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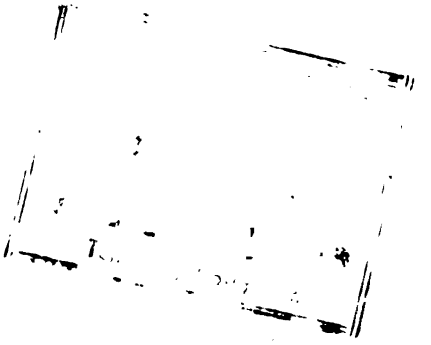

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"GLOBALIZATION OF AGRICULTURAL RESEARCH"

ABSTRACTS

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GLOBALIZATION OF AGRICULTURAL RESEARCH: A CGIAR PERSPECTIVE

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Agricultural development is key to tackling the global challenges of hunger, poverty, and environmental degradation. Worldwide, 800 million people, mostly women and children, go hungry every day. More than a billion people live on less than a dollar a day, and twice that many live on less than $2 per day. Poverty is a predominantly rural phenomenon. Agriculture is the biggest user of land and water resources, and research that helps to reduce agriculture's ecological footprint is essential for conserving the environment.

Despite the centrality of agriculture in development, public investments in agricultural research are stagnating worldwide, growing by just 0.2 percent annually during 1991-96, compared with 2.2 percent during the 1980s. In Africa there was no growth at all, while Latin America fared better with growth in spending of 2.9 percent per year during 1991-96. Returning agricultural and rural development issues to the top of the development agenda must become a priority, especially since all indicators – biophysical, economic, and social – show that improvements in agriculture lead to balanced development. Agricultural research, a key driver of technological change in agriculture, must be marshaled for sustainable development.

A revolution (in information and communication technology and biotechnology) is underway, and whole genomes of plants, animals, and food crops have been decoded, including the human genome. The intense debate on biotechnology shows no sign of abating. Increasingly discussion about agricultural research is intertwined with tough issues such as private sector control of intellectual property rights, ethics, and biosafety. North-South and South-South scientific partnerships, ability to harness new information and communication technologies, and networking opportunities will all be necessary to tackle the daunting developmental challenges described above. The presentation will focus on the globalization of agricultural research, with an emphasis on challenges for Latin America, including key issues faced by the research communities such as mobilizing human, technical and financial resources, and the need for networking. It will highlight the power of agricultural research partnerships as a proven way of breaking the nexus of poverty, hunger and environmental degradation.

CAN SMALL FARMERS BE WINNERS IN A GLOBALIZING WORLD?

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Director, CIAT

Competitive agriculture is crucial to sustaining rural livelihoods because agriculture is a major source of employment and income for rural people. Although nonfarm income is important for many rural poor, few instances exist where their livelihoods can be sustained at an acceptable level without competitive agriculture.

Simultaneously, economic and political barriers to international trade are eroding, both within regional trading blocks such as NAFTA (North American Free Trade Agreement) and MERCOSUR (Mercado Común del Sur), and globally, through the WTO (World Trade Organization). This increasing globalization further intensifies the competitive pressures on tropical small farmers and other producers. What small farmers need to be successful in this context should guide our research priorities. Some examples and possibilities are explored.

GLOBALIZATION AND THE THREAT FROM INVASIVE, ALIEN SPECIES

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Globalization has led to a dramatic increase in trade and travel; alien or immigrant species are now being exchanged, either deliberately or accidentally, at unprecedented rates between geographically-isolated regions, countries and continents. Thus, the natural barriers or borders which once separated the World's flora and fauna no longer exist and few, if any, areas remain free of biotic invasions. Invasive, alien species pose a potent and burgeoning threat to both natural and agricultural ecosystems, to such an extent that they have assumed the status of major players on the World stage.

This paper outlines some of the reasons why immigrant species, with particular reference to weeds and plant diseases in the Americas, become invasive, including: escape from their natural enemies; changes in agronomic practices; and human-aided disturbances of indigenous communities. Prevention of invasions through quarantine, backed-up by pest risk assessments, is obviously the best (most economical) cure, especially measured against post-entry control, leading to the conclusion that both national and international quarantine procedures need to be re-assessed. CGIAR Centres should play a pivotal role in the international policing of agricultural pests. Indeed, they may actually be the source of some of these biotic invasions, albeit unwittingly. In this context, the recent pantropical movement of itch grass or "caminadora" (*Rottboellia cochinchinensis*) – now a major weed of agroecosystems throughout Latin America – is analysed.

Invasive diseases of crop plants are also reviewed, concentrating on tropical tree crops, in particular: cocoa, coffee and rubber. Three fungal pathogens, *Moniliophthora roreri* (cocoa frosty pod), *Crinipellis perniciosa* (witches' broom of cocoa) and, *Microcyclus ulei* (South American leaf blight of rubber) are highlighted, all of which have the potential to destabilize world commodity markets.

For many of these biotic invasions, conventional control methods are either prohibitively expensive, impractical (especially over vast areas), environmentally undesirable, or indeed, a combination of all these. Potentially, biological control offers a safer, cheaper and sustainable management optionThe classical approach, based on the introduction and release of exotic, coevolved natural enemies, is considered here to be a viable alternative for the control of alien pest targets, especially invasive weeds and plant diseases, either alone or within an integrated management programme. Some of these biocontrol initiatives in Latin America are discussed.

The final conclusion is, that if the threat from invasive, alien species is not addressed more cohesively and comprehensively, then the global consequences could be catastrophic, including the creation of depauperate ecosystems dominated by alien, cosmopolitan species. The long-term, knock-on effects are unpredictable but, undoubtedly, they will be profound.

