THE LINK BETWEEN BIODIVERSITY AND SUSTAINABLE DEVELOPMENT: LESSONS FROM INBio's BIOPROSPECTING PROGRAM IN COSTA RICA

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The quest for a sustainable development model

In its quest for a human sustainable development model Costa Rica, as many other countries, faces the challenge of how to establish a proper balance among a complex interaction of economic, social and environmental factors (Estado de la Nación, 2002). With a territory of 51,100 km^2 (about the size of West Virginia), the country is home to an estimated number of 500,000 species of plants, animals and microorganisms, representing nearly 5% of all the world's diversity of organisms (Obando, 2002). How to protect this biological wealth while simultaneously promoting the social and economic development of the country represents a challenge of singular complexity and magnitude.

Congruent with its new proposed paradigm and development model, Costa Rica is devoting nearly a third of its territory to the conservation into perpetuity of its rich biological diversity. This represents a major investment for any country, but particularly for a small developing country like ours, as this means renouncing to the short-term gains of non-sustainable utilization of resources in this significant portion of the territory.

The environmental concerns and decisions to protect the natural patrimony of the country must be put in the context of the historical development path followed by Costa Rica since 1940. This period is characterized by a stable political system based on a disarmed democratic government, high economic growth rates and substantial advancement in social indicators. United Nations Development Program's Human Development Index (0.71) places Costa Rica in a remarkably high position in the world. Some of the country's evolution indicators are summarized in Table 1. Remarkably, with a modest GNP per capita of less than US$ 4,028, the country has attained among others, life expectancy, health and literacy indicators similar to many developed countries in the North. Notably, human population has quintupled in this period and is expected to double in the next three decades, stabilizing at approximately 8 million people around 2030. Nearly 20% of the population remains poor and mostly concentrated in rural areas (Estado de la Nación, 2002).

Table 1. Costa Rica's evolution indicators (1940-2000)*

INDICATOR	UNIT	1940	1960	1980	2000
Human development index	Coef.	N.D.	0.55	0.75	0.71
Population	1000	656	1.199	2.276	3.943
Poor homes	%	N.D.	50	19	21
Life expectancy at birth	years	46.9	62.5	72.6	77.4
Infant mortality	1000	123	68	19	10.2
Literacy	%	73	84	90	95
GNP percapita	US $ 1990	702	1.08	2.022	4.028

*The scale for the calculation was modified between 1980 and 2000.
Source: Estado de la Nación (2002).

Figure 1 presents some selected social, economic and environment indicators, highlighting the significant changes that have occurred in the last decades, and the close relationship that seems to exist among those indicators.

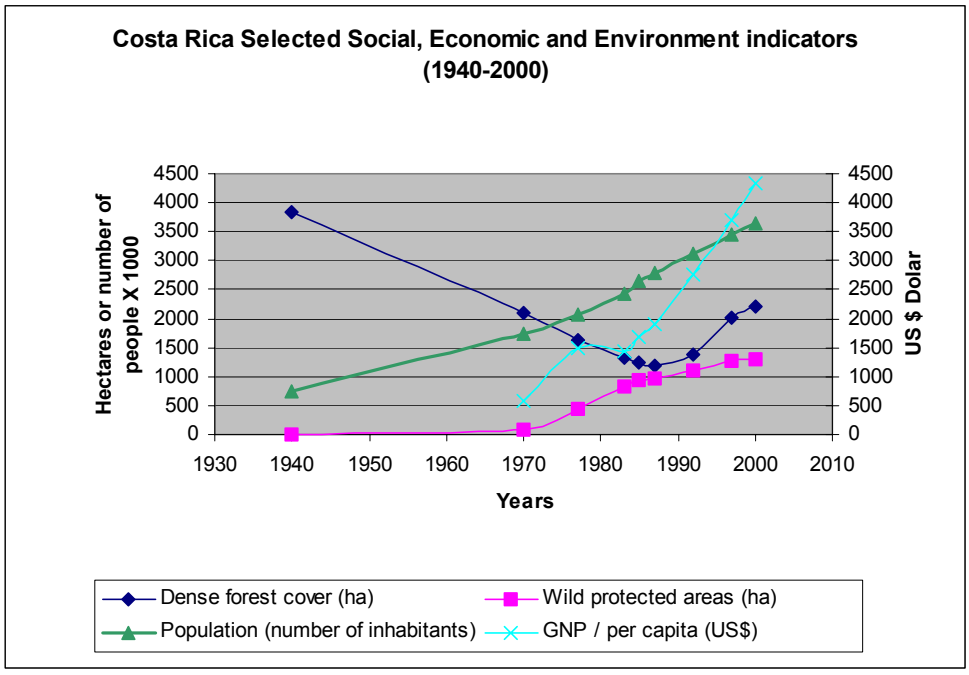

Figure 1. Costa Rica: Selected social, economic and environmental indicators (1940-2000).

