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International Network for Bamboo and Rattan
Anyuan Building
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Chaoyang District, Beijing
P.R. of CHINA.

# ANCIENT GRASS, FUTURE NATURAL RESOURCE

## The National Bamboo Project of Costa Rica: a Case Study of the Role of Bamboo in International Development

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# FOREWORD

Before the advent of industrialization and cash-based transactions, bamboo had played a significant role in the self-sustaining economies in many nations that are now grouped together as developing countries (it still does in some remote parts of these countries yet untouched by modern economics). This is hardly surprising, considering that bamboo is the fastest growing and most useful plant in the world. One of its most common use was as a building material for shelters. Bamboo houses were a tradition and even today, millions of rural houses in Asia prominently feature bamboo in their construction. Research has proved bamboo's admirable engineering and mechanical qualities, and its aesthetics have never been in question. Still, when it comes to construction, bamboo has largely remained a poor man's choice.

There have been attempts in different parts of the world to address this paradox: scientists, engineers, designers, development practitioners have all contributed to these efforts that aimed to win recognition for bamboo as a modern and immensely useful material. One major initiative occurred in Costa Rica,under the aegis of the National Bamboo Project. The project was remarkable in that it started against heavy odds: (1) timber was the construction material of preference in Costa Rica and hence, even among the poor, bamboo could not claim any favor; (2) Guadua, the bamboo species found ideal for the planned construction, was in short supply in the country and hence, had to be cultivated; and (3) there was no readily available technology to build with, and the project had to undertake serious research and development before it could show any visible results. Despite these odds, the project showed all the resilience of bamboo to emerge a success.

In this addition to the *INBAR Working Paper* Series, Ms Karina Quintans, of the Ohio University Master of Arts in International Affairs Program, examines the appropriateness and sustainability of bamboo housing technology as developed and employed by the National Bamboo Project. It is hoped that the study will induce those interested in development and technological issues to take a fresh and closer look at bamboo, particularly its usefulness as a tool in socio-economic development.

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Lastly, I alone am responsible for opinions expressed or errors that may be present in this study; they are not a reflection of those who have contributed to the research that went into the making of this study.

***Karina Quintans***

# CONTENTS

# 1 INTRODUCTION

Poverty in tropical countries has bewildered development practitioners for decades. Despite various development-oriented efforts, mostly by Western countries, the conditions of poverty have not only persisted but worsened. Development through large-scale industrialization has brought wealth and luxury to only small numbers of urban elite, while leaving large rural populations to scrape for resources. Development initiatives have often displaced rural families from lands which they have been cultivating at subsistence level or to produce food for selling in local markets. Many farmers have been forced to become mere wage laborers for estate-owning elites. Not only have the rural people been left with few employment options to support their livelihood, it has also become difficult to buy the food that they once used to produce themselves. Absence of land and decent wage-earning opportunities have also taken away shelters, relegating them to lives in makeshift homes.

As rural people became wage laborers, producing crops for what became export-laden economies, their wealth transferred into the hands of the small urban elite class and Western investors. Income disparities widened significantly between urban and rural populations. Urban areas experienced enormous growth, and urban wealth created substantial infrastructures ‘in education, health facilities, services and utilities, and employment, not to mention the availability of basic human necessities such as food and shelter. At the same time, underdevelopment persisted in rural communities where lack of wealth led to declines in socio-economic status.

One of the effects of greater urban development has been a high rate of rural to urban migration. Rural underdevelopment necessitated the search for better opportunities elsewhere. Employment, higher wages, and access to education and health care have been major . impetuses for urban migration. Unfortunately, these opportunities often proved illusory as many migrants woke to the harsh realization of being unqualified for urban service jobs. Thus, migration served only to perpetuate their state of underemployment and impoverishment.‘Again, people were living in makeshift homes along the periphery of urban “paradises”. These urban shantytowns were no better than their rural counterparts — there was no running water, electricity, or access to education and health systems, and their shelters could barely withstand a heavy wind or rain.

Another major effect of urban development and rural underdevelopment has been extensive environmental degradation resulting from deforestation. Massive projects, such as dams to produce hydroelectric power, have cleared large areas of forest. These projects have alsd marginalized rural peasants and other indigenous communities by pushing them off their land and forcing them to relocate in alternative sites, leading to further clearing of massive tracts of forested lands for rehabilitation by uprooted people. Development of tropical countries into export economies has only intensified the rate of deforestation. Forests were clear-cut to make land available to raise cattle for beef exports, to sustain the timber trade, and for the large-scale production of profitable cash crops for export. Agricultural industrialization has also served to severely divest rich tropical lands of their natural resource base. The result of all these development initiatives has been a vicious cycle of mass impoverishment and environmental degradation. It is time to think as to what might happen to the livelihoods of those living in tropical countries if and when their natural resources become completely exhausted.

With the realization that past several development initiatives cannot be deemed successful, newer attempts are taking a more grassroots approach, instead of the trickle-down version of development through industrialization and capitalism. The belief is that community level work is a better approach to poverty alleviation. Newer initiatives also advocate that real participation by community members in the development process is a key element for successful and sustainable social and economic betterment. Furthermore, recognizing that a continual disregard for the environment and natural resources may actually impede or even halt development, there is greater emphasis now on environmentally sound initiatives.

Harvesting of non-timber forest products (NTFPs) is an environmentally sound development effort with a great deal of potential. This practice offers an alternative to clear-cutting and stripping forests to the point of zero utility — sustainable extraction of plant resources for the benefit of present and future generations. Current projects such as the Tagua Initiative by Conservation International and the Ngali nut project run by the Biodiversity Conservation Network are two good examples of this kind of environmentally sustainable development. Working at the community level, these projects deal with the extraction of nuts and seeds, and create value-added products, such as buttons, to generate more income than the sale of only raw materials. Medicines, cosmetics and dyes are some of the other value-added products that come from NTFPs.

Belcher (1995) points out that bamboo and rattan are the most important NTFPs, both economically and socially, in the Asian region. Bamboo is particularly interesting in that it shows a promising future as a resource for environmentally sustainable development. For instance, its timber-like qualities have implications for indirectly curbing the deforestation resulting from timber demand. Because it is an abundant and inexpensive resource with strong historical and traditional uses in less developed countries (LDCs), it would be logical to use bamboo as a socio-economic resource for development initiatives in these places.

Having learned that capitalism and industrialization do not necessarily lead to poverty alleviation in LDCs, the search for more "fitting" technologies has become important. Makofske and Karlin (1995) advocate better technologies, which can reduce environmental damage and increase the incomes of local people while preserving natural resources for future use. This idea is particularly important for resource-poor people who, in the past, have not had much choice regarding their manner of survival. As previously mentioned, many of these people have been driven to overexploit natural resources, leading to extensive environmental damage. With a new emphasis on sustainable use, implementing technologies and methodologies to compensate the resource-poor without compromising the environment would result in more equitable development for present and future generations of people, besides being better for the natural environment.

Today, there are bamboo advocates who are examining historical and traditional bamboo technologies and how these can be implemented more effectively to improve people's lives in developing countries. Case study research on bamboo utilization allows for the improvement of methodologies and updating of information: something that is especially important for the development and use of appropriate technology because the impact of a chosen technology and its implementation are important for learning purposes (Hyman 1987).

A good case study on the use of appropriate technology is a bamboo housing project located in Costa Rica. This project, which began in 1986, has successfully applied a bamboo technology, principally for providing a low-cost housing alternative in the poorer rural areas of Costa Rica. Lack of housing is a major problem in developing countries, and governments are being constantly burdened with mounting housing shortages (Farrelly 1984). Ham (1990) feels that these debt-ridden governments are beginning to realize that a partial return to indigenous materials and methods can help mitigate this problem. This means, as asserted in the *Global Report* for Human Settlements (Habitat 1987), using technologies consistent with a country's resource endowments which are economically and ecologically sustainable. With the knowledge that bamboo has had a major part in Asian housing and in areas of South America, there are significant implications for reducing housing deficits — especially because building materials in developing countries have typically been of limited supply, expensive, of low quality and used inappropriately (Habitat 1987).

Farrelly (1984) states that sheltering people should not mean implementing housing projects, but rather, making resources available, re awakening traditional skills and playing midwife to new forms of old solutions, so that people can resume responsibility for self-shelter. Considering its historical uses, bamboo could have a major role in housing solutions for all developing nations. As Farrelly (1984) notes fortunately, world housing needs generally fall in areas where the climate is most conducive for bamboo growth.

With this information in mind, it is worthwhile to study the National Bamboo Project (Proyecto National de Bambu-PNB) of Costa Rica as an example of the use of bamboo in appropriate and sustainable technology for development (Appendix A). Costa Rica, like many other developing countries, has experienced massive housing shortage. The high cost of building materials has prevented people with scarce resources from being able to afford some type of dignified and decent home. PNB has found a solution to this problem by utilizing bamboo as a primary building material, thereby reducing the cost of a home by 20%. This has opened the housing market to a greater population, particularly in the rural areas of Costa Rica. From the perspective of the development practitioner, there are many benefits resulting from the use of bamboo, besides its low cost. This includes active participation from community members, including women and children, in bamboo development projects and the favorable environmental implications of bamboo.

The following is a documentation of information gathered from research on PNB. This case study seeks to evaluate project operations because its success may be significant for all development practitioners concerned with housing shortages nationally, regionally or internationally. It may also be significant for practitioners concerned with development which is environmentally, economically and socially healthy. These are important points for the reduction of poverty in LDCs.

# 2 LITERATURE REVIEW

Bamboo has enormous potential for alleviating many problems — both environmental and social — facing the world today. The increasing rate of tropical deforestation makes the search for alternative natural resources important. The characteristics of bamboo make it a perfect solution for the environmental and social consequences of tropical deforestation. Its biological characteristics make it a perfect tool for preventing soil erosion (Austin et al. 1970) and reducing carbon dioxide levels in the atmosphere. Additionally, its qualities of strength, light weight and flexibility make it a viable alternative to tropical timbers that typically supply the furniture and building materials industries. Lastly, bamboo has rapid growth capabilities enabling it to reach maturity within three to five years. Therefore, bamboo is an ideal economic investment that can be utilized in many different manners.

Research in Southeast Asia has recorded over a thousand ways in which bamboo has been put to use "serving the most mundane purposes and the most refined" (Austin et al. 1970). For instance, bamboo has been an extremely practical source of material in traditional Asian housing and construction. It is very easy to work with, even with the most simple and basic tools. It is easy to put together, and easily repaired or replaced when damaged. It is strong yet supple, and can resist even earthquakes. According to some, it is more resilient than any other type of housing frame (United Nations 1972). There is even a specific traditional methodology practiced by villagers in building construction. Some common problems are also solved by use of bamboo in housing structures. For instance, in Thailand, it is common to find a bamboo house built on top of a bamboo raft. In this form, it offers a practical solution to seasonal flooding often occurring in areas of Thailand.

In a villager's house, bamboo can be found as a pillar, a wall, part of the floor, rafters and roof, although some of these bambao structures are now being replaced by modem material such as cement or paneling. Bamboo is still quite commonly used as scaffolding in modem day building construction because of its light but strong structure.

In addition to being part of the housing structure itself, bamboo can also be found in virtually every room of rural homes. As a kitchen utensil, it serves as a spoon, cup and skewer. It can also be woven into baskets and mats. According to the film "Bamboo, the Miracle Grass" produced by the International Development Research Centre (IDRC), the weaving technique for these items is considered an original bamboo technology that has continued to serve as the basis for the construction of many other bamboo items. Bamboo can be made into plates, trays (for drying produce in the sun or winnowing rice), containers for holding seeds and collecting harvest, and water-tight cooking vessels. It can also be worked into a piece of furniture, such as a table or chair. Inside kitchen cabinets made of bamboo, one can find containers of bamboo shoots -- an important part of diet of many Asian cultures. The sap from the bamboo stem is kept for its medicinal and curative effects on ailments such as asthma. Other extracts from bamboo are used for poultices and to treat gonorrhea or kidney trouble in Malaysia. In Cambodia, bamboo nodes are used to treat chest complaints and urogenital disorders (Piper 1992).

In a garden, bamboo has use as an ornamental plant or as part of the garden fencing. Inside a garden shed, there may be a bamboo ladder, tools with bamboo handles, bamboo fishing poles, hunting gear niade of bamboo, or bamboo shavings and scraps for firewood. Bamboo can also be found built into small foot bridges, irrigation piping and water pumps.

Bamboo finds use in many other items such as paper, musical instruments, weaponry, handicrafts and boats. It has a central role in many folk tales and traditional practices.

Grazing farm animals are sometimes fed bamboo fodder, known to be as nutritious as other common fodder grasses. Bamboo hay contains four times as much protein as other fodder grasses according to an article *in* the *Economist* (Anonymous 1990). It is also the chief food of Pandas in the bamboo forests of China.

## Bamboo Characteristics

Although bamboo is a wood-like plant, it belongs to the grass family and is known to be one of the fastest growing plants in the world. Its growth rate ranges from 30 to 100 cm per day. The bamboo plant has an extensive rhizome system, which stores a tremendous amount of nutrients required for the plant's rapid growth. The rhizome also actively takes part in vegetative propagation by branching out from this underground root system (Austin et al. 1970). This reproductive behavior gives bamboo its reputation as an "active spreading plant" which "unless inhibited, will extend growth over a large area" (Austin et al. 1970). Bamboo can grow to a height of 36 m with a diameter of l-30 cm (United Nations 1972). A culm (stem) can reach its full height in a matter of two to three months. Considering the above characteristics, it is easy to believe that bamboo is the fastest growing, highest yielding renewable natural resource (Lessard and Chouinard 1980).

Although bamboo grows on mountain ranges under forest canopies, and along riverbanks and other lowland water courses, it thrives most in monsoon forests (United Nations 1972). Factors affecting the growth pattern and distribution of bamboo are altitude, soil permeability, and most importantly, rainfall. Altitude plays a role in determining the distribution of the different species and growth forms of bamboo of which there are two — monopodial and sympodial. Monopodial growth is typical of more temperate climates, while sympodial is predominant in tropical climates.

The most puzzling aspect of the bamboo life cycle is its flowering behavior. Bamboo is mostly monocarpic: following its flowering, the bamboo plant dies. It also flowers gregariously: flowering of a particular species may occur all at once and spread to involve whole populations across groves, area, region or even the world. Flowering occurs at intervals ranging up to 120 years depending on the species (Austin et al. 1970). The mechanism that triggers bamboo to flower gregariously has not yet been fully understood.

There are over 1,000 species of bamboo (Sharma 1980). Bamboos are native to both temperate and tropical climates, and therefore naturally distributed all over the world, with the exception of Europe and Antarctica (McClure 1966). However, they are most abundant in Asia, primarily China, India and Japan. Southeast Asia contains nearly half of the world's species (Piper 1992). .Madagascar has an abundance of endemic genera and species in comparison to the rest of the African continent (McClure 1966). Australia also has a few native species. There are several species native to the New World; Guadua species, perhaps the most widespread, are found throughout Latin America, predominantly in Ecuador and Colombia.

