Sub-Optimal Equilibriums
in the Carbon Forestry Game: Why Bamboo Should Win But Will Not

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List of abbreviations

AIJ	Activities Implemented Jointly
AR	Afforestation and Reforestation
B-C Ratio	Benefit Cost Ratio
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CO2e	Carbon Dioxide equivalent
COP	Conference of the Parties
DBH	Diameter at Breast Height
DNA	Designated National Authority
DOE	Designated Operational Entity
EB	Executive Board
ERPA	Emission Reductions Purchase Agreement
ERU	Emission Reduction Units
ETS	European Trading System
FAO	United Nations Food and Agriculture Organization
FSC	Forest Stewardship Council
GHG	Green House Gases
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
JI	Joint Implementation
LoA	Letter of Agreement
Meth Panel	Methodology Panel

NPV	Net Present Value
PDD	Project Design Document
SRWC	Short Rotation Woody Crops
UNFCCC	United Nations Framework Convention on Climate Change
VER	Verified Emission Reduction

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Abstract

So far in the competition for recognition of forestry projects under the CDM, little attention has been paid to the comparative advantage of different trees species. Yet once the first carbon revenues start rolling in, it would be logical for project planners to turn their attention to maximizing revenues with products that store the most carbon per hectare (ha). Indeed, in the academic world, many papers have already been written about the comparative advantage of different tree species with the expectation that forestry projects would be planned to maximize carbon sequestration. This paper begins with evidence that a non-tree species—bamboo—may be one of the species most well-suited to the CDM's goals of maximizing carbon revenues and promoting sustainable development. Noting however, that no CDM projects have been or are being prepared for bamboo, it asks, if bamboo should be the rational choice for project developers, and if it is then what is leading the developers to make sub-optimal decisions.

This paper finds that project developers are not focusing on competitive carbon sequestration rates or optimal sustainability because of high transaction costs, high risk of non-approval, and low carbon revenues. Further, sustainability is given a back seat in the project design because there are few financial paybacks for sustainability: most of the external benefits are still not captured in the price. The main conclusion of this study is that national governments and the CDM Executive Board should support forestry projects with more capacity development and financial support in order to attain the goals set out for the Clean Development Mechanism.

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Chapter 1

The Big Ideas

Introduction

Heading into 2007, climate change and the costs it will impose are in the news nearly daily and the next years should be witness to the rapid development of both voluntary and mandatory emissions trading markets for green-house gases (GHG). Part of the so-called carbon trade (which includes other GHG beyond carbon dioxide) will be the use of forestry projects to either sequester carbon or substitute for fossil-fuels. The theory of using forestry for emission reductions is that they are a natural sink for carbon and that increasing forest cover will have environmental and economic benefits that contribute to the goals of sustainable development. Also, putting a value on forests should prevent unnecessary deforestation, which releases significant additional amounts of carbon dioxide and methane.

According to the goals of the Kyoto Protocol and related documents developed by the governing bodies of the UN Framework Convention on Climate Change, carbon forestry projects should promote sustainable development and use carbon revenues to make projects possible that would otherwise not be financially viable or otherwise have been hindered. Thus, projects with a high value for sustainable development should be given preferred treatment. Further, since revenues from carbon sequestration or mitigation will be determined by markets, project developers are expected to have an incentive to maximize revenue by maximizing carbon sequestration in the forest biomass.

In preparation for the trade of forest carbon credits, many scientists devoted themselves to studies on the effectiveness of carbon sequestration in various tree crops in various climates, and many forestry carbon projects were started either as pilot programs or with the full intent of qualifying for Kyoto credits. Yet, three things have not happened, which should have if the system is working to fulfill its intent of promoting sustainable development and carbon reduction.

First, the vast majority of the studies were done on the potential of various well-known tree species, and very little was done on bamboo species, although the plant is well-known for its amazing productivity, i.e. biomass accumulation. Second, no bamboo projects were proposed and even in the projects that propose using a variety of natural species, only two projects attempting registration mention bamboo as one of the variety of species to be cultivated. Third, the projects proposals do not attempt to justify the use of species based on the amount of carbon that they will be able to sequester. There is no analysis of other species that would have been appropriate and the opportunity cost of not choosing them, in terms of carbon sequestration as well as sustainable development.

These omissions suggest that the carbon markets for forestry credits are at a suboptimal equilibrium; caught at a point where there are barriers to, or simply no incentives for, attempting to maximize carbon sequestration or social and environmental benefits. Research for this paper began in the summer of 2006, as the author was asked to explore the possibility of developing carbon credits from bamboo projects by the International Network for Bamboo and Rattan (INBAR), an international organization based in Beijing. Although the potential of bamboo in terms of size, distribution and processing is not as well known as for many commercial soft and hardwood tree species, the fact that no experiments have been made to date with its use for carbon sequestration is puzzling, because as will be discussed, enough is known about bamboo to indicate that many species are highly useful for both carbon sequestration and sustainable development purposes which could be combined in one or several projects, in plantations or natural forest settings. Thus, as asserted above, the case of bamboo is illustrative of the shortcomings of the regulatory framework and market for CDM forestry credits.

The paper thus asks, is bamboo the rational choice for CDM forestry? If it is, then why is it not being used? That is, what is causing the market to stay at this suboptimal equilibrium? Using this framework, this paper will analyze the development of carbon forestry projects, particularly for registration under the Clean Development Mechanism (CDM) of the Kyoto Protocol, will explain why bamboo could be an optimal carbon crop, and will identify the political and economic forces that bar its use and those that keep forestry projects from reaching optimal results. The paper closes with recommendations for stronger governance to ensure that the goals of CDM carbon forestry projects are met and the mechanism is not co-opted to subsidize unsustainable forest based industries that do little to provide long-term livelihood or environmental benefits.

The UNFCCC, the Kyoto Protocol, forests and the CDM

Studies on the mechanics of carbon trading under the Clean Development Mechanism (CDM) of the Kyoto Protocol have blossomed since the 2004 ratification of the Protocol, which requires participating developed nations to adopt policies to reduce GHG emissions to their 1990 levels and sets reduction targets for the first commitment period from 2008-2012. New project proposals are reviewed by the United Nations Framework Convention on Climate Change (UNFCCC), established over a decade ago, in their CDM unit. The CDM is one of the “tools” envisioned by the treaty framers that will help developing countries benefit from the treaty and also benefit developed countries. Reducing emissions in developing countries is expected to be much less costly than it would be in the signatory countries.

With the Protocol's entry into force in 2005, expected revenues from CDM projects have moved from the realm of probability to tangible reality. In fact, for those selling on the mandatory European Carbon market, the ETS, which began trading in 2006, and for some other players selling to funds or banks, CDM credits are already being sold in future contracts. Nearly 600 projects are registered through the CDM board[1], which means their credits will be valid in the period 2008-2012. Although only one forestry projects has made it through the entire CDM registration process, seven more are in validation and seven methodologies for afforestation or reforestation (A/R) have been approved. Approximately twenty more A/R projects are in the registration process, most still working on approval for their methodologies. (various sources)

The idea of using forests as terrestrial sinks is relatively old. The first voluntary projects were established in the US in the early 1990s, mainly focusing on the environmental value of forest preservation or stewardship. The voluntary price was about 19 US cents per ton of carbon (70 US cents per ton of CO2). (Neef and Henders, 2007) In 1995, the first Conference of the Parties of the UNFCCC (COP1) launched the pilot phase for carbon trading activities, called Activities Implemented Jointly (AIJ). Under AIJ, eighteen forestry projects were implemented.[2]

Yet there has always been controversy around whether forestry projects should be included in the CDM, and the debate has slowed the development of rules governing forestry projects. The Kyoto Protocol was signed in 1997, but it wasn't until 2001 at COP7 in Marrakech that the parties agreed to allow forestry projects at all, limiting them to afforestation and reforestation activities. (UNFCCC, 2001) Meanwhile, a complete set of rules and modalities had already been set for emission reduction projects (forestry projects are considered "sink" rather than reduction projects). (Neef and Henders, 2007).

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[1] As of April 2007, 595 projects were registered according to the UNFCCC CDM site: www.cdm.unfccc.int/
[2] UNFCCC AIJ information from their web portal, as of April 2007.

Rules and modalities for forestry projects were not laid out until December 2003 in Milan at COP9. (UNFCCC, 2003) Many key questions are still unresolved, and are being discussed this year, such as whether avoided deforestation should count, or sequestration in products, or whether energy generation and sequestration can be combined in one project.

Scientists do agree that forests, or more generally "terrestrial sinks" which may include grasslands and other ecosystems" can have a significant influence on the concentration of CO2 in the atmosphere. In the IPCC's special report on Land Use, Land-Use Change and Forestry (LULUCF) (IPCC,2000), the panel estimated that land use changes including deforestation contribute 1.6 million gigatons of carbon (Gt C) plus or minus 0.8 Gt C. Of total emissions from land-use changes since 1850, 90 percent is estimated to stem from deforestation (IPCC 2001, Ch.3), which means that about 1.4 Gt C yearly can be attributed to deforestation, most of which occurs in tropical countries in the current era. All in all, about 10 to 25 percent of anthropogenic C02 emissions come from deforestation. This makes it the second largest sector source of C02 after fossil fuel combustion. (FAO, 2006c), a fact which the author has heard quoted widely in by NGO's and other actors in the climate change arena. Regenerating forests cannot reabsorb the released carbon as quickly as it is being released from deforestation now, but they can make a significant contribution. Further, if forests become more valuable through the efforts to value the carbon sequestered in them, the overall rate of deforestation should slow.

Based on estimates from the 2000 IPCC report on LULUCF, Cairns and Lasserre (2006) estimate that the forestry sector could offset about 10 percent of annual GHG emissions, if vigorous measures were taken to improve forest management and increase the forest area. Since the goal of the Kyoto Protocol is only to reduce global emission by five percent, forestry could help achieve a majority of the required reductions if it was politically and economically desirable.

According to the Marrakech Accords, only afforestation and reforestation (A/R) projects are allowed under the CDM. Natural regeneration of secondary forests on degraded land and avoided deforestation is excluded – which narrows the scope of the possible reductions through forests considerably. Rather than being able to reduce 10 to 25 percent of total emissions the maximum scope for A/R is 10 percent.

In the 1997 text of the Kyoto Protocol, it was not clear if forestry projects would qualify for carbon trading schemes at all, and the use of forests as sinks is still controversial. The most important reason for this is the *impermanence* issue: all trees eventually release the carbon they store as they decompose, either during their natural life cycle, after unexpected destruction, or after harvest. To address the impermanence issue, it was decided to grant credits generated from sequestration only for limited and renewable terms.

A natural forest stores a constant "pool" of carbon in biomass and soil. It is possible that the pool can be retained forever as new trees replace old; but it is also possible that the forest can be harvested or burned at any time, and re-growth of the stock will take decades and may be hindered by further harvest or other destruction. Reductions in emissions from energy-efficiency projects or fossil-fuel substitution, on the other hand, are regarded as permanent reductions – if natural gas instead of gasoline is burned one day, the emissions that would have occurred if gasoline had been burned that day are saved—and cannot recur even if the car switches back to its normal fuel the next day. For this reason, one 2005 paper described credits from forest sinks as "rented carbon," (Gutierréz 2006) which might be desirable mainly for companies that do not have the capital to buy credits. Since there is still no certainty about the required reductions after the first trading period of the Kyoto protocol from 2008-2012, the credits may become more desirable for companies or countries that predict targets will be lowered or abandoned in 2013.

Some non-governmental actors also felt that the CDM rules should pay more attention to sustainability and should more strictly regulate plans for mono-culture plantations. A third concern is that CDM forestry projects would cause harm to local peoples or ecosystems if, for example, plantations replaced natural forests or if native people were denied use of traditional lands or otherwise do not benefit from the carbon credit projects. (Granda 2005; Rainforest Foundation, CDM Watch, Global Witness, SinksWatch, Forest Peoples Programme, Environmental Defense, World Rainforest Movement, and Down to Earth, 2005)

CDM Forestry Rules: The Framework for A/R Projects

Under the CDM mechanism, which is the only part of the Kyoto Protocol that involves countries not subject to emission cap requirements, investors from countries subject to caps (Annex I countries) receive Certified Emission Reductions (CERs) for emission reduction projects in developing countries. All CDM projects are subject to three broad criteria, as specified in Article 12 of the Kyoto Protocol (UNFCCC, 1997):

1. They must “result in real, measurable and long-term benefits” to climate change mitigation.
2. The emissions reductions must be “additional to any that would occur in the absence of certified project activity.”
3. The projects must assist host countries in “achieving sustainable development and contributing to the ultimate objective of the Convention.”

Further, CERs can only be produced from projects initiated after 2000, and at least for the first commitment period (2008-2012) CDM can be used to meet only 5% or less of reductions in each Annex 1 country; and forestry projects are capped at 1% of each country’s reduction requirements. (Point Carbon 2006, 11) Caps in the period after 2012 have yet to be determined. Points two and three of the above list are the most crucial and most difficult goals to fulfill, from the evidence of project developers and their critics.

Forestry Credits - tCERs and lCERs

To address the issue of impermanence, carbon credits from CDM forestry projects are valid for a limited time: either for five years, 20 or 30 years. The 20 and 30 years credits have to be recertified every 5 years. The five-year credits are called tCERs and the longer term credits are called lCERS. Projects using both types choose a crediting period of either 20 or 30 years. A twenty year period is renewable up to three times for a total maximum lifetime of 60 years. Once the credits expire, the owners must buy new forestry credits or permanent CERs from non-forest GHG mitigation projects. (UNFCCC CDM 2004) The credits can either be replaced by forestry credits or permanent credits, but if forestry credits are chosen, tCERS should replace tCERS and lCERS should replace lCERS. (UNFCCC CDM 2004)

One of the newest advisory publications for CDM A/R project developers notes that tCERS will usually be preferred over lCERs and that in both cases, most project developers might choose to opt for a single crediting period of 20 or 30 years to lower expected risk and cost. (Pearson, Walker, and Brown, 2006) That is because, if the lCERs fail the 5-year verification at any time, they expire immediately and the project developer faces the responsibility of buying replacements. The temporary CERs are never valid for longer than 5 years, so the project developer does not face liability if the amount of credits drops from period to period. Further, since it is not certain that the Kyoto system will continue, the value of registering for a renewal period after the first 20 years is low. (Pearson, Walker, and Brown, 2006) A 2005 estimate predicts forestry CERs will be 14-30% of non-forestry CERs. (Manguiat 2005) Since the amount purchased in forward contracts so far has been so limited, it is still difficult to estimate a realistic price, as will be discussed later.

Development Advantages of Forestry Carbon Projects

In March 2007, a CDM expert at the World Bank commenting on the prospects for forestry projects noted that it was a pity that A/R was not accepted in the EU ETS and had seen so little development because forestry or LULUCF projects more broadly, hold the greatest potential for sustainable development projects in Africa. (Pinna, 2007) The reasoning behind this statement is that the poorest countries and the poorest regions of poor countries contribute little to emissions, have little infrastructure, and often suffer from water and soil depletion or erosion problems, so terrestrial sink projects are the most promising for development and poverty alleviation. In 2006, all of Africa accounted for only 1.4% of the carbon market volume, according to a recent World Bank report on carbon markets and Africa. (Capoor and Ambrosi, 2006) The report begins by noting with regret that carbon sequestration from improvements to agriculture and avoided deforestation are excluded from the CDM and that the EU ETS and thus their share in the potentially "multi-billion dollar global carbon market." (Ibid.) They also note that Africa's share of the CDM market is even less than its share in global foreign direct investment. (Ibid.) Although the report focuses on the effect on Africa, the critique could easily be expanded to all poor rural regions, although the amount of conflict and political instability in many African countries might further increase the risks of project development in Africa.

A Developing Market Mechanism

The CDM is one of the "flexible" mechanisms allowed under Article 3 of the Kyoto Protocol, which are supposed to be based on market mechanisms. However, creating markets for environmental goods is still a new experiment in governance, and creating a global market for environmental goods has never been tried before. Not surprisingly, the market for CERs is still limited and the entries to barriers are high. The market for forestry credits is particularly limited and fragmented. This will be discussed more in following sections, but a brief introduction is given here.