Modified from Gámez & Obando (2003).

The major investments made in social welfare and education from 1948 and onwards, associated also to changes in the economic model, are clearly linked to the increase in the GNP/capita. As in many other Latin American countries, Costa Rica's development model during 1940-1970 was largely based on a non-sustainable agricultural use of its natural resource base, which led to a significant reduction of the country's forest cover and less of its rich biodiversity, as well as rapid degradation of land, resulting from the concomitant soil and water problems. By 1970 the evident environmental crisis began to trigger an increased public awareness and concern about its short and long-term consequences. A succession of correct political decisions and actions in the following decades allowed the country to consolidate a solid system of wild protected areas, reduce its forest loss, and recover significant dense forest cover. These efforts involved numerous and diverse sectors of society, and attracted significant international support and recognition to the country. The shift in environmental degradation trends clearly coincided with the significant improvement of the social and economic conditions of the country, and the drift towards a service-oriented economy (Gámez & Obando, 2003).

The sustainable utilization of biological diversity

As established in its National Biodiversity Conservation and Sustainable Use Strategy (MINAE, 2000) Costa Rica's biodiversity conservation policy is based on the "save, know, use" trilogy of principles. "Save" means protecting representative samples of the country's biodiversity through a system of protected areas. "Know" means knowing the biodiversity that exists in the country and particularly in its protected areas, and "use", means using sustainably this biodiversity for the social and economic benefit of the country. An increased awareness of the many different values of biodiversity by society as a whole is expected to help attain its conservation, as its contributions to the improvement of people's quality of life become increasingly evident and recognized. Otherwise, those areas devoted to biodiversity conservation run the risk of being converted to other forms of utilization, not compatible with conservation.

The sustainable utilization of biodiversity is already making significant contributions to the social and economic development Costa Rica in several different ways. These include nature oriented tourism, payment of environmental services and bioprospecting.

Nature oriented tourism has become one of the most important economic activities of the country. Figure 2 compares the foreign exchange (US$) generated between 1950-2000 by selected agricultural activities (coffee, bananas and beef), forestry (timber) and nature oriented tourism. It is evident that from an economic perspective, the investment in biodiversity conservation has been the most productive one to the country. Ecoturism is generating more income to the country with significantly less environmental impact, than that caused by other forms of direct exploitation of natural resources, such as timber or cattle ranching. The combined environmental impact of the latter two activities account

for the loss of over one third of Costa Rica's forest, with other collateral effects, such as the soil erosion, flooding and other natural disasters.