## Bamboo Utilization Research and Cultivation Issues

Published information on bamboo utilization research had been limited by the lack of serious interest. Until recently, there had not been much attention on bamboo and its potential role as a timber substitute. Some researchers explained this in the following manner: "The abundance of bamboo in South and Southeast Asia is probably responsible for the apathy towards its development. Concern usually comes only when a resource is completely lacking or is scarce" (Lessard and Chouinard 1980). In Malaysia, bamboo had even been considered a weed that interferes with timber growth and regeneration (Ng 1980). Because bamboo grows well naturally, its potential for cultivation had been disregarded, although better agricultural practices could greatly increase its yield (Austin et al. 1970). With increased concern for the environment, however, there has been mounting interest in bamboo cultivation and technology research.

The following is a brief discussion on the recommendations for research contained in a report of the United Nations Department of Economic and Social Affairs entitled *The Use of Bamboo and Reed in Building Construction* (United Nations 1972). These recommendations essentially addressed what have been termed as "the barriers to greater usage of bamboo".

IMPROVED PRESERVATION TO GUARD AGAINST INSECTS, RO'ITING AND FIRE

Within the bamboo culm, there is a high level of moisture which later leads to rotting, or splitting when drying and during usage, thereby shortening its natural durability. Its low durability is also exacerbated as bamboo attracts wood boring insects. Some research based on already existing traditional methods for bamboo preservation addresses these issues.

CULTIVATION OF SELECT SPECIES.

The need for this type of research stems from the ecological, cultural and economic implications of bamboo deforestation. The issue of diminishing supplies of bamboo is a primaiy example of ecological problems. Most of the bamboo harvested comes from natural forests. As with any forest, bamboo appears to be plentiful to the naked eye. This perception has led to poor harvest management as people continue to clear-cut not only hardwood forests but also bamboo forests, with little attention to conservation and regeneration. This is also occurring in Colombia where Guadua bamboo use is widespread, threatening it to extinction (Farrelly 1984). The demand from growing populations, the consequent overexploitation of natural bamboo forests and the absence of regeneration practices are beginning to cause shortages of certain bamboo species.

Poor harvest management has had negative economic consequences. For example, heavy demand for bamboo outside of Southeast Asia has led to premature harvesting and hence, poor quality material. This has caused a decline in the export of bamboo products, for example, in Indonesia, adversely affecting both rural and urban economies. The cooperative sector and the handicrafts export industry may be seriously hurt in the future if enhanced bamboo cultivation and better harvest management are not given serious consideration as means of maintaining raw material supply.

Threats to particular bamboo species also have cultural implications, in places such as Western Java. Presently, the supply of the high quality bamboo species *bambu hitam* (black bamboo), used to make traditional musical instruments, is being exhausted by the furniture and handicrafts industries. Large-scale industries, inherently more economically powerful than musical instrument makers operating as cottage industries, are threatening the survival of this craft through their monopoly of this bamboo species (Widjaja 1980). Cultivation of bamboo could help relieve some of these problems. Proper selection and cutting of bamboo culms at the right age (Austin et al. 1970) would also result in an increase in the quality and the yield of bamboo culms.

Selection of species for cultivation is also -essential for animal conservation. For instance, the survival of the Pandas in China depends on the availability of certain species of bamboo, their staple food.

IMPROVED METHODS FOR FASTENING

Better fastening techniques would lengthen the durability of bamboo structures. According to Austin et al. **(1970),** traditional fastening materials have been pegs or bindings instead of nails or other metal fasteners. However, more recent research has proved that bamboo can be joined by glue and be laminated like wood.

BAMBOO AND REED PARTICLE BOARD

Successful research in this area would release a lot of pressure on tropical timber. The increase in demand for tropical timber has been for plywood and veneer processing used extensively in house remodeling and boat fixtures. Bamboo has great potential for this market.

ARCHITECT-DESIGNED MODEL HOUSES

Research in this field would also solve some of the problems related to tropical deforestation by reducing emphasis on traditional tropical timbers designed into modern housing construction. It would also be advantageous to poor people as refining the overall housing structure wili reduce future damage and need for repair. Furthermore, research could reveal other uses for bamboo, such as replacing steel in concrete beams. The *Global Report on Human Settlements* (Habitat **1987)** confirms that most developing countries are investing in the growth of the indigenous construction sector through innovations in low-cost building materials and construction techniques. The focus, however, is now on the use of locally available raw materials, such as bamboo, which they see as promising for use in concrete reinforcement.

Since the making of the above recommendations, there have been some advancements in these research areas. Bamboo housing technology has improved, notably in Colombia and Costa Rica. There have also been considerable advancements in preservation techniques. Bamboo plyboards and particle boards have been developed in China. Major world institutions have started taking active roles in the development of bamboo. Both the United Nations Development Programme (UNDP) and the Food and Agricultural Organization (FAO) have invested in the saving of endangered bamboo forests and the establishment of new bamboo plantations (DeCastro 1994).

Cultivation and production are among the areas deemed imperative for further research. Even recent bamboo gatherings have defined newer and more extensive research agenda in these areas. Conservation and biodiversity also continue to be issues closely related to cultivation (Anonymous 1995). Identifying priority species and superior genotypes for cultivation, and matching them with their optimal agroclimatic zones, are still weak areas in research. It is now very clear that natural bamboo stands alone cannot meet the growing demand; it is essential to turn to plantation development. But, in the case of natural stands, it is necessary to learn to harvest at the right place and time without destroying regeneration capacity (DeCastro 1994).

Newer research needs, as discussed and agreed upon in recent gatherings, place less emphasis on developing technology and methodologies and more on applying, transferring and sharing technology and information. The following areas emerge as key themes of these newer research needs (INBAR 1995):

1. Information availability, guidelines/manuals, networking;
2. Training;
3. Socio-economics;
4. Promotion/communication and information campaigns;
5. Participation of NGOs and other development organizations; and
6. Technology improvements/enhancements (products, housing).

The above list underscores the need for collaboration among all parties interested in bamboo and among target groups for future involvement.

## Current Bamboo Research Centers and Projects

Although historically bamboo research has been scant and scattered, several research centres in Asia have been studying bamboo since several decades. Examples include: the Hin-Lap Research Station in Kanchanaburi Province of Thailand; Lembaga Biologi Nasional, Estate Crop Research Institute, Lembaga Penelitian Hasil Hutan (Forest Product Research Institute) and Lembaga Penelitian Masalah Bangunan (Building Research Institute) in Indonesia; and the Forest Research Institute in Dehra Dun, India.

In terms of projects, a Thai-Japanese union has looked at the selection of a bamboo species for cash crop cultivation, examining its growth, yield, effect of fertilization, propagation and flowering (Smitinand and Ramyarangsi 1980). Both in Japan and Indonesia, research is currently being carried out on bamboo pulp for paper making. China and India are doing research in the area of plybamboo.

There are several organizations and associations working to bring together people interested in bamboo: the American Bamboo Society, the European Bamboo Society, the Japanese Bamboo Society, the Jamaican Bamboo Society, etc. The emphasis on bamboo use in development projects that address human welfare and the environment has led to the emergence of organizations dedicated to these ideas. In Bali, Indonesia, the Environmental Bamboo Foundation was founded in 1993. The Integrated Rural Bamboo Project was established in 1994 in India to investigate the improvement and utilization of rural bamboo (Boa 1996). Institutions such as the International Bamboo Association (IBA) and the International Network for Bamboo and Rattan (INBAR) have been providing support to bamboo researchers and acting as linkages for bamboo practitioners around the world.

Many of these organizations and people have come together in the past to exchange ideas and information on bamboo. To date, five such international workshops and four international congresses have been held. The most recent gathering (June 1995) in Bali, Indonesia combined the two events and brought together bamboo enthusiasts, scientists, businessmen, policy-makers, artists, architects, designers and environmentalists. One of the outcomes from the Bali conference was that INBAR was accorded the primary role in bamboo information networking, technology transfer, the formation of bamboo utilization guidelines and furthering research in the area of bamboo (and rattan) socio-economic studies. All of these activities will be supported by IBA (Anonymous 1995).

## Potential Applications of Bamboo

### ENVIRONMENTAL SOLUTIONS - SOIL EROSION

Because of the extensive rhizome system that lies primarily in the top foot of soil, bamboo works well to prevent soil erosion occurring in flood plains, along riverbanks and on steep hillsides. It can control landslides, keep flooded rivers along their natural course and slow the speed of the water flow (Austin et al. 1970).

### CARBON DIOXIDE BUILDUP

According to the Environmental Bamboo Foundation (EBF), bamboo's growth habits allow it to produce more oxygen than equivalent stands of trees. This aspect holds significant implications for the reduction of atmospheric carbon dioxide — the greenhouse gas and a major environmental issue today — as planting and replanting of bamboo in groves and plantations could help mitigate- this problem.

### TROPICAL TIMBER DEPLETION

Harvesting of bamboo is frequent since it reaches maturity within 3-4 years, and new shoots appear regularly and in great numbers. Replenishment and regrowth are quite fast and efficient in comparison to tropical timber trees, which have life cycles that are two to ten times longer. Bamboo increases its biomass by l0-30% per year which far exceeds that of trees, which is *2-5%* annually, according to EBF. Also, bamboo produces more cellulosic material per acre than southern pine wood (Austin et al. 1970). Evidently, bamboo is a more sustainable resource than tropical timber trees and hence, it could realistically replace or supplement tropical trees in many industries that are facing raw material shortages.

### DEVELOPMENT SOLUTIONS

#### TENSILE STRENGTH

Studies in Puerto Rico have shown that the species *Bambusa tulda* can withstand up to 52,000 pounds per square inch (psi) before breaking (Farrelly 1984). In comparison, walnut wood takes 20,000 psi and steel for reinforced concrete withstands 60,000 psi. This makes bamboo wood a potential alternative, at least in some applications, to steel which requires more energy for processing. Its strength and flexibility also make it a viable material for building shelters that offer protection against hurricanes and earthquakes.

#### ECONOMICS

Because harvesting of bamboo can be quite frequent, return on investment comes much quicker than investment in tropical timber plantations. Therefore, bamboo community forestry projects are economically more attractive, especially for small farmers with little capital. There is a considerable potential for bamboo's use in rural development projects aimed at providing sustainable economic opportunities for the poor. Its high yield capability makes it a good cash crop for income generation, and thereby for improvement in the living standards, in rural areas. Incorporating value-added manufacturing into bamboo community forestry projects makes them even more advantageous to rural people, who usually earn the least profit as mere suppliers of raw materials. As Farrelly (1984) states: ".... .socially just forms of bamboo development will be an important aspect for future designs for exploiting the plant."

In summation, bamboo's excellent growth, mechanical and engineering properties make it a fine alternative to tropical timber. Unfortunately, bamboo is still dubbed the "poor man's timber", representing a social stigma (Willcox 1992). Perhaps this attitude towards bamboo will change with the increased urgency of environmental issues and with more dedicated attention to the poverty problem. More widespread education and communication are needed, mobilizing people to support greater research on solutions and alternatives to deforestation, proper implementation and utilization of research results for the betterment of resource-poor people: all with bamboo in a pivotal role.

# 3 RESEARCH ISSUES

It is estimated that the "current world production of bamboo represents a seven billion dollar industry which directly touches one-third of all the earth's population" (Willcox 1992). Therefore, promotion of bamboo conservation and sustainability is vital for its future, not only as a viable alternative to tropical timber used in industries but also as a useful tool for employment and income generation in rural areas.

Myers (1984) argues that timber plays a part in more activities of a modem economy than any other commodity, especially in the United States where the average American utilizes about 1% tons of wood per year. He also points out that the consumption of timber has continued to increase over the last 30 years, especially in the more developed world. Depletion of tropical forests has had a ripple effect on the environment. Forests regulate rainfall which is abundant and frequent in the tropics. Without the sponge effect of trees, flooding occurs causing soil erosion, sedimentation of rivers and other waterways, and soil leaching. Trees on hillsides minimize the detrimental effect of landslides, rockfalls and earthquakes. On a larger scale, trees contribute to the control of atmospheric carbon dioxide and thus to the curbing of global warming. Loss of biodiversity that accompanies loss of forests is an equally critical issue since we are not completely knowledgeable about what is being lost.

In his book The *Primary* Source, Myers (1984) discusses some alternatives that may halt the depletion of tropical forests; these include the use of secondary forests and tree plantations. This is where, bamboo experts believe, bamboo can take on a major role. Considering the characteristics of bamboo, it seems logical to utilize this woody plant to help solve many of the environmental problems associated with deforestation. Moreover, its strong cultural links make bamboo optimal for development initiatives which seek to alleviate poverty.

The purpose of this study is to examine the role of bamboo in rural development through its use in appropriate and sustainable technology. It proceeds on the basis that by investigating how current projects are utilizing bamboo to resolve issues of poverty in LDCs, one can learn how to optimally employ this natural resource to mitigate the problems associated with poverty. Issues discussed earlier — such as cultivation and management of bamboo, bamboo preservation, architecture, and development of other bamboo products — are re-examined in more detail as advancements in these areas will certainly help development practitioners to effectively utilize bamboo in their initiatives aimed at the environment and people.

PNB of Costa Rica has used bamboo as an alternative low-cost building material in a participatory construction program. The research goal was to be able to identify strengths and weaknesses of the project, and to measure its mark of achievement in development using bamboo as an appropriate and sustainable technology, to learn how it may be improved if necessary, and to make recommendations for further research and future offspring projects or endeavors for PNB.

This study looks at the process of implementing bamboo as a development tool, and its promotion and prominence as a less expensive, alternative material used to address a housing shortage in Costa Rica. It identifies all the key players, their role in and contribution to solving the housing problem, as well as how the target group or beneficiaries of bamboo homes participate in and are affected by the process. This case study also aims to allow others to evaluate its transferability to their respective countries to solve their own housing shortages. Portions of the case study may also be useful for evaluating the feasibility of initiating bamboo micro-enterprises for the purposes. of rural socio-economic development .

## Methodology

Undertaking this research entailed a wide variety of activities. Extensive literature research served to acquire an understanding of the history of bamboo in developing countries in terms of its uses, past research accomplishments and future trends. Research also uncovered numerous institutions and organizations involved in bamboo research and utilization, such as the Proyecto Nacional de Bambu (PNB) of Costa Rica. The literature also rendered a basic understanding of bamboo's biological nature.

Four months — from August 1995 through mid-December 1995 — were spent investigating PNB's activities. The following primary sites of project operations were visited (Appendix A):

1. Bamboo furniture workshop, Guapiles
2. Bamboo plantation, Guapiles
3. Panel production facility, Pocora
4. Panel production facility, Orotina
5. Housing project, Orotina
6. Center for the Investigation of Bamboo Applied Technology, Milan0
7. Bamboo nursery / vegetative propagation bank, Guapiles

Several informal interviews were conducted with PNB personnel and others working with bamboo. On the suggestion of Francisco Rodriguez of the PNB Construction Department, the county of Orotina, specifically the community of Coyolar, was visited (Fig. 1). The area had a good mix of people with different employment situations. PNB had twice built houses in the area, once during the pilot phase of the project when about 30 houses were built entirely through self-help construction, and after the pilot project when 20 houses were constructed partly through self-help. At the time, PNB was also building a third set of about 40 houses under contract. PNB's involvement in Coyolar had also brought infrastructural developments such as paved roads, electricity and running water. Thus, there was an interesting history, both from the community perspective as well as project perspective in terms of the area's overall development. The first two-day exploratory trip to Orotina was followed by another trip a month later. During the second trip, several beneficiaries of the PNB houses were interviewed.