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FORMATION OF ADDED VALUE IN AGRICULTURE[1]

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The paper reviews the concept of aggregated value in agriculture. It highlights the options through transformation of primary products, the acquisition of services and the provision of environmental services. It endorses the need to generate aggregate value at the farm level, as a most desirable option, to improve farm income. It reveals the limitations in the agricultural export strategy in Latin America, on the basis of primary products; neglecting in this way the potential to increase employment and incomes in rural areas.

1 Documento presentado a la Conferencia "Globalización de la Investigación Agrícola", CATIE, Turrialba Costa Rica 25-27 de Febrero 2002.

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VALUE ADDING, AGROENTERPRISE AND POVERTY REDUCTION: A TERRITORIAL APPROACH FOR RURAL BUSINESS DEVELOPMENT

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Introduction

Major strides have been made in the past decades in improving agricultural productivity throughout the developed and developing world but, despite this success, rural poverty remains high on the global agenda. Small holders faces substantial barriers to achieving improved livelihoods as commodity prices decline, national and global markets integrate leading to increased competitivity, public sector reform reduces both direct and indirect assistance and natural resources become scarcer. Against this somber backdrop, however, opportunities exist for rural populations to improve their livelihoods through adding value, diversification of income activities and organization.

Background

Since the decade of the 1970s, many rural areas of the developing world have seen two parallel processes advance. On the one hand, increasing agricultural productivity due to improved varieties and management techniques promoted by the Green Revolution has led to greater yields and, paradoxically, declining real prices. This situation, due to inelastic demand, has allowed some areas to achieve food security but not escape from economic poverty. On the other hand, the last thirty years have witnessed an increase in the rate of natural resource deterioration with fragile ecosystems being exploited by populations with few incentives or opportunities to implement sustainable management practices in a profitable fashion.

In addition to these longer-term processes, other trends have been at work during the last decade. Prime among these is the move towards globalization. In the agrifood sector globalization has meant vertical integration, market survival based on competitivity and food safety and increased reliance on information and technology. The small holders who have adapted successfully to these new conditions have done so through organization, integration with market chains and actors and through the acquisition of business and marketing skills.
Public sector reform and reduction is a second important trend, especially in the context of Latin America, in regards to rural areas. In concrete terms public sector reform has led to a reduction in state support for agriculture and, in turn, increased reliance on private sector actors to link farmers with markets. While some success stories exist, in the majority of cases the private sector has proven incapable of replacing previous state services due to high transaction costs, dispersed clientele and low (or non-existent) profits. As a result positive change has focused on privileged areas - those that possess infrastructure, market links, positive stocks of human, natural and economic capital, among other factors - while vast areas have seen their local and regional economies stagnate.

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In light of these trends, rural livelihood strategies have begun to diversify beyond production to include both farm and non-farm income sources. This strategy is logical given declining real prices for basic agricultural commodities and an increase in the value added off-farm through post-harvest processing and marketing (Rosegrant *et al.*, 2001). According to recent work in Latin America, some 50% of rural incomes are now non-agricultural (Berdegue) while up to 80% of the value of final product is a result of postharvest processing and marketing (find cite).

Importance of value adding and agroenterprises for poverty reduction

A brief review of the above trends shows that increased agricultural productivity is not sufficient to improve rural livelihoods within a context of globalization, declining commodity prices, public sector reform and increasing natural resource degradation. A focus on post-harvest activities could prove useful as a poverty-reduction tool if it leads to increased farm and non-farm employment and income.

In order to take advantage of the poverty reduction potential of value adding and agroenterprises, however, the resultant activities must be competitive and sustainable. Competitivity can be understood in this context as: (a) the achievement of lower production costs through the efficient use of existing financial, human and natural resources; (b) a market orientation which produces the right product for the right buyer; (c) business and marketing skills and organization which leads to economies of scale, and; (d) improved links with market chains, information and technologies. The sustainability of these activities should be measured in economic, social and environmental terms.

Post-harvest activities and agroenterprises could act as a catalyst to reduce rural poverty if the identification of opportunities (markets, products and presentations) and existing bottle-necks (production, post-harvest, marketing, business organization or support services) allows the integration of research and development agendas to produce solutions that allow small holders to take advantage of new opportunities.

A territorial approach for Rural Business Development

The Rural Agroenterprise Development Project at CIAT has developed a territorial approach to achieve this integration in practice. The method includes four interrelated processes, which seek to build local capacity to improve market links for small holders. Initial emphasis is on building organization and consensus for rural agroenterprise development. This occurs through a characterization of the territory and the development of a common action plan carried out by community, private sector, governmental and non-governmental actors. Once a local agroenterprise interest group exists, local capacities are developed in identification of market opportunities and intelligence, the prioritization and development of integrated agroenterprise projects and the provision of pertinent and sustainable business development services.

This process has been carried out in three of CIAT's reference sites: Pucallpa (Peru), Cauca (Colombia) and Yorito (Honduras). Results to date have been positive with local agroenterprise committees identifying existing or new market opportunities, building a capacity to collect and disseminate market intelligence, developing integrated agroenterprise projects and achieving increases in small holder incomes as a result.

GLOBAL RESEARCH CHALLENGES: INCLUDING SMALL HOLDERS IN RURAL DEVELOPMENT[1]

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Agricultural research has been "globalized" since at least the 1960s when the International Agricultural Research Center system was inaugurated, the Green Revolution emerged, and the agricultural research gurus from the foundations, universities, USAID, the IARCs, and some national agricultural research programs began globetrotting. In the 1970s, multiple cropping research, as an example, became international, if not global, in scope. In Central America it involved an IARC (IRRI), a regional research organization (CATIE), a national agricultural research institute (CENTA in El Salvador), and a U.S. university (Florida). And at least in El Salvador, this work was also multidisciplinary. It was also during this period of time that the term "farming systems" began to be applied by the globetrotters to activities around the world, including Guatemala and Colombia. These were all multidisciplinary activities oriented specifically toward small holders. Also in the 1970s, animals began to be incorporated into what were previously crop-biased "farming systems."