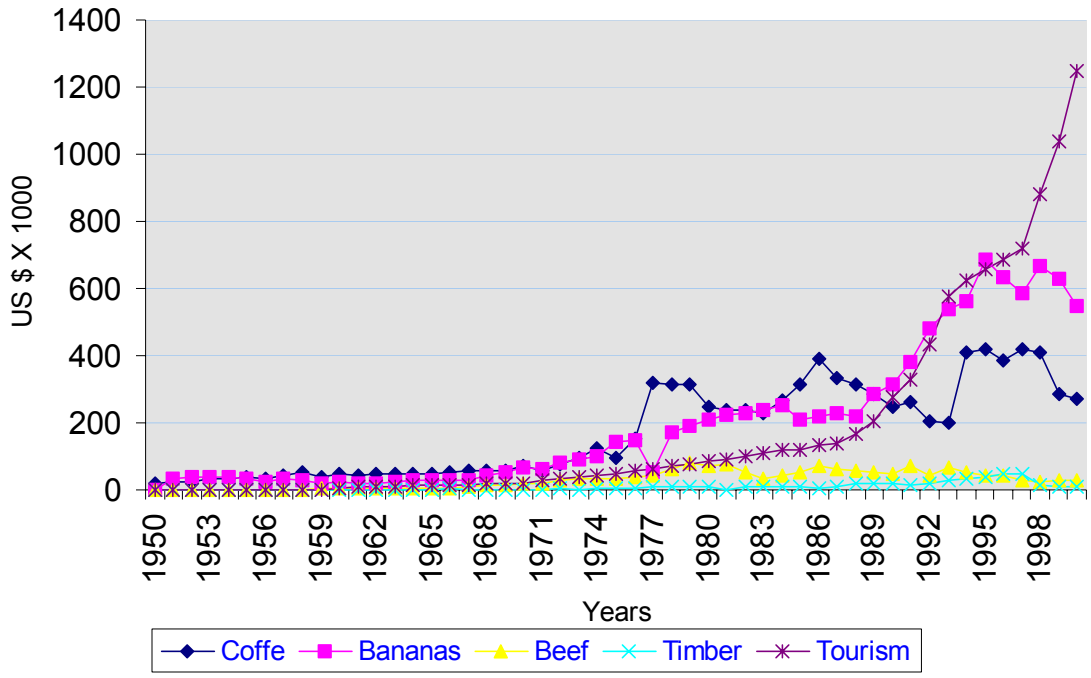

Figure 2. Costa Rica foreign exchange (US $) generated by selected agricultural and forest products and tourism (1950-2000).

Source: MIDEPLAN. Principales indicadores de Costa Rica. San José. Costa Rica. 1998 / Watson, U. *et al*. Making space for better forestry. Policy that works for forest and people. No 6. CCT, IIED / JUNAFORCA. 1998 / MINAE - FONAFIFO, Costa Rica hacia la sostenibilidad de sus recursos forestales.1998 / SEPSA-MAG, 2000.

Viewed as a non-consumptive, indirect use of biodiversity resources, nature oriented tourisms has proven to be a more intelligent form of sustainable use of land and natural resources. The combined effect of the existence of a system of protected areas, with magnificent examples of tropical biodiversity and scenic natural beauty of the country, the social and economic stability and cultural characteristics, proper governmental policies and the active involvement and participation of the private sector, have contributed to make nature-oriented tourism a more sustainable form of intelligent utilization of natural resources. In addition, the particular characteristics of its development, judged by international standards, have positioned Costa Rica as a leader this industry, in terms of benefits and efficiency (Obando & Zamora, 2001).

As another form of economic valuation of biodiversity, Costa Rica has also pioneered the payment of environmental services provided by ecosystems. The valuation of water production, CO_2 fixation, biodiversity conservation and protection of scenic beauties by forests in both private and public properties, and

the corresponding payment of these provided ecosystem services, are bringing direct economic benefits to forest owners. Simultaneously, these benefits contribute directly to the cost of conservation and protection of forests (Barrantes, 2001).

An example of this approach is the successful initiative of the Empresa de Servicios Públicos de Heredia (ESPH), a local public water and power utility, that decided to create economic instruments to implement water resource protection in order to guarantee future water availability to the community. Figure 3 illustrates the user's direct payment of the water and watershed protection, service. The Braulio Carrillo National Park, which protects good part of the critical watershed, and private owners who are entitled for compensation for the opportunity cost, receive a direct payment for the service provided by forest ecosystems in their land (Gámez, 2001).