Discussions were also held with personnel from the Ministry of Housing and Human Settlements, the Institute of Agrarian Development and the Home Mortgage Bank (BANHVI). Several project documents and reports were reviewed for a greater understanding of project preparation, history, strategy, description, financial aspects, future plans, etc.

# 4 THE NATIONAL BAMBOO PROJECT

## The Country

Costa Rica is a small Central American country with a total area of 51,000 $km^2$. Its population in 1993 was approximately 3.3 million, largely Spanish descendants. A portion of the population comes from about five indigenous groups that live primarily on reserved areas.

Successful development achieved in Costa Rica in recent decades is in part evidenced in the decisions by the United States Agency for International Development (USAID) and the United States Peace Corps to terminate their missions in Costa Rica. Despite some persisting problems, Costa Rica has made significant advance in its overall socio-economic development. Although development indicators by themselves do not give complete pictures, referencing them over time can provide a general sketch (see Tables l-2).

The Costa Rican government allocates more of its funds to social programs than any other of its counterparts in the region. It has the least income inequality **(USAID** 1995) and is known to have the best health conditions in the region.

Costa Rica has been ruled by a constitutional democratic government for over one hundred years. The government's primary objectives in recent times. have been to concentrate on government restructuring, the environment and fiscal crisis alleviation **(USAID 1995).** Overall, this country has experienced far greater economic, political and social stability than any of its neighboring countries.

Table 1: Costa Rica — development indicators

| Indicator | 1995 |
|---|---|
| Population growth rate | 2.3% |
| Unemployment rate | 4.2% |
| Economic growth rate | 4.5% |
| Inflation rate | 19.8% |

Source: USAID 1995

| Indicator | 1970 | 1993 |
|---|---|---|
| GDP (mil. US$) | 985 | 7,577 |
| Agriculture as % of GDP | 23 | 15 |
| Industry as % of GDP | 24 | 26 |
| Manufacturing as % **of** GDP | – | 19 |
| Services as **%** of GDP | 53 | 59 |

Source: World -Bank 1995

| Government expenditure (%) | 1.980 | 1993 |
|---|---|---|
| Defense | 2.60 | |
| Education | 24.6 | 22.3 |
| Health | 28.7 | 28.5 |
| Housing/social welfare | 9.5 | 10.8 |
| Economic services | 18.2 | 97 . |
| Others | 16.4 | 28.7 |
| Total as % of GNP* | 26.3 | 26.7 |

8* GNP in 1993US$2 150 million

Source: World Bank 1995

| Income distribution | 1989 |
|---|---|
| Lowest 20% | 4.0 |
| Second quintile | 91. |
| Third quintile | 14.3 |
| Fourth quintile | 21.9 |
| Highest 20% | 50.8 |
| Highest 10% | 34.1 |

Source: World Bank 1995

| | |
|---|---|
| Population with access to safe water (1991) | 94% |

Source: World Bank 1995

Table 2: Costa Rica — ranking among developing countries

| Parameters | 1992 |
|---|---|
| Human Development Index[a] | 9 |
| Life expectancy | 3 |
| Access to safe water (1988-91) | 17 |
| Adult literacy | 11 |
| Real GDP per capita (1991) | 23 |
| GNP per capita (1991) | 26 |

a: The Human Development Index is a number which encompasses life expectancy, adult literacy, mean years of schooling, and purchasing power parity based on real GDP per capita. It is an indicator developed to measure progress over time and which is better utilized when comparing country to country. Also, it accounts for a greater human element when evaluating development instead of only measuring development through economic terms, such as GNP per capita, which was historically the case.

Source: UNDP 1994

## The Problem

One of the consequences of deforestation in Costa Rica was an increased cost of building homes owing to scarce timber supplies. Newer construction technologies were introduced using masonry or concrete, but these were also costly and have generally only been introduced in urban areas. The economic crisis of the 1970s and 1980s created greater problems for housing in Costa Rica. Higher interest rates and 100% inflation, along with limited housing options, low income levels and a progressive elevation of construction material prices made it extremely difficult for people with scarce resources to rent a home, much less enter the home buying market. A 1988 PNB report states that 56% of the population had an annual income of less than US$500, 34% of the population had an annual income of US$500-1,000, and 10% of the population had an annual income above US$l,000. A small house of 65 $m^2$ with three rooms plus enough land to hold the house had a cost of US$3,100. A family would have had to earn at least US$1,900 per year to be able to make a monthly mortgage payment of US$52 for 15 years. Clearly, this disqualified a majority of the national population from owning .their own home.

As of 1995, the housing deficit was estimated by the Ministry of Housing and Human Settlements at 163,000 units with a growth rate of 24,000 per year. Of this deficit, 53% was in the rural areas. The government's goal at present is at minimum, to arrest the growth of the housing deficit. A reduction in the base deficit of 163,000 houses is more desirable, but difficult owing to the high costs involved.

## The Solution

In 1986, the Costa Rican government established the National Financing System for Housing. This system had evolved over the years and consisted of multiple entities, each with its own objectives, rules and regulations. Because of this, the housing problem appeared to be haphazardly addressed.

During the administration of President Oscar Arias (1986~90), the system was overhauled and reorganized. Four main objectives were defined in the reorganization to effectively address the housing problem:

1. Consolidation of resources;
2. Regulation of resources;
3. Stimulation of social interest housing construction; and
4. Control of uniform financing options.

At this time, the *bono familiar de vivienda* program became official and was to be managed by the Ministry of Housing and Human Settlements (MIVAH). Financing was to be administered by the House Mortgage Bank (BANHVI).

In the beginning, *bono familiar de vivienda* was a ten-year loan at zero interest. However, during the administration of Calderon, it was converted into a donation. The *bono de vivienda* is part of the social interest housing program which the Costa Rican government hopes to stimulate. With a growing housing deficit, concentrated primarily in rural areas among people of scarce resources and lower income, the government hopes to foster an increase in the number of entities that will help mitigate the housing problem.

The *bono de vivienda* can be used for different purposes:

1. Land purchase and house construction;
2. Construction of a house;
3. Improvement or expansion of a house;
4. Purchase of a house being rented; or
5. Titling or legalization of property.

To qualify for it, the family unit must be earning less than four minimum salaries. At one minimum salary, the financing system assumes zero capacity for receiving any other credit for obtaining a home, so this family would receive a complete *bono de vivienda* equaling 978,000 colones (about US$5,120). With two to four minimum salaries, a prorated amount of *bono* is given (Table 3).

Table 3: *Bono de vivienda* — amount awarded based on monthly* salary

| Monthly salary | | Bono amount | |
|---|---|---|---|
| Colon | us$ | Colon | us$ |
| 97 500 | 510 | 100 000 | 524 |
| 32 500 | 170 | 978 000 | 5 120 |

The government's social housing program has financing from two funds: the National Fund for Housing, which constitutes the *bono familiar de vivienda,* and the Fund for Housing Subsidies. About 33% is funded from annual income taxes and money from the Fund for Social Development. Another three percent comes from the national budget and other contributions from public, private, national and/or international entities.

## The Project

ORIGIN

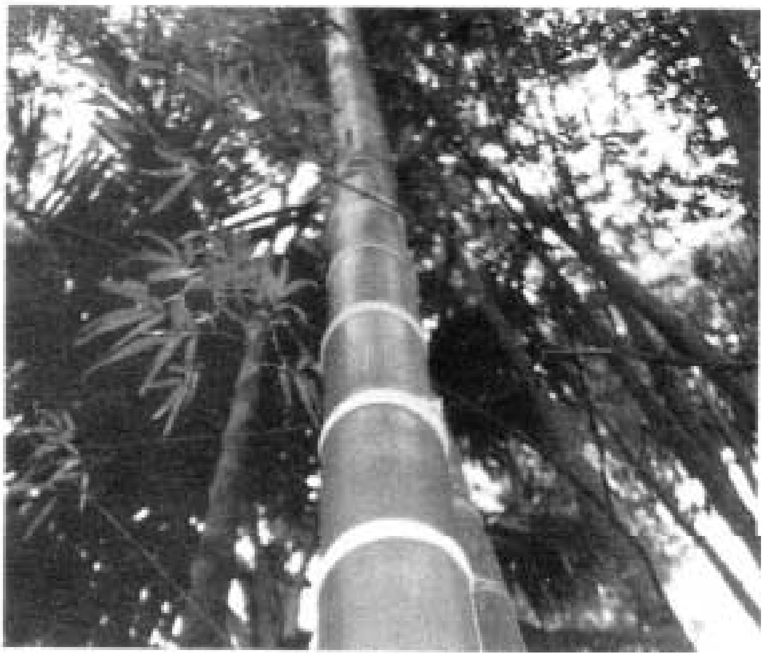
As mentioned earlier, the main. aim of the government is to check the growth rate of housing deficit. To this end, it has followed a policy of fostering housing initiatives. PNB was started in 1986 (Fig. 2) under architect Ana Cecilia Chaves who implemented a plan to utilize bamboo as an alternative low-cost building material in a self-build construction program in the poorer rural areas of the country. The construction tethnology applied to build housing was heavily supported by PNB's bamboo research and development component. Through extensive research, PNB gained the solid knowledge required for its work in areas such

Fig. 2: National Bamboo Project headquarters, San Sebastian, San Jose

as the cultivation and management of bamboo plantations, the physical and mechanical properties of bamboo, preservation of bamboo, and the structural behavior of bamboo in buildings including its behavior during seismic activity.

## *Guadua* bamboo

PNB chose to utilize a species of bamboo called *Guadua* (Fig. 3) because of its grain, length



and mechanical resistance. *Guadua* bamboo is native to Central and South America, and is known to be the strongest and most durable bamboo in the Americas (Farrelly 1984). It has been an essential element in the socio-economic development of many areas of Colombia (Farrelly 1984). Both Colombia and Ecuador have histories of over one hundred years utilizing *Guadua* bamboo for housing construction. Farrelly (1984) quotes McClure in saying that *Guadua* is more lombia, where it abounds, than is bamboo in any area of the Far East, with the possible exception of Java. It is from these countries that PNB learned and adapted the housing technology. Research on bamboo construction methods has been conducted also in Peru, Guatemala and Brazil.

PNB felt that the following reasons justified the use of bamboo for housing construction:

1. Traditional uses of bamboo exist;
2. It has rapid growth and maturity;
3. It has mechanical advantages during seismic activity;
4. Low cost;
5. It is easily accessible to users from sectors with scarce resources;
6. Its versatility offers multiple technological options;
7. It is easily integrated with advanced technology; and
8. It can be integrated into complementary housing structures.

PNB uses two different species of *Guadua* — *Guadua angustifolia* and *Guadua aculeata.* G. *aculeata* is taller (28 m) and thicker (18 cm inner diameter, 3 cm wall thickness). G. *angustifolia,* although shorter (22 m) and thinner (12 cm inner diameter, 1.5 cm wall thickness), has more fibers per unit area and is therefore, stronger and more resistant. G. *aculeat* is used for making laths for housing (see following section on *tablilla). G. angustifolia* is used more for furniture and major structural elements in building construction, mostly in unsplit form. These structural elements can be seen in Figs. 4-6.

Fig. 4: Guadua bamboo as structural element,El Tapir Restaurant by PNB

Fig. 5: El Tapir Restaurant, designed and built by PNB

## Guadua plantation and *fablilla*

PNB presently counts about 300 ha of bamboo planted in Guapiles, Arena1 and Golfito (Fig. 7). The location of these sites reduces bamboo transportation costs to PNB homes built throughout the country's rural areas. The three plantations are of different ages. Guapiles was established in 1988 and is therefore, the oldest plantation (Fig. 8). Arena1 was established in 1989 and Golfito in 1990. Each.plantation has sections of different ages. The method for cultivating the earlier stands of bamboo was vegetative propagation. However, some of the

Fig. 6: A square bamboo table, designed and built by Brian Erickson

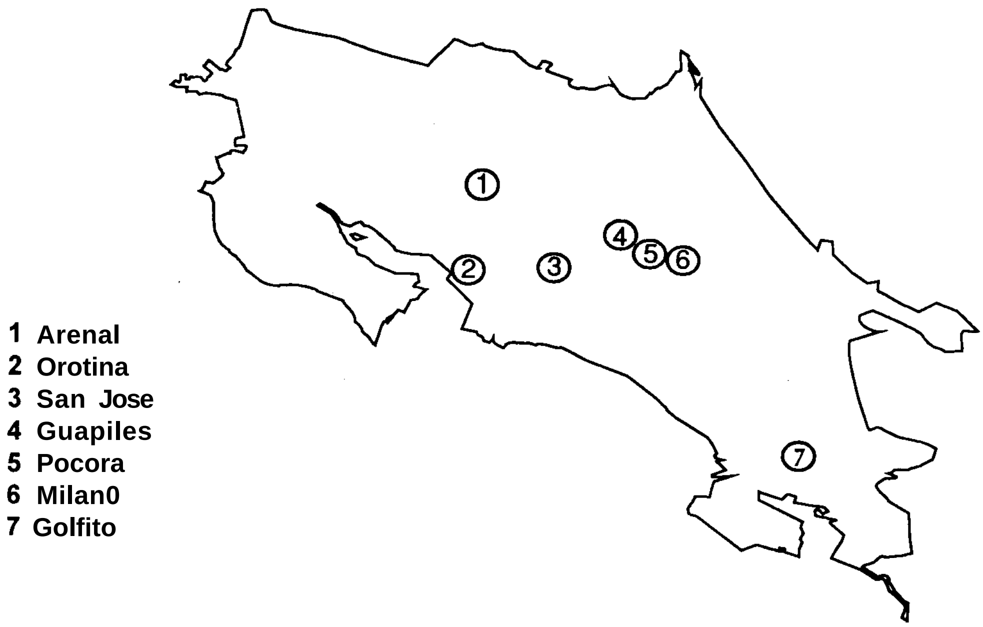



Fig. 7: Project sites in Costa Rica (not to scale)

Fig. 8: Guadua plantation, Diamantes Experimental Station, Guapiles

more recent plantings have used seeds from a section of the Guapiles site which flowered in 1994.