The only mandatory market for carbon credits in 2006 is the European Trading System (ETS). However, carbon credits from forestry projects are not eligible for trade on the ETS during the current period from 2005-2007. As recently as 2004, experts predicted that they would be accepted in the 2008-2012 ETS period (Schlamadinger 2004, 7), but the new national allocations plans were issued without their inclusion. However, negotiations are currently underway on setting the stage for the EU emissions trading after 2012 and a recent communication from the commission seemed to indicate that future plans would include efforts to halt and reverse deforestation in developing countries. (EU Commission 2007) Thus, it seems likely that forestry credits will be included in the post-2012 regime in the EU. Even the most important voluntary market, the Chicago Climate Exchange (CCX) in the US, only allows forestry credits from projects in the US and in Brazil. (Flynn 2004, 15) Other climate exchanges in Europe follow the rules of the ETS. There is thus no mandatory market for forestry credits presently, though they will be accepted under the global Kyoto mechanism starting in 2008. Meanwhile, voluntary and semi-voluntary retail markets have developed, most in anticipation of the 2008-2012 trading period. Some projects bypass the UNFCCC or other government mechanisms to get certification from NGOs like the FSC of "Verified Emission Reductions" or VERs that are sold in private carbon offset programs. In voluntary programs, the prices paid for one ton of CO2 reduction with forestry may range from US$1- US$20. The scope of voluntary markets will probably shrink in 2008 as there will be little incentive to buy voluntary rather than mandatory emissions credits. In the US, there will still be a PR incentive for buying voluntary credits, but a voluntary market is inherently limited.

Most forestry projects so far have been financed directly by companies, NGOs, ecological funds, and governments acting proactively and voluntarily (Pye-Smith 2000), often in cooperation with the United Nations Framework Convention on Climate Change CDM pilot program called Activities Implemented Jointly(AIJ), (UNFCCC Kyoto Mechanisms. 2006) or the Forest Stewardship Council (FSC). International aid organizations are also involved.

Notably, the World Bank has developed a fund specifically for the development of forestry based carbon sink projects called the BioCarbonFund (World Bank Carbon Finance Unit 2006) in preparation for Kyoto motivated trading. The World Bank seems dedicated to further support of forestry projects, and announced in March 2007 that it was opening the second *tranche* of funds for CDM forestry and land-use change. (World Bank Carbon Finance Unit, 2007) The Asian Development Bank also had a CDM financing program open to forestry projects, but this was a pilot program open from 2003-2006 and is now closed. (ADB 2007)

The development of a market for forestry based carbon credits has been hindered most significantly so far by the failure of the majority of projects submitting proposals since 2000 to qualify for the CDM. As mentioned previously, only one A/R project has been registered so far, although fair progress was made in 2006 with 5 projects making it to the verification stage. The learning curve will probably be steep and the author expects that at least 6 and perhaps as many as 10 A/R projects will make it to registration before the 2008-2012 period begins.

Summary: Forestry Projects Intent and Development

Forestry projects have a strong potential to contribute to the goals of the Kyoto Protocol and of the Clean Development Mechanism; that is, to reduce overall emissions to 5% below their 1990 levels, to promote efficient and cost-effective reductions, and to promote sustainable development with social, environmental and economic benefits to developing countries. However, the development of rules for forestry projects has been slow and acceptance by investors and key governmental and NGO actors has been even slower. Project developers face a great deal of risk in developing forestry projects, because of natural risks such as fire, but even more risk stems from political and regulatory uncertainty and uncertainty about the market value of forestry carbon credits. As a result, only one project was able to be registered in the CDM by the beginning of 2007 and little further funding seems available for new forestry projects. Further consequences of project planning under uncertainty will be discussed following the introduction to the carbon sequestration and livelihood potential of bamboo species.

Chapter 2

Our Protagonist: The Livelihood Resource, Bamboo

Bamboo is a grass, biologically, but a grass of great diversity and utility more closely related to trees in its use and appearance, than a grass. It is widely recognized a plant of great cultural and practical importance in many Asian countries and even in parts of Central and South America and Africa. It is most abundant in subtropical and tropical climates but some varieties are also cultivated in North American and Europe. There are estimated to be 1200 species, or perhaps as many as 1500. (Lobovikov et al, in press)

Despite the wide distribution and prominent role in many cultures, there are still large gaps in knowledge about the extent, variety, and quality of bamboo species around the world. This is due primarily to the fact that the plant is currently undervalued in many regions where it occurs and also due to the fact that it occurs in remote areas with little investment. It is commonly referred to as the "poor man's timber" in India and other countries. Many rural people are dependent on bamboo for their housing but generally hope to trade in their bamboo housing for concrete or wood when they are wealthy enough because they associate it with poverty. On the other hand, it is now sometimes referred to as "green gold" in areas such as Anji, China where bamboo cultivation has made large contributions to the local economy.

The gaps in the knowledge about bamboo biology and extent are also due to the great diversity of the species globally. The UN FAO, the International Network for Bamboo and Rattan and the Chinese Government have been the main supporters of a global assessment of bamboo resources, which will be summarized here. However, even this newest assessment (Lobovikov et al, in press) is not able to guess what the original extent of the species has been in previous times or to what extent it could or should be extended. What is known is that bamboo stocks are often overexploited and neglected in natural forests, and that bamboo has been successfully grown in a variety of non-native environments and has shown itself to be very hardy and adaptable.

Most varieties are cultivated or otherwise harvested for their hollow stems (culms) that can be used as "timber" or processed for other fiber and softwood uses such as mats, paper, or even fiber for cloth. The shoots of several abundant species are also edible, yielding edible starch, and the leaves can be used as animal fodder. INBAR estimates that 2 billion people live in areas where bamboo grows, though only a fraction are able to take advantage of, or aware of, the income generating opportunities that its processing for housing, food, paper etc. offers. (INBAR, 2004)

A short list of bamboo's advantages from a livelihood development perspective follows, adapted from an INBAR introductory fact sheet:

1) It can be harvested annually and non-destructively, as clear cutting is detrimental to the stands but selective harvesting increases productivity.
2) Bamboo establishes quickly with the first harvest generally available in 3-4 years or in some cases even in two years. (Stand maturity is generally reached in 5-6 years at the most.)
3) The investment required for establishing a plantation is quite low compared to most commercial tree species as bamboo is cheap.
4) The plant regenerates itself and continues to yield for long periods, dozens of years in most cases and often up to 50 or 70 years. Flowering can break this cycle for a few years, but does produce plenty of seeds for planting a new crop. This also means that the risk of crop destruction through natural disaster or illegal harvest is also smaller than for virtually all tree species, considering that the plantation can be regenerated in less than 5 years.
5) Bamboo responds well to management and the same variety can be up to 20 times more productive when managed as in the wild without managed harvest.
6) Bamboo can be grown on peripheral or non-cropping land in addition to food crops.

7) Bamboo can be intercropped, particularly with shallow rooted food or cash crops.

(INBAR, 2004)

Bamboo also has processing characteristics that are advantageous for livelihood programs:

1) The wide range of products that it can be used for increases the cultivators' flexibility to respond to changing markets.

2) The range of skills for cultivating, processing and marketing bamboo can be developed on a community basis, and lends itself to community projects.

3) Value can be added to bamboo products even with limited technical skills, for example for producing split and woven products, tools, handicrafts and artisan paper. It is also useful for housing and utensils in local markets.

4) A range of returns are possible, depending on the investment and desired outcome. Home processing activities can be established at virtually no cost, while large scale processing will require larger investments but may also provide greater returns.

5) The relatively light weight of the product and absence of large branches makes bamboo "gender insensitive" and lends itself to processing by women as well as men.

6) Bamboo can be processed at home in cottage industries for many applications. Further processing expertise is often already present form in areas with native bamboo species.

7) As a commodity, semi-processing and other skilled processing such as coloring, splitting and weaving adds value that can be kept in a community.

(INBAR, 2004)

Studies done in China in some particularly successful projects have shown that 75-90 percent of bamboo biomass can and in some places is being processed, from the rhizomes (roots) to the leaves, so that little waste is generated and left to decompose and add to methane or CO2 emissions. (Zhu, In press)

Distribution and Extent of Bamboo Resources

The first attempt at a global assessment of bamboo stock was made relatively recently, in 1980 as a joint project between the UN Food and Agriculture Organization (FAO) and the UN Environment Programme (UNEP). However, only 13 countries participated in that year. (FAO, 2005) In the newest estimate (Lobovikov et al., in press), which was based on survey conducted in 2005, participation outside of Asia was still a problem, though the number of participating countries has increased greatly since 1980. The methodologies for measuring the stock and the level of detail also varied greatly, which is another difficulty with the data gathered.

Generally, Asian countries are the undisputed winners in terms of area covered by bamboo as well as the diversity of species and uses. However, despite its strong associations with Asian culture, natural varieties of bamboo do grow in Africa and in South America as well, and some non-native species are also cultivated for livelihood or housing projects. In particular, the native *Guadua angustifolia* bamboo species has a prominent role in traditional construction in South America.

The question of what counts as a “bamboo forest” is still an issue in the survey results. Bamboo often grows intermixed with other species, may be intercropped, and often grows on marginal land as well as growing in groves of pure bamboo. Some countries may have counted only pure groves, other mixed forests with some bamboo. Some also include plantation bamboo in their overall forest estimates.

Bamboo Resource Trends

As processing technologies and markets for bamboo products grew rapidly in Asia over the last several decades the resources were overexploited in some areas and local governments responded in some cases with regulations or even bans on harvesting bamboo in forests (Lobovikov et al., in press, 25). In Asia, the area of bamboo forest has expanded by about 10% in the last decade as bamboo products have become more popular and profitable, however most of the increase has been in a few species. China in particular, has planted large areas of the versatile and large "Moso" bamboo, *Phyllostachys pubescens*, which has edible shoots and large culms, and also grows in a variety of environments.

Diversity of Species

There are two broad categories of bamboo, the *monopodial* and *sympodial*. Monopodial species generally originate in subtropical environments, spread rapidly and grow in stands similar to pine trees. The moso bamboo that is so popular in China, and also in Japan, is monopodial. Sympodial species are mainly found in tropical regions, grow in clumps and do not spread slowly. Some of the largest bamboos are sympodial, however more studies have been done on monopodial varieties. (Bystriakova, 2003a)

China alone has over 500 species of native bamboos. Japan, India, Indonesia, Myanmar and Malaysia also report more than 100 species in each country. (Lobovikov et al, in press, 34) However, in some cases only a few species are cultivated and many stocks have declined with overuse of the natural stands. In particular, Myanmar reported that the stock of their most usable bamboo species (*Melocanna bambusoides*) declined from 51.3% to 36.2% of bamboo stock from 1990 to 2000. Some other species expanded their cover in deforested or degraded areas. (Lobovikov et al., in press, 34)

Africa has far fewer native bamboo species, although Madagascar is a bit of an exception. Tanzania reported four native species, the largest number of native species for any of the African countries on the mainland. East African countries, particularly around Lake Victoria have the best conditions for raising many varieties of bamboo (Lobovikov et al, in press), and may have more native, but unreported species. Madagascar has 32 native species and one introduced species. (INBAR 2005)

There are 20 genera and over 429 species of bamboo native to Latin America. Brazil has the largest diversity, though various sources cite between 232 to 135 species. Grouped together, Venezuala and Colombia have over 50 species and species in Ecuador, Costa Rica, Peru and Mexico sum up to 30. (Lobovikov et al, in press)

Asia

In Asia, 16 countries participated and reported about 25 million hectares of bamboo forest. India and China reported the largest extent with 10.8 million and 5.4 million hectares respectively. The next largest extent of bamboo forests were reported in Indonesia, Laos, Myanmar and Thailand. (Lobovikov et al., in press) Overall, about four percent of forests in Southeast Asia are estimated to be bamboo. The highest percentage of bamboo in forests were reported in India, Laos and Sri Lanka, with bamboo accounting for over 10 percent of the forest in each country. (FAO,2005). The total area of forests in Asia containing some bamboo may be much larger. A 2003 study (Bystriakova, Kapos, Lysenko and Stapleton, 2003b) of bamboo biodiversity in the Asia-Pacific region estimated:

> Over 6.3 million km (63 million hectares) of Asian forest potentially contains bamboo, with highest densities indicated from northeastern India through Burma to southern China, and through Sumatra to Borneo. The highest figures for potential species richness (144 spp per square km) were recorded in forests of south China, including Hainan Island.

The same study (Ibid., 1839) comments further that the most biodiversity is concentrated in a few Chinese provinces with favorable conditions, but notes that knowledge of biodiversity also reflects the amount of study done.

> The highest diversity of bamboos is found in the Guangxi, Guangdong, and Hainan provinces in southern China, where climatic conditions are ideal for bamboos and a large elevational range provides a variety of habitat types. The magnitude of diversity recorded for this region probably reflects intense research efforts prompted by the economic and social importance of bamboos there. On the other hand, low diversity elsewhere, especially in bordering countries, indicates that the observed patterns may be in part due to variable research effort.

Africa

Less is known about bamboo resources in Africa, though INBAR has been cultivating projects in several African countries with local partner organizations. Five countries took part in the survey and reported 2.7 million hectares, constituting 4.1 percent of their total forest area, most of which was reported in Ethiopia, and Nigeria. In fact, Nigeria reported more than 14 percent of the forest cover as bamboo, indicating that they counted all forests with some bamboo as bamboo forests. Ethiopia reported a more believable 6.5 percent of forest area as bamboo. (Lobovikov et al., in press) Several other countries have some extent of bamboo forests or plantations, but did not take part. INBAR has an office in Ghana for example and participants in 2003 workshop reported prolific bamboo resources in the country. (INBAR, 2003) The greatest diversity of bamboo species in Africa is found in Madagascar. (Lobovikov et al., in press)

Central and South America

INBAR estimates a total of 11 million hectares of bamboo forest in Latin America, with Brazil, Chile, Columbia, Ecuador and Mexico having the largest areas. However, only Chile and Ecuador participated in the 2005 survey. Chile reported about 0.9 million ha in 2000 and Ecuador reported 20,000 thousand ha in 2005 with 5000 ha from plantations. (Lobovikov et al., in press)

The authors of the 2005 study on bamboo resources attribute the lack of reliable data in Latin American and Africa to the low valuation of the resource. (ibid.) Many still regard bamboo as an undesirable weed and exploitation is limited to low-value traditional manufacturing. (ibid.) On the other hand, three countries in the northern half of South America, Colombia, Ecuador and Brazil, have developed limited commercial development. In this region, as mentioned previously, *Guadua angustifolia* and also the *G. amplexifolia* are native species with a long history of use in construction. The countries also use three introduced species: *Bambusa vulgaris, B. tuldoides*, and *Phyllostachys aurea*. (ibid.)

Table 1: Extent of Bamboo Forest in Asia and Africa (1000 ha)

Countries	Extent Bamboo Forest Reported 2005 Total	Total Forest Area FAO 2005	Est. Percent of Total Forest
Asia			
Bangladesh	**83.01**	**871**	**9.50**
Cambodia	29	10447	0.30
China	**5444**	**197290**	**2.80**
India	**11361**	**67701**	**16.80**
Indonesia	**2081**	**88495**	**2.40**
Japan	154	24868	0.60
S Korea	6.1	6265	0.10
Laos	**1612**	**16142**	**10.00**
Malaysia	**677**	**20890**	**3.20**
Myanmar	859	32222	2.70
Pakistan	20	1902	1.10
Papua New Guinea	45	29437	0.20
Sri Lanka	2.6	1933	0.10
Thailand	261	14520	1.80
The Philippines	172	7162	2.40
Vietnam	**813**	**12931**	**6.30**
Total Asia	**23,620**	**533076**	**4.40**
Ratio, %	100	100	
Africa			
Ethiopia	**849**	**13000**	**6.50**
Kenya	124	3522	3.50
Nigeria	**1590**	**11089**	**14.30**
Tanzania	128	35257	0.40
Uganda	67	3627	1.80
Total Africa	**2758**	**66495**	**4.10**
Ratio, %	**100**	**100**	

Source: FAO/INBAR International Workshop on Global Bamboo Resources Assessment, Beijing, 9-11 May 2005 (Adapted from Lobovikov et al, in press)

Table 2: Estimated Extent of Bamboo Forest in Latin and Central America (1000 ha)

Countries	Area of bamboo in 2000, from the country reports, 000 ha	Estimated area of forest with bamboo, 000 ha	Area of bamboo plantations, 000ha*	Total forest area, 000 ha	Est. Percent of Total Forest Area
Argentina		2,000	-	33,021	6.1
Bolivia		**5,000**	**-**	**58,740**	**8.5**
Brazil		8,000	100	477,698	1.7
Chile	**899**	**4,000**	**n/a**	**16,121**	**24.8**
Colombia		80	5	60,728	0.1
Costa Rica		5	2	2,391	0.2
Ecuador	9	20	5	10,893	0.2
Mexico		5	2	64,238	0.0
Paraguay		170	-	18,475	0.9
Peru		**7,000**	**-**	**68,742**	**10.2**
Total	**908**	**26,280**	**114**	**811,047**	**3.2**

Source: FAO/INBAR International Workshop on Global Bamboo Resources Assessment, Beijing, 9-11 May 2005 (Adapted from Lobovikov et al, in press)

Bamboo Uses and Industries

Based on estimations from 1999 and 2000, up to 2.5 billion people in the world use 20 million tons of bamboo yearly (Lobovikov et al, 2006; Scurlock et al 2000). However, it is also estimated that about 80 percent of bamboo is used locally and not included in most statistics, so the real tonnage figure may be significantly higher. (Scurlock, 2000) The utilization of bamboo has a very long history in the world, particularly in Asian countries but also in Africa and Latin America. Traditional bamboo products include paper, construction and housing materials, household tools, handicrafts, furniture, weavings, carvings, and boats. Bamboo housing and construction materials from the large Latin American species *Guadua angustifolia* were also an important part of culture in countries like Colombia and Ecuador. Industrial processing of the plant began first in India and China with pulp production for paper making. The first bamboo paper was made around AD 100 in China and the first paper mill was established in the 6th century AD. The first mechanized bamboo paper mill was established in India in 1912.