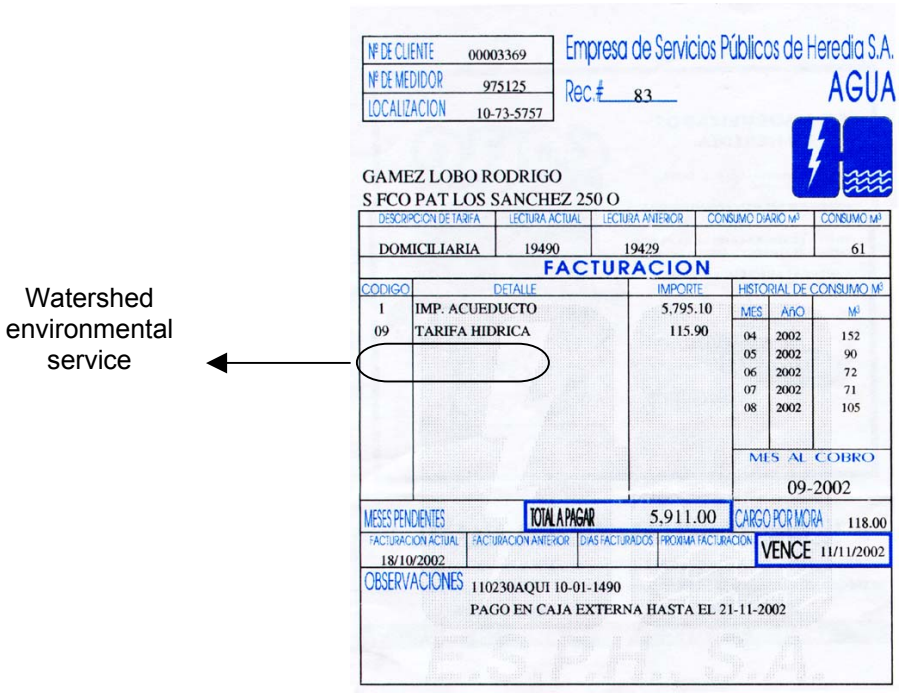

Figure 3. Direct payment of forest watershed protection service in Heredia, Costa Rica.

Bioprospecting, done right, has been viewed by INBio in Costa Rica as another form of sustainable utilization and economic valuation of biodiversity, as well as a means to support the conservation of biological diversity (Eisner, 1989; Reid *et al*., 1993;). From this perspective, INBio's 12-year bioprospecting experience is summarized in the following section.

INBio's bioprospecting experience in Costa Rica

Ever since INBio entered the land mark commercial bioprospecting research collaboration agreement (RCA) in September 1991 with the pharmaceutical corporation Merck & Co., this agreement and the much broader experience gradually gained in bioprospecting by the institution, has been examined in detail from different perspectives (Mateo, 2001; Reid *et al*., 1993; Sittenfeld & Villers, 1994; Tamayo *et al*, 2003). In spite of the fact that numerous other RCAs exist all over the world, the INBio-Merck agreement has been the subject of frequent reference in many writings on the subject (Laird, 2002; ten Kate & Laird, 1999).

The continued international interest in INBio's experience in prospecting Costa Rica's biodiversity is exemplified in the statement made in August 2002 by the Executive Secretary of the CBD, during the IV Conference on the Parties (COP 6) held at The Hague:…"*A well known example of an access and benefit sharing contract was agreed between Diversa Corporation and the Costa Rican National Biodiversity Institute (INBio) in 1995 and renewed in 1989...".* (CBD, 2002).

The learning-by-doing experience of INBio in its search for fair and equitable benefit-sharing mechanisms of development of biodiversity resources, for the purposes described before, seems to fulfill the expected role stated since its inception in 1990-1991. That is to serve as a model to be followed, but a promising pilot project that offers important and valuable lessons relevant to the success of similar bioprospecting ventures elsewhere (Reid *et al*., 1993). But there are negative views of the institutional initiatives. INBio's initiative and experience has been negatively criticized by some environmental groups, which still view it as an advanced form of biopiracy (Kloppenburg & Rodríguez, 1992; Martínez, 2002).

*The criteria and terms of the Research Collaborative Agreements used by INBio***.** The criteria and terms followed in the original INBio-Merck & Co. RCA (Sittenfeld & Gámez, 1993), which ensured INBio's conservation mission, constituted a milestone for future negotiations and with minor improvements, are still maintained today. They were recently summarized (Tamayo *et al*., 2003) and appear below:

- ✓ Access is limited to a given amount of samples from natural resources and is facilitated for a limited period of time (exclusivity terms are limited), under terms established by the existing national legislation and a framework legal agreement between INBio and the Ministry of the Environment and Energy (MINAE)
- ✓ Taking into account the existing technical and scientific capacities, a significant part of the research should be carried out locally, and associated research costs, as defined in the research budget, should be entirely covered by the industrial partner;

- ✓ An up front payment of a minimum of 10%, when applicable, is included in the research budget, and is transferred directly to MINAE for exclusive conservation purposes;
- ✓ Benefit sharing mechanisms are negotiated beforehand and include among others:
    - o Milestone payments for the discovery and development phases of a potential product, (to be shared 50:50 with MINAE);*
    - o A percentage of royalties on net sales of the final product, covering derivatives from any original natural scaffolds and/or any technology derived thereof, (also to be shared 50:50 with MINAE);*
    - o Intellectual property rights apply and contemplate the possible participation in discoveries of INBio's scientists (joint patents and publications);
- ✓ Technology transfer and local capacity building must insured, including training of local scientists in state-of-the-art technologies;
- ✓ The discovery and development of a product is restricted to non-destructive uses of natural resources and must be entirely consistent with the national legislation dealing with access to genetic resources and developments thereof.