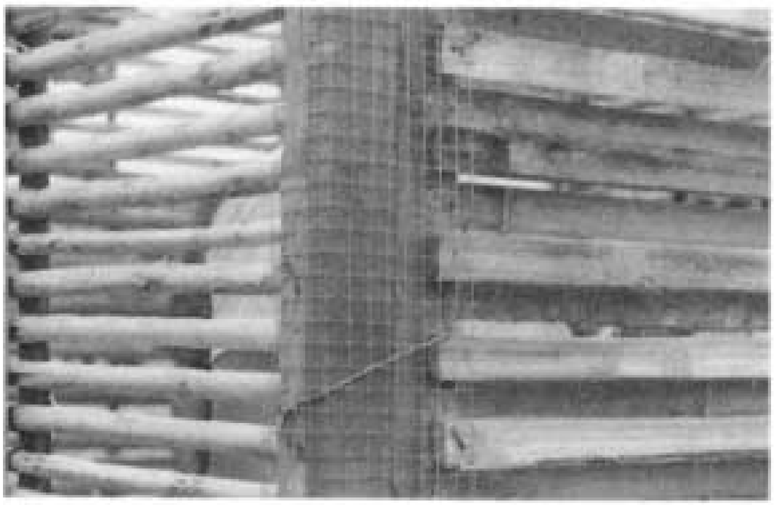


Fig. 9. Cana brava panel (left side) joined with a tablilla panel (right side)

There is a current plan to plant an additional 500 ha. The overall target is a total of 2,000 ha planted country-wide. During the pilot phase of PNB, bamboo material for construction was supplied from bamboo groves on the property of EARTH. According to PNB, the Guapiles plantation would be fully ready to produce culms for house construction beginning in 1998, with an annual production of 50,000 culms per year.

In the meantime, PNB has also been using a type of cane plant called *cana brava* which grows abundantly in various zones of the country (Fig. 9). The use of this cane has actually proved to be comparable to the use of bamboo lath, called *tablilla,* in house construction. The cost of *cana brava* is about 30 colones or US$0.16 per piece.

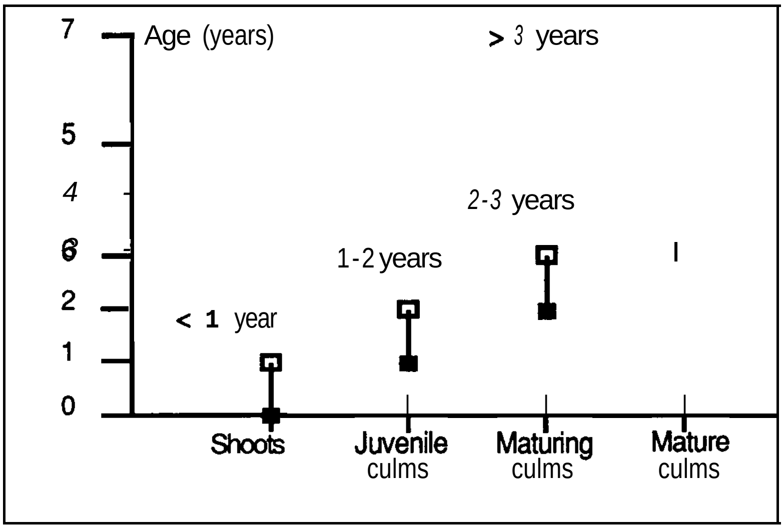



Fig. 10: Age categories of bamboo for inventory

Before each harvest, an inventory is taken to ascertain the number of bamboo culms per hectare (Fig. 10). After the inventory, about 33-55% of the mature culms are cut in three stages. First, all mature culms damaged by insect attack, and those that are broken, crooked or have tipped over are removed. Next, the thinner mature culms are cut for furniture. Finally, all thicker culms are cut for use in housing. Each plantation is cultivating a particular species of *Guadua*. Arena1 plantation which cultivates G. *angustifolia* has a yield of 10,176 culms annually, while the *G. aculeata* plantation in Guapiles has an annual yield of 51,200 culms. The cost of production and maintenance per hectare are as follows (applicable for both species of bamboo, although G. aculeata may be slightly costlier owing to the cost of seeds):

Annual production costs = US$357
(cost of plants, land clearing, planting)
Annual maintenance costs = US$252
(3 cleanings, 2 herbicide applications, 2 fertilizations)

Note: Costs do not include social security costs (22% of wages).

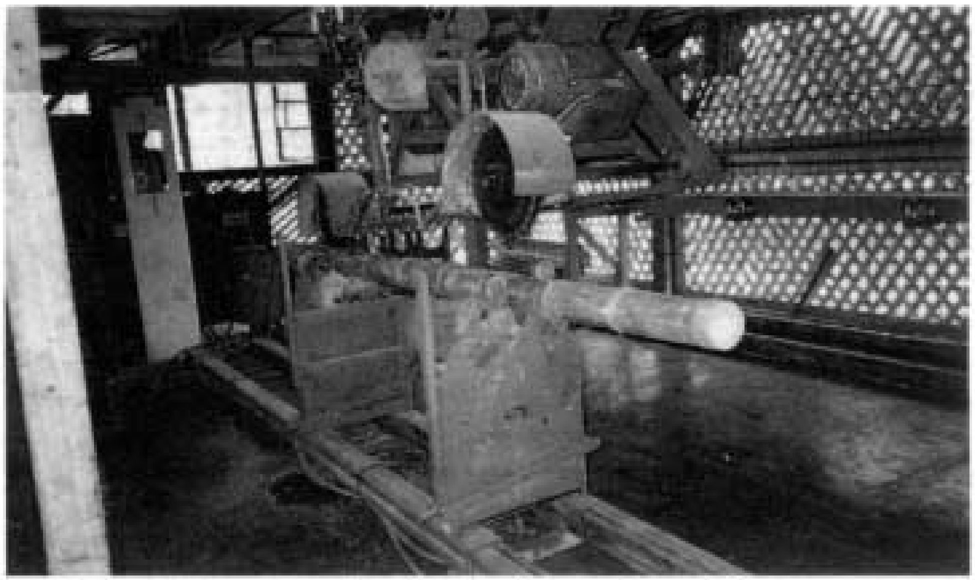


Fig. 11: Cutting bamboo culm into tab/i//a, at CITAB, Milan0

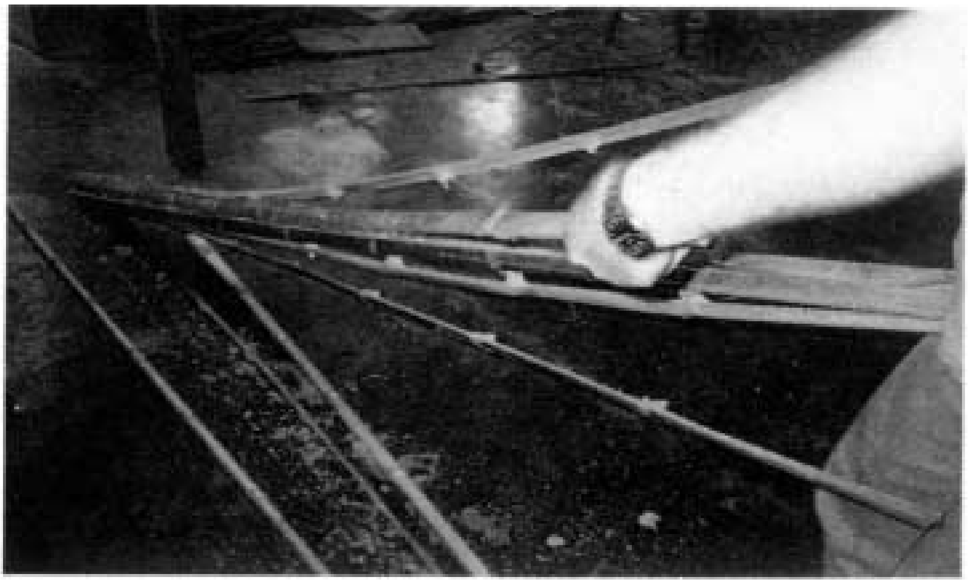


Fig.' 12: Splitting a cut bamboo culm into narrow strips

*Tablillas* are made from mature bamboo culms (about 7-8 years old) with a diameter of at least 10 cm. A culm yields three or four pieces, each 3 m in length. These pieces, on an average, gives seven tablias of l-2.5 cm width. Presently, a double-blade machine located at the Milano site is used to make *tablilla* (Figs. **11, 12).** The blades run the length of the culm making a cut; then the bamboo culm is rotated and the blade runs back in the other direction. This makes the task somewhat labor intensive and time consuming, but improvements can be made to the machine to make the task considerably easier. The production cost of a tablilla is estimated at 20 colones or US$0.II.

## Vegetative propagation bank

An intern from France studying **agronomy** and development recently completed the construction of a vegetative propagation bank at the Diamantes Experimental Station in Guapiles for *Guadua* adantico or G. angustifolia (Fig. 13). This bank was created through the Colombian method called "chusquin". In July 1994, a section of the Guapiles plantation had flowered and PNB was able to extract seeds. After germination and a growth period of 1½ years, these plants were transferred into the vegetative propagation bank. A portion of the leaves of these small plants was removed to reduce transpiration and dehydration. Under the chusquin method, the roots and rhizomes were then segregated and cut to obtain more plants for the bank.

In the bank, there are 5,000 plants with 30 cm of space between each to allow growth. There are 18 different plots, each measuring 21 x **1.2** m. The total bank measures 40 x 21 m. A 41 x 23 m screen covers the bank, reducing the amount of sunlight hitting the plants by 60% and preventing excessive dehydration. The Forestry Department will be adding an irrigation system for the dry season (January through March in Costa Rica).

The French intern's intent is to assess the growth behavior of the bamboo by using different mixes of chemical or organic soils and fertilizers. The-goal is to determine the best soil for producing the most number of plants in the least amount of time. PNB would like to extract 15,000 plants every four months from the bank for transfer into plantations.

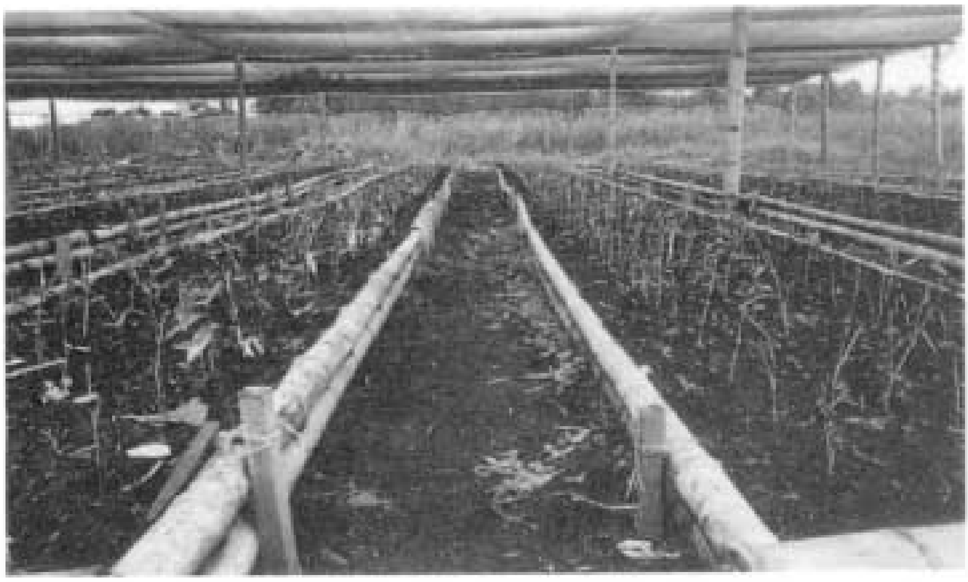


Fig. 13: Bamboo nursery at Diamantes Experimental .Station, Guapiles

## Preservation

Two processes of preservation are used at PNB: boucherie, which is used for whole culms, and dip diffusion which is used for bamboo laths *(tablillas).* The boucherie treatment is the process of sap displacement in the bamboo culm using a boron preservative. A rubber capping is attached to one side of the bamboo culm. A pressure machine then pushes the boron mix through the walls of the bamboo culm, all the way through to the opposite end. The internal sap is replaced with the boron chemical to preserve the bamboo. A pH test is performed on the opposite end to make sure that all of the sap has been displaced.

Fig. 14: Dip diffusion tank for preserving the bamboo tablilla

This process can take from 40 minutes to several hours, depending on the size of the culm being treated (a culm of lo-12 cm diameter would take 40 minutes at minimum). Harvested culms must be treated immediately after being cut. After treatment, the culms are air-dried for about 90 days. This rnethod of preservation is simple and cost-effective; however, its duration and effectiveness are dependent on the species, moisture content and the preservative used (Liese 1992). Intensive research done by PNB has proved it effective for use with Guadua bamboo.

PNB uses treated bamboo culms both for furniture and fcr structural elements in architecture. Full bamboo culms have not yet been incorporated into the structure of the bamboo homes built for the beneficiaries of the social interest housing program. They have been used, however, for major structural elements in a restaurant (Figs. 4, 5) and some office buildings. The dip diffusion system uses the same boron preservative solution. In this case, however, it is used to treat sets of *tablillas* — already split and dried bamboo laths which are immersed into a tank filled with the boron solution (Fig. 14): This process is less time consuming — about ten minutes per set. These treated *tablillas* are then used to build-the bamboo houses in rural areas under the social interest housing program.

## The Technology

Ham (1990) states: "Successful low income housing must not only address economic and physical structure parameters, but should also address how such dwellings will affect the social and cultural organization of the inhabitants." In many instances, the mention of a bamboo house creates the image of a hut-like structure, signifying a very rustic, open edifice, exposed to wind and rain, and demanding constant repair and replacement of structural materials. Clearly, the introduction of this type of structure would not be received well in developing countries moving towards modernization.

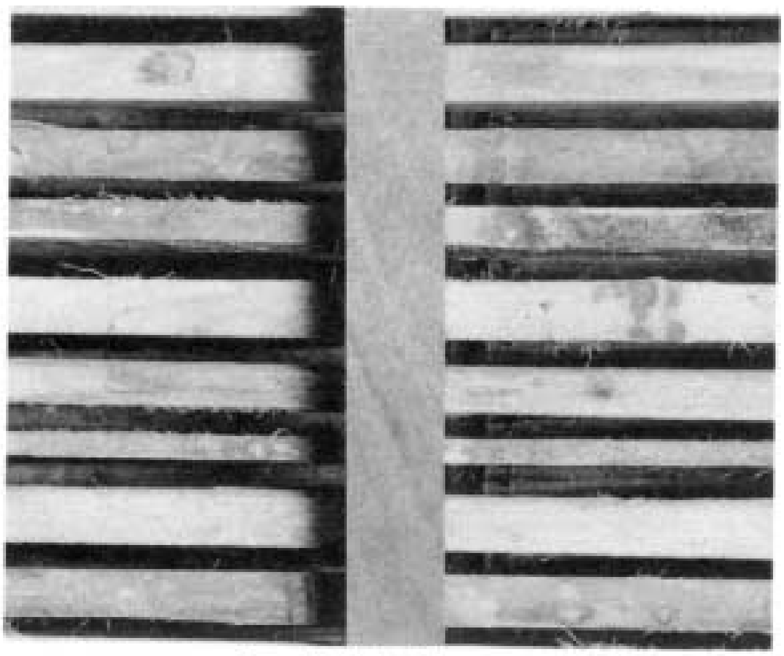


Fig. 15: A *tablilla* panel

To overcome this image, PNB adapted the use of bamboo to a modern housing design. There are basically three sizes of houses built by PNB — 31.3 $m^2$, 37.7 $m^2$ and 46 $m^2$ =with a total of 20 different layouts. The house has a foundation of cement block supporting a structural frame of panels. Strips of wood make up the basic panel frame, while *ta blillas* are attached horizontally to cover the entire panel (Figs. 15, 16) which lessens the need for more expensive wood and/or cement blocks in the structure. A 37.7 $m^2$ size house uses

Fig. 16: Making house panels at the EARTH facility in Pocora

about 15 panels. Each panel uses about *60 tablillas.* In the beginning stages of the project, bamboo *esterilla* (Fig. 17) was used instead of *tablilla,* but producing this form of bamboo proved to be more labor intensive and less efficient esterilla is made by splitting open the bamboo culm and carefully flattening it out). The panels are then covered with a cement and sand mixture (Fig. 18). Roofing is made of corrugated tin (Fig. *19)*

Fig. 17: Bamboo esterilla

The resulting house looks quite modem and culturally fitting, very much in the style of a typical Costa Rican home (Fig. 20, 21). In engineering terms, bamboo homes will last 30-40 years. Hence, its durability equates to that of houses built with wood. Although timber still constitutes about 25-30% of the house structure, PNB hopes to eventually replace more wood pieces with bamboo.