Despite this long history of a globalized research effort, a number of factors exist that have made ineffective our quest to include small holders in rural development. Chief among these is their great diversity. We tend to work where we can see broadly adoptable results and these efforts are supported by industry. Land is not necessarily the most limiting resource on small farms, yet we tend to look mostly at "yield" increasing technology measured in output per unit land area. "Our" crops are not necessarily the priority crops of the farmers, yet relatively little effort has been put in minor crops and in livestock. Average farms do not exist, yet we frequently work with averages. Thus our technology tends not to be appropriate for the poorer half of the population. Thus they are not able to benefit from existing rural development efforts.

But small farms are not going away. Even though as a percent of the population, rural numbers are decreasing, farm populations in most countries in Latin America are still increasing. Therefore, it is time to take the challenge of including them in rural development. We need to work with the diversity that is both a characteristic of these small farms and a critical need of their livelihood systems. A multidisciplinary methodology that is broadly adaptable, but that conserves this diversity and can lead to different technologies for diverse groups of the poorest farmers is described in the paper.

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GEOGRAPHY OF POVERTY, TERRITORIAL GROWTH, AND RURAL DEVELOPMENT

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1. Rural poverty and the importance of local growth to reduce poverty.
2. Determinants of regional growth.
3. Determinants of local growth.
4. Rural development for the economic incorporation of the poor to local growth.
5. Conclusions: toward a "new" rural development strategy for the international development agencies.

The majority of poverty in Central America is rural. We argue that successful reduction of rural poverty requires the decentralization of growth toward the regions where the poor are located and that have absolute advantages in some activities. Design of a rural poverty reduction strategy thus requires (1) characterizing the geography of poverty, (2) promoting regional and local growth, and (3) using rural development interventions to incorporate the poor to the opportunities created by local growth.

CONCEPTS AND METHODOLOGIES FOR ANALYZING PROMISING STRATEGIES FOR RURAL DEVELOPMENT IN CENTRAL AMERICA

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Rural development strategies have evolved over time but have neither led to a significant increase in rural incomes nor to a reduction in rural poverty and natural resource degradation. Much of Central America's rural areas can be classified as less-favored lands with relatively adverse biophysical conditions and low socio-economic development. Even though the majority of the population lives in these less-favored areas, the latter have been relatively neglected by both the private and the public sector. In addition, structural adjustment measures stemming from the "Washington consensus" (and based on liberalization measures, reduced role of the state and decentralization) have made most farmers in these areas worse off due to a lack of attention to market failure and insufficient institutional development. What is needed then is a re-thinking of the "Washington consensus" with respect to what strategies are needed to successfully foster rural development, with due attention to the majority of rural dwellers who are small and medium scale farmers. To help this process and to steer away from the one-size-fits-all policy recommendation packages of the past, the concept of development pathways is presented. This concept can be used to determine the comparative advantages of a certain area or community which then can serve as guidelines for policy making and public investment strategies. The two key questions regarding rural development strategies should be: (1) What level of investment and what policies are needed in order to raise rural incomes and achieve a reduction in poverty levels? (2) What are sensible policy options for increasing agricultural production without compromising the natural resources base? Even though 'win-win' policies are preferable, they are typically difficult to achieve. Therefore, an important task of the agricultural research community is to identify the trade-offs that are usually involved in most policy options and quantify these to the best extent possible. Such trade-offs usually refer to income-environment trade-offs (or income vs. sustainability).

The second part of the presentation aims to demonstrate the relevance of the work of a previous, long term research collaboration between Wageningen University of the Netherlands, CATIE and the Costa Rican Ministry of Agriculture and Livestock (called REPOSA or Research Program on Sustainability in Agriculture), that focused on analyzing alternative options for sustainable land use at different scale levels. Four hypotheses that have widespread relevance for rural development are formulated and verified by making use of a highly interdisciplinary and quantitative methodology for regional land use analysis. Even though all examples given are for the Atlantic Zone of Costa Rica, the methodology has also been used at the watershed level and is sufficient generic to be applied in other regions and countries as well.

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DEVELOPMENT OF IPM STRATEGIES TO REMOVE QUARANTINE BARRIERS RESTRICTING EXPORT OF AGRICULTURAL COMMODITIES

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World trade in fresh fruits and vegetables and other agricultural products is expanding rapidly to meet demands on existing markets and to supply new markets resulting from international trade agreements. Accompanying increased trade in agricultural commodities is the increased risk for inadvertently transporting quarantine pests to countries or regions where they do not already occur. Quarantines are erected to protect agriculture from exotic pests, as the establishment of new pests can be costly due to increased crop damage and quarantine restrictions on trade. Several approaches are available to exclude exotic pests from exported commodities. A single post-harvest treatment applied to the commodity, such as heat, cold, or irradiation, is the most common method of quarantine pest control. However, a range of alternative analytical techniques and mitigation options exist. Multiple or combination treatments, non-host status, pest-free areas, systems approaches, and a variety of specially designed inspection schemes have also provided the basis for establishing quarantine security. The best example of quarantine IPM is the systems approach. The systems approach integrates many biological and physical factors with operational procedures to cumulatively provide quarantine security. The components of the systems approach can vary widely, but commonly include pest survey, trapping and sampling, field treatment, cultural practices, host resistance, post-harvest safeguards, limited harvest period, limited sales distribution, and restrictions on crop maturity at harvest. Multiple safeguards provide redundancy so that if one mitigating measure fails other safeguards exist that still reduce the risk to a negligible level. Since systems approaches rely heavily on a sound knowledge of the pest and host biology and how they relate to each other, the programs can be time-consuming and costly to develop. Research needs to improve quarantine IPM are the development of optimal trapping designs for low level pest populations, improved pheromone or plant-based lures, dispersal studies, large-area pest suppression tactics, studies of the ecological limitations of pests, and improved risk assessment methodology.