Among the different factors which determine the feasibility of establishing and implementing the above-mentioned criteria and terms, institutional capacities, as well as political and legal frameworks are of fundamental importance.

According to the INBio/MINAE collaborative agreement, INBio conducts its bioprospecting activities, with a few exceptional cases, only in MINAE's protected areas. Contrary to the situation prevalent in many countries throughout the world, protected wildlands in Costa Rica have no inhabitants, local farmers or indigenous people. This is the reason why the distribution of monetary benefits in the INBio/MINAE agreement does not contemplate directly these particular sectors of society.

It is important to understand that in the case of Costa Rica, the majority of the local Indian population (around 1% of the total) live in reserves which comprise nearly 6% of the national territory, and posses their own rules and regulations. It has been INBio's policy not to seek the access to either biotic resources in Indian reserves or their traditional knowledge. The terms through which both resources and knowledge may be accessed, are clearly established in Costa Rica's biodiversity law (Asamblea Legislativa, 1998).

The development of institutional capacities. Using and applying criteria of modern organizations, and taking advantage of the particular conditions of the

* As a public-interest, non-profit organisation, INBio would invest its corresponding part entirely in the compliance of its biodiversity conservation mission.

country and its scientific and technological conditions, INBio has been able to build a solid internal capacity for capturing information on natural resources, processing and transferring this information to society, in different formats for different users and uses. Its main thematic areas of activity include biodiversity inventorying and monitoring, bioinformatics, education and bioliteracy, wild land management and bioprospecting, all operating in a closely interlinked fashion. In 2001, the bioprospecting budget represented 11% of the total institutional budget (INBio, Annual Report 2001), and has historically fluctuated around 11 and 17%.

INBio's institutional capacity rests largely on strategic alliances with the Government, the academic and the private sector, nationally and internationally (Gámez, 1999; Zeledón, 2000).

Costa Rica has established appropriate legal frameworks to deal with conservation of genetic resources, its access and its sustainable use which have facilitated the establishment of CRAs. The Biodiversity Law, by Costa Rican Congress (Asamblea Legislativa, 1998), in full compliance with the terms of the CBD, defines the conditions, in which bioprospecting activities should be carried out in Costa Rica. On this issue, INBio's experience was very important and was taken into account in defining the benefit sharing and intellectual property rights mechanisms for RCAs negotiated by institutions or individuals in the country.

Throughout the years INBio's approach has proven to be successful under the particular conditions of Costa Rica. To date, INBio has signed more than 20 agreements with industry, (Table 2) and the total of the research budgets have come to represent an investment of US$ 0.5 M per year for bioprospecting activities and US$0.5 M per year for capacity building, technology transfer, and institutional empowerment. The latter are of transcendental relevance, as they steadily increase INBio's capacity to negotiate fair and equitable agreements. It is a clear institutional objective to maximise the institutional participation and the information value added to the particular products shared with the commercial partner. In the very competitive and dynamic technological sector, it is vital to increase the local capacity by means of training and technology transfer, ensuring the institutional participation in the overall process of discovery and development of final products.

Two major accomplishments have resulted from the implementation of policies and strategies established by INBio. One is the increasing scientific and technological participation of the institution in the development of final products, and second, the sharing of benefits (monetary and non monetary), as well as the risks inherent to industrial developments. Both factors contribute to the development of long-lasting partnerships.

A new type of partnership with local enterprises. The projects developed with Follajes Ticos, la Gavilana, Laboratorios Lisan, Bouganvillea and Agrobiot (Table 2), all local Costa Rican small-medium size enterprises, received financial support (risk-capital) from funds donated by the Interamerican Development Bank (IDB). INBio's main contribution was technological support and know-how, while enterprises provided with their own knowledge and capital. If successful in

their projects, enterprises will return to a revolving fund the financial resources donated by IDB to fund future initiative. In case of failure, the risk-capital would not be returned.

Table 2. Most significant research collaborative agreements with industry and academia (1991-2002)*.