As mentioned earlier, earthquake resistance is a trait of bamboo making it optimal for housing technology in seismic areas. An earthquake of magnitude 7.5 on the Richter scale occurred in the Limon proince of Costa Rica in 1991 just after PNB had built about 30 houses about 30 km-from the epicenter of the quake. PNB's homes were largely unaffected by the earthquake, while numerous conventional houses and roadways were severely damaged. This incident brought a great deal of repute to PNB and, more importantly, to

Fig. 18: Mounted paneling partially covered with cement/sand mixture

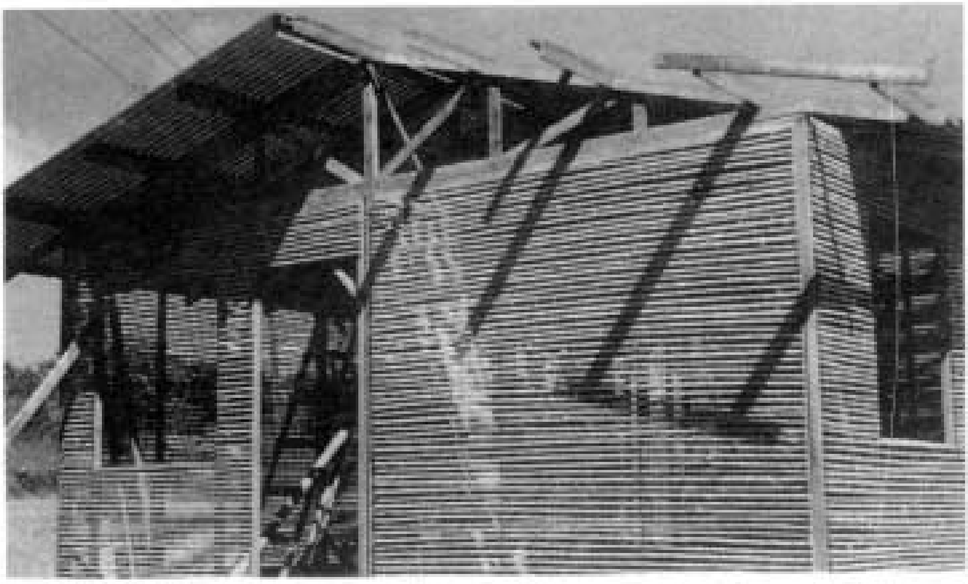


Fig. 19: Bamboo house – internal frame with paneling and corrugated roof

bamboo housing technology; it was highly acclaimed in local and international news (Martinez *(992)*.

Of all the advantages of bamboo housing technology, the most important is its low cost that does not sacrifice quality, durability nor space. Instead, it allows an option that is feasible for populations of scarce resources. The difference in material prices is considerable in comparison to the “modern” materials. For instance, concrete block wall costs about US$38/ linear meter while *cana brava* panel costs only about US$26.25 (Picado 1992). It has also

Fig. 20: Bamboo house by PNB

Fig. 21: Example of a typical home not made of bamboo in Costa Rica

been estimated by PNB that a norma , pre-fabricated house costs about US$111.10/m$^2$ while a PNB home costs just US$83/m$^2$.

## The Approach

- PNB's housing construction is implemented as a community project. This means that there must be a group of beneficiaries interested in bamboo homes within a community in order for PNB to agree to build in that community'. One family unit alone from a community does not qualify.

The government institution that addresses housing problems in Costa Rica is the Ministry of Housing and Human Settlements (MIVAH). MIVAH coordinates with other national institutions involved in the aspects of employment and rural development in order to tackle the problem of housing in an integrated manner.

The administrative entity for the bono de &vie&z is the Housing Mortgage Bank (BANHVI). However, BANHVI does not deal directly with the applicants; it funnels money for the *bono de vivienda* program to authorized banking entities. It is these entities that process applications for the *bono de vivienda.*

An applicant needs to work with the county housing committees. These committees are facilitators of the *bono de vivienda* program, determining the eligibility of applicants by verifying information concerning the applicant's economic status. On being approved, the candidate may choose the construction enterprise. If PNB is chosen, the applicant is grouped with other beneficiaries who have chosen to work with PNB. Once a sufficiently large group is formed, PNB begins an orientation course for the applicants. The PNB Department of Formalization introduces the applicants to:

1. The history of PNB;
2. The structure of PNB;
3. Details of bamboo houses;
4. Benefits of a bamboo house;
5. Contributions expected from the families (beneficiaries); and
6. Contributions and role of PNB.

The Department also conducts technical studies (assessment of land conditions for construction purposes), legal studies and socio-economic studies for each applicant. Once these studies have been approved, the paperwork passes to BANHVI requesting the transfer of the bono *de vivienda.* From an authorized banking institution under BANHVI the *bono* is transferred directly to PNB. Upon receipt of the funds, the construction begins.

## Self-help construction

A basic-advantage of bamboo housing technology is that it is fairly simple. Hence, use of this technology in a self-help housing program was feasible for PNB, making highly trained construction workers unnecessary and again, keeping down costs. PNB, believed that implementing the self-help approach was very important for individual growth and for stirring a sense of community through the practice of applying technical knowledge and the development of group cooperation habits (Ham 1990).

For the self-help program, manuals were developed to inform and teach the beneficiaries about the tasks involved in the construction of their homes and the organization and process of construction. Seven types of manuals were produced:

1. Self-help housing and mutual cooperation;
2. The role of women in self-help housing;
3. Land preparation and layout of the house;
4. Applying cement plaster — bamboo house;
5. Applying cement plaster *cana brava* house;

6. Frames, doors and windows of the house; and
7. Maintenance of the house.

From the community, groups of five to six people were formed, and each group built five to seven houses. Each group built its houses simultaneously so that all five to seven houses were, at the same stage of construction at any time. There were about 33 tasks involved with the construction of the house (Appendix B). A team of PNB technicians supervised these group units on a daily basis. These technicians came from a construction school and were trained by Roger Chaves who has extensive experience in bamboo construction methods. These technicians gained hands-on training by building four prototype homes at the site which became the headquarters of PNB in Cristo Rey, San Jose (Ham 1990). The technicians received training also for working with rural community groups.

## Contracted construction

Contracted construction is carried out by a team of workers with a hierarchy of skill. For instance, in a 153-house project in Orotina county, PNB placed three of its technicians to manage and supervise the construction; each technician was in charge of 51 homes and responsible for overseeing a team of 11 contractors who were the on-site builders. The contractors head the on-site construction along with ***operarios*** (workers) and ***peones*** (day laborers). There are usually five to eight ***operarios*** and ***peones*** per contractor. There is also a head engineer on site to oversee the entire process, solve technical problems and for administrative tasks.

Under this scheme, all houses in a project are also built simultaneously. Technicians normally visit the site in alternate days, and are responsible for the receipt and delivery of materials, quality control and inspection of construction processes. Contractors guide the day-today construction with a group of workers and laborers. The contractors are paid about 172,000 colones (US$900) per 31.5 $m^2$ house (which is the minimum salary for a construction contractor deemed by government guidelines) or 225,000 colones (US$l 178) per 46 $m^2$ house.

## Construction costs

The breakdown of costs of building a PNB house is given in Table 4. The total cost indicated here works out the same as the US$83/$m^2$ mentioned in the previous section, The Technology. This amount multiplied by 46 $m^2$ equals US$3 818. Please note that the calculations assume a steady inflation rate and no changes in cost reduction technology.

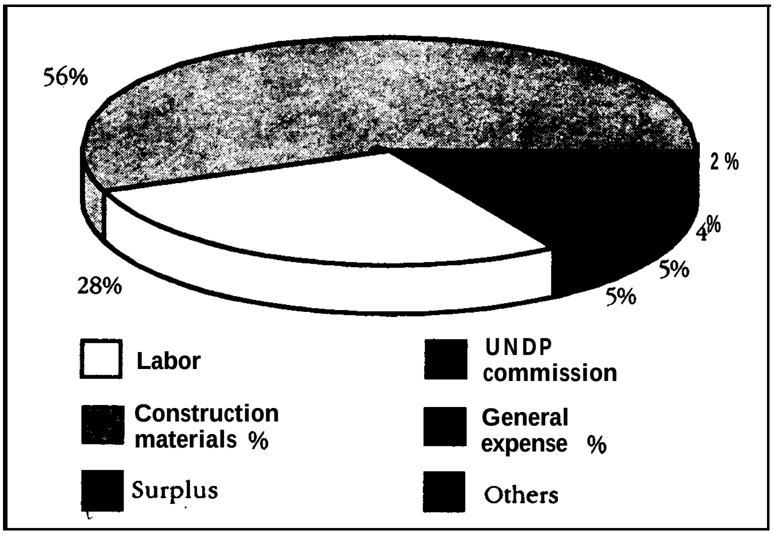



Fig. 22: Breakdown of house building costs

Table 4: Construction costs — breakdown per house of 46 $m^2$

| Item | Amount (US$) |
|---|---|
| Administrative help | 19.90 |
| Amenities | 19.90 |
| Construction materials* | 2 180.45 |
| Combustibles/lubricants | 11.52 |
| Vehicle maintenance | 12.57 |
| Labor | 1 055.24 |
| General expense** | 154.22 |
| Surplus | 181.78 |
| UNDP commission | 181.78 |
| Total | 3 817.36 |

Source: PNB 1993

Notes: * Substituting *cana brava* with *tablilla* results in $36.65 reduction in material cost.
** 5% charge for indirect costs of production.

## The Evolution

PNB has evolved through four phases to reach its current status. During the first three, it remained in project state. During the fourth stage which began in 1996, the project was transformed into a non-profit organization. The following is an outline of the four phases PNB has undergone.

PREPARATORY PHASE (SEPTEMBER 1986 THROUGH DECEMBER 1987)

Funding : OIT – US$3 700 (donation); BCIE – US$40,000 (non-reimbursable loan); UNDP – US$15,000 (donation); and Habitat – US$9,000 (donation).

**Major consultants:** Oscar Hidalgo, Colombia architect; Jorge Gutierrez, University of Costa Rica – engineer; and Oscar Arce, Technological Institute of Costa Rica -engineer.

The preparatory phase marks the official beginning of the National Bamboo Project of Costa Rica. During this time, the focus was on attracting the interest and financial support of various institutions and individuals, as well as on the development of project plans.

PHASE I — PILOT PHASE (JANUARY 1988 THROUGH DECEMBER 1991)

**Funding** : The Dutch Government – US$3,700,000 (donation); and UNDP – US$300,000 (donation).

OBJECTIVES:

1. Construction of 760 bamboo houses in 38 rural communities and areas reserved for indigenous people;
2. Cultivation of 700 ha of *Guadua angustifolia* and

3. Education of more than 1,000 professionals, technicians and family heads in cultivation, production, preservation and use of bamboo for housing.

Because of bamboo's image as "poor man's timber," it took nearly six months of the pilot phase to successfully promote the idea of bamboo houses, convincing the beneficiaries of the housing quality and explaining that these houses were not merely huts. During this stage, there were a series of community meetings to discuss the project with the potential beneficiaries. The project staff showed videos and photos, and explained the entire process of construction and the benefits of the housing system.

During the pilot project phase, house construction in certain communities was implemented through the self-help program. This could have been a deterrent because many of the potential beneficiaries were either subsistence farmers or did not have steady work. Participation would require them to sacrifice their time normally devoted to their livelihood. However, PNB had made arrangements with the United Nations World Food Program to compensate the beneficiaries with basic food necessities. This program also gave the equivalent of **US$11.75** as a monthly loan to be used as needed (Ham 1990).

**At** the onset of the pilot phase, the *bono de vivienda* was still a loan and had not yet been written off as a donation. Therefore, repayment was part of the housing subsidy program. The terms of this 15-year loan were: repayment began one year after completion of construction at 300 colones per month (US$l.57) for the first **12** months, and 400 colones per month (US$2.09) for the following 14 years. Single women who were heads of family were allowed an additional year for repayment (Ham 1990). Also, PNB did not require down payment for the housing construction. However, beginning **1991,** the housing loans were given payment without obligation.

Twenty communities participated in the pilot phase of PNB located in various regions of Costa Rica (Appendix C). The selection of these communities and the beneficiaries were based on several factors (Appendices D, E). Three of the selected were indigenous communities (Boruca, Terraba, Rey Curre), where the construction was implemented as a 100% self-help program. Many of the other communities built their homes through partial self-help owing to time and financial factors. Through the program of self-help, construction lasted about eight months; the construction took only half that time in a partial self-help program and three months when fully contracted out. PNB built approximately 348 houses during this phase — about 55% short of its original goal of 760 houses.

During the pilot phase, PNB also put a great deal of effort into the cultivation and preservation of *Guadua* bamboo. It started its plantations in Guapiles, Arena1 and Golfito during this time and studied optimal methodologies for cultivation. However, only 150 ha of land was planted instead of the originally planned 700 ha.

Although the project was utilizing bamboo in the form of *esterilla,* it established a fabrication plant in Pocora for the production of bamboo and *cana brava* housing panels. These panels utilized bamboo in the form of tablilla *Cana* brava is similar in form, although it is purchased as ready-to-use thin canes, These pre-fabricated panels have made construction less intensive, less complex, more efficient and more economical.

Substantial research and development were' carried out during this phase on the physical and mechanical properties of bamboo and *cana brava,* bamboo preservation, and the behavior and capacity of bamboo structural components and joints. These developments were pivotal for the success in bamboo housing.

## PHASE II (JANUARY 1992 THROUGH DECEMBER 1995)

Funding : The Dutch Government – US$2,300,000 (grant); UNDP – US$300,000 (grant); and Denmark – US$450,000 (grant).

Major consultants : Prof. Walter Liese, University of Hamburg, Germany – wood preservation; Prof. Jules Janssen, Eindhoven University, The Netherlands – construction, quality control and cultivation; and Francisco Castano, Colombia – engineer.