(Dhamodaran et al, 2003) Papermaking was followed much later by the first production of chopsticks from industrial production in Japan in the 1950's. (Zhu and Lobovikov, 2006)

In the 1960's and 70's further industrial processing was carried out particularly in Taiwan where panels, flooring and mats were also produced industrially. Since then, the industrial bamboo sector in China has been expanding and new technologies for processing have been developed. Culm, food and chemical processing, as well charcoal production and the development of new products like bamboo clothing and bamboo veneers are the most frequent new bamboo industries. (Zhu and Lobovikov, 2006)

At the same time however, traditional uses and technologies continue to be widespread throughout the world where bamboo grows. The plant is a particularly useful resource for poor and rural communities. (INBAR, 2004) However, traditional knowledge about bamboo use is often lost, and wild stands are over harvested. A lack of opportunities for training and dissemination of technical knowledge still hinders the development of bamboo enterprises in most countries. The amount of bamboo resources available to communities is shrinking in many cases due to this ignorance about its proper management and optimal use. (Bystriakova, et al., 2003a) There is also a trade in illegally harvested bamboo for timber at least in some areas of South Asia which also pressures the resources. (Talukdar, 2004)

Peculiarities Compared to Wood

Bamboo is a woody grass and has some unique features that substantially differentiate it from wood. The plant is a very useful substitute and often superior substitute to wood, but it cannot be treated exactly like wood. Particularly the hollow stems require different handling, cutting and construction techniques for optimal results. The high silica content of the stems also easily dulls saws developed for wood processing. (INBAR, Cleuren 2004) Its large diversity in the products that can be made from bamboo but seldom from tree species, including food and food additives, clothing and odor absorbers, also differentiate it from wood.

Market Development

The market development of bamboo industries is often hindered because of a lack of knowledge and training as well as supply chains and infrastructure for bamboo products. Natural bamboo stands are also dwindling even though it is such a productive plant, due to over-harvesting and poor or no management. Bamboo stands, especially those for timber, must be harvested selectively every year to produce optimal timber. The poles cannot be stored without preservation for long periods and deteriorate faster than wood once deterioration sets in. (It should be noted however, that most woods also deteriorate quickly without treatment.) Post harvest destruction of bamboo culms through fungi or the powder beetle (*Sinoxylon sp*.) is also a problem without treatment. Beyond chemical treatment, this problem can be mitigated by harvesting the culms when the starch content is low, i.e. after the shoot season. (Cleuren, INBAR, 2004)

Egrarious flowering, which causes bamboo stands to die off for several years, is another business risk that has caused the demise of several bamboo projects. (INBAR, Cleuren 2004) In India, the flowering of some species is also associated with large rat populations that have decimated food crops. (Talukdar, 2004) Knowledge about the species, proper insurance and some financial reserves must be available for this instance. Yet compared to the risk of fire or other destruction of tree plantations that might take twenty or more years to replenish, the impact of bamboo flowering is relatively low, since bamboo will replenish within about 5 years.

Trade and Economic Value

Wood and Forest Products

In 2000, approximately 3.3 billion cubic meters of wood were harvested, and the value of all timber harvested was about US$400 billion. (MEA 2005). Approximately 25 percent was traded internationally, with the majority of imports bound for OECD countries, followed by China, (Ibid) About 15 percent of the global timber trade, about US$10 billion, may be illegal (Contreras-Hermosilla, 2002), though global estimates are hard to make and varies by region—with Asia usually leading the statistics, followed by Africa. (Nilsson and Bull, 2005) This high percentage reflects the difficulty of monitoring remote forest areas and the weak government agencies in countries with rich timber resources. Overall, as many as 300 million people depend on forest ecosystems to meet subsistence needs. (FAO, 2006a) Non-timber forest products are used for purposes ranging from food, fodder and medicines to construction materials and handicrafts, however wood as fuel is still the most important forest product for many. The FAO estimates half of global wood removals are for fuelwood. (FAO, 2006a) In the developing world, fuelwood accounts for 80 percent of all wood use, providing the main energy source for 2.6 billion people. (MEA, 2005)

Trade in Bamboo Products

In 2000, about US$ 2.5 billion in bamboo was exported globally with China, Indonesia and Vietnam leading the list of exporting countries. Raw bamboo export was about US$ 89 million. The main importers, Japan, the European Community, the USA and Hong Kong, bought about 80% of the total. (Lobovikov et al, 2006) Within this category, the total value of raw bamboo exports was US$89.15 million in 2000, according to INBAR's trade database. The export value of raw bamboo from China accounted for 28 percent of this figure, followed by Indonesia at 12 percent, and Vietnam at 8.6 percent. Malaysia and Myanmar were also minor exporters.The most important processing centers are in Singapore and Hong Kong. (Lobovikov and Hong, 2004)

Seventy-one percent of total world imports of bamboo products went to Japan, the European Economic Community (EEC), the USA and Hong Kong in 2000. The US was the largest market, accounting for 32 percent of exports (US$899.14 million). Japan was the next largest importer at 12.5 percent; and was followed in order of decreasing magnitude by Germany, France, Hong Kong, the UK, and the Netherlands. (Lobovikov and Hong, 2004)

Bamboo trade statistics are not entirely accurate because official classifications do not recognize many new bamboo products such as bamboo flooring and paper as "bamboo." The best estimate of bamboo world trade is approximately US$5 billion to US$7 billion annually, a figure comparable to the value of bananas and cotton. (Lobovikov and Hong, 2004)

In comparison to the value of harvested timber, trade in bamboo products makes up something like one percent. The total value of the resources used are necessarily much higher however, since about 80 percent of bamboo is estimated to be used locally (Scurlock, 2000) and does not enter trade statistics.

Bamboo for Energy

Using bamboo for biofuel applications may be the newest and least developed of the bamboo uses, but the interest in this area is growing. Bamboo's high value in other products has discouraged resource on fuel use. Yet, since nearly half the wood harvested in the world is used for fuel, mainly in poor countries (FAO 2006), and since interest in biomass for clean fuel in developed countries has been increasing rapidly, it seems likely that interest in bamboo for fuel develop in the next years.

Untreated, bamboo is not an ideal fuel compared to wood, as it tends to burn very quickly, however, in the most recent survey of bamboo resources and utilization around the world, many participating countries indicated that bamboo energy use is substantial in the rural areas. (Lobovikov et al., 2006) Although the charcoal has higher valued added-markets, bamboo charcoal is one way to convert bamboo to an efficient fuel, and it is already used for barbeque briquettes.

At least some research has been done on gasification, which is probably the most promising energy application. By pyrolysis, bamboo can be converted in three valuable products: bamboo charcoal, oil and gas. Changing the pyrolysis parameters changes the products shares depending on the purpose and market conditions. Bamboo oil can be burned for energy, but also has applications in pharmaceuticals, creams and beverages. (Lobovikov et al., 2006) There are three main reasons that bamboo charcoal could become a competitive commodity: (1) bamboo grows faster and has a shorter rotation cycle than competing tree species, (2) bamboo charcoal caloric and absorption properties are similar or better compared to the properties of wood charcoal, (3) bamboo charcoal is cheaper and it is easier to produce. (Lobovikov et al., 2006)

Competitiveness of Bamboo Products

Bamboo faces several barriers that lowers its competitiveness compared to other tropical woods. Most of the barriers involve lack of markets, supply chains, infrastructure etc as well as awareness-building and training. Generally, the bamboo sector suffers from limited organization and standardization. Entrepreneurs often work in informal market segments, or they are badly organized. Further, information on pricing, processing and industrial manufacturing is not publicly available in many countries, because universities, research institutes and government institutions pay only marginal attention to the bamboo sector. (Cleuren 2004)

Domestic users in tropical countries still think of bamboo as a resource for temporary solutions that is prone to infestation and rotting, i.e. the “poor man’s timber.” This image is fostered by the tradition of using bamboo without preservatives and the fact that trained architects and carpenters lack experience with the material. In the developed world, there is a small market of environmentally conscious consumers interested in bamboo flooring and housing etc, however the further development of the market is hampered by a lack of codes and standardization and doubts about the durability of the material. (Cleuren, 2004)

Environmental and Social Effects of Bamboo

A hardy and quick-growing plant native to many regions in the world, bamboo is valuable not only as a resource for poverty alleviation and economic development but also can play an important role in landscape and restoration, fostering biodiversity and improving soil and water.

Environmental Benefits and Biodiversity

A 2003 joint study between the UNEP and INBAR showed that more than 400 bamboo species (about one third of the total species) are threatened by deforestation. Beyond the need to protect the biodiversity of the bamboo species however, bamboos are an important element of many ecosystems and bamboo forests are often indicators of areas with high biodiversity. (Bystriakova, Kapos, Stapleton and Lysenko, 2003a) Bamboo is often used for soil conservation and enrichment and watershed protection purposes. It also provides a favorable environment, particularly in mixed forests, for many types of wildlife. In China, 3 million hectares of bamboo forests distributed in high mountainous regions, in the Yangtze river watershed and in plantations along riverbank, lakes and sea shores help protect natural ecosystems as well as providing habitat for wildlife, the most famous variety of which is the giant panda. (Ibid)

Bamboos often flourish in moist or tropical old-growth forests and have been associated with the livelihood of a number of threatened plants and animals. Beyond the giant panda, some of these species include the red panda, the Himalayan black bear, the smallest known bat—which roosts in the *Gigantochloa scortechinni*—and more than 15 Asian birds and several little-known invertebrates. (Bystriakova, et al., 2003a)

The extensive rhizome system of the bamboos, found mainly in the top layers of soil, is one of the main reasons for its positive effect on soil stabilization and securing hydrological functions of catchments and rivers. (Bystriakova, et al., 2003) In an example from India, bamboo plantations were established as part of a development project from 1995 to 2003 on land degraded by decades of brick mining. The degraded land which had only supported grass in 1995 had been converted to bamboo plantations and some farmers had been able to resume farming on the rehabilitated soil by 2003. (Kutty and Narayanan, 2003)

In some cases, early attempts at high-yielding bamboo stands have actually caused some negative effects to the ecosystem. This was mainly caused by practices such as raising the harvesting intensity to the point that not enough biomass was returned to the soil, loosening the soil and applying chemical fertilizers and herbicides, cultivating large monocultures, and not allowing sufficient undergrowth. (Fu and Lou, 2002) These practices lowered soil fertility and long-term productivity and actually caused some soil erosion as well as water pollution from fertilizers. According to a 2002 paper, modern bamboo management avoids these problems with selective harvesting of mature culms, balancing the input and output of nutrients, managing, allowing undergrowth, avoiding chemical inputs and using organic fertilizers. (Fu and Lou, 2002)

A 2006 paper by bamboo expert Zhu Zhaohua, says that the bamboo plantations in the successful Lin'an County were mostly planted on degraded waste and sloping lands. The resulting forests had a favorable impact on the community: processing boosted the local economy, tourists were also attracted to the bamboo hillsides, and the water and soil quality were improved. He also noted that experiments showed that the water and soil improvement capacity of bamboo plantations are 1.5 times that of the Masson's pine (Pinus massoniana), and 1.3 times that of Chinese fir (Cunninghamia lanceointa). (Zhu, 2006) Unfortunately, there are no figures available comparing the soil and water enhancement of bamboo to eucalyptus and teak.

The Link to Rural Livelihoods and Poverty

Many countries have large bamboo resources in public forests, while others could easily cultivate bamboo resources either as a new plant or by reintroducing threatened native species. Livelihood strategies for the rural poor often include the use of bamboo for housing, utensils, and the collection of bamboo timber or shoots for sale—all in the informal sector. (INBAR and Cleuren, 2004) Much processing of bamboo can be done at home, which is optimal for increasing income opportunities for women and children. (Although child labor is not something that is generally desired, children's contribution to family income is often crucial in poor and farming communities around the world, and if the work can be done in the home and part time, it does not preclude attending school as well.) Beyond traditional handicrafts and furniture, the weaving of mat boards, which have industrial uses, is an example of a promising activity for generating income in the home in India, though the supply chain and market needs to be developed further. (INBAR et al., 2004)

Evidence from China

The Chinese market for bamboo products and cultivation has been developing rapidly since the market reforms of the 1980's. Although the Chinese government has supported bamboo plantation development since the 1950's, the potential of the plant for development has only become evident now that market and legal reforms have given the sector a boost. (Zhu and Lobovikov, 2006) Several counties have shown strong growth related from bamboo cultivation and processing and bamboo projects are being encouraged for rural poverty alleviation in several provinces. Some notable examples of poverty alleviation and sustainable development from bamboo cultivation are provided by two counties in Zhejiang Province, Muchuan county in Suchuan and Xinzi county in Guangdong. (Zhu et al., 2006)

In Anji county in Zhejiang, which is becoming well-known for its bamboo processing centers, the bamboo sector is now worth about US$625 million and has 865 bamboo processing enterprises with 40% of the population owning bamboo plantations and participating in bamboo plantation management. Although the county was plagued by widespread poverty in the 1980s, the average income is now US$781, well above the Chinese and international poverty line.[3] () Processing supplies 40,000 jobs, of which 80% are taken by women. (Zhu and Lobovikov, 2006) Anji County also followed a "greening" strategy of cultivating a mixed forest on degraded hillsides. The efforts began in the 1990's and farmers were encouraged to plant mixed tea, fruit trees and bamboo species with high economic value on unproductive croplands, as well as creating mixed broadleaf and coniferous forests. According to a case study, villagers previously managed forests unsustainably for charcoal and now appreciate the benefits of economic forestry/agroforestry that will benefit their children and grandchildren as well as the current generation. (Jianyin, Taotao, Hongyu, in publication)

In neighboring Lin'an county, which began bamboo cultivation in the 1980s, the annual output of the bamboo sector increased from 20 million 1.8 billion RMB from the 1980's to 2005. The county specializes particularly in the production of edible shoots and 60% of the farmers are involved in shoot production. The average income is now 4294 RMB (about US $535), with 36% of the income per capita deriving from shoots. After about 3 years of cultivation, the shoot plantations yield about US$ 5,625 per hectare annually. (Zhu et al., 2006)

Two more examples of the livelihood benefits of bamboo projects are available from Sichuan and Guangdong. Government officials in Muchuan county, a poor area in Sichuan, began promoting and developing the bamboo paper industry in the 1990's. Average income is still lower than $1 a day, at about US$237 per capita, but the income from bamboo cultivation has brought a 33.8% increase in the per capita income for farmers since the project begin. (Zhu and Lobovikov, 2006) A county specializing in bamboo cultivation for weaving products, Xinyi county in Guangdong, had a total output of about US$ 117 million in 2003 and exported US$70 million of that to markets in Europe, North American and Southeast Asia. Poverty statistics were

[3] Rural poverty is still widespread in China. In 2003, 9 percent of Chinese were still living on US$1 or less a day. (Rural Survey Organization, 2004)

not available, but the bamboo enterprises directly employ 5,100 people and the bamboo sector is estimated to involve at least 50,000 people. (Zhu et al., 2006)

Bamboo materials are often very cheap and can be made into durable attractive housing for the poor. The Hogar de Cristo foundation in Eucuador for example has been producing low-cost housing for the poor since 1971. The foundation receives US$140 per house from the government and produces 55 houses a day with its total 170 employees and its guadua plantation which employs and trains local people. (Spijkerman and Kessler, 2003) Many traditional bamboo structures used untreated bamboo timber, which degrades relatively quickly, but new technologies allow cheap housing that will last for decades. Bamboo is also an excellent resource for temporary disaster housing. INBAR is developing several projects in this area using the new "flat pack" bamboo panels.

Barriers to Livelihood Development with Bamboo

In some cases, strict regulations on gathering forest products in an effort to prevent deforestation and protect forest health conflict with livelihood development goals. In the case of bamboo, informal cultivation of natural stands is tradition and can be managed quite sustainably, and many regulations place unnecessary limits on livelihood use.

Bamboo's potential for poverty alleviation would be helped with an integrated bamboo sector development with links between the rural poor and buyers or processors. Another approach is to slowly develop skills and capacity for local skilled management (versus collection in natural forests) and processing. Integrated bamboo development approach should include developing markets, offering on the job-training in technical and management skills, securing the resource base with land-tenure reform, community forestry. Providing management guidance and incentives for cultivation and enterprises would also be helpful. (INBAR et al., 2004)

Financial Viability of Bamboo Projects

A Chinese study from 2003 concluded that the value added for bamboo products in China is between 20-40 percent and that the low entry and exit barriers helped spur growth of bamboo industries in China. (Zhang, 2003) Other studies also support the conclusion that bamboo cultivation and processing can be quite profitable, if proper management is applied and the value in the supply chain is captured by the cultivator rather than a middleman—a challenge in most agricultural industries.