MOVING IPM TO LARGER SPATIAL SCALES AND HIGHER LEVELS OF INTEGRATION

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The operational unit for most IPM programs implemented throughout the world to date has been the individual crop field. Depending on the crop and the region of the world a crop field can be just a fraction of a hectare, as the small holdings of subsistence farmers in Asia, Africa, or Central and South America, or the small plots of specialty vegetable or ornamental seed producers in developed countries of Europe and North America. At the other extreme, fields can cover several thousand hectares of a monocrop, such as soybean, in the western reaches of the states of Rondonia and Mato Grosso, Brazil. There are inherent difficulties in implementing IPM in very small or in very large fields. Current programs, based on local scouting and field based economic injury levels to support control decisions, perform at their best if the target field unit ranges from ten to a few hundred hectares. There are reasons for this dependency of current IPM programs on field size and these will be discussed in greater detail.

IPM represents a significant advancement over pest control systems of the 1940s, 50s, and 60s that were based on calendar sprays. The level of integration of some of the best programs, however, still is limited to the use of combinations of a few control tactics for individual pests in each pest category. Seldom are interactions among pest classes taken into consideration and cropping systems often are adopted with little or no consideration of ecological impacts, particularly impacts on pest incidence and severity. The need for consideration of these multiple factors for the advancement of IPM to higher levels of integration is imperative.

To advance pest management systems to higher levels of integration it will be necessary to expand the spatial scale of programs from the individual field to the broader agroecosystem, and beyond to the ecological region. We believe that true multidisciplinary integration can only be achieved if ecological processes are viewed at the community and ecosystems levels. Expansion of the research and implementation focus to the ecological region will lead to those higher levels of integration.

FARMER LEARNING LINKED TO ECOLOGICAL PROCESSES FOR BETTER PEST MANAGEMENT: CHALLENGES TO CATIE AND ITS PARTNERS

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Program for ecologically-based participatory implementation of IPM and coffee agroforestry

Farmers in Central America face variability and uncertainty. The past decades brought hurricanes Mitch, Joan, Gilbert, and others. Droughts don't receive names, they don't destroy roads or bridges, but they erode rural wellbeing for more extended periods. This weather variability affects crop growth, alters the effectiveness of cropping practices, and influences food web dynamics, including pests. The year with average rainfall is unusual. For farm families weather variability means making decisions in crop and pest management under extreme uncertainty. When will rains start? When will they let up? Will the drought be interrupted by a hurricane? How can I design my pest management strategy for both excess and shortage of rain?

Variability has manifested itself in dimensions beyond weather. In recent decades new pests have been introduced into the Isthmus. To name a few – coffee berry borer, coffee rust, itch grass, Monilia, black sigatoka. Technological change has favored the spread of certain exisiting pests. Irrigation and year round cropping have favored white flies and virus in vegetables and beans; shade reduction in coffee has accentuated iron spot, nematodes, and annual weeds in coffee. Overuse of pesticides continues to contribute to local pest outbreaks.

Over the same time period prices for agricultural products have fluctuated wildly. International coffee prices have fallen below $50 twice, but have also surged to over $200. At the same time the market has diversified into niche products which were unknown a decade ago– gourmet, organic, fair trade, and bird-friendly.

What has science and development offered to farmers in these conditions? Four approaches can be identified:

- Input assembly approach – standard varieties and agrochemical inputs with best average performance to override variability. This Green Revolution model produced yield increments on the best soils, but resulting monocultures are characterized by pest vulnerability, excessive pesticide use, and high costs.

after the introduction of the crops to the region. These figures are a good indication of the importance the (Central) American region has with regard to the conservation and the sustainable use of these resources. A large part of these genetic resources can (still) be found in the Central American region, both in *ex situ* collections as well as in farmers' fields and in natural habitats. These resources are however seriously threatened as genetic erosion continues to cause irreversible losses of invaluable genetic diversity, a process that can only be stopped when farming communities can take full advantage of exploiting these resources and by strengthening the *ex situ* conservation and use efforts in support of development.

CATIE maintains important collections of PGRFA, some with an international status, which have been collected in the region and donated to CATIE over many decades. The availability of this material will certainly be affected by these new ABS conditions. It is suggested that CATIE considers placing these collections under the auspices of FAO as part of the International Network of *Ex situ* Collections, under the same conditions as the CGIAR collections. This will not only give an international legal status to the collections, and thus clarify the responsibilities and rights of CATIE as well as those of the providers of this germplasm, but will also provide opportunities to the institute to participate in international initiatives such as the Global Conservation Trust.

The Central American region is one of the important centers of crop diversity and it has contributed several economically important crops to the world such as maize, beans, tomatoes, cucurbits, avocados and others. During the last five hundred years or so CATIE has made significant contributions to an increased knowledge of these crops through its research programme, to their improvement through plant breeding and better agronomic practices, as well as to their conservation. Furthermore, the institute has been instrumental in educating and training generations of scientists from the region in the area of conservation as well as in plant breeding and agronomy, all activities that have substantially benefited the entire region and other parts of the world. Several other regional initiatives related to the conservation and use of PGRFA, including the Meso-American network REMERFI, are important partners for CATIE to promote and coordinate its efforts in the conservation and use of PGRFA. CATIE should increase and strengthen its efforts in this area since a strong regional PGRFA programme may be the most efficient and cost-effective complement to the existing, sometimes rather weak, national efforts.