OBJECTIVES:

1. Consolidation of cultivation, production and treatment of bamboo;
2. Consolidation of social interest housing activity;
3. Institutionalization, promotion and diversification of bamboo uses;
4. Planting of additional 500 ha of bamboo by BCIE;
5. Establishment of the Center for the Investigation of Bamboo Applied Technology (CITAB) in cooperation with the University of Costa Rica and the Technological Institute of Costa Rica (Appendix A);
6. Planting of bamboo in additional 300 ha by PNB (proposal to MIRENEM); and
7. Development of a Regional Social Housing Project in Central America.

This phase of PNB was essentially a continuation of construction, and research and development. At this time, though still named Proyecto Nacional de Bambu, PNB had ended its project stage and begun to function as an entity offering low-cost housing solutions through the government's *bono de vivienda* program. During this phase, PNB built approximately 1,990 houses.

Beginning Phase II, PNB discontinued 100% self-help construction, primarily because of financial and time constraints, and moved to 20% self-help plus 80% contract (there were some cases in which construction is 100% contracted). The self-help portion of the process took about one week each, both at the beginning and the end of construction.

Phase II also showed some advances in R&D for the commercialization and industrialization of bamboo products such as bamboo laminates and furniture (Picado 1992). Basically, PNB was moving in the direction of becoming totally vertically integrated. It purports to eventually become fully self-sufficient in cultivation, preservation, housing construction and pre-fabrication of housing panels, and to start the commercialization of these operations (Picado 1992).

## BAMBOO FURNITURE

Part of PNB's bamboo products diversification plan is to commercialize its line of bamboo furniture prototypes. These pieces were designed and produced by Brian Erickson, who started with PNB in the early 90s. Mr Erickson has developed a number of designs (Fig. 23), some of which make use of *tablilla,* incorporating "ergonomics, comfort and rustic elegance into his designs which capitalize on the unique traits of bamboo of strength, flexibility and natural beauty" (Tunison 1993). The use of tablilla is unique and unlike most Asian bamboo furniture which usually incorporates the entire round bamboo in making furniture. The *tablilla* furniture of Mr Erickson have notably well-built structures and make no noise when shifting.

Prototype production is staffed by Mr Erickson and three craft workers. Mr Erickson plans to add another two or three during 1996. Currently, PNB is beginning an amplification of its

Fig. 23: Guadua bamboo furniture by Brian Erickson (on the right)

production facility located in Guapiles at the Diamantes Experimental Station. By mid-1996, this facility should be ready to mass produce the furniture, although the artistic nature of Mr. Erickson's designs and the manner of assembling the furniture do not entirely lend themselves to mass production.

RESEARCH AND DEVELOPMENT — CITAB

The Center for the Investigation of Bamboo Applied Technology (CITAB) has three missions One is to do research to further improve PNB's housing technology. In this respect, the goal is to reduce the amount of wood still used for the structural frame, reduce the cost, and improve the ease of transportation and the efficiency of the construction process. A prospective advance in this area is the application of bamboo *tablilla* curtains.

CITAB research includes the investigation of other potential commercial uses of bamboo. The work accomplished in this area could prove to be significant for the future utilization of bamboo, especially regarding its use as a wood 'alternative. Bamboo laminates, fiberboard,

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'The initial plan is to use a select a number of pieces to attract tourists, hotels and restaurants, and the expatriate community of Costa Rica. With the help of graduate students looking for thesis work, some market studies have been carried out to assist in the commercial development of Mr Erickson's furniture: market study with an analysis of the retail costs of competing furniture in the San Jose area, an assessment of the market demand for bamboo furniture, ways and means for marketing the furniture, exploration of potential sites for exhibitions and sale, etc. Despite the long and strong history of locally made wood furniture and the high percentage of furniture in the market, the exotic nature of bamboo makes the prospects for Mr Erickson's bamboo furniture promising.

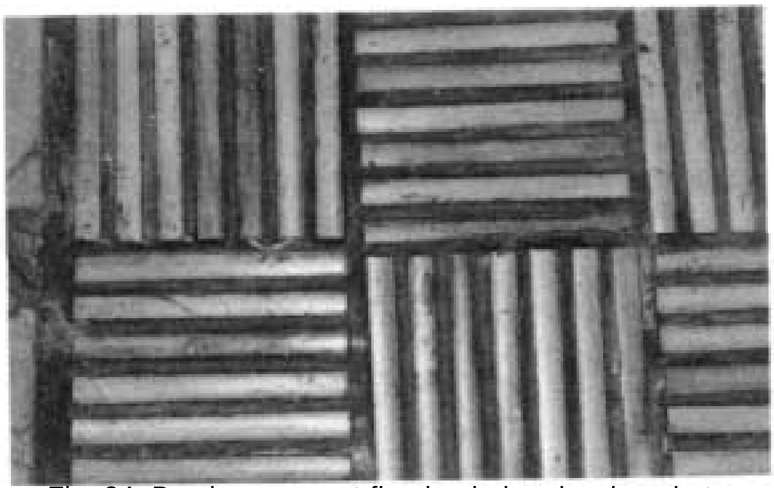

Fig. 24: Bamboo parquet flooring being developed at CITAB, Milano

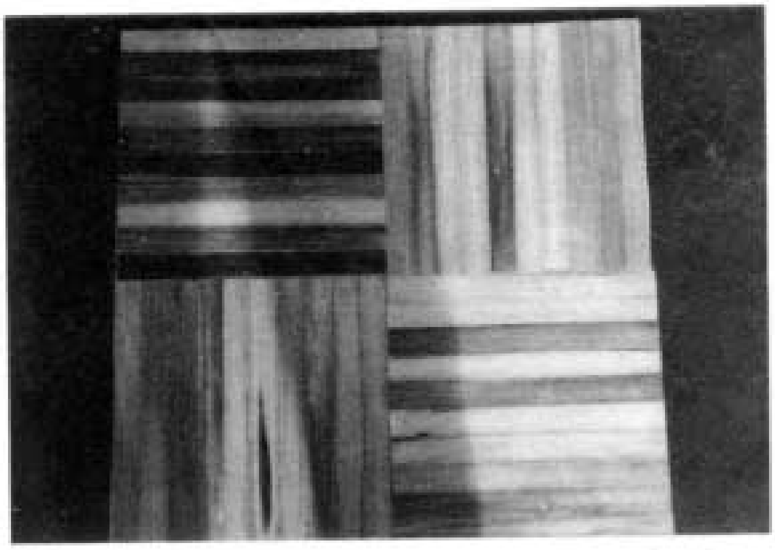

Fig. 25: Bamboo.flooring experiment at PNB headquaters, San Jose

plyboard and parquet fllooring are some of the products being developed (Figs. 24, 25). Paper is another product being considered for production. Other core areas of CITAB are technology transfer and information dissemination. PNB has already begun to collaborate with other Central American countries which are just beginning to implement bamboo projects of their own. In November 1995, a United Nations sponsored seminar on bamboo housing project implementation was organized. Representatives from all Central American countries, Bolivia and Cuba attended this seminar.

CITAB's work is supported by researchers and consultants from Eindhovkn University (The Netherlands), the University of Hamburg (Germany), the Building and Social Housing Foundation (The United Kingdom), the Technological Institute of Costa Rica, and the University of Costa Rica.

PHASE III JANUARY 1996 ONWARDS)

Beginning this phase, PNB changed its official name to the Bamboo Foundation. As a foundation, it essentially functions as a private enterprise and no longer as a project. It has been calculated that a minimum of 1,200 houses must be built per year for the Foundation to survive (donated funds had all exhausted) and continue to provide low-cost housing option to the rural population. The Foundation must generate extra funds to meet its other objectives and continue investing in better technologies, acquisition of advanced equipment and appointment of qualified staff, carrying out technology transfer, and maintain all other functions of a private enterprise (Picado 1992). To meet these requirements, the Foundation has set the annual construction goal at 1,600 houses.

An average of 11.7 houses can be built from the bamboo produced on 1 ha. With 150 ha of bamboo growing in Guapiles, this translates into a construction capacity of about 1 755 houses per year from the Guapiles plantation alone; well above the project goal of **1** 600 houses per year.

PNB has always been managed and operated by an in-country, interdisciplinary team. Specialists were hired to implement project plans for each area: construction, forestry, and research and development(refer to Appendix F for the organizational chart of PNB). The project also hires interns from universities in Europe, Costa Rica and the United States. The hiring of students is a mutually beneficial relationship as it provides the project with "free" resources and in turn, creates great learning opportunities for aspiring students in numerous areas of interest, such as engineering, architecture, development, agronomy, business, sociology, and specifically, bamboo-related subjects. To date, the project has had about a dozen interns.

# 5 GENERAL ANALYSIS

Before starting to examine whether or not bamboo is ideal for developing appropriate and sustainable technology, the terms 'appropriate technology' and 'sustainable technology' need to be defined. Although these are terms which have been defined by several people in many ways, this discussion chooses to work with the definitions set forth by Eric Hyman of Appropriate Technology International, a development organization based in Washington, D.C. According to Hyman (1995), appropriate technology is:

1. small in scale, uses domestically produced equipment and locally available raw materials;
2. less capital intensive;
3. has low investment costs per job created;
4. less dependent on scarce foreign exchange;
5. easier to operate, maintain and repair, with commonly obtainable skills;
6. has fewer unintended, negative social or environmental impacts; and
7. relies on human or animal power or other renewable energy forms, but is labor-. saving compared to traditional production methods.

Sustainable technology (Hyman 1995):

1. enhances the carrying capacity of the natural resource base by making a productive activity more environmentally benign;
2. substitutes alternative means of earning livelihoods in place of those that damage critical environments;
3. adapts production to degraded or depleted natural resources, and promotes the restoration of damaged ecosystems;
4. prevents, controls, or mitigates adverse environmental impacts;
5. indirectly improves natural resource use by reducing poverty, increasing education levels and stabilizing population growth;
6. is economically viable;
7. is culturally acceptable;
8. avoids any significant environmental/natural resource impacts — especially risks to public health or safety, irreversible changes in land use, loss of biodiversity or violation of international agreements; and
9. should not have negative social impacts especially the displacement of vulnerable ethnic minorities.

In summarizing these definitions, some keywords and themes seem predominant: local dependence, simple, friendly, useful, not environmentally destructive, culturally sensitive, capacity building, low cost and access. Bamboo technology of PNB has met many of these defining terms of appropriate and sustainable technology. The following analysis will examine each of the aforementioned keywords and how the project does or does not address those issues.

## LOCAL DEPENDENCE

By planting 300 ha of bamboo and having an end-goal of 2,000 ha, PNB has established a base for the local supply of the primary building material. In doing this, it lessens the need to use expensive imports such as cement and masonry blocks, and expensive local supplies of timber. Considering the prolific growth characteristics of bamboo, the supply generated by the plantations should remain indefinitely reliable. Moreover, PNB has extensively researched and documented optimal plantation management techniques thereby increasing the reliability of supply into the future.

The machinery utilized double-bladed machine for splitting bamboo canes into tablilla, preservation equipment, etc.) is designed locally by project employees in collaboration with the Technological Institute of Costa Rica and the University of Costa Rica's Engineering Department. Other equipment and tools used are simple and minimal — machetes, saws, staple guns, etc.

Local dependence also refers to not being dependent on foreign capital or foreign exchange. With the cost of producing tablilla at about 20 colones per strip (US$0.10), there is no need for large amounts of capital.

## SIMPLE, FRIENDLY AND USEFUI

Bamboo has been used for centuries in developing countries all over the world. The over 1,000 recorded uses — housing structures being one of them — attest to bamboo's level of utility and friendliness. PNB has capitalized on these aspects of bamboo by upgrading indigenous housing technology to a larger scale. Two factors in the PNB construction process also assert that bamboo is friendly, simple and useful. Although the housing technology has been adapted for more modern use, the methods developed were to be used in a participatory process of construction, thereby implying its culturally appropriate and simplistic nature. This includes the participation of women and children in the process. It may also be noted that although the contractors hired under the contracted construction system did not have previous skills in working with bamboo, they did not face any problems in applying the technology. The level of the technology developed is simple enough to do on-site training of workers and still complete the job within three to four months. This theme Is further developed below.

## CAPACITY BUILDING

Educating numerous individuals to work with bamboo creates a new base of skilled people that can lead to the expansion of local housing industries utilizing local resources such as bamboo. Hiring contracted labor within the communities where PNB builds homes helps to enhance the skill levels of these hired workers who may or may not have previous work experience. After completing a housing project with PNB, these contracted workers can either be re-hired for future PNB projects or even begin their own local housing industries by applying their skills working with bamboo in some other manner. This produces a sound employment situation which, in turn, will reduce poverty and stabilize the population (Hyman 1995).

## NOT ENVIRONMENTALLY DESTRUCTIVE

One major justification for using bamboo is that it is not environmentally destructive; widespread planting and use of bamboo would actually mend the environnent, not destroy it. Carbon dioxide buildup and soil erosion are the two principal environmental problems that bamboo can help reduce. Further, widespread use of bamboo as a timber alternative could lessen demand for timber, and thus halt or slow down the rate of deforestation. This would be especially helpful in Costa Rica, which has used timber for over 100 years but has very little primary forest remaining intact (Nygren 1995). Hence, PNB is helping to promote these activities with its bamboo enterprise. The project's inception and ensuing success will be a catalyst for the future of bamboo In sustainable development.

As mentioned earlier, loss of biodiversity is a critical environmental issue resulting from deforestation. Some may argue that widespread planting of bamboo forests does not address this issue, and may even have negative environmental impacts because of its monocultural nature. However, bamboo itself is experiencing a loss of species owing to rapid depletion of bamboo groves and therefore, replanting is only helping to mend this problem. Moreover, planting of bamboo groves is not necessarily to replace the loss of timber forests and their biodiversity; rather, it may help mitigate the exploitation of such timber forests by providing an alternative resource, in which case forest biodiversity is preserved through the protection of and reduction in the destruction of tropical rainforests.

## CLASS AND CULTURAL SENSITIVITY

At present, PNB is specifically targeting people in the low-income groups with its bamboo housing option. However, considering its past traditional uses and its future utility as an alternative natural resource, it is clear that bamboo cart be used in ways that will be attractive for all classes of people: low-cost housing for the resource-poor, exotic furniture for higher-end markets, paper for a variety of markets, plyboard and parquet flooring for international markets, etc. Moreover, as noted earlier, the design of bamboo houses was made to fit in culturally; the PNB house designs are quite similar to other typical Costa Rican houses (Figs. 20, 21).

## LOW COST AND ACCESS

The main justification for the utilization of bamboo is its low production cost. Studies show that processing bamboo requires only one-eighth of the energy that concrete needs to create a building material of the same bearing capacity. In comparison to steel, bamboo needs only about one-fiftieth the amount of energy for processing (Roach 1996). By utilizing bamboo as a primary material in construction, PNB has been able to offer an alternative housing option that is 20% less in cost than other choices available. This has opened up the market significantly – now many more people have access to a completed home that is within the amount of bono de vivienda. Furthermore, employees of the project have explained that the poorest people residing in extremely remote and undeveloped areas where infrastructure is lacking (paved roads, for example) now have a housing option open to them. PNB claims that it is the only construction organization that is willing to build for people living on remote, difficult terrains (at times when road access is difficult or waterways such as rivers make access arduous, transport of materials is done on horseback). The low costs involved in bamboo production make it possible to build in these areas without compromising the quality of the home.