A 2003 study of bamboo's suitability to replace timber in Malaysia found that the internal rate of return (IRR) for a bamboo timber plantation over 15 years was 22.9 percent. The NPV at a 10 percent discount was lower than the estimates for Acacia mangium, teak and sentang woods, but bamboo had a quicker pay-back period and lower upfront investment. (Mohmod, Abd, Latif, Abd. Razak Othman and Norhini Haron, 2003) A bamboo flooring project from plantation establishment to the finished product was quoted in 1997 at an IRR of 48 percent. (Ibid.)

Although these projects were more industrial in flavor, rural livelihood development with bamboo is more common and can also be profitable. A hand-made bamboo paper project in China had an average IRR of 17.75 percent with the break-even point reached in 4.78 years. (INBAR, 2002) A 1998 study in India estimated the average IRR for rural bamboo plantation projects at 14.51 percent after only 6 years. Rural community cultivation for small-scale use showed an IRR of 43.22 percent after 8 years. The main barriers to bamboo cultivation in this case were found to be lack of knowledge of cultivation and management techniques. (Indian Council of Forestry Research and & Education and INBAR. 1998).

On the other hand, a 2003 study of *Guadua angustifolia* cultivation in Ecuador (Spijkerman and Kessler, 2003) illustrates some typical problems that make bamboo unprofitable for farmers. In Ecuador, more than 95 percent of the bamboo is used for construction and agriculture, with each culm worth about US$1.40, which includes two 6-meter poles and a top used as a banana-prop. Farmers often sell the stand for about US$0.20 per 6-meter pole to middlemen who clear-cut the stand, an inefficient method which also inhibits regeneration of the stand. A 3-acre plot managed unsustainably was estimated to produce about 100 culms a year. A well-managed and selectively harvested stand however, will yield up to 1,200 mature culms per year, each worth about $1.40 as mentioned above, but sold for 40 cents. The required investment for this plantation would be $1000 per ha for the first three unproductive years. (Spijkerman and Kessler, 2003) If the farmer only captured half the value (70 cents) and increased the yield to 600 culms yearly, he would generate US$420, which would yield a payback period of 5.4 years and an IRR of 8 percent in 6 years, or 26 percent in 10 years. If the farmer captured all the value and achieved a maximum yield, the IRR over 6 years would be 71 percent. This does not calculate in the cost of labor, but still represents a robust return for a commodity product.

Many communities could benefit from bamboo cultivation, but lack funding and resources to start projects. Carbon revenue could put many more of these projects in the range of financial viability even in very poor areas. If for example each tCER was worth just US$2 one hectare with an average biomass of just 100 tonnes total would generate 100/2 *3.67 CO2e*US$2 = US$367 per ha every 5 years, or $73.4 annually, just in carbon revenue. So just one hectare would mean a twenty percent increase in annual income for a family living off of US$1/day. Whether or not this revenue expectation is realistic given the high transaction costs of CDM projects will be discussed again later in the paper.

Bamboo as a Carbon Sink

Compared with other tropical tree crops being cultivated for carbon sequestration or fuel-switching under the CDM, bamboo may reveal several advantages on sustainability grounds as well as pure carbon-fixing capability. Many tree plantation projects have faced criticism either for environmental reasons or because they do not promote pro-poor development. Bamboo however is usually cultivated exactly for pro-poor livelihood development in rural tropical areas, and/or soil conservation and the promotion of biodiversity.

In tropical areas, the annual biomass production per hectare of many bamboo species is very competitive with other favored tree crops. In some cases, even natural stands rather than plantations can have biomass per hectare as high as favored tree plantations. The following section summarizes the carbon sequestration and sustainability aspects of different types of forests and specific tree species that might compete with bamboo for CDM projects.

Forests

Temperate forests generally store large amounts of carbon in the soil of forest systems around the world and can achieve impressive storage in above-ground biomass as well. Tropical forests on the other hand store most of the carbon in above-ground biomass and generally surpass temperate forests for total carbon storage in mature stands. According to the FAO Global Forest Resource Assessment 2005 (see Table 1), the tropical forests of West-Central Africa have the highest total carbon stocks per hectare, at an average of 222.9 t C/ha (818 t CO_2e/ha). These forests also had the highest average carbon stock in living biomass at 155.0 t C/ha. The highest average soil carbon stock in forests was found in European forests at 112.9 t C/ha of forest soil.

These figures are of course averages for primary or secondary natural forests. Some stands under good growing conditions surpass these figures. For example, a study of different temperate tree species modeled a stand of Norway Spruce at a total sequestration reaching nearly 300 t C/ha, most of this reached in the first 100 years. This study included sequestration in products, but in that total, only 25-35 t C were stored in products, and approximately 100-150 tonnes in the soil. (Masera et al, 2003)The estimate for a stand of Douglas-Fir and Beech in

Europe was similar; with total carbon slightly more than 300 t C/ha with slightly more carbon

Region/ subregion	**Living biomass**	**Dead wood**	**Litter**	**Soil**	**Total carbon**
West-Central Africa	**155.0**	7.6	2.1	56.0	**222.9**
South and SE Asia	77.0	9.0	2.7	68.4	157.1
Europe	57.0	14.0	6.1	**112.9**	176.9
Caribbean	99.7	8.8	2.2	70.5	181.2
Central America	119.4	**14.4**	2.1	43.4	179.2
N. America	57.8	8.8	**15.4**	35.8	117.8
Oceania	55.0	7.4	9.5	101.2	173.1
South America	110.0	9.2	4.2	71.7	**194.6**

Table 1: Carbon stock per hectare 2005 in forests (Source: FAO 2006a)

stored in the soil (150-175 t C) than the biomass. (Masera et al 2003, 190-193). On average in this study, forests stored 141 to 271 tC/ha, with living biomass accounting for 62 to 103 t C/ha and the rest stored in the soil and products (Masera et al 2003)

Bamboo Plantation Sequestration Compared to Natural Forests

In fact, several bamboo plantations have reached total biomass carbon storage in the range of natural forests, and in less than 7 years rather than 40-100 years. The two highest figures for carbon stocks in bamboo biomass are 91 t C/ha for *Phyllostachys pubescens* (Isagi et al 1997), a temperate (monopodial) species and then 149 t C/ha for *Bambusa bambos*, a tropical species grown in India (Shanmughavel et al, 2002). Of course, these were plantation bamboo grown in good conditions and with optimal management. However, in general, very little study has been done on the tropical semipodial bamboo species, though the largest bamboo species from visual evidence are semipodial. The study on *Bambusa bambos* is the exception to this rule and indicates that other species may also sequester carbon at similar rates.

In the 2005 study of global bamboo resources, China submitted total biomass estimates for bamboo forests. The government estimated bamboo biomass at 166.67±137.39 ton/ha for the abundant "moso" bamboo (*P. heterocycla "pubescens"*) and 119.35±91.69 ton/ha for the other species. (Lobovikov et al., in press) This translates to about 83.3 t C/ha on average for moso and 60 t C/ha for other varieties. Compared to the average tree biomass storage ing the Masera et al study (2003) which ranged from 62 to 103 t C/ha, this indicates that even unmanaged stands of moso bamboo can be quite competitive with temperate forests in above-ground sequestration.

More research needs to be done on the carbon storage in bamboo forest soils, and the average storage in bamboo products, to be able to make a more exact comparison. Bamboo stands are generally not expected to reach the carbon sequestration potential of natural forest systems in all climates, but they can be very competitive in select tropical environments where large bamboo species grow well.

Moreover, forest mature slowly, but the value of carbon sequestration projects is now based on the amount of new carbon stored in the short term: five years for tCERs and twenty or thirty years for lCERs. Once the growth figures for various species are averaged for their annual or 5 year average storage of carbon, the benefits of fast-growing crops like bamboo become plainly evident. Bamboos reach maturity in very short cycles (between 4-8 years), the figures for their maximal biomass production are very close to the 5 year tCER cycle.

In the section below, some figures from bamboo species will be compared for their five year performance with several tropical tree species to further illustrate this point.

Comparison of Some Tropical Trees to Bamboo

A 2006 study using five different tropical tree crops (*Alnus. Jorrullensis, Cordia alliodora, Cupressus lusitanica, Eucalyptus grandis, and Pinus patula*[4]) recorded a mean annual production of carbon storage (t/ha/yr) of 7.14. This translates to an average 14.28 tonnes of above-ground biomass production annually or a 5 year biomass productivity of 71.4 t/ha. Among the 5 species studied, the *Cupressus lusitanica* had the lowest annual biomass production at 7.46 t/ha annually and the *Pinus patula* trumped the Eucalyptus and Cordia by about three tones to produce the highest annual biomass of 19.86 t/ha/yr. This highest figure would mean the *P. patula* plantations produced about 99.3 t /ha of above-ground biomass after 5 years, or 49.5 t C/ha. (Guttiérez et al., 2006).

The temperate or subtropical *Phyllostachys pubescens* (moso bamboo), grown widely in China and Japan, has been measured at above - ground biomass of 137.9 t/ha in a natural stand with the total biomass including soil and roots reaching 182.5 (Isagi et al.,1997) As this species reaches maximal density at 5-8 years (Hangzhou Great Tang Bamboo Co. Ltd. 2005), the average yearly production should be about 17.24 –27.58 t/ha in above-ground biomass; well above the average for the trees mentioned in the previous section and perhaps higher than the *P. patula*: the moso may produce about 86.2 – 137.9 t biomass and 43.2 – 68.95 t C/ha in 5 years, compared to the 49.5 t C/ha in the pine species *P. patula*.

The tropical *Bambusa bambos* has been measured at above ground biomass 287 t/ha or 298 t/ha of total biomass after 6 years (Shanmughavel et al., 2002). This corresponds to a mean annual increment of 47.8 t/ha – almost twice that of the P. patula. (Guttiérez et al., 2006) The five year sequestration would be around 119.5 t C/ha, again twice the pine's 5 year sequestration.

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[4] *Alnus. Jorrullensis* is an evergreen alder tree. The *Cordia alliodora* is grown widely in Central America and valued for its timber. *Cupressus lusitanica* is the Mexican cypress. *Pinus Patula* is known as Mexican weeping pine. *Eucalyptus grandis,* also known as Rose gum,is one of the most commercially important Eucalyptus species globally.

Bamboos also have the advantage of fixing carbon in rhizomes, which do not die at harvest, as tree roots do—which means that the below-ground biomass sequestration is stable and must not be subtracted after harvest. Furthermore, some species may fix much more carbon in their culms at harvestable age than in the leaf or branch biomass of tree species. A 2002 study of *Guadua angustifolia* concluded that 90 percent of biomass was stored in the culms and rhizomes at maturation, so almost all of the biomass after harvest would not decay, but either be stored in durable products or in below-ground biomass (Riano et al 2002). The *B. bambos* was cited as storing 96 percent of its biomass above-ground at harvest. (Shanmughavel et al, 2002)

Tropical Wood and Bamboo Productivity	**Mean Annual Increment of Carbon (t C /ha/yr)**	**Mean Annual Above-Ground Biomass (t/ha/yr)**	**Carbon storage above-ground 5-year (t C/ha)**	**Above-ground biomass at 5 years (t /ha)**
Cupressus lusitanica	3.63	7.46	18.15	36.3
Alnus. jorrullensis	5.73	11.46	28.65	57.3
Eucalyptus grandis	8.07	16.14	40.35	80.7
Cordia alliodora	8.37	16.74	41.85	83.7
Pinus patula	9.93	19.86	49.65	99.3
Tree MEAN	**7.14**	**14.28**	**35.7**	**71.4**
Phyllostachys pubescens	**8.62 - 13.79**	**17.24 - 27.58**	**43.1 - 68.95**	**86.2 – 137.9**
Bambusa bambos	**23.9**	**47.8**	**119.5**	**239**

Table 2: Annual and 5-year productivity of several subtropical or tropical species (above-ground) Source: Gutierrez et al 2006; Isagi et al 1997, Shanmughavel et al 2002

Eucalyptus

Eucalyptus has become a very popular, economical tree crop over the last decade, particularly for fuel-wood or paper production. It is hardy and grows quickly; however Eucalyptus plantations have gotten bad grades for sustainability in several prominent cases including the Plantar project in Brazil (Rainforest Foundation et al, 2005) and the APP plantations in Yunnan, China (Greenpeace 2004a and 2004b, Qin and Wu, 2004). In Brazil, Eucalyptus has been cultivated in plantations for generations, but a 2004 study raised questions about the sustainability of the newer species, due to its high nutrient requirement and potential to deplete the soil and water supplies. (Binkley and Stape, 2004)

The newer high growth varieties need increasingly large amounts of water and fertilizer; raising questions about impact on soil quality, soil carbon, soil salinity and water availability. In fact this study concluded few soils would be capable of supporting the high growth species for more than one to two rotations (Binkley and Stape 2004). Nevertheless, they seem to be enjoying continued popularity in many afforestation projects, as will be shown later, and are usually chosen for fuel wood or for pulp and paper production,.

The normal high- yield Eucalyptus grown for the Plantar project are estimated at 17.5 t/ha/year (slightly more than the *E. Grandis* in the table above) and are harvested at 7 years (Plantar S/A Planejamento 2000). However, the project developers claim some new clones reach 21 t/ha annually. (Ibid.) Total biomass per hectare at maturity (7 yrs), assuming 17.5 t/ha/yr are achieved would be 122.5 t/ha. If the high producing clones reach 21 t/ha/yr, total biomass would be 147 t/ha/yr.

Referring to the previous section, moso bamboo has been measured at 137.5 t /ha/yr, with an average annual production of 17.24 – 27.58 t /ha/yr. Thus the annual increment is very similar, though the Eucalyptus would reach a total biomass that is somewhat higher due to 7 years of growth rather than the average 5-6 years for moso.

The *B. bambos* would easily surpass the Plantar Eucalyptus, assuming good growing conditions. Again referring to the previous section, it has been measured at a total above ground biomass 287 t/ha with mean annual production of around 47.8 t/ha/yr – almost twice that of the Eucalyptus clones.

Bamboo species could easily compete with Eucalyptus for CDM project funding due to its similar short rotation growing cycle and growing climates; moreover if judged on sustainability and livelihood development bamboo may often be at an advantage. They would be at a disadvantage is the project intent was to simply burn the biomass as fuel wood, since bamboo burns quickly. More research however, needs to be done on the efficiency of bamboo for fuel as charcoal and biogas to determine bamboo's competitiveness as a source of fuel.

Most bamboo charcoal today is produced for high-quality finished products rather than fuel and little research has been done on gasification with bamboo (El Bassam, Nassir, D. Meier, Ch. Gerdes and A.M. Korte. 2002). If the Eucalyptus were cultivated for pulp and paper production, it seems bamboo would be an ideal substitute, unless there were technical barriers to switching from Eucalyptus pulp to bamboo.

Teak

A well-known and valuable tropical hardwood, teak yields more biomass per ha in mature plantations than bamboo or other short-rotation crops, but it grows slowly and usually needs a rotation of at 35 to 80 years, depending on the country, rate of growth and desired hardness. Though some may be cut as early as 25 years, the average is 50 years (Schmincke 2000).

Plants such as teak that are cultivated mainly for high value timber products rather than as multi-use crops may not compete directly with bamboo; however it may be useful to make a comparison of the carbon and economic benefits. A so-called precious wood like teak might *de facto* be assumed a more valuable crop when high production multi-use crops like bamboo may actually be more useful for conservation and income generation for community development in many cases.

Teak is one of the top five tropical hardwood species by plantation area in the world, with most plantations in Southeast Asian countries like India, Myanmar and Thailand, but also in tropical African countries like Nigeria and Ghana (Krishnapillay, 2000). Teak cultivation seems to have generated few negative headlines on sustainability criteria so far. However, teak plantations can encourage soil erosion if grown too densely (World Bank Carbon Finance Unit 2006). Teak also does not grow well on marginal or problem soils; but is best suited to deep, well-drained and fertile soils in tropical areas. It also requires a high calcium content of the soil for healthy growth (Krishnapillay, 2000).

A BioCarbon Fund (BCF-a World Bank fund) project for reforesting degraded pastureland with teak in Nicaragua is expected to sequester a net 1.2 million t CO2 over 4,000 ha by 18 years after project begin. (World Bank Carbon Finance Unit 2006) This averages to 81.74 t C/ha, using the conversion 1 t C is equivalent to 3.67 t C02. Because this figure is net—measuring the difference between the total and the baseline scenario—it is difficult to say what the total biomass/ha is from the project documents. The project's sequestration should be lower than the maximum potential, since the trees were spaced widely to prevent soil erosion and allow a thick ground cover. (World Bank Carbon Finance Unit 2006) If the net is for example, two thirds of the total sequestration, then there would be about 123 t C/ha sequestered in 18 years, or about 7 t C/ha (14 t biomass/ha) annually. This assumption may be overly generous however, as teak is a slow-growth species, and this is much higher than a second study on teak.