Industry or Academic partner	Natural resources accessed or main goal	Application fields	Research activities in Costa Rica
Cornell University	INBio's capacity building	Chemistry	1990-1992
Merck & Co	Plants, insects, micro organisms	Human and animal health	1991-1999
British Technology Group	DMDP, compound with nematocidal activity	Pest control	1992-present
ECOS	*Lonchocarpus felipei*, source of DMDP	Pest control	1993-present
Cornell University and NIH	Insects	Human health	1993-1999
Bristol Myers & Squibb	Insects	Human health	1994-1998
Givaudan Roure	Plants	Fragrances and essences	1995-1998
University of Massachusetts	Plants and insects	Biological pest control	1995-1998
Diversa	DNA from Bacteria	Biotech industry	1995-present
INDENA SPA	Plants	Human health	1996-present
Phytera Inc.	Plants	Human health	1998-2000
Strathclyde University	Plants	Human health	1997-2000
Eli Lilly	Plants	Human health and agriculture	1999-2000
Akkadix Corporation	Bacteria	Pest control	1999-2001
Follajes Ticos	Plants	Ornamental horticulture	2000-present
La Gavilana S.A.	*Trichoderma* spp	Biological pest control	2000-present
Laboratorios Lisan S.A.	None	Phytopharmaceuticals	2000-present
Bouganvillea S.A.	None	Biological pest contro	2000-present
Agrobiot S.A.	Plants	Ornamental horticulture	2000-present
Guelph University	Plants	Agriculture and Conservation	2000-present
Florida Ice & Farm	None	Technical and scientific support	2001-present
ChagasSpaceProgram	Plants, fungi	Human health	2001-present
SACRO	Plants	Ornamental horticulture	2002-

*Modified from Tamayo *et al*., 2003.

The above mentioned projects represent a different category of partnership developed by INBio's Bioprospecting program. As stated before, the partners are all small local enterprises, developing little-costly projects for small local market, with partly-donated modest funding and requiring relatively low, simple technologies and shorter time for their developments. Contrary to the big

and complex projects carried out with the large transnational corporations, these small and simpler projects, while not totally completed yet, are already considered successful initiatives, likely to make singular contributions in terms of profits, employment and more value-added agro-industrial developments.

The main achievements. It is popular knowledge (Tamayo *et al*., 2003) that the development of a product might take 5-20 years of research depending on the field (agricultural, biotechnological or pharmaceutical applications), and might require the investment of hundreds of millions of US dollars until final products reach the market. Pharmaceutical and agriculture product discovery is a highly costly, high-risk and low probability form of research. A recent estimate indicates that the investment needed on an 11 year period of research is over US$800 M (Watkins, 2002). These considerations clearly indicate that it is still early to expect products from Costa Rican biodiversity to be launched into the commercial market. This is not only the case for INBio but for other bioprospecting initiatives around the world (Moran *et al*., 2001; ten Kate and Laird, 1999).

On the other hand, it is most likely that simpler products from the IDB funded projects could be commercialised locally or internationally in some cases, before any blockbuster in the USA or Europe. In any case, the impact and relevance to the institutional mission, particularly because of the potential contribution to the valuation of biological diversity and improvement of quality of life of society could be significant.

Some of the main tangible benefits arising from bioprospecting activities at INBio and discussed in previous sections, are summarized in Table 3 (Tamayo *et al*., 2003). In terms of direct monetary benefits, the total of all research budgets amount to nearly US$ 10, 8 M. The value of the technology acquired and infrastructure developed is probably worth several million dollars. Over US$600,000 corresponding to the 10% of the research budgets[*], went directly to conservation activities carried out by MINAE. A significant contribution of more than US$2 M total, corresponding to research expenditures (salaries, equipment, infrastructures, laboratory supplies, etc) was transferred to MINAE's Guanacaste Conservation Area, to the University of Costa Rica and to the National University of Costa Rica. These organisations have been part of strategic alliances for the execution of research projects.

Although not highly significant in monetary terms, approximately US$0.6 in milestone payments have been shared 50:50 with MINAE, according to the established agreement. No royalty payments have been received yet, although some promising products could likely reach the market in the next few years.

