutions and key actors regarding the opportunities and the needs that the KBBE represents for small scale and rural development, and consequently the need to mobilize resources significantly strengthening biotechnology capacities at the developing countries level. While this is done, there is also the need to start moving at the research level. Here there is a pressing lack of more detailed information about the opportunities themselves. As mentioned, there is amle evidence on large-scale cases, but little well substantiated prospective on what the new KBBE environment can bring to the small scale and the rural areas. As science applications in this field are enlarging, their scope (in many situations only on-paper potential), are becoming real and feasible, both scientifically and from the economic point of view. Additional and more quantitative studies are required to better select the possible win-win options to specific small scale actor, and also to support awareness rising at the policy level. Beyond this, research should be focusing on to main fronts. One is the expansion of the small scale energy pilot experiences to other feedstocks, as to have a more varied menu of options that better reflects the diversity usually found in rural areas. The second is the development of more standardized methodologies for the evaluation of biodiversity and its potential use, that are able to fully integrate the empirical knowledge that local communities can offer with the advanced genomic technologies required for the proper valorization of the available diversity.

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