In a study on teak's carbon capacity conducted in Ghana by the International Tropical Timber Organization (ITTO), two teak plantations with 40 year rotations were estimated to accumulate 107 and 126 t C/ha respectively (indicating a biomass of 214 t/ha and 252 t/ha). This is a very large stock, but since it was reached in 40 years, this indicates an annual production of 3.15 t C /ha/yr, or an average productivity of 15.75 t C /ha every five years on the higher growth plantation. After adding carbon sequestered in soil and teak products over the 40 year cycle, the plantations were measured at 165 t C/ha and 191 t C/ha respectively (330 and 382 t biomass/ha) in biomass, soil and products. ((Boateng, 2005) This indicates an average annual sequestration rate of 4.13 – 4.78 t C/ha, and a 5 year sequestration average of 20.63 – 23.88 t C/ha—including biomass, soil and products.

To compare these figures again briefly to some bamboo species:

The moso bamboo achieved above-ground biomass of 137.9 t/ha in a natural stand, and is generally harvested at 5-8 years. Every 5 years it would produce at least 86.25t / ha biomass total and sequester 43.12 t C/ha, almost twice as much as the teak plantation average – although this does not account for soil or product sequestration. The Bambusa bambos with 287 t/ha above-ground biomass in 6 years would produce about 239 t biomass/ha and sequester 119.5 t C/ha every 5 years, nearly five times as much as the Ghana teak plantation. Interestingly, the production figures cited for Bambusa bambo's mature total biomass at 6 years is in fact even higher than that of the teak at 40 years: 149 t C/ha versus only 126 t C/ha. Though this *B. bambos* stand may be well above average for the species, it could lose half its biomass and still produce 2.5 times as much as the teak annually.

Sequestration over the Long-Term and Sequestration in Products

Of course, the rub in a comparison to a long-rotation crop like teak is how many credits will be generated after forty years. After 40 years, the bamboo will not have any more standing biomass than it did at 5-8 years. On the other hand, the bamboo crop will be harvested annually and will continually produce new culms, so every five years the amount of carbon sequestered on one ha will be the same. The teak cannot withstand more than minimal harvest without losing biomass and compromising the quality of the wood, so the main income from products will not come until the end of the project. If the continuing sequestration in durable products were added to the total carbon sequestration figure, bamboo's productivity would be reflected in longer cycles. It is reasonable to suspect that healthy moso stands could reach or exceed the long-term sequestration

	Mean annual biomass productivity above-ground (t/ ha/yr)	**Mean Annual Increment of Carbon (t C /ha/yr)**	Carbon storage above-ground, 5-yr ave. (t C/ha)	Total biomass carbon storage at maturation (t C/ha)	Total est. carbon storage incl. products (t C/ha)	Citation
Teak (*Tectona Grandis*)	6.3	**3.15**	**15.75**	126 (40 yrs)	**191 (40 yrs)**	Boateng 2005
Eucalyptus grandis	16.14	**8.07**	**40.35**	no data	no data	Gutierrez et al 2006
Plantar high-yield Eucalyptus	17.5	**8.75**	**43.75**	61.25 (7 yrs only above-ground)	no data	Plantar 2000
Plantar clones Eucalyptus	21	**10.5**	**52.5**	73.5 (7 yrs only above-ground)	no data	Plantar 2000
Phyllostachys pubescens	17.24 - 27.58	**8.62 - 13.79**	**43.12 - 68.95**	92 t C/ha (5-8 years)	**159.4 (20 yrs)**	Isagi et al 1997
Bambusa Bambos	47.8	**23.9**	**119.5**	149 t C/ha (6 years)	**442.15 (20 yrs)**	Shanmug-havel and Francis 2002

Table 3: Comparing teak, eucalyptus and two bamboos species

levels of the largest trees using this strategy. There are several accounting tools that have been developed to figure in products in the sequestration totals—however they have not yet been applied to bamboo and would need to be adjusted, presumably, to the different uses and product lives of the bamboo crops.

A "back of the envelope" estimation for an optimal usage twenty year cycle for moso bamboo could be made as follows:

Assuming the bamboo products are harvested at 5 years,

Assuming the products have an average 15 year life after harvest and that 90% of the plant is processed and 75% of the processed biomass is converted to durable products, and

Using the low-end biomass estimate of 43.12 t C/ha, for moso bamboo harvested at 5 years Then:

43.12 t C/ha is sequestered in a constantly renewing pool. To this figure we add

43.12 t C/ha regenerated for four harvests* 90% use* 75% use in durable products for a total of

43.12 t C/ha + 116.42 t C/ha =

159.54 t C/ha after 20 years (585.5 t CO2e/ha)

This is nearly as much as the teak plantations—produced in half the time. The *B.bambos* result is much higher, using the figures from the Shanmughavel study.

At 119.5 t C/ha every five years, the twenty year figure would be:

119.5 + (119.5 * 90% * 75% *4 harvests) = 119.5 + 322.65 =

442.15 t C/ha (1,622.7 t CO2e/ha)

If the products made from bamboo are assumed to have a longer lifetime, then the total sequestration would naturally increase.

Net Carbon Storage

Generally, the studies on the suitability of various species for carbon sequestration do not offer estimates of the net carbon storage (after subtracting the initial and projected carbon stocks and GHG releases due to the project implementation). This is unfortunate because the net sequestration is the most important element, and is the main figure reported in the detailed project design documents (PDDs) required of CDM projects. One 2003 study did offer estimates for net sequestration however, and ranged from *negative* 30 t C/ha for a selective logging system in a degraded tropical forest to 114 t C/ha for the Douglas-fir beech forest (Masera et al 2003:191, 193). The negative figure naturally stands out – and may not be as unusual as it seems. In this case, it resulted from the degraded land and the method of harvest. In another evaluation of projects applying for CDM in Brazil, palm oil plantations were also found to be net contributors to GHG. (Van Vliet et al 2003)

Since no studies have modeled a CDM project using bamboo, an accurate estimate of net carbon sequestration for bamboo cannot yet be made, and will naturally vary depending on project design. Bamboo may show advantages in this aspect if it is grown in a suitable climate requiring little fertilizer or irrigation and using manual harvest, etc. The processing methods of the harvested biomass will also have a large effect on the net GHG removals.

Beyond Carbon: Other Reasons Bamboo is Suited to the CDM

Many of bamboo's characteristics that make it a useful crop for livelihood development work could also yield significant advantages for CDM projects:

- It must be harvested every 4-7 years, depending on species and uses, and should be harvested selectively. This means the carbon variation that would result from species that are usually clear cut is not be a problem. The carbon pool should remain the same every five years at monitoring and verification – which simplifies the project methodology.
- Selective harvesting actually increases the yield. In India it was shown that management of one species increased the annual yield by 20 times. (INBAR 2004)
- Bamboo establishes rapidly after planting, with a mature stand usually reached within 4-6 years. Thus small and large investments pay-off quickly and provide communities with a source of raw materials for a variety of uses.
- Investments to start a bamboo plantation are likely to be lower than that for trees species
- Bamboos can be grown on marginal, peripheral and non-cropped land or be intercropped or rotated with other species and crops.
- Bamboo is an excellent and traditional livelihood development tool, which can be used for raw, semi-processed, or finished materials and sold on local, regional or international markets. Most wood species do not offer the same range of product possibilities and processing may require larger and more sophisticated facilities (INBAR 2004).

Chapter 3

Great Expectations? Qualifying and Financing for CDM A/R

The following section will address the requirements for CDM A/R projects and the experiences with CDM A/R projects. The end of the section will address market and non-market barriers that might keep project developers from making optimal choices.

Although no projects have been developed for bamboo specifically, it will be shown that there is no reason why bamboo cannot qualify for A/R projects. Bamboo easily meets the definition of forest set out by both the FAO and the UNFCCC, though there is some confusion about the UNFCCC definition. (FAO, 2003; UNFCCC CDM, 2005a) Further, its carbon sequestration rate exceeds that of competing tree species in many circumstances. It has also been shown to have desirable characteristics for the production of biofuel such as a high energy and cellulose content. (El Bassam, 2003) Though bamboo forests are often composed of a mix of bamboo and other tree species, this should pose few barriers to measuring the carbon stored in the forests. In fact, many current forestry projects for carbon trade use a mix of species for environmental purposes. Bamboo is also often grown on small plots and on marginal land, however it is also possible to bundle many small plots under one project as long as accurate measurement is made, so even this sort of cultivation could qualify for carbon trading.

Thus, the main impediments to the development of bamboo projects for carbon trade under the CDM are administrative and political. Implementation partners must be found and the first methodology and project proposal still have to be developed and submitted to the CDM methodology panel and board. This will probably require a “CDM bamboo champion.”

The CDM A/R Project Cycle

The development of a CDM certified project involves several steps and considerable upfront costs. The first hurdle for a CDM AR project is the submission of the project proposal, otherwise known as the Project Design Document (PDD).

Prior to this stage, a good deal must be invested in researching the financial and environmental feasibility, the exact location and project boundaries, the project participants, funding, monitoring methods, the legal environment, etc. (Pearson et al 2005). The host-countries "Designated National Authority" must also approve of the project and methodology. (Chadwick et al, 2006)

The PDD however, remains essentially useless before the Executive Board (EB) of the CDM approves the methodology for the project. The development of an appropriate methodology is at the heart of registering a CDM project and one of the most difficult barriers. The methodology must prove that all three of the core requirements will be met and can be proven to be met with a scientific basis for measuring and monitoring the project emissions and carbon absorption.

The project methodology must be approved by two entities. First, a "Designated Operational Entity" (DOE) must validate the methodology. Thereafter, the DOE submits the methodology and the PDD to the CDM EB, which must also give its approval.

If the project chooses to use a previously approved methodology, the project can proceed to the validation stage. If the project proposes a modified or new methodology, then the methodology must be reviewed and approved along with the project design proposal before the process can move forward. (Manguiat et al, 2005, 10)

As of 2004, no AR CDM project methodology had been approved although nearly a dozen had been submitted. The first was approved in early 2006, and two more had been approved by mid-2006. There are currently seven approved methodologies[5], mainly applying to projects that have been in the pipeline for quite some time.

The scale of the transaction costs seems likely to keep smaller landholder's from registering projects, however there is also a simplified procedure including pre-developed methodologies and a lower registration fee for small-scale CDM projects that produce less than 8,000 t CO2e.

Validation and Registration

If the methodology and design are approved, the DOE can validate the project based on the project design and its adherence to the principles of CDM. After this, the project can be registered with the CDM EB. (Manguiat 2005, 10)

Verification, Monitoring, Certification and Issuance

After registration, the project must be verified, monitored, and certified before the carbon credits are issued. The timing for the first verification can be chosen by the project participants. Thereafter, a DOE will review the emission monitoring reports every five years for continued verification and certification of emission reductions. (Emmer 2005)

The project participants should carry out the monitoring according to a plan presented in the project design document. The DOE will review the monitoring results in the verification process, confirming the change in GHG emissions resulting from the project. In the case of tCERs, the DOE verifies the GHG reductions for credit after the first 5-years. In the case of

[5] As of April 2007, as listed on the CDM A/R approved methodologies page: http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

lCERs, the DOE reviews the activity since the last review until the project end. (Manguiat et al. 2005, 10-11; Chadwick 2006)

After verification and at project end, a DOE must certify that the project achieved the net anthropogenic emission reductions as verified by the first DOE. The certification is then submitted to the CDM registry and CERs are issued on its basis. For all but small-scale projects, two different DOE's must be involved: the first validates the project before registration and the second verifies and certifies the project. (Manguiat et al. 2005, 12; Pearson et al 2005) The DOE's will also check to see if environmental and socio-economic criteria have been fulfilled. (UNFCCC CDM 2004)

For tCERs this means that the credits are available to be sold at the end of the 5 year period they were issued in and are valid for the next 5 year crediting period. For example, they are measured and issued in 2008-2012 and count for the period 2013-2017. For lCERs, credits will be issued after the first validation for that accrediting period and will have to be replaced after the project end. That is, for example, 30 year lCERs can be issued in the 2008-2012 period based on actual biomass measured during the verification in that period and will not have to be replaced until 6 crediting periods (30 years) later. However, the credits have to be recertified every 5 years. If the biomass measured is lower than at issuance, the buyer has to replace the now missing credits with credits from another source. If biomass has accumulated since the last recertification, additional lCERs will be issued on the basis of the new biomass each time. However, the new lCERs are only valid till project end. (UNFCCC CDM 2004)

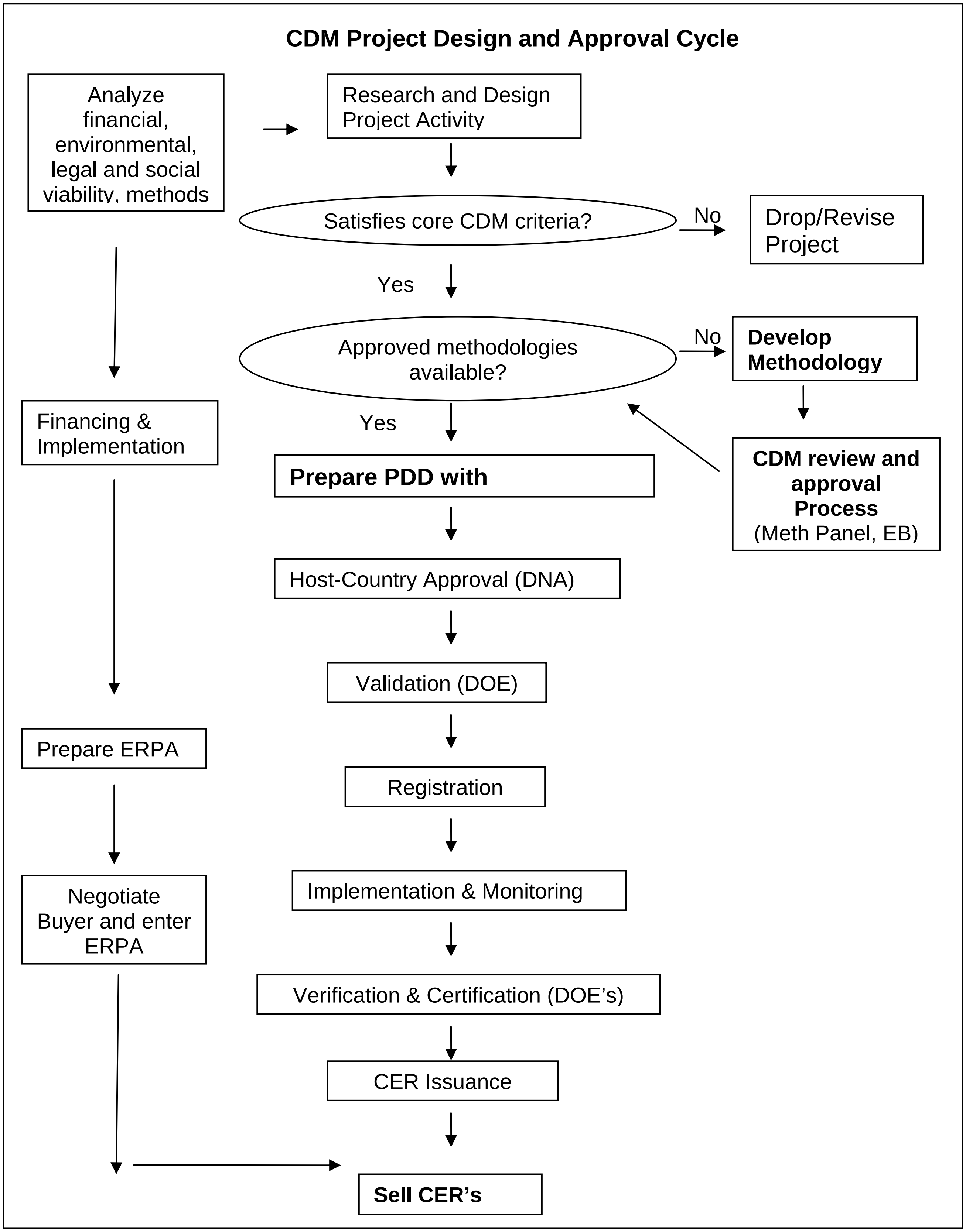

Figure 1: CDM Process and CER issuance
Based on illustrations from Kubo 2005 and Crisil 2005

Modalities for CDM Forestry Projects

Technical details for forestry projects and guidelines produced by the UNFCCC working group on afforestation and reforestation CDM projects (A/R CDM) were developed in Marrakech in 2001. However it was only threes years later at COP10 in Buenos Aires in 2004 that specific definitions for land use changes were laid out to help standardize the measurement of AR projects. In the previous year, the IPCC had issued a good practice manual, GPG LULUCF, (IPCC 2003) which became the basis for evaluating the quality of AR methodologies. Not following IPCC guidelines along with lack of technical expertise were one of the key reasons for the rejection of several of the first AR projects. (Kaegi and Schoene 2005).