In addition to the above reasons for CATIE to consider an increased involvement at the international and regional level in PGRFA activities it should be noted that CATIE's core activities are all related to (agro-) biodiversity conservation and use. Its research programme entails many activities that directly contribute to the development of better conservation and natural resources management strategies and methodologies, as well as to their sustainable use. These outputs are finding their way into the extension work as well as the development projects that CATIE is implementing. CATIE's education and training activities are essential for building capacity in the entire region. By strengthening its expertise and leadership in PGRFA

conservation and use, by taking full advantage of the expertise and experience it already has in related areas, CATIE will certainly be able to accomplish its mission in the region more effectively and successfully.

At the national level, governments are facing the challenge of having to implement the CBD, as well as other international conventions and agreements, such as the WTO-TRIPs agreement and the Cartagena protocol on biosafety, that have a direct bearing on the conservation and sustainable use of PGRFA. In order to get the most benefit from these efforts it will be indispensable to combine the local and national needs and interests with the obligations of these international conventions and agreements. This will require a good understanding and knowledge of the national needs and interests as well as of the international instruments. There are good reasons and opportunities to seek regional cooperation in these implementation processes and it seems that CATIE is well placed to play a facilitating role in this.

In most of CATIE's member countries good progress has been made over the past decade or so in conserving and utilizing threatened PGRFA. However, these efforts will need to be more sustainable and will have to increase in scope and intensity in order to stop the continuing losses of important genetic resources in the region. Stronger national commitments will be needed to allow the countries to benefit more from their own genetic resources, as well as from those conserved and improved elsewhere. This will also provide a solid basis for effective regional cooperation on conservation and use efforts and to take advantage of international opportunities. CATIE is well positioned to assist countries in these substantial national duties and to assume more responsibility in the regional coordination efforts.

It can be argued that local farming communities play the most important role in the conservation and use of PGRFA. Male and female farmers are not only the custodians of these resources they are also the creators of most of the diversity that still can be found in traditional agricultural production systems, including home gardens. This diversity is an integral part of their culture, it allows crops to evolve under changing conditions, and is one of the key ingredients of any agriculturally based development process. It is at the level of the farmers and farming communities where the impact of sustainable utilization of the genetic resources will take place and where the expectations of sharing the benefits derived from this utilization, be it locally or elsewhere, are highest. Much of CATIE's research products as well as the services it provides could and should be brought to bear at the community level. This requires well functioning national systems, as they form the interface between CATIE and the local communities. It also requires that the outputs and services of CATIE's research coincide with the needs of the local communities.

UTILIZATION OF THE INTERNATIONAL CACAO GERMPLASM COLLECTIONS: PROSPECTING FOR DISEASE RESISTANCE GENES

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The USDA-ARS cacao genetics program is based at the Subtropical Horticulture Research Station in Miami, Florida. The primary goal of the program is to develop a biotechnology-based approach to solving two destructive disease problems, witches broom and frosty pod rot, in Central and South America. In addition, the USDA-ARS and M&M Mars Corporation are coordinating an international bioinformatics project that feeds information into national and regional breeding programs.

Using a candidate gene approach (CGA) we have isolated 74 resistance gene homologues (RGH) from cacao. These 74 RGH can be placed into 11 different groups based on sequence homology. Some of the groups represent a single locus with multiple alleles while other groups contain multiple loci. The CGA has also been used to isolate 16 WRKY genes from cacao. WRKY gene products are transcription factors that regulate the hypersensitive response to pathogen attack. We are using RGH and WRKY genes as markers in populations segregating for disease resistance and among certain accessions in the germplasm collections. Disease resistance genes are often clustered, allowing the identification of blocks of genes that co-segregate. The use of RGH and WRKY genes as makers has advantages over randomly distributed markers like simple sequence repeats. These advantage and the usefulness of these types of markers will be discussed.

THE IMPACT OF BIOTECHNOLOGY AND GENOMICS RESEARCH ON THE PROVISION AND UTILIZATION OF PLANT GENETIC RESOURCES

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The process of selection during plant breeding inevitably leads to the gradual erosion in the genetic base of a crop. Fears that this may render crops susceptible to changes in the epidemiology of pests or diseases have been borne out in dramatic fashion in several well-documented cases. Perhaps the most celebrated of these being the potato famine of Northern Europe in the 1840s caused by the sudden spread of late blight (*Phytophthora infestans*) and more recently, the 1970 southern maize leaf blight (*Bipolaris maydis*) epidemic in the maize crop of the USA.

The Twentieth Century was marked by concerted efforts, initially by individual countries but increasingly by International bodies, to partly reverse the process of genetic erosion. There have been essentially two aspects to this activity. First, unimproved or partly improved material has been made freely available to breeders in genetic repositories known as germplasm collections. Second, collaborative schemes have been initiated to generate elite material with direct utility in breeding programmes. In spite of these initiatives, breeders for the vast majority of staple food crops have only sparingly used wild germplasm in the production of commercial cultivars. In part, this can be attributed to poor genetic evaluation of wild material for desirable traits but is largely due to the protracted process of removing unwanted genetic material linked to the targeted genes by backcrossing.

This paper discusses how biotechnology, molecular biology and genomics information will have a profound effect on the value of germplasm collections and should influence future priorities for management and utilization strategies.