Hyman (1987) states that the "appropriateness" of a technological solution is judged essentially on the expected socio-economic impacts on the poor as well as environmental impacts. However, few technologies are likely to meet all the criteria for appropriateness and sustainability. With this in mind, it is possible to concede that PNB has successfully employed

Guadua bamboo for rural housing in Costa Rica. It can thus be concluded that PNB has sufficiently met the criteria for what is deemed appropriate and sustainable technology.

## The future of PNB

The transformation of PNB as a private enterprise (under the name of Bamboo Foundation; however, for the sake of converience this study will continue to use the name PNB) has brought with it several financial implications. Prior to becoming private, PNB was not required to pay tax on Income from housing construction or on construction supplies. The project also had not paid for the social security of its staff nor the expense referred to as aguinaldo — an extra financial provision made at the end of every calendar year to help cover holiday costs of the staff. Privatization has changed all that.

Another significant Implication is that as a private entity PNB cannot receive any land from the government for plantations. This may hinder the goal to plant bamboo on 2,000 ha countrywide. In light of these ramifications, a rethinking and modification of Income generation plans may be required not only to remain sustainable but also to achieve PNB's goals for bamboo application and utilization.

Considering the historical level of demand for PNB in counties such as Orotina, bamboo housing seems especially promising for PNB's future. Three consecutive projects occurring in Orotina at the beneficiaries' request is highly indicative of this. There is considerable potential for the spread of demand to rural areas across the country where housing shortages among the low-income groups are still prevalent. PNB believes that demand will always exist for its bamboo houses because it offers a very economical and complete home, and therefore, there is a market niche into which PNB fits perfectly.

Despite its achievements, PNB is yet to meet all 'its objectives as defined in earlier project phases. The following are some key objectives yet to be realized by PNB:

1. Immediate planting of an additional 500 ha of bamboo;
2. Development of a regional social housing project in Central America;
3. Consolidation of the cultivation, production and treatment of bamboo; and
4. Commercialization of bamboo furniture prototypes.

It must also be pointed out that, according to project documents (Robles 1992, etc.) and interviews, the future income generation plans of PNB include also the following:

1. Production of 2,300 panel packages. per year to be sold in the local market to other construction outfits so that they will have a low cost alternative for building in rural areas;
2. Sale of bamboo plants;
3. Sale of bamboo machinery and/or equipment;
4. Establishment of a construction consulting business whereby PNB offers its technical services to other public or private institutions building houses in Costa Rica;
5. Establishment of a construction business which offers bamboo construction technology for tourist facilities such as hotels, restaurants, cabins, country homes and beachfront property;

6. Offering eco tours to the bamboo plantations, bambusetum (bamboo garden in Guapiles), the furniture factory and the panel fabrication plants, similar to "coffee tours" offered to tourists to Costa Rica; and
7. Establishment of a training system offering seminars to other interested parties, whether national or international, in the utilization and management of bamboo.

The last ifem is particularly important for the development of bamboo as a global solution to housing. As mentioned earlier, a return to indigenous construction materials and methods is an important trend in the housing sectors of developing countries. However, some gaps that exist prevent more widespread implementation of bamboo housing. According to the United Nations Centre for Human Settlements (Habitat 1972), one problem is that the knowledge for producing and using innovative, locally produced and inexpensive building material is limited to a few laboratories and research institutions. A gap in technology transfer exists and is in part because of the non-existent link between investors, manufacturers and research institution (Habitat 1987). Another issue is that there is a lack of standards and building codes for bamboo. Jules Janssen, of Eindhoven University in the Netherlands and a major consultant to PNB, states that a lack of codes and standards may be interpreted as a prohibition to build with bamboo. Under the auspices of INBAR, he and a team of researchers are currently working to establish an international building code for bamboo (Roach 1996).

Efforts are being made in Asia and the Pacific to create better linkages through the establishment of the Regional Network in Asia for Low-cost Building Material Technologies and Construction Systems. The purpose of this network is to function as a focal point for information exchange concerning indigenous building materials and low-cost construction systems that are appropriate for low-cost housing (Habirat 1987). Since PNB has made major advancements in housing, its participation in the network and offering training to interested parties will contribute significantly to meeting its overriding objective — to solve the problem of housing shortages — both nationally and internationally.

# 6 IMPACT ANALYSIS

As with all projects, it is essential to evaluate the impact that PNB has had on Costa Rica's development. Environmental impact analysis today is an essential element to the planning and design of development projects of many types. Although the term "environmental" may typically connote "the natural surroundings", the impact analysis here will use it in the manner that most national legislation describe the term: as including the natural environment (air, land,, water, ecosystems, biological diversity, fauna, flora, agricultural land, other natural resources, etc.), the social environment (culture, religion, aesthetics of surroundings, public health, history, heritage, access to facilities and social services, etc.), and the economic environment (infrastructure, employment opportunity, industry and economic growth, income, etc.) (Biswas and Geping 1987).

The following analysis, because of the research focus of this study, will confine to providing a profile of the environmental, social and economic impacts, rendering quantitative data where possible. A more in-depth impact analysis is therefore a suggestion for further research.

## Environmental Impacts

The use of bamboo gives rise to a few, very important environmental impacts. The overriding impact directly emerging from the bamboo project is a decrease In atmospheric carbon dioxide — a gas giving rise to the greenhouse effect and global warming. As mentioned earlier, bamboo's growth habits allow it to produce more oxygen than equivalent stands of trees. According to calculations performed by PNB, an average of 17.4 metric tons of carbon are captured per hectare of Guadua bamboo per year. At this rate, the present 300 ha of bamboo planted by PNB sequester 5,220 tons and the planned 2,000 ha of bamboo plantations will capture 34,800 tons of carbon dioxide per year.

Myers (1984) informs that atmospheric carbon dioxide is increasing by about 2.54 billion tons per year, stemming mostly from factories and automobiles burning fossil fuels, and this is still on the increase. Although the amount of carbon dioxide that would be sequestered by PNR's bamboo plantations is minute in comparison, this does not discount its value in contributing to an improvement in environmental conditions, particularly in regard to a prevention of climate change from global warming. The current and projected contribution to carbon dioxide reduction to the year 2006 can be seen in Table 5.

Environmental impacts currently immeasurable are bamboo's effect on soil erosion and deforestation. Although the author's research did not gather information concerning the planting of bamboo in soil erosion areas, the chosen location for the planned 2,000 ha of bamboo plantation is significant. Agricultural land is Costa Rica's most valuable natural resource (Nelson 1983). and the planting of bamboo on degraded, deforested lands could be a particularly promising venture for small farmers in rural areas. According to a 1980 estimate, 1.5 million ha of land in Costa Rica are suitable for forestry — both natural and plantation — constituting 30% of the 5.1 million ha of arable land (Nelson 1983). Clearly there is tremendous room for the expansion of bamboo forestry in this country.

With deforestation rampant, another environmental incentive for using bamboo in a modem housing project is the minimization of timber demand, leading to less pressure on existing forests. Logically, this has implications for the conservation of biodiversity and of nature in general. This impact is, however, immeasurable at this point in time. It must also be noted here that currently PNB is reaching a people who neither truly had access to the housing market nor constituted a significant portion of the timber demand. Therefore, it is riot necessarily curbing a source of timber demand, although it might be curbing a source of timber supplies. If PNB is able to fully capture its potential market through the commercialization of ***tablilla*** panels, sale of bamboo furniture and plants, and supply of bamboo architectural and construction services, it could eventually build up an effective impact on the demand for timber both inside and outside of Costa Rica.

Table 5: PNB's~ contribution to the, reduction of atmospheric CO, (estimate)

| Year | Area (ha) | | Amount of CO, sequestered (t) | Cumulative reduction in CO. (t) |
|---|---|---|---|---|
| | added | total | | |
| 1988 | 0 | 150 | 2 610 | 2 610 |
| 1989' | 75 | 225 | 3 915 | 6 525 |
| 1990' | 75 | 300 | 5 220 | 11 745 |
| 1991 | 0 | 300 | 5 220 | 16 965 |
| 1992 | 0 | 300 | 5 220 | 22 185 |
| 1993 | 0 | 300 | 5 220 | 27 405 |
| 1994 | 0 | 300 | 5 220 | 32 625 |
| 1995 | 0 | 300 | 5 220 | 37 845 |
| 1996 | 0 | 300 | 5 220 | 43 065 |
| 1997 | 500 | 800 | 13 920 | 56 985 |
| 1998 | 500 | 1 300 | 22 620 | 79 605 |
| 1999 | 500 | 1 800 | 31 320 | 110 925 |
| 2000 | 500 | 2 300 | 40 020 | 150 945 |
| 2001 | 0 | 2 300 | 40 020 | 190 965 |
| 2002 | 0 | 2 300 | 40 020 | 230 985 |
| 2003 | 0 | 2 300 | 40 020 | 271 005 |
| 2004 | 0 | 2 300 | 40 020 | 311 025 |
| 2005 | 0 | 2 300 | 40 020 | 351 045 |
| 2006 | 0 | 2 300 | 40 020 | 391 065 |

'Assumed figures.

## Social and Economic Impacts

With the establishment of bamboo plantations and panel factories, and with the implementation of bamboo housing, PNB is certain to have made notable social and economic impacts, primarily through training and job creation. The participation of Costa Rican families in the project activities from the project's inception has resulted in the training and education of, according to PNB's reckoning, thousands of people. Considering that the Orotina project as discussed earlier had employed on an average 103 people for the construction of 153 houses, the implications of the project for nationwide employment is high. Although limited research cannot confirm the exact number of past construction projects, future projections can be made based on the available information. A ratio of 103 employees to 153 houses (or a factor of 0.6732) translates as employment for about 808 persons annually at the rate of 1,200 houses per year. This is from construction alone, and does not include jobs that will be created by the 2,000 ha bamboo plantation, the additional panel factories required to cater to the construction of 1,200 houses per year, or the bamboo research and development activities that will happen over the course of the project's evolution.

The construction technology itself has an impact on family pride, dignity and security. Not only will the social character of the communities be changed, but also an acceptable standard of living will be available to the more than 163,000 families in Costa Rica who are without proper housing. Life security will be increased through the resistance of bamboo housing to seismic activities, as proved during the Limon earthquake. Finally, the participatory nature of the venture will foster and strengthen the sense of community organization and social integration by bringing together large groups of families.

All things considered, the promotion of bamboo as a viable cash crop would certainly have a ripple effect, leading to environmentally sustainable development through employment and income generation opportunities. It will also ensure a secure natural resource base into the future. The growth of the bamboo industry in Costa Rica's 1.5 million ha of arable forest land can certainly curb urban migration and affect settlement patterns in the rural countryside, with the location of bamboo housing, plantations and cottage industries playing a major part. Finally, the stimulation of a local bamboo industry will have ramifications in terms of fueling the national economy through the sustainable use of local resources and the potential export of bamboo products — a benign alternative to the more destructive timber industry.

## Addressing Housing Deficits in Other Countries

The evaluation of PNB is important on a global scale also, as the lack of housing is a problem common to many less developed countries. Although the existence of PNB seems to be heavily reliant on the government housing subsidy program, the worldwide scope for the use of bamboo in modern housing must be considered.

Specifically, the transfer of thii housing technology is crucial for other countries in Central America where the housing deficit affects about 2 million families. Bamboo's demonstrated resistance to natural disasters is important for countries such as the Philippines, Bangladesh, Indonesia, and several others in the Caribbean region. The employment potential of a bamboo-based industry is also of considerable significance to many developing nations. In conclusion, this study recommends further in-depth monitoring and evaluation of PNB over rhe next few years in order to effectively implement bamboo-based industries worldwide to solve problems resulting from unsustainable development activities.

# 7 RECOMMENDATIONS

## Bamboo Education

In addition to the future plans and unrealized objectives of PNB mentioned earlier, there are some actions that could be important for the future of bamboo in development, as well as the future of PNB.

Farrelly (1984) makes two important points regarding bamboo education. First, he points out that no bamboo farm or study center exists to train those with an interest in the plant. Second, he strongly advocates the need to address teachers and to help them reflect on the possibilities of bamboo's use in their particular climate and cultural context. For example, he informs us that in Colombia, although Guadua bamboo use is ingrained in the culture and economy — even in urban construction — it is not mentioned in school books. This he found to be true for all Latin American countries between Mexico and Peru.

Considering the solid knowledge base it has in the areas of bamboo cultivation, production, preservation and construction, PNB could play a leading role in the education of people locally, regionally or globally through the creation of a bamboo school. This idea is already included in PNB's future plans, but not to the extent required. Not only must the transfer of knowledge cover the key areas listed above, but also include, in good measure, a discussion of bamboo's social, economic and environmental benefits. Hence, the following outline is recommended for bamboo education.

1. The establishment of a bamboo training school that all interested parties can access; particularly, local farmers who could transform this knowledge into employment and income, whether it be through bamboo cultivation or small-scale industries in rural areas selling bamboo as a building material or in other product forms.

2. Education, in its broadest sense, can also take the form of information campaigns through lectures, the use of media, exhibits and demonstrations. This includes raising public awareness about PNB and bamboo. Target groups of this information campaign will be schools, colleges and universities, tourist facilities (hotels, restaurants), biological research stations, and locations such as embassies, cultural centers and museums. Fostering interest among these groups of people is critical for future support of bamboo endeavors.

3. Disseminating information on PNB's services and products through literature, such as pamphlets and catalogues. The target groups for this "marketing scheme" are architects and designers, hotels and restaurants, and furniture distributors and retailers.

4. As an expansion of the eco tourism plan, a bamboo museum can be established with artefacts, information and displays from all places in the world where bamboo is culturally and economically significant.

It is necessary to recognize that the housing subsidy program provided by the Costa Rican government calls into question the sustainability of PNB. The bono de vivienda program makes PNB vulnerable as it is being supported by a single client — the government. An exploration of other avenues is urgently needed for arranging housing finance to the rural people so that bamboo housing constructibn will continue, independent of government programs which are not always sure to exist.

All these recommendations presuppose the sustainability of project operations and builds on the important role of bamboo in development. With PNB's achievements, it has the potential to take a leading role in national and international developments in bamboo. Its knowledge base in the cultivation, production and utilization of bamboo would be critical for aiding other countries to address similar problems in the area of housing. If PNB continues to be successful in gaining full interest and support in Costa Rica, the result could be an expansion of operations well beyond the national boundaries. The spread of knowledge and education about bamboos and their applications will assist in fostering greater interest and support for bamboo as a viable alternative resource for both developing and developed countries whose economic endeavors are inextricably linked and whose future survival lies in environmentally, socially and economically just practices. Bamboo — a rediscovered and revived natural resource — is an answer to this call. It is new life for old traditions.

## Future Research

The potential of PNB is far-reaching and the research possibilities numerous. Considering the great deal of deforestation that Costa Rica has suffered on the one hand, and the success of PNB on the other, further research into the potential of bamboo must play a greater role in the economy of Costa Rica. It would be especially important at the grassroots level as the rural people's lives could be improved through the development of small-scale bamboo industries, perhaps with the assistance of the PNB. It could also involve examining where bamboo could serve to check soil erosion.