Some of the key rules and modalities relevant to A/R projects are:

- Proving Additionality
- Establishing the land eligibility
- Developing the baseline and project scenario
- Measuring the carbon stock base and changes in the carbon pools
- Monitoring the Project
- Measuring "Leakage"

Additionality - Verified Extra Removal of GHG

Additionality was defined at COP 9 as follows:

> *"An afforestation or reforestation project activity under the CDM is additional if the actual net greenhouse gas removals by sinks are increased above the sum of the changes in carbon stocks in the carbon pools within the project boundary that would have occurred in the absence of the registered CDM afforestation or reforestation project activity."* (Manguiat et al. 2005)

Thus, the entire project centers around proving that "additionality" has been met—from proving land eligibility to measuring new carbon sequestration and providing evidence that the project could never have been carried out without the CDM framework. However, the criteria for formally proving additionality has been unclear and has proved to be one of the key stumbling blocks for projects developers. In 2005 the UNFCCC approved a "tool" for guiding project developers through an additionality proof, which should standardize the evidence submitted and the judgments on fulfillment. The formal tool for additionality makes reference to all other criteria for project eligibility but centers around the financial analysis. Project developers may use either a financial analysis showing that the project would not meet the required rate of return without the prospect of CER revenues, or a barriers analysis detailing barriers to investment that can only be overcome or avoided using the CDM project. (UNFCCC CDM, 2005a)

The Investment Analysis and Other Barriers to Implementation

In some ways, CDM projects look a bit like a catch-22, because they are supposed to employ market mechanisms for environmental services, but the projects cannot be profitable in themselves. The intended loophole out of this conundrum is that the projects can make a profit, i.e. be economically viable, if the profitability derives from expected sale of the carbon credits. Proving that economic viability can only be reached with CER sales is another key component of the additionality proof. As mentioned above, the tool for proof of additionality for A/R projects was approved in 2005 at the 21st meeting of the executive board in Bonn Germany. (UNFCCC CDM, 2005a). It lays out fairly clear criteria which should assist new project developers and lay to rest some of the debate about whether additionality was sufficiently proven in previously submitted CDM AR projects.

The first and core step of proving additionality is identifying the alternatives to the project, addressing the enforcement of laws and land eligibility, and selecting a baseline scenario. At this point, the proof must move on to an investment analysis. However, there is another loophole—if the investment analysis is failed, the developers may present a barriers analysis.

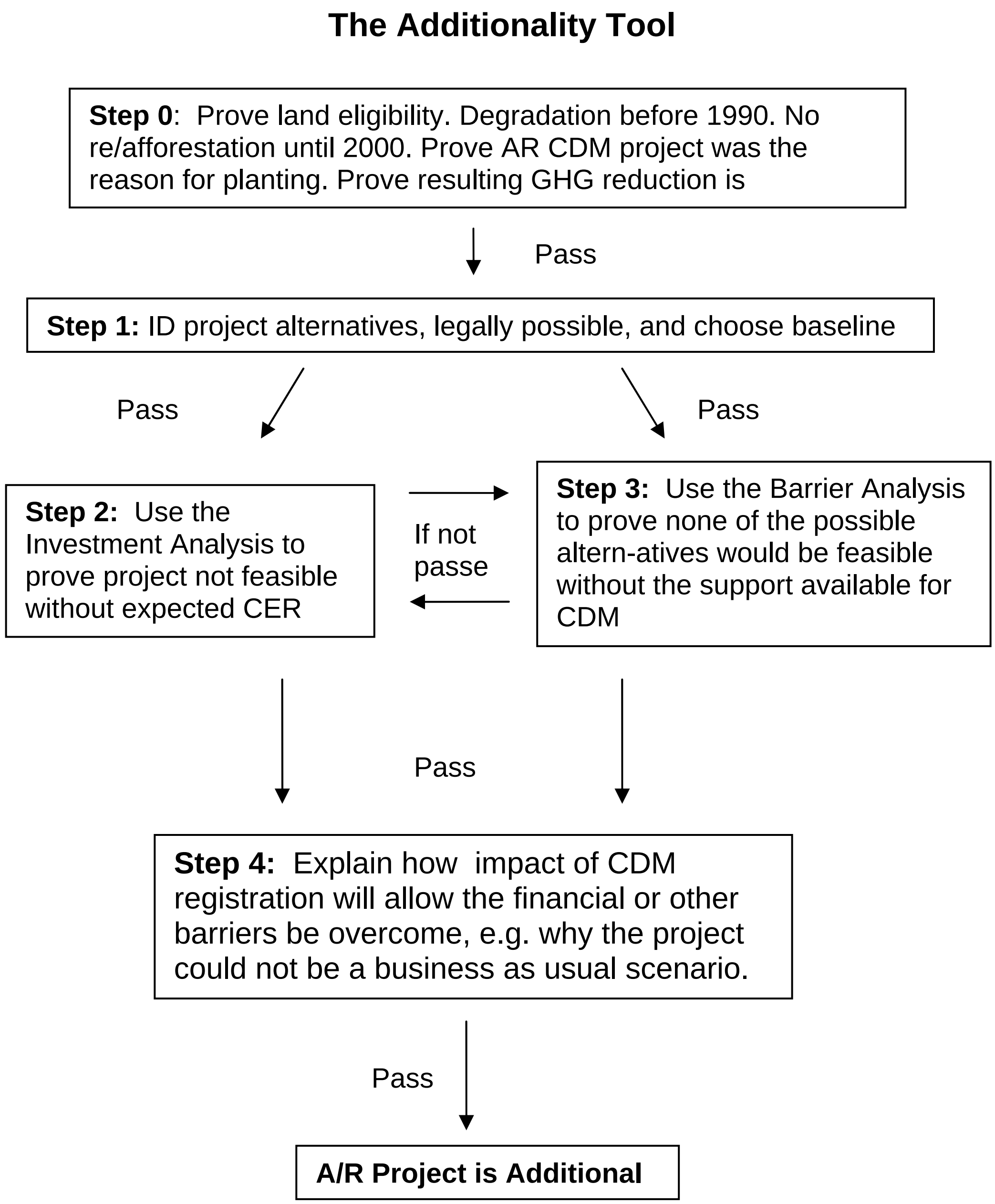

Figure 2: Steps to proof of Additionality (Adapted from UNFCCC CDM 2005a)

For the investment analysis, one option is to present a simple cost analysis showing no project benefits other than CDM revenue. The second option is an actual investment analysis. For the investment analysis, the project authors may identify which financial indicator is most appropriate for financial decision making in their project, such as the internal rate of return (IRR), required rate of return (RRR), net present value (NPV), or a cost-benefit ratio. A benchmark analysis is then applied that should represent *standard returns in the market*, appropriately discounted for risk and opportunity costs. The applicable benchmark rate can be shown with government bond rates, commercial lending rates, or if only one company is involved, the company's weighted average capital cost. The benchmark should also be shown to have been used for similar projects in the past.

The investment analysis should show either that the project does not return the benchmark rate without financial benefits from the CDM, or that the CDM project proposal is not as financially attractive as an alternative use for the land (the baseline). After the investment analysis, the project developers must present a sensitivity analysis that shows the conclusions reached in the investment analysis are robust results for a range of varying assumptions about the land use and costs etc.

If the investment analysis fails the sensitivity analysis, then the project developers move on to a barriers analysis. This analysis should show that the proposed project activity faces barriers that would hinder its implementation without the CDM framework and benefits but that the baseline scenario does not face these barriers. The barriers may be financial, social, institutional, ecological etc. as long as it can be proven that they hinder the CDM project but not at least one other viable alternative to CDM.

After successfully passing either the investment or barriers analysis, the project proposal should address the impact of CDM registration. The impact should show that CDM registration will create benefits and incentives that will alleviate the financial or other hurdles mentioned in the steps before. (UNFCC CDM 2005a)

Land Eligibility

The requirements for A/R CDM land eligibility are as follows:

Deforested before 1990, Project Begin Not Before 2000

The project land must have been deforested or degraded before 1990 and not have been satisfactorily restored since. (Manguiat 2005, 13) Also, the project implementation cannot have begun before the year 2000. (UNFCCC CDM, 2005a)

Not a Forest Now, Will Become a Forest Through Project

The land must not currently meet the minimum definition of a forest, will not meet the definition if left alone, but will meet the definition with the project activity. The CDM definition of forested land, decided at COP 10 in 2004, is defined by minimums. The minimum land area must be between 0.1-1 hectare, with a minimum crown cover of 10-30 % and a minimum height of 2-5 meters. (Cosmann et al 2005) Each host-country's DNA must select their definition of a forest and report to the CDM EB before any CDM AR projects can start. (Manguiat, 2005, 13)

Land Tenure Must be Resolved

Issues of land tenure for project implementation and receipt of carbon credits must be satisfactorily resolved. Any other legal issues such as forest access by the community must be resolved and the local stakeholders must have been adequately consulted and informed of project plans. (UNFCCC CDM, 2005a; 2004)

Baseline and Project Scenario

Creating a project baseline involves measuring the current state of the land and its most likely use and resulting carbon change without any CDM project activity. This should be done using a dynamic and stratified model of the vegetation. (Cosmann et al. 2005, 23-24). The estimation should include projections of human intervention (anthropogenic change) such as agricultural conversion, soil erosion and anthropogenic fires. It should also include natural changes or indirect human impacts such as changing wildlife, the intrusion of invading species and climate change. (Cosmann et al 2005)

Leakage
The project scenario must also subtract carbon sequestered for "leakage" due to the CDM project activity. "Leakage" is a change in carbon flows outside of the project boundaries due to the project activity. One example of leakage would be a reforestation project that displaced farmers who then cleared new land for cultivation outside of the project. (Pearson et al., 2005, 5) Other examples of leakage could be more subtle, such as emissions caused by the transport of materials to the project site.

Monitoring
Monitoring is the developer's responsibility and is only verified by a DOE. This involves collecting data through modeling, remote sensing and on-site sampling to verify the accumulation of biomass. (Cosmann et al., 2005, 24) The monitoring will measure only the carbon pools and GHG releases defined in the project proposal.

Defining and Choosing the Carbon Pools

Biomass is converted to a carbon estimates using the standard ratio of 50 percent carbon per unit of biomass. This standard conversion has been widely accepted as a fairly accurate substitute measure of carbon content since Brown's 1997 FAO study on measuring biomass. Carbon estimates are converted to CO2 equivalents (CO2e) by multiplying tons of carbon per hectare by 3.67. Carbon sequestration in bamboo species would be measured in the same way, however using different equations to estimate the biomass and sequestration in soils.

To ensure additionality, only some of the carbon pools will be measured in most cases. It is, for example, difficult to prove that project activity resulted in an increase in soil carbon content, or in some cases in litter, so many projects measure only above-ground and below-ground biomass in the tree species. Biomass measurements for the trunk are usually made using the diameter at breast height measurement (DBH at 1.3 m) which is then converted into biomass using equations developed for the tree species (Emmer 2005, 7). Interestingly, most projects also do not attempt to measure below ground biomass through sampling, but use a standard ratio that assumes below ground biomass is 26 percent of the above ground biomass. The IPCC guidelines recommend using this ratio or 'locally derived data' as good practice due to the 'lack of standard methods and the time consuming nature of monitoring below ground biomass.' (IPCC 2003) Soil sampling is subject to a separate set of requirements.

Further study on the actual carbon content of different tree species would be very useful in order to more precisely determine which tree species store more carbon in which conditions.

The Missing Carbon Pool – Sequestration in Products

Another question important for monitoring carbon pools is whether or not sequestration in durable products derived from timber can be counted. Several studies on sequestration have measured sequestration in products and argued for their inclusion to provide incentives for producers and consumers to conserve and use the wood products efficiently. (Boateng, 2005; Cairns 2005) The current guidelines however, do not recognize sequestration in products. (Pearson et al 2003; UNFCCC CDM 2004) The issue has been raised repeatedly, but no action has been taken so far, and the accounting rules assume that all carbon is released upon harvest. In May 2006 the scientific advisory body of the CDM decided to gather even more evidence and debate again in May 2007. (UNFCCC, 2006) The 2006 IPCC guidance handbook does include a chapter on sequestration in hard-wood products, though it acknowledges that the UNFCCC has not made a decision on the issue. (Pingoud et al, 2006)

Estimation of Non-CO2 GHG gases

Forestry projects are generally aimed only at reducing CO2 emissions, but project activity may involve the release of methane (CH4) and nitrous oxide (N2O), which are both much more potent global warming gases than CO2. Project monitoring must include subtractions of CO2e for the release of these gases through the use of machinery, fires, drainage of wetlands, and fertilization. (Pearson et al 2005, 33)

What to Grow and Where?

Although neither the CER buyers nor the CDM officials are officially interested in a comparison of which trees are best at storing carbon in which circumstances, the project financers should be. Unfortunately, only limited research has been carried out on the specific carbon sequestration capacity of different species. More is known about the optimal rates of growth of different species, so growth estimates still proxy for carbon content.

Some considerations that could be important for project developers are listed below:

- Younger trees rate of sequestration increases much more quickly than mature trees – but mature trees represent a larger over-all pool. (Cosmann et al, 2005)
- Carbon sequestration may be higher in longer lived trees with higher wood density than short-lived, less dense, fast-growing trees. (Cosmann et al, 2005)
- Total carbon sequestration peaks at different ages for different trees
- Species should be chosen carefully: As mentioned, a palm oil plantation was actually a net source of carbon. (Van Vliet et al., 2003)
- Geography matters: tropical forests store more above-ground biomass than temperate, but temperate forests store much more carbon in the soil. (FAO 2006a) Also, biomass production is dependent on the quality of the soil and availability of water. So plantations will sequester the most carbon in good growing conditions – but degraded landscapes, one of the prime targets of CDM, should be less productive in the first years and may even require the application of fertilizer. Both factors, low productivity and the need for fertilizer, naturally reduce the net emission reductions and increase costs.

Simplifications for Small-scale Projects

Small-Scale AR projects will be subject to most of the same problems and considerations. However, to lower transaction costs, as mentioned earlier, small-scale projects are subject to simplified requirements and procedures and as well as a lower registration fee. The Marrakech Accords defined small-scale projects as those that emit less then 15,000 t of CO_2 equivalent annually and reduce GHG emissions from the business as usual scenario. (UNFCCC CDM, 2002). However, small-scale A/R projects are now limited to only 8,000 t CO_2e of sequestration in sinks annually, which would limit most projects to well-under 500 ha.

The projects should also be developed and implemented by low-income communities or individuals. (UNFCCC CDM 2004) Small-scale projects also benefit from pre-approved and simplified methodologies; simplified requirements for the PDD and monitoring, the ability to bundle small plots for a larger projects; being allowed to use the same DOE for validation; verification and certification; and they pay only US$5000 for registration. (UNFCCC CDM 2003b)

Will Bamboo be Recognized as a "Tree"?

The host-country DNA's definition may affect whether bamboo or other "non-woody" (herbaceous) species like palms or bushes can be considered for A/R sequestration projects. (Dutschke et al, 2006, 59) A 2006 study on the risks and chances of combining forestry and biofuel projects, commented that there was a gray area on the definition of trees and that host country governments might want to exclude "non-woody" species like "palms, bamboo and bushes." (Ibid) On the other hand, the term tree seems slowly to be replaced in many official documents with the term "woody biomass", and the majority of bamboo are woody species rather than herbaceous. Thus it must be assumed that the Dutschke article was referring to the few herbaceous bamboos and not to bamboo as a class.

However, the author sent a questionnaire to an electronic list of GHG project experts asking if bamboo would be eligible for CDM A/R; and only received three answers, all of varying opinions and all asking for further information. One expert thought that DNA's had already excluded bamboo as a class, but the author has not been able to confirm this. Apparently, limited familiarity with large bamboo species on the side of government agencies, CDM officials and the project developers themselves present the largest danger to a bamboo project developer. A FAO paper published in 2006 summed the problem for country DNA's in their choice of how to define eligible land as follows:

> **"The definition of a tree:** The Marrakech Accords do not define a tree. According to FAO, a tree is: "a woody perennial with a single main stem, or, in the case of coppice, with several stems, having a more or less definite crown; includes bamboos, palms and other woody plants meeting the above criteria" (FAO 2005). Banana plantations would not qualify as forests, even though the constraints of minimum height, area, crown cover might be satisfied. Conversely, oil-palm plantations, bamboos, or fruit orchards may be eligible if they match the definition." (Neeff, von Luepke and Schoene, 2006)

Thus, the FAO opinion favors the inclusion of bamboo, as well as palms, but confirms that the UNFCCC has left the definition vague and given host-country DNA's considerable flexibility.