CATIE'S AGROFORESTRY RESEARCH PRIORITIES*

John Beer
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During the last 25 years, CATIE has had an agroforestry research programme, based on the study of traditional agroforestry systems in Latin America. Through the quantification of the biophysical and socioeconomic interactions in existing, modified and new agroforestry systems, including systems imported from other regions of the world, the factors that limit production, profitability and the conservation of natural resources are identified and modified. The requirements of each system (or technology) are studied in order to identify areas where they can be recommended. The principal research levels are plant, plantation (field) and farm but also, in cases such as the evaluation and promotion of incentives for "clean production", it is necessary to integrate information from superior levels such as micro-watershed, region, country and even global.

CATIE's actual agroforestry research priorities, that take into account the large and rapid changes in framework conditions due to commercial globalization and other tendancies such as changes in consumer preferences, are: 1) development and validation of environmentally friendly animal husbandry technologies, including land diversification of cattle ranches using forestry plantations, alternative crops and silvopastoral systems as well as pasture improvement in optimal areas for cattle; 2) domestication of indigenous fruit trees in multistrata agroforestry systems, including studies of markets and methods of organizing producer groups that will be linked with the selection and improvement of local germplasm as well as the management options and productivity evaluations of these fruit trees; 3) quantification and valuation of the enviromental services of agrosilvicultural (especially with coffee and cacao) and silvopastoral systems using biophysical studies (e.g. biodiversity, C capture and water quality) in pilot studies where the level of the environmental incentives needed to promote sustainable and profitable agriculture for small – medium farmers will be calculated and tested. In all three of these priority themes it is necessary to include evaluations of quality as well as commercial productivity of the agricultural crop, animal and tree components. There also will be an increasing emphasis on how to gain added value through rural agroindustry and / or targeting speciality markets such as the growing demand for organic products.

In the future, it is hoped to include a new research thrust focused on agroforestry systems that include shade tolerant annuals that produce root and tuber crops in view of the growing demand (especially for export) for these tropical products. In general there will be an increased use of modelling to integrate information from diverse sources (levels, themes) in order to synthesize the results of specific studies from different sites and hence influence different levels cf society from politicians to farmers.

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TRANSFORMING LIVES AND LANDSCAPES: ICRAF'S RESEARCH AND DEVELOPMENT IN LATIN AMERICA

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The International Centre for Research in Agroforestry (ICRAF) started operations in Latin America in 1993, emphasizing research dealing with tree genetic conservation and domestication, land rehabilitation and nutrient cycling, and crop improvement in southern Mexico and in the Amazon. In 1995, it started a fourth research thrust dealing with the alternatives to slash and burn - seeking to better understand the dynamics driving tropical deforestation and shifting cultivation in the Amazon - in association with CIFOR, CIAT, INIA in Peru and EMBRAPA in Brazil. In 2000, ICRAF added two additional thrusts to its research program in the region: socio-economic and policy research, and valuation of environmental services derived from tropical eco-systems, at the farm, multi-farm, watershed, and global levels, trying to link productivity with climate change, biodiversity conservation, and ecosystem health. That same year, the institution adopted a new policy whereby research and development were seen as a synergistic continuum, therefore establishing very ambitious goals with respect to the number of people to be reached by ICRAF's technologies in the developing World.

Main research results to date include substantial contributions in the domestication of four tree species, in devising profitable and highly demanded agroforestry systems adapted to poor, tropical soils, and a best-bet matrix for land uses in the Brazilian Western Amazon. In the R&D continuum, it has implemented a very effective consortium-like approach, involving more than 10 partners, which make co-investments in complementary research and development with attractive rates of return on investment, and with much higher potential for scaling-up and adoption by farmers throughout the region. ICRAF has also been successful in promoting agroforestry as a mainstream science, and as a profession throughout the Tropics, and in particular in Latin America.

The institutional R&D strategy for the next 9 years is people-centered; public goods led, and contemplates expanding ICRAF's research and development work to Mesoamerica and the Andes, and seeking to establish new, long-term partnerships with institutions such as CATIE.

BRINGING SCIENCE AND TECHNOLOGY TO BEAR ON HIGH-VALUE PLANTS AND FUNGI: CASE STUDIES FOR PRODUCTION OF NATURAL PRODUCTS

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The vast chemical diversity in higher plants and fungi serves as a large reservoir for natural products and lead chemistries useful to agriculture and medicine. Mankind has adapted to many uses of this diversity of secondary metabolites throughout the centuries. At present, mankind still relies on over 25% of medicines derived directly from plants, while antibiotics are predominantly derived from microorganisms. The phytodietary supplement market continues to show gains worldwide with up to $4 billion sales annually, and "functional" foods are being touted as the next food revolution. In the new arena of alternative crops, specialty plants can offer economic alternatives to traditional crops based on their high market value per unit mass and pricing structures based on active constituents.

There are a number of challenges, however, to bring many of these systems from a wild-harvested and environmentally unsustainable basis to one in which varietal improvement and standardized cultivation practices can improve yields and protect diversity within the natural environment. Selection of varieties or cultivars having the desired characteristics is critical, such as selective breeding for improved chemical constituent profiles or selection of cultivars from diverse genetic populations to identify superior germplasm. Traditional gross agronomic characteristics such as bulk yield and uniformity of growth and maturity for harvest are secondary to the development of varieties with high chemotypes for the desired product. Depending on plant attributes, such as length to harvest, concentration of actives, and suitability for field planting, superior germplasm may be converted to cell cultures for controlled fermentation to yield products in the case of phytopharmaceuticals.