The non-monetary benefits of the RCA have been considered by INBio as equal, if not more important is many cases, than the monetary ones. A similar conclusion has been reached by other countries and institutions (ten Kate & Laird, 1999). The scientific and technological capacity developed by the

[*] Academic research budgets do not include the 10% access fee, as governmental financial resources are mostly of governmental origin.

institution in its 12 years of bioprospecting experience is considered as one of its more important assets, which as discussed before, has contributed directly and significantly to the formulation of proper national policy and legislation regulating the access to, and benefit sharing derived from biodiversity resources (Asamblea Legislativa, 1998; MINAE, 2000). The contribution made to the scientific and technological development of the country through this approach is substantial, and among other considerations has enabled the institution to receive important international scientific awards and recognitions (Gámez, 2000).

Table 3. Monetary and non-monetary benefits derived by INBio from bioprospecting*.

Monetary Benefits
1. Totally funded local research budgets
2. Technology transfer and infrastructure
3. Up front payments for conservation
4. Strengthening of research capacity of local scientific institutions
5. Milestone and royalty payments shared with MINAE
Non Monetary Benefits
1. Training of human resources
2. Empowerment of human resource
3. Technology transfer
4. Shared research results and information
5. Negotiations expertise developed
6. Market Information
7. Improvement of local legislation on conservation issues

*Modified from Tamayo *et al*., 2003.

The direct outputs in terms of products derived from the RCAs entered by INBio include patents on compounds, specific promising compounds with biological activity identified or not, biological control microbes (fungi and bacteria) and nutraceutics, among others (Tamayo *et al*., 2003). As stated before, it is likely that one or more of these products will reach the market in the near future, the likelihood being higher for the “low-tech” modest domestic projects with small

enterprises, rather than for the costly and complex “high-tech” initiatives carried out with the major international partners.

The future of bioprospecting in INBio and Costa Rica

Bioprospecting in the way done by INBio (Tamayo *et al*. 2003), has provided both the institution and Costa Rica with a vast and complex experience on access, legislation and uses of genetic and biochemical resources. Equally important, the gradual acquisition of intellectual scientific capacities and know-how, as well as state of the art technologies, has enabled INBio to position itself as a biotechnological entity capable of providing industrial partners innovative products and services with significant added value. The know-how and experience gained in initiatives with international industrial partners also proved to be of singular value when applied to local small enterprises. The experience gained with the IDB funded initiative is demonstrating that agreements with local enterprises are not only possible, but may result in the development of final marketable products in a shorter period of time, with the subsequent promotion of local economic development. This may also have a significant positive impact in the awareness and perceptions on the values and opportunities offered by biodiversity, in both the general public and governmental decision makers.

An example of the latter is the decision made by the Ministry of Science and Technology of Costa Rica, endorsed by the MINAE and the Government as a whole, to negotiate a multi-million research loan from IDB, in order to promote the development of the local biotechnology industry. Based on the experience and capacities developed by the national universities and INBio, and the increased awareness of the potential opportunities offered by the rich biodiversity of the country, a major investment in biotechnological research and development was considered politically appropriate and opportune. The possibilities for the application of modern biotechnological solutions for local problems in health and nutrition, general agriculture and industry in general, may be only limited by financial resources, and not by imagination.

Based on the positive experience gained to the present, INBio will evidently continue to promote the development of biotechnological research activities with different academic or industrial partners. New approaches in microbial and gene prospecting will be explored, addressing their potential application in the pharmaceutical and cosmetic industry, as well as in agriculture.

In the field of chemical prospecting, INBio foresees more value-added agreements with academia and international biotechnological partners. This is largely due to the acquisition through donation, of several preparative automated fractionators, which allow the isolation of significant amounts of pure compounds in a high throughput fashion. The screening of large number of natural products is now possible with the additional advantage of securing the partners the re-supply of any compound.

Finally it may be concluded that, as in other cases (McManis, 2003), when social and economic conditions are given favouring biodiversity conservation and scientific and technological development, biotechnology or biodiversity prospecting as a whole, emerge as a most valuable scientific tools to realize the potential of the biodiversity of a country. Clearly, as in the case of Costa Rica, bioprospecting is one of several other approaches to realize such potential. Ecoturism or the direct payment for environmental services as discussed above, offer other significant opportunities of making non destructive uses of tropical biodiversity for the benefit of the country. The scientific and technological, legal and commercial requirements of bioprospecting initiatives are inherently more complex than other forms of non-destructive use of biodiversity.

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