If bamboo are not blocked for political or bureaucratic reasons, bamboo should face no difficulty meeting the core requirements for a forest. For moso bamboo for example, the crown cover ranges from 50%-90% when the density of culms ranges from 1,500~4,200 culms/ha. The tropical (semipodial) clumping bamboos may have an uneven distribution per hectare but should still fall well-above the crown requirement. The height requirement is also easily fulfilled for any bamboo species that would likely be used for carbon sequestration. The moso bamboo for example is often quoted at maximum heights of 80 feet and average heights of 40 feet (12 to 23 meters). The relatively small area requirements theoretically would allow small-landholder or village participation with small plots of bamboo grown around farms and houses, although making small projects economically feasible is that will most likely only be overcome with government support.

Bioenergy Projects

Bioenergy projects utilizing woody crops would not fall under the A/R guidelines. That is, a bioenergy project might have an A/R component, but the part of the project applying for mitigation credits would be subject to normal CDM rules. (Dutschke et al, 2006)

More exactly, currently there is no combined methodology for terrestrial sequestration and bioenergy. Developing one will be subject to considerable difficulty because there is a separate methodology panel for A/R projects and no A/R experts on the regular Methodology Panel, so it is not certain who would review the methodology or if they would be able to combine to make a judgement. So far, the only option is to submit two methodologies and register the project as two projects, one for sequestration and one for generation of energy from fuel. (Dutschke et al, 2006) Forestry projects for bioenergy may want to register for forestry sequestration credits first to account for the standing and renewing plantation stock, followed by fuel-switch credits from the production of bionenergy from a complete or selective harvest of the plantation. The controversial Plantar project in Brazil is an example of this strategy.

From a financial perspective, the bioenergy component would probably be more valuable since the CERs are permanent, while forestry CERs are discounted for their limited validity of 5-30 years. Many bioenergy projects have been approved and CERs from these sorts of projects are already being traded on the European carbon markets.

Financial Viability of Forestry CDM

The actual revenue to be gained from forestry CERs is, to employ a useful cliché, the million dollar question. As mentioned earlier, some experts predict their value at 14-30% of the CER price (Manguiat et al 2005), but the evolution of the CER price and the expectations for forestry projects are certain to change during the next 5 and next 10 years. When planning a forestry project, the planners must estimate their expected revenue as many years in advance as it takes for the project to reach a worthwhile biomass for CER issuance, and with the risk that the project will not be approved at all – which is still a problematic exercise at this point. Changes in global weather, economy and politics will also affect the supply and demand in hard to predict ways. Developing a CDM project also involves considerable upfront and transaction costs, including funds for research and the project design, funds for development of the methodologies, legal and administrative costs for the project approval process, monitoring and verification costs, and delivery risk and brokerage fees. (Chadwick, 2006)

The Carbon Market – And Forestry's Place

This year, a decade after Kyoto and six years after the decision to include forestry in the CDM, a guidebook on "the commercialization of CDM forestry projects" (Neef and Henders, 2007:1) notes that forestry activities have high potential to meet the CDM goals, but that the potential will not be realized unless they manage to transform their sequestration into meaningful revenue streams. (Ibid.) Other categories of CDM projects are already generating revenues and fuelling many new investments in alternate energy technologies. Forestry projects on the other hand, are still struggling for legitimacy and markets.

In 2005, 374 million tCO2e globally, were transacted at a value of USUS$2.7 billion with an average price of USUS$7.23. CDM credits accounted for 49.2% of the volume and commanded 27.2% of the market and in the first quarter of 2006. (World Bank Carbon Finance Unit and IETA. 2006) Yet from January 2005 to March 2006, land use change projects (i.e. AR) made up only 1% of the market share. (ibid)

In fact, in the last two years, more than 992 million tons of CO2e worth US$18 billion were traded in the international carbon market. (Neef and Henders, 2007) This would indicate an average final value of about $18 per credit. In the ETS, CER's were trading for about 85% of the European Reduction Units (ERUs) in the first months of 2007. (Rentsch, 2007)

Predictions of the future price of tCERs and ICERs are mainly speculative—nevertheless, a ballpark estimation can be attempted. The price of 1 t CO2e hovered briefly around €30 on the mandatory European market in the spring of 2006 but fell to half that (€15) by midsummer (Carbon Point, 2006). If mandatory ERUs are worth €15 (currently about US$18), permanent CERs would be worth US$15.30 and forestry credits would now be worth US$2.14 to US$4.59, assuming a value of 14-30% of other CERs. Yet this is the final value. Project developers will sell their CERs upfront before they are delivered in order to get financing. CDM project developers are now actually selling their future credits at about $8 per CER, following a decision by China to establish a minimum price of $8. (Rentsch, 2007) In this case, forestry CERs would only bring in between something like US$1 to US$2.50. To make this figure even more depressing, innovations that make industrial emission reductions cheaper may continue to depress the world price even as more countries enter the market.

Given the uncertainty of both carbon and timber prices, Gutierréz et al (2006) concluded that forestry management will be more profitable using the 5-year tCERs than the minimum 20 year lCERs, which do not allow the flexibility to sell some of the timber at 5 year intervals. In that study, a profit maximization analysis for CDM forestry projects, if timber prices remained high and carbon credits were around US$5, fast growing short rotation crops with harvest or thinning every 5 years were the most profitable. However, if forestry credits reached US$13, the optimal rotation length reached 40 years. At lower prices, earlier and intensive thinning for timber revenues were more profitable than waiting for the maximum carbon storage to be reached.

The next section shows that these prices will not be enough to justify many if not most carbon forestry projects unless they have other substantial sources of revenue, i.e. from valuable products after harvest. The 2006 market conditions in fact prompted one author to remark, “Under current price expectations, the pure carbon value will hardly motivate additional (forestry) projects.” (Dutschke et al, 2006)

Revenues and Costs

When planning a forestry project, the planners must estimate their expected revenue as many years in advance as it takes for the project to reach a worthwhile biomass for CER issuance, and with the risk that the project will not be approved at all – which is still quite likely. Changes in global weather, economy and politics will also affect the supply and demand in hard to predict ways. Developing a CDM project also involves considerable upfront and transaction costs, as well as financing costs, delivery risk and brokerage fees. (Chadwick et al, 2006)

Transaction Costs

In the case of CDM forestry projects, transaction costs are not measured just in fractions of percents, but are very substantial. The 2007 guide (Neef and Henders) to commercialization of forestry projects lists the following transaction costs:

- US$ 60,000 – 180,000 for project preparation
- US$ 15,000-25,000 for validation
- Variable monitoring costs (It seems reasonable to budget at least US$15,000.)
- US$15,000- $25,000 for verification by a Designated Operation Entity (DOE).
- Registration fee and Issuance Fee: For the first 15,000 CERs, US$0.10 per credit, all additional CERs exceeding 15,000 cost US$0.20/CER. A project expecting 50,000 CERs annually would pay $8500 upfront for registration.
- Adaptation levy: 2 percent of issued CERs are retained by the EB for adaptation funds.
- Taxes : Some countries claim a further share of CERs for the Letter of Approval (LoA).

Based on these cost estimates, a project expecting 50,000 forestry CERs would pay at least US$99,500 even without considering taxes and monitoring costs. If the project issuers sold to the World Bank at $3.50 per forestry CER, they would generate revenue of $171,500 and transaction costs would eat up at least 58% of the carbon revenue. This makes it very clear that the project must generate revenue from other sources considering the substantial costs for land, materials and labor as well as financing, which are needed to implement a forestry project.

Financing

Most CDM credits are currently sold through "Emission Reduction Purchase Agreements" (ERPAs) that are negotiated well before the registration of the project due to the need for upfront financing. The price for each credit is lower the earlier the agreement is negotiated and the higher the delivery risk for the credits.

Again referring to the new guide for commercializing CDM forestry projects, Neef and Henders (2007) explain that CDM projects are generally financed with some debt and finance, with carbon sales acting as a "sweetener" for an otherwise uninteresting position. Forestry carbon projects with their sustainability and additionality requirements, may "provide carbon credits at competitive rates" (Neeff and Heners 2007) once implemented but have a hard time attracting finance up front for a number of reasons. CDM forestry projects involve:

- high upfront costs for land, materials, infrastructure, and studies
- delayed returns on investment—from a minimum of 7 years to more frequent time span of twenty or more years
- little access to needed resources, poor infrastructure, and no insurance
- low rates of return compared to other sectors
- high risks from weather and political variability

(Neef et al 2007)

CDM A/R Project	Considered CER Price	Considered time frame	IRR w/o CERS	IRR w/ CERS
Moldova Soil Conservation Project	US$3.5	100 yrs	4.2%	5.8%
Facilitating reforestation for Guangxi watershed management in the Pearl River Basin, China	US$3	20 yrs	8.4%	15.8%
The Mountain Pine Reforestation Project	NA	NA	<15%	>15%
Treinta y Tres afforestation combined with livestock intensification	NA	30 yrs	10.8%	NA
Rio Adquidaban Reforestation Project (RA)	US$15	24 yrs	8%	15%
Kikonda Forest Reserve Reforestation Project	US$5	24 yrs	7.6%	14%
Los Eucaliptus afforestation project	US$3.5	52 yrs	8.4%	10%
Mexico Seawater Forestry Project	US$3	20 yrs	11.9%	12.9%
Afforestation for Combating Desertification in Aohan County, Northern China	US$3	20 yrs	4.1%	13.6%
Carbon Sequestration in Small and Medium Farms in the Brunca Region, Costa Rica (COOPEAGRI)	US$3.8	20 yrs	14.4%	21%
Treinta y tres afforestation on grassland	NA	20 yrs	10.3%	12.5%
Reforestation on degraded land for sustainable wood production of woodchips in the eastern coast of the Democratic Republic of Madagascar	US$10	30 yrs	5.1%	10%

Table 3: IRRs and expected prices from selected draft PDD's
(Reproduced from Neeff and Henders, 2007)

Variable Prices and Variable Costs

Looking at the cost of implementation, disregarding the costs for CDM registration, a wide range of figures have been reported for A/R projects so far, from less than US$1 to US$68 per ton of avoided CO2e. In 2000, the IPCC quoted undiscounted costs from AIJ projects at US$3.67 - US$30.67 per t CO2e, or US$1-US$10 per t C. (Van Vliet, Faaij and Diepernink 2003) A joint OECD and IEA review of forestry projects (Ellis 2003) noted that several projects reported costs under US$6/tCO2e, but the estimations ranged from US$1.48/t CO2e to US$68 /t CO2e. (Ellis, 2003) Opportunity cost might also not be factored in to many early studies reporting low costs. A case specific analysis involving laurel plantations in different climate zones in Ecuador (Benitéz-Ponce 2005, 63-65) estimated minimum necessary revenues of US$9 to US$16 per tCER accounting or US$8 to US$15 per lCER to switch from agriculture to forestry; due to lost revenue from not using the land for pasture or other crops.

Another 2003 review of six AIJ forestry projects (Van Vliet et al., 2003) noted some developers had reported real costs under US$0.82 per t CO2e . However, after analyzing the projects, the study authors concluded the real costs varied by project from US$1.15 to US$ 4.19 per t CO2e. Of these projects, only two were profitable without CER revenue. The study also showed that the reported cost estimates could vary by as much as 200 percent depending on the assumptions made about accounting systems, costs and the discount rate. (Van Vliet et al., 2003) On the other hand, the authors also noted that the scarcity of capital in developing countries will continue to help justify CDM registration even for otherwise profitable projects, which generally entail considerable upfront capital. (Van Vliet et al 2003) However, given the considerable costs of CDM A/R registration, this prediction may not be born out. Of course, that prediction was also made in 2003, and it may not have been clear then how high the registration costs would be.

On a related note, most agroforestry projects will not benefit from an attempt at CDM registration. Agroforestry is a very popular development concept, but intercropping produces only a few carbon credits per ha, so the revenues would not outweigh the costs of attempting CDM registration. A 2005 study of the benefits from switching from maize monocropping to agroforestry in Indonesia concluded that participating in the carbon market would be profitable *in the absence of transaction costs* (Wise and Cacho 2005) – which is, as we have seen, an unrealistic scenario unless some beneficient third party agreed to take over all of the project design and registration costs.

Chapter 4:

The Results: The Projects Prepared So Far…[6]

Interestingly (and damningly) the main issue in designing CDM projects for forestry up until mid 2006 at least has not been on which species are most suitable for climate and sustainable development, but rather just on fulfilling the technical requirements for project approval and registration – starting with developing the methodology. Sustainability in terms of environmental and social or economic benefits are given fairly cursory attention. For example, several PDD's state, in essence, only that soil erosion will be controlled and that local people will have employment due to the project.

What the PDD's Tell Us

Referring to Table 3, it becomes evident that project developers have made widely varying assumptions about the prices they will receive for their credits, and the ones who have estimated prices of more than US$4 seem to be either foolhardy or trying to make a case for a project that would be viable even without CERs. However, the more recent projects seem to gravitate around the $3 per credit and a time frame of 20 years, which is reasonable if they gain support from the World Bank. At first glance, it may seem puzzling that the projected IRR's are remarkably similar with or without carbon revenues.

Reading through the PDD's (all PDDs are available on the UNFCCC CDM website), it becomes clear that many project developers are gravitating toward commercially viable projects that provide either high long-term returns or that have a short rotation and easily available

[6] All information in this section unless noted otherwise is from the PDDs submitted to the CDM EB and available on their website.

market. The most favored tree species are fast growing paper and pulp trees followed by trees for timber, especially eucalyptus and pine trees, followed by some teak plantations. These trees are seldom native and particularly in the case of Eucalyptus, intensive plantation growth can raise concerns about soil depletion and loss of biodiversity, and their cultivation is often backed by large international paper companies (Binkley and Stape, 2004; Greenpeace, 2004a and 2004b)

The exceptions are programs backed by environmental NGOs or by an environmentally minded host-country development program, neither of which are under an obligation to make a return, and which focus on mixed forests for livelihood purposes and environmental restoration. Sustainability seems to be shortchanged in many projects, though it is too early to say which ones will make it to registration or not. Some projects are even based on schemes to afforest areas that do not naturally support forests, particularly in Uruguay—these scheme seems unlikely to benefit the natural ecosystem or soil carbon balance even if it does generate income.

In fact, the trends evident in the PDDs seems to confirms the model predictions made by Gutierrez et al (2006) that low prices will lead to short rotation crops for intensive harvesting.

By early 2007, one project had been registered, five were in validation, and approximately 20 more were requesting registration, some using already approved methodologies.

#1 Registered

Pearl River Delta Restoration: The first approved methodology and registered project

The main goals of the Pearl River Delta CDM project are to alleviate poverty, reduce threats to local forests, improve biodiversity and protect the Pearl River watershed. The project will replant shrub land, grassland, and open tree land with cover less than 20%. The project plans to plant a mix of species, 75% of which are native to the area. Of the non-native species, Eucalyptus makes up the bulk and is expected to be used for fuelwood, some harvesting for timber will also be conducted. Finance was provided by World Bank and government funds.

#2 Approved but not in Validation

Assisted Natural Regeneration on Degraded Land in Albania (AR-AM0003)

This project pioneered the third approved methodology. The project will reforest highly degraded land with a multi functional broadleaf and mixed broadleaf forest of native species. Only one non-native species, the Robinia, will be used, and will not be planted in monoculture plantations, although it will make up about 30% of the species mix. The Robinia is justified by its usefulness for firewood, poles, fodder and honey production. The project is implemented and financed by the Government of Albania, a Japanese grant and contributions from "beneficiaries" (BioCarbon Fund project information).

In Validation

#3 Reforestation of severely degraded landmass in Khammam District of Andhra Pradesh, India under ITC Social Forestry Project.

This project involves growing plantations of fast growing Eucalyptus for firewood and pulp production for paper mills. Regarding sustainability, the developers state that the species are non-native but have been grown in the area for 200 years and are not sensitive to variations in rainfall, and that locals will benefit from the income.

#4 Bagepalli CDM Reforestation Programme

The Bagepalli project seems exceptionally ambitious on the sustainability front. The developers plan to plant a wide variety of native trees and other woody plants that should provide fruit, fodder, fuel and timber for local farmers as well as improving the soil. The PDD states that Eucalyptus is bad for the soil and is thus not included. The PDD does not provide financial information, referencing investment barriers instead. It must be assumed that funding will be provided by NGO’s or public sources as the project is clearly not commercial.

#5 Moldova Soil Conservation Project (AR-AM0002)

The soil conservation project in Moldova is almost five times larger in scale than the Pearl River project - reforesting 19, 768 ha of degraded and eroded state and communal agricultural land in different areas of the country. The project, financed by the World Bank, will use a mix of native and semi-exotic species, and each site will be replanted with more than one species and some shrubs. The semi-exotic species are meant to provide fuel wood, but the project description also claims that these “adapted naturalized” species are more valuable for the first stage of land reclamation and soil stabilization, as the native species require better soil conditions. The native species also include the slow growing oak, which will be planted in a second cycle. This project would also clearly not be possible without generous public funding, as the return over 40 years is only 4.7 percent with carbon revenues from the Bank.