Another challenge is that many alternative crops, especially in the case of superior germplasm or improved varieties, are not easily propagated from seed. In this case, micropropagation techniques may be useful to produce large numbers of genetically identical plants. Although this technique is labor-intensive for most field-scale crops, micropropagation can be useful to quickly move selected germplasm from a laboratory setting into field testing for continued selection and to shorten the time needed to develop standard agronomic and handling practices. Also, with advances in technology in developing cheaper methods, it may be possible to use micropropagated plants or artificial seeds developed from somatic embryos to rapidly produce genetically superior materials.

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We have used several approaches in establishing two alternative crops in our laboratory. In the first example, taxol from Taxus sp., we have taken a cell culture approach to supplying the phytopharmaceutical drug, while in the second example, hypericins and hyperforins from St. John's wort, we have undertaken a chemotype screen in order to identify superior germplasm for micropropagation.

Taxol®, (trademark by Bristol-Myers Squibb; generic name is paclitaxel) is a diterpene secondary metabolite originally isolated from the Pacific yew tree (*Taxus brevifolia*), used for cancer therapies. The limited supply of Taxol from the original source, *Taxus brevifolia*, prompted intense efforts to develop alternative sources; chemical synthesis is not economically viable, but semisynthesis using a natural precursor has been a useful strategy. With increasing applications in medicine and its use earlier in the course of intervention, however, the supply and cost of Taxol still continue as important issues. It is clear that in the future, biological material will continue to be important sources of Taxol or its synthetic progenitors, either from plants or from cell cultures. In the laboratory, we initiated over 1,200 callus cultures from individual embryos of wild-collected seed of five different Taxus species that were then used in a selection screen. Out of our initial cultures, approximately 1% met the criteria for further selection for development as taxol-producing cell lines. Following the development of optimal culturing conditions, we have been able to achieve a production capacity of 117 mg/L culture within a 12 day culture period, as compared to 0.01% taxol available from the bark of a 100 year old tree. There are now three commercial companies worldwide producing taxol and related taxanes in large-scale (10,000 L) fermentations for therapeutic use.

Our second example, St. John's wort (*Hypericum perforatum*), is classified as a phytomedicinal plant in Germany, but is a dietary supplement on the US market. Sales of St. John's wort are approximately $500 million (US) worldwide, with approximately $100 million in US sales. St. Johns' wort is prescribed for mild to moderate depression in Germany, while it is still undergoing clinical trials in the US for depression, and it may be tested for viral and cancer therapies. In the case of St. John's wort, two classes of compounds, hypericins and hyperforins, have been associated with the touted health benefits of this plant, thus complicating the chemical profile for chemotyping. Originally much of the market of St. John's wort was supplied via wild crafting, although current market demand is in an oversupply status due to commercial farms inputs, although product quality and variability continue to be major issues.

In the case of St. John's wort, we developed rapid HPLC methods to screen wild populations in order to identify areas of high chemotypes for subsequent seed collections. Seeds have been germinated in sterile conditions and meristems used to establish genetically identical populations for chemical screening. Selections have been based on the combination of plant vigor and chemotype. Plans for the further development of this plant include optimization strategies for enhanced growth and phytochemical yield, and micropropagation of superior germplasm.

These two examples from temperate climates illustrate the challenges as well as the opportunities that alternative crops can offer. With the increasing exploitation of wild plant populations, it becomes increasingly important to develop alternative and sustainable strategies using science and technology to develop alternative crops into marketable and economic realities. The same cases can be made for using fungi in searches for novel natural products.

The scope and size of the fungal kingdom has only been appreciated relatively recently. Until the early 1980s, the number of fungal species was estimated to be roughly 70,000. Today, conservative estimates put the number of fungal species at roughly 1.5 million, and only a tiny fraction, less than 5%, has been explored taxonomically. An even tinier fraction has been explored chemically, and those that have been chemically explored are not a statistical sample of those potentially available. These estimates for fungal diversity are supported by taxonomic results, and the rate of cataloging new species is still increasing. Not only do these new sources vastly increase the number of fungal species, they also suggest that these fungi will produce secondary metabolites. Fungi in the ecological niches associated with insects, soil, dung, or plants interact with many other organisms, and these interactions are likely to be moderated by small molecules. It is also worth noting that the ecological niches occupied by these fungi are disappearing.

In our work on discovery of natural products from fungi, we have taken a molecular approach to initially screen fungi for their potential to produce either polyketides or nonribosomally-derived peptides. This work has been conducted in collaboration with Olen Yoder, Gillian Turgeon, and Jon Clardy of Cornell University, and Alice Churchill of Boyce Thompson Institute, Ithaca, NY. The principal source materials are from the USDA, ARS Collection of Entomopathogenic Fungal Cultures (ARSEF), the world's largest germplasm repository for fungal pathogens of invertebrates. Growing many of these genetically and ecologically diverse fungi in sufficient amounts to isolate compounds is a daunting task. Little is known of the chemistry profiles of many of the isolates of this collection, which includes fungi in parasitic or saprophytic associations with insects, nematodes, and other fungi. An alternative approach used by this group was to identify genes for polyketide synthases (PKS) from these organisms to determine those that might have unique PKS, and therefore are more likely to have unique and interesting polyketides.

We used a degenerate PCR primer approach to detect and characterize PKS fragments in a genetically diverse group of insect- and nematode- associated fungi for which the capacity to produce polyketides is largely undescribed. Out of a starting group of 157 fungal isolates representing 73 genera, 92 isolates contained a putative KS domain. Thus, the PCR-based screening may be a rapid, efficient technique to identify PKS fragments from among a wide distribution of fungi. Sequence analysis of the fragments derived from the highly conserved KS domain of PKS genes indicated groupings of fungal genes distinct from those already reported in Genbank. This work showed that PKS genes are widespread and diverse among insect- and nematode-associated fungi. The clustering of the entomophagous fungi within clades hints that they may have a distinct grouping of PKS genes. This study is the first step in determining whether these novel PKS genes and their polyketide products are functionally dedicated to the specialized activities of these organisms.