Another research effort could be a more in-depth business evaluation on the sustainability of PNB's core mission of low-cost housing while managing other business ventures such as furniture commercialization, among many others (bamboo parquet flooring, fiberboard, paper and plyboard are all strong possibilities). The income from these businesses would ensure the survival of the project's social housing project and also allow the project to continue developing its knowledge base in bamboo applications.

Researchers in general, could also study housing shortages in other countries and explore the possibility of implementing bamboo housing projects in those countries. Since PNB has been quite successful in utilizing bamboo for rural housing, its experience has considerable relevance to the question of housing shortages in other tropical countries. Therefore, research in this area is strongly recommended.

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# APPENDIX A

## Description of Project Operation Sites

NATIONAL BAMBOO PROJECT OF COSTA RICA (NOW THE BAMBOO FOUNDATION) HEADQUARTERS, SAN SEBASTIAN, SAN JOSE

Located just south of downtown San Jose in a depressed area, this is the site for the main office. Currently, it is made up of 11 bamboo houses, four of which were the original prototypes for their housing construction during the pilot stage (see Fig. 2).

DIAMANTES EXPERIMENTAL STATION, GUAPILES, LIMON

This site is located 1% hours north-east of San Jose. Currently, 150 ha of bamboo plantations are situated here. Also located at Diamantes is the bamboo furniture factory which produces prototypes for future commercialization. A Guadua vegetative propagation bank is also located at Diamantes, housing about 5,000 bamboo plants for future transplant. Finally, the Diamantes plantation also has a bambusetum containing several bamboo species planted by PNB.

CENTER FOR THE INVESTIGATION OF BAMBOO APPLIED TECHNOLOGY, MILANO, LIMON

Located a little farther east past Guapiles, CITAB is where a great deal of research and development has taken place in applied technologies for housing construction. CITAB is currently focused on technologies that would find other uses for bamboo such as flooring material.

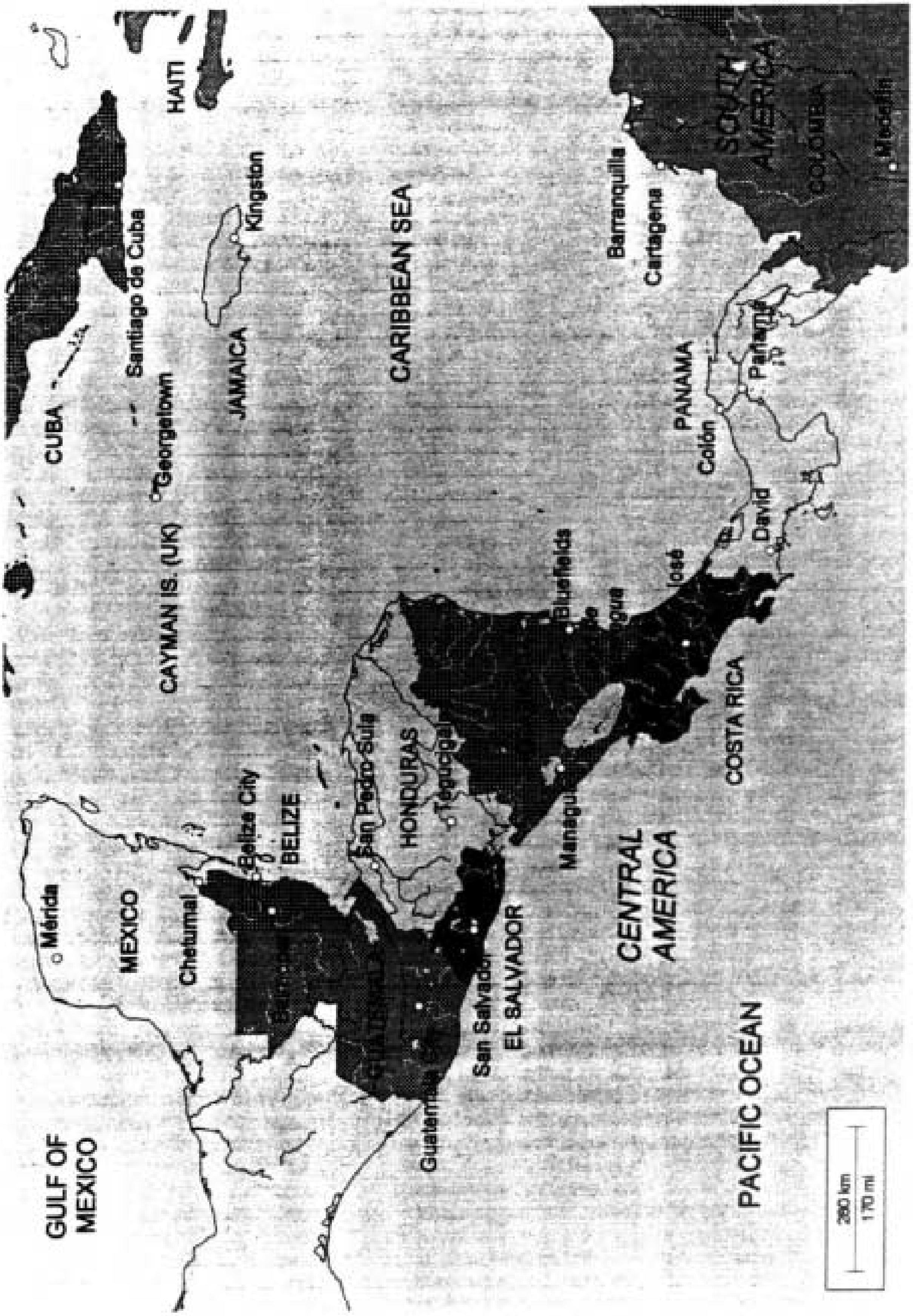
PANEL FACTORIES, POCORA, LIMON AND OROTINA, PUNTARENAS

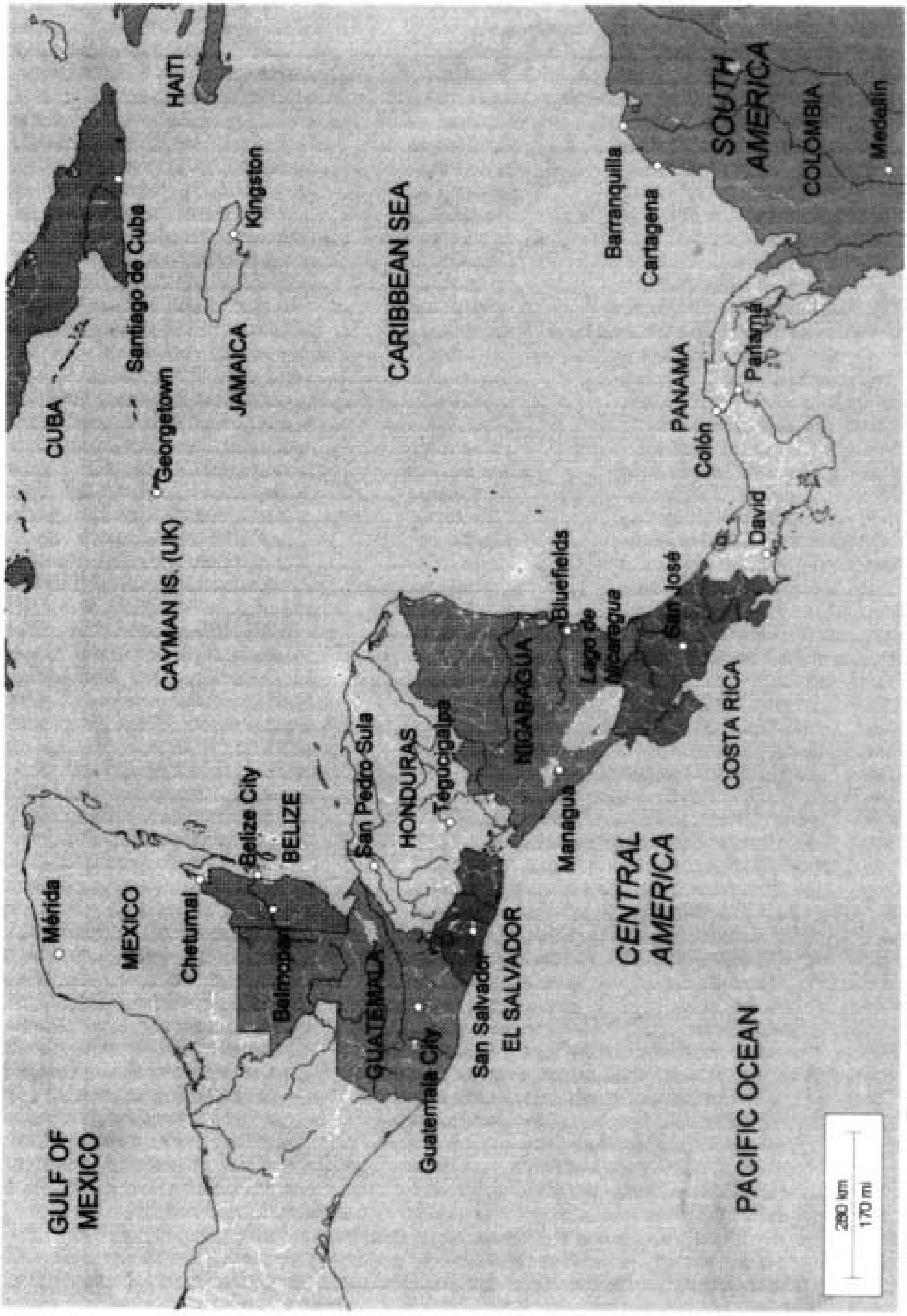
Panel production in Pocora is located on the campus of the Agricultural School of the Humid Tropical Region in Limon. It is also just east of Guapiles and has the capacity to produce enough panels for 60 houses per week. A temporary site for panel production is located in Orotina, Puntarenas (2 hours west of San Jose) to reduce transport costs to this area. This facility is currently producing enough panels to build 20 houses per week.

OTHER PLANTATION SITES AND PRESERVATION FACILITIES

Another 150 ha of bamboo plantation are in Arena1 (4 hours north-west of San Jose) and Golfito (6 hours south-east of San Jose). Boucherie process facility for bamboo preservation was formerly located in Milano at CITAB. At the time of this study, the equipment (mobile) has been transferred to Arena1 where plantation thinning was taking place. After Arenal, the equipment will be moved to Guapiles and then to Golfito where thinning will take place subsequently. Eventually, the preservation equipment will be permanently located at the plantation sites.

**Map of Central America**




GULF OF MEXICO
MEXICO
Mérida
Chetumal
Belmopan
BELIZE
Belize City
GUATEMALA
Guatemala City
San Salvador
EL SALVADOR
HONDURAS
San Pedro Sula
Tegucigalpa
NICARAGUA
Managua
Lago de Nicaragua
Bluefields
San José
COSTA RICA
David
PANAMA
Colón
Panamá
CENTRAL AMERICA
PACIFIC OCEAN
CAYMAN IS. (UK)
Georgetown
CUBA
Santiago de Cuba
JAMAICA
Kingston
HAITI
CARIBBEAN SEA
Barranquilla
Cartagena
SOUTH AMERICA
COLOMBIA
Medellín
280 km
170 mi

# APPENDIX B

## Tasks Involved in Housing Construction

te: the self-build activities last about one week both at the beginning of construction and the end.

| | |
|---|---|
| 1. Cleaning and clearing of land | Self-build |
| 2. Leveling | Self-build |
| 3. Layout | Self-build |
| 4. Dig ditches | Self-build |
| 5. Framework preparation | |
| 6. Framework arrangement | |
| 7. Plate placement | |
| 8. Cement block arrangement | |
| 9. Crossbeams | |
| 10. Panel preparation | |
| 11. Frame preparation | |
| 12. Mount panels | |
| 13. Mount frame | |
| 14. Mounts doorpost and nails | |
| 15. Mount cover and tiebeam/ridge | |
| 16. Install electric ducts | |
| 17. Prepare panels for cement plaster application | |
| 18. Plastering/Mortar application | |
| 19. Stain cement plaster | |
| 20. Apply finishing | |
| 21. Arrange pipes for plumbing | |
| 22. Flooring and finishing | |
| 23. Pavement | |
| 24. Plumbing installation | |
| 25. Prepare doors and windows | |
| 26. Arrange doors and windows | |
| 27. Connect running water | |
| 28. Install bathroom fixtures | |
| 29. Dig ditches for septic tank and drainage pipes | Self-build |
| 30. Arrange septic tank and drainage pipes | Self-build |
| 31. Prepare manholes | Self-build |
| 32. Install electrical fixtures | Self-build |
| 33. Paint | Self-build |

# APPENDIX C

## Pilot Project Communities

| | Housing sites | Houses built |
|---|---|---|
| 1. | Rio Grande Paquera | 31 |
| 2. | Salinas | 18 |
| 3. | Lagunillas | 16 |
| 4. | Coyolar | 20 |
| 5. | Paso Agres | 20 |
| 6. | San Francisco | 21 |
| 7. | Balsa de Atenas | 18 |
| 8. | Vicentinos | 6 |
| 9. | Rio Frio | 21 |
| 10. | Milan0 | 5 |
| 11. | Matina | 123 |
| 12. | Rio Banano | 30 |
| 13. | Terraba | 29 |
| 14. | Rey Curre | 28 |
| 15. | Boruca | 35 |
| 16. | Maryland | 24 |
| 17. | La Argentina | 17 |
| 18. | La Lucha | 21 |
| 19. | San Luis de Zarcero | 10 |
| 20. | Arena1 | 2 |
| | Total | 348 |

# APPENDIX D

## Criteria for Selection of Pilot Project Communities

1. Must be a rural community.
2. It must be accessible at all times of the year.
3. Must make use of bamboo or cana brava
4. Must have grave housing necessity.
5. Must be a community with low level incomes.
6. Must be endorsed by an institution or association.
7. Must have a local housing committee to represent the community.
8. Needs a number of potential beneficiaries, not less than 15 and no more than 30.
9. Must accept/approve of the technical and organizational plans of PNB.
10. Must be disposed to work through the self-help program.
11. Must be disposed to sign an agreement and regulation regarding the self-help housing program and terms of financing.
12. Must have basic infrastructure such as water supply, schooling, etc.
13. Must have easy vehicular access into the designated construction lots.
14. Must have terrain in good, clear condition for construction.
15. Must have at least 2 ha of communal land to cultivate Guadua bamboo.

# APPENDIX E

## Criteria for Selection of Beneficiaries for Pilot Project

1. Must belong to a community selected for participation in the pilot project.
2. Must have a local lot not more than 2 km from the town center.
3. Must be a united family (primary and secondary relatives).
4. The intended lot must meet minimum conditions for construction.
5. Does not have a decent house.
6. Must belong to a community organization.
7. Must have a low level of income.
8. Must accept construction with bamboo or cana ***brava***
9. Must complete the PNB survey.
10. Must commit to work at all stages of the process.
11. Must accept the organization of PNB.
12. Must become familiar with PNB, sign an agreement, rules and regulations and terms of payment
13. Must not have been a beneficiary in any other social housing program, public or private.

# APPENDIX F

## Organizational Chart of PNB