STRATEGIES FOR DISCOVERY AND DEVELOPMENT OF NATURAL PRODUCTS AS PART OF AN ALTERNATIVE CROP DEVELOPMENT PROCESS

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Natural products are often high value compounds with pharmaceutical, nutraceutical, pesticidal, or other uses. Thus, plants that produce these compounds are potential alternative crops. Hundreds of thousands of plant species (most of them tropical) each produce many different secondary products. The identities of many of these compounds are still unknown. When the probable number of compounds is multiplied times the number of potential uses, millions of possibilities are evident. We have only scratched the surface in determining uses of phytochemicals.

Several strategies can be used to simplify the discovery process. A relatively simple approach is to look for new uses of known compounds produced by plants. For example, the discovery of the nutraceutical value of resveratrol has resulted the harvesting and processing of native grapes in Mississippi for the botanical supplement industry.

Another approach is to discover new compounds with significant uses. The first step is to decide what plant will be studied. Taxonomic, ethnobotanic, anatomical, and chemical ecology clues can be used to identify plant species likely to produce compounds of interest. An example of the ethnobotanical approach the study of *Artemisia annua* because of its anti-malarial activity from traditional Chinese medicine. Taxonomically-related species may be better sources of compounds of interest or of related new compounds. The genus *Podophyllum* will be discussed as an example of considering taxonomic relationships in the search for better sources of compounds. The newly developing field of chemical ecology is reporting complex chemical interactions between plant species and other organisms. The use of a chemical in nature can predict a use for humanity. Lastly, secretory and sequestering anatomical features can predict the presence of compounds with strong biological activity.

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Once a plant source is chosen, the process of bioassay-directed isolation of compounds of interest begins. This procedure has been streamlined over the past decade with the advent to microbioassays and automated, tandem analytical instrumentation. Informatics is very important in minimizing rediscovery, predicting uses, and coordination of multidisciplinary efforts between botanists, chemists, physiologists, geneticists, and biochemists. Capturing and retaining intellectual property associated with natural products and their use can be an important part of development also.

The linkage of discovery to development and commercialization will be discussed. When a compound with a significant commercial use is identified, the economics of production must be determined. This is a complex question, involving marketplace alternatives and cost of production by cultivation and extraction. Selection of chemotypes, development of best cultivation practices, and finding the most cost effective extraction can be challenging. Identification the critical genes encoding enzymes for synthesis of the compound could be useful in improving production or imparting production into other organisms.

There is no highly organized organization with the resources to do all the things enumerated above. This area of research is fragmented by discipline, end use (pharmaceutics, pesticides, etc.), and research sector (private vs. public; discovery vs. development). Countries like Brazil have the resources to devise a national strategy to mine its chemical biodiversity, using a vertically and horizontally integrated approach. Other counties of Latin America could only effectively do such research through research consortia or coalitions in which multidisciplinary efforts are coordinated. This will improve the efficiency and increase the speed of discovery.

THE DOMESTICATION OF TROPICAL TREES FOR NON-TIMBER FOREST PRODUCTS

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This paper presents quantitative data on fruit and nut traits in two indigenous fruit trees from West Africa (*Irvingia gabonensis* and *Dacryodes edulis*), which has led to the identification of trees meeting ideotypes based on several traits desirable in putative cultivars. The same data also indicates changes in population structure that provide pointers to the level of domestication already achieved by subsistence farmers.

This study was part of a larger project investigating the socio-economic and biophysical constraints to indigenous tree cultivation, and was also part of a larger participatory tree domestication programme. It was also linked to the wider agroforestry initiatives of ICRAF seeking to integrate commercially and traditionally valuable indigenous trees within tropical farming systems. This is being done in order to provide marketable products from farms that will generate cash for resource-poor rural and peri-urban households, while at the same time also promoting more sustainable mixed species, multi-strata farming systems.

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THE NON TRADITIONAL EXPORT OF TRADITIONAL CROPS

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In the last two decades the export of nontraditional crops from Latin America has gone through substantial growth. Producers in the highland areas have learned to produce many nontraditional temperate-climate crops such as cabbage, broccoli, snowpeas, and asparagus for export during seasons when production is limited in many northern countries. Although this recent development has resulted in the improved economies of many rural areas, it has also contributed to environmental problems through the increased use of chemicals and lack of appropriate soil conservation measures. At the same time that producers have switched to high-value export crops, acreages devoted to traditional crops have diminished with the potential loss of much indigenous germplasm.

An opportunity exists now to promote the export and sale of many little-known traditional crops, thus helping to conserve these cultigens that have been produced for centuries by local farmers. Many of these plants are well-adapted to the varied ecological niches of the Latin American landscape and producers have learned to farm them with a minimum of external industrial inputs. Many of the highland crops are not adaptable to more temperate latitudes because of daylength and nighttime temperature constraints.

Affluent consumers are now accustomed (almost addicted) to experimenting with new foods. Some writers have referred to this as the "yuppie taste". Kiwi fruit and carambolas are now a common sight in many grocery stores and on many banquet tables.

Ethnic crops have also been a major growth industry. The Latin American farmer through well-coordinated campaigns could take more advantage of these rapidly growing markets. The result could well be that limited resource farmers could have greater access to international markets for little-known crops and, perhaps, with less negative consequences to the environment and less erosion of traditional varieties.