#6 Uganda Nile Basin Reforestation Project No.3

This project is one of the few small scale projects and could thus avail itself of a pre-approved methodology. Seventy five percent of the plantings are of a large pine species which will be harvested for timber after approximately 20 years. It provides no cost and revenue data, but considering that it is mainly a timber project, might provide fairly good returns.

#7 Small-scale Reforestation for Landscape Restoration (Yunnan, China)

The second small scale project proposed the project in Tengchong, Yunnan, is sponsored by two environmental NGOs and has primarily environmental and livelihood benefits. A mix of all native species are being planted as a buffer forest around a nature reserve. No financial returns are given, and it must be assumed that it is primarily a development project with no financial return to speak of.

#8- 14 Projects with Methodologies under consideration

Seven new projects have submitted new methodologies to the EB which are currently under review. Of these, four intent to plant mainly commercial wood species of either Eucalyptus, teak or pine for timber or paper industries. One of these commercial projects, the "San Carlos" Land Restoration Through Silvopastoral Systems, is planning to implement forestry plantations on native grasslands in Uruguay with the intent of generating revenues from timber and pulp as well as cattle-ranching in some silviopasture areas. It expects an IRR of 10.96 percent without carbon revenues and 13.6 percent with carbon revenue. There seems to be no justification for why the grassland should not be restored rather than afforested, however the Uruguayan government has encouraged commercial plantations of eucalyptus and pine trees for several decades.

B Methodologies

#15 Rubber outgrowing and carbon sequestration in Ghana (ROCS-Ghana)

The Ghanian rubber project is supported by ODA funds and is intended to foster a local sustainable industry of rubber harvesting.

C Methodologies (#16-24)

Nine more projects had their methodologies rejected and most are expected to resubmit after revisions. Of these, at least 4 involve mainly commercial plantations, and two more are planned for afforestation in Uruguay.

Why methodologies or projects are rejected

According to a 2005 survey of rejected AR methodologies, many of the problems from unsuccessfully submitted methodologies can be generalized as *not following the rules* well enough. The CDM methodology panel expects exactness, precision and conservatism and many project developers did not adequately demonstrate these principles when addressing topics such as defining project boundaries, including non-CO2 gases, deciding which carbon pools to measure etc. (Kaegi and Schoene, 2005). More specifically the following problems were often cited:

- Land eligibility was not properly assessed
- The methodology was often not specific enough about how and why project assumptions would be met
- Project specific data was used for the methodology although the methodology should be general enough to be applied to other project areas.
- Project boundaries and stratification were not addressed adequately and correctly
- Baseline scenarios were based on events outside the project bounds, did not differentiate by strata, used unclear methods, forgot to include non-forest land uses.
- Economic tools and socio-economic data were referenced but not provided..
- The Additionality Tool provided by the CDM EB was not used adequately or plausibly.
- Leakage was not treated adequately.
- Non-CO2 GHGs should have been included but were not.
- The choices of and changes in carbon pools were not adequately explained.
- Quality assurance not convincing.
- Requirements of transparency and conservativeness were not met.

(Kaegi and Schoene, 2005)

Forests for Bioenergy and Fossil-Fuel Substitution

An important debate around CDM forestry projects is whether trees should really be grown for sequestration or if it is more economical and beneficial to concentrate on using trees for fossil-fuel substitution. Following the trend of pessimists about the viability of tree plantations grown mainly for sequestration credits, a 2004 study predicted that growing more short-rotation woody crops for fossil fuel substitution will soon be more effective than sequestration (Baral and Guha 2004). The critical factors for this transition will be the improvements of and falling costs for biomass-based technologies such as a biomass integrated falsifier and steam injected gas turbines. Comparing forest sequestration to reductions through utilizing SRWC for energy, the benefits of fuel substitution became obvious after about 50 years when forest growth began leveling off. After 100 years, the forest in this study would sequester about 160 t C/ha but the fuel would have offset 275 to 450 t C/ha depending on the technology used.

Two Brazilian projects that applied for CDM A/R registration generated a good deal of controversy because their goal was just that – to grow a certain pool of trees to be used as fuel. Eventually one of the projects, Plantar, resubmitted a new methodology to the CDM that abandoned the forestry element and concentrated on mitigation of methane emissions from using wood versus coke to fuel the pig-iron industry. The other project had its methodology rejected three times and has apparently not attempted to submit a fourth time.

Beyond the intent to use the trees for fuel, the projects were controversial because the industry involved was so large and so “dirty” and seemingly antithetical to “sustainable” development and because they proposed to plant very large tracts of very fast growing Eucalyptus. Plantar was also supported by the World Bank BioCarbon Fund.

Both projects involving large eucalyptus plantations in Minais Gerais Brazil, which would be converted to charcoal and burned in substitution for coke. Prior to the project submissions, the industries had also been using wood charcoal, but were considering a switch to coke as increasing deforestation had made wood prices rise. Just the size of the Plantar project gives rise to doubt its sustainability. The designers reported in 2003 that the 23,000 ha of monoculture plantations would produce 4.4 million CERs, which was slightly more than all the projects combined in the World Bank BioCarbon Fund at the time. (Rainforest Foundation et al., 2005) The key problem for these projects however, were that they were submitted as "avoided fuel switch" projects. This meant that the companies would continue to use eucalyptus charcoal instead of transferring to (dirtier) coke only if they could get CDM revenue—leaving a slight taste of blackmail in the observer's mouth.

Yet, despite the problems with these projects, they graphically illustrate the great interest in and potential for, using trees and other woody plants for alternative energy sources rather than sequestration. A recent guide (Dutschke et al, 2006) on combining forestry with biomass highlights the advantages, such as increasing carbon revenues and making forestry projects viable and perhaps competitive with other biofuel projects. Yet combined projects are not yet technically feasible as separate methodology boards consider forestry and other CDM projects.

If the CDM EB moves to make a combined sequestration and bioenergy project possible, projects involving both bamboo and other fast growing woody species will become more viable. Of course, Eucalyptus and pine will still be prime choices from a commercial perspective since the species are well known and very productive. Also charcoal and gasification technologies for these species have likely been tested already, while commercial energy technologies for bamboo are still being developed.

Summary of CDM Forestry Project Development So Far

There seems to have been a fair amount of enthusiasm for forestry projects in the 1990s and first years of the second millennium. However, the number of new projects seems to be slowing since then as the magnitude of the transaction costs and low carbon values becomes clear. In the wake of forest restoration projects, more projects are already showing up with plain commercial intent, particularly involving quick growing species like Eucalyptus and pine for timber and pulp production. Many joint implementation projects seem to have sold their credits on the voluntary market rather than keep battling for CDM registration. One the other hand, projects with funds from development or environmental organizations with no clear mandate for commercial viability are still funding a few projects. The project development costs should fall somewhat as all sides gain experience.

Overall, both the sequestration element and the focus on sustainable development in the current CDM A/R projects seems to be taking a backseat to being registered at all, and to the commercial use of the wood. Net annual sequestration per hectare in CO2e varies between less than one tonne and nearly 100 tonnes; but with most reporting values between 5 and 12 t CO2e per hectare annually (based on PDD information), even for projects mainly focusing on Eucalyptus. Given that non-clone Eucalyptus species easily sequester 7-9 tonnes of carbon per hectare (t C/ha) annually (Binkley and Stape, 2004), which translates to 25 t CO2e to 33 t CO2e, then only about one third of the potential for sequestration is being used. To be fair, the net sequestration must subtract baseline carbon and leakage, which might account for one third of the total potential. In that case, a Eucalyptus plantation could be expected to produce somewhere between 16 – 22 t CO2e per ha annually—and the current projects are still producing only half of this potential. The most logical conclusion is that the price uncertainty and heavy registration costs are driving projects towards heavier thinning.

So is Bamboo the Rational CDM A/R Choice?

This paper proposed at the beginning that bamboo should be “a” or perhaps “the” rational choice for CDM forestry projects. The evidence indicates that it is according to theory; but that it is not in practice because of high transaction costs and the failure of the mechanism to capture the full value of sustainable forestry. Thus, this paper concludes that the CDM forestry market is indeed at a sub-optimal equilibrium.

The ceteris paribas to this hypothesis that (large) bamboo is the rational CDM forestry choice, is that the local conditions must be suited to the bamboo and that there is degraded or deforested land that is eligible for the CDM and that would benefit from a first generation bamboo crop or the establishment of a permanent stand of large bamboo. These conditions hold for many and diverse areas throughout Asia, Africa and Central America where the climate is suitable, there are many tracts of deforested and degraded land, and bamboo are native (or a non-invasive sympodial variety could be introduced).

Bamboo is the rational choice because, as has been shown, it can provide a package of desirable benefits that are not rivaled by tree species:

- **Carbon:** Many varieties sequester amounts of carbon comparable to or superior to other favored CDM tree crops. Furthermore, they are capable of storing that amount of carbon in a very short period, so that maximum carbon revenues can be attained in a very short time and the payback period on the investment can be reached within the first five-year trading period. The only comparable tree crop in terms of quick growth is the eucalyptus.
- **Cost:** The upfront investment for establishing a bamboo forest or plantation should be lower than for tree crops. As unprocessed bamboo is still valued less than wood (and because it grows so quickly), the propagation materials should also be cheaper than for

favored tree species[7]. Considering that these projects should benefit poor communities, and considering the very high transaction costs involved with registration, this factor could be crucial for getting CDM forestry off the ground.

- **Environment:** Modern bamboo management produces high-yielding, renewable resources that do not require chemical fertilizers and do not deplete the soil. The rhizome system of roots has even been shown to have water and soil erosion capacities superior to many tree species. Further, many bamboo species are endangered or associated with endangered species, so forest with endangered bamboo species would be an important contribution to biodiversity preservation.
- **Livelihoods/Community Development:** Bamboo is a versatile product that can be processed into finished or semi-finished products in the home in many cases. It is easier to process than timber because of its light weight; and it can be grown on marginal land near or around houses as well as in large stands. As new industries develop for bamboo, communities that invest in modern processing for building materials, furniture, fabrics, food or fuel have the opportunity to benefit from capturing high returns on finished products. Bamboo processing can also be very efficient, with up to 90 percent of the biomass utilized at harvest, from the leaves to the rhizomes. Many bamboo projects have already been shown to have impressive poverty alleviation results.

Bamboo is not the rational choice if one looks at the actual conditions that CDM forestry projects are currently subject to.

- The high-costs of project-preparation and registration drive the projects towards "safe" rather than optimal results by using the most-well known species with well established

[7] Bamboo propagation techniques were not covered in this paper. It should be noted that some training is required. Bamboo seeds are seldom available so the propagation involves using cuttings from the desired species.

markets and supply chains. There is no room for investment in optimization by cultivating less well-known species that require new investments in training or study. Bamboo could be a project developer's nightmare because they have to pioneer the first methodology for bamboo and counter skeptics who feel that bamboo should not qualify because it is not a tree. Further, except in China and India, they might have to import technical experts familiar with bamboo agronomy and processing.

- The markets for new bamboo products and the processing systems for producing them are not well-known or established outside of China, India and a few other neighboring countries. Most of the processing is still traditional and low-value added.
- Local people might protest at the cultivation of bamboo. Project developers might in some cases have to first prove that bamboo is a valuable crop since it is often viewed as the "poor mans timber."
- The market for bamboo products is dominated so far by China and India, who have developed domestic and export markets as well as supply chains for bamboo. This might discourage project developers outside of China, because competition with Chinese and Indian products might lower the profits, and because capacity and supply chains need to be developed in other countries.

Chapter 5

What It All Means

What this really all means is that the forestry program of the CDM is failing to live up to its goals since the requirements and many uncertainties push project developers toward these “safe-bet” status quo projects rather than optimal projects. Project developer’s main goal is to satisfy the technical requirements for registration and ensure that they have access to non-carbon revenue streams—which means that they must either be funded by public-interest sources such as NGOs or governments, or they must concentrate on highly profitable tree crops with established markets and supply chains.

Once established, bamboo cultivation has proven to be a very profitable investment in many projects in China and India. However, the potential is not as widely recognized as for the quintessential pulp and charcoal tree, Eucalyptus, or other large and well-known timber species such as pines and teak (for tropical climates). Furthermore, the technical and bureaucratic barriers to registering a new type of forestry project are very high, as mentioned, and push towards projects copying previously approved project methodologies.

In Chapter 1, the reasons for the development of CDM forestry projects were described. Essentially, forests are still undervalued in current markets since much of their benefits are realized in public good externalities such as environmental benefits and common property livelihood resources. They are also undervalued because of the difficulties of monitoring forest stands and preventing illegal harvest, and because governments often sell the concessions for less than market value. The fact that most deforestation occurs in poor countries exacerbates the problems for weak monitoring and corrupt practices in selling timber concessions.

The argument for recognizing forests carbon sequestration services are twofold. First, it was hoped to put a value on this externality and thus slow or reverse the trends of deforestation. Second, it was hoped that these projects would contribute to sustainable development and poverty alleviation in some of the poorest areas of some of the poorest countries. Land use change projects are the most viable of the CDM projects for areas that do not have developed industries and infrastructures.

In Chapter 2 it has been shown that bamboo is a very useful, versatile forest crop that has very desirable characteristics for forestry CDM, from environmental benefits to low cost to high potential for poverty alleviation. It has also been shown that the tree species that might compete with it are not superior in terms of carbon sequestration and that bamboo is particularly well-suited to the short five year crediting cycles under the Kyoto Protocol.

However, Chapter 3 and Chapter 4 have illustrated why CDM forestry has had such little success so far. The technical requirements were decided late and are exceedingly complex, which prevented many already developed projects from qualifying. The rules for CDM forestry also limit the market value of the credits produced and are not well accepted on the few fledgling carbon markets that have developed since 2005. Since the overall market for CDM credits is still in seen as risky and undeveloped, this is a heavy blow for forestry projects. A further blow is that the projects can not count sequestration in products, but have to assume that all the carbon is released from the trees as soon as they are harvested. Investments now flow to other CDM categories where the emission reduction is easier to prove and the involvement with the local community may be less complex or necessary, such replacing CFC technologies, flaring methane from a landfill or producing ethanol.

The CDM mechanism provides too little support for project developers to meet the high upfront establishment and transaction costs. Forestry has always been a risky business, and if it is required to invest in sustainable practices, it quickly become unprofitable due to the competition from unsustainably harvested products.

As a result, there is a great deal is being invested in studying alternative fuels, but there are few funds for studying car bon sequestration and sustainable development through forestry. Thus the CDM A/R projects of choice are for commercial timber or paper projects, followed by a few charitably oriented preservation projects which have little do to with markets. Overall, the areas that would benefit most from the environmental and social welfare effects of forestry projects have the least capacity to attract and support these projects.

A Familiar Tale

Those familiar with international forestry negotiations should not be surprised at the results from the experience with CDM A/R. Sustainable forestry is most important to Southern economies and generally receives token interest in a North that is preoccupied with projects that bring higher returns for the North. Within the South, emerging economies with less primary forest open to harvest also have little incentive to support agreements that would limit their supply of cheap timber. Thus, it seems that the failure of carbon forestry to take off can be explained by the political economics of North-South and South-South relations and the dragging progress of an international agreement on forestry.

Firstly, the forestry projects were approved much later in the game and with much more controversy than energy conservation and alternative energy projects – even those that involve converting massive amounts of cropland for fuel use, which often raises the hackles of food security analysts. This uncertain and slow progress seems to be a reflection, or result, of the controversy over how to ensure sustainable forest management without impinging on state sovereignty or creating moral hazard issues by financing preservation or reforestation. Many NGOs were, or are, critical of forestry CDM not only because they suspected that the projects would not be sustainable, but also because they were afraid that local peoples would be exploited and/or shut out of forests that they depended on for their livelihood. Now, socioeconomic impacts on local people must be addressed as well as environmental impacts, but there is still room for abuse.

Secondly, the support from the North for these projects, which are of the most interest in LDCs and poorer and more remote areas of other developing countries, is minimal. In fact, the EU withdrew its support entirely, apparently preferring to continue support for forestry through traditional, if so far equally ineffective (judging from the rates of deforestation and land conversion) channels. Some critical Northern voices are afraid that resource rich Southern countries will be able to get funding for "doing nothing" but managing their resources responsibly, which is in their interest anyway, and see a general moral hazard in the proposition.

Third, the North does not wish to recognize sequestration in products, which would increase carbon revenues from forestry projects considerably. This may be explained by a fear that recognition would increase the incentive to harvest trees more intensely, or it may be a lack of interest in a complex topic of minimal interest to the North.

Fourth, the largest developing country players in the CDM game, China, India and Brazil have most CDM projects and also have some of the world's largest reserves of forest and degraded land. However, they do not seem to be pushing forestry issues, as they are currently benefiting from an influx of investment in energy projects and mitigation of CFCs. Actually, both developed countries and China and India have an interest in pursuing these "low-hanging" fruits first (especially CFCs since their warming potential and thus the carbon revenues for mitigation are extremely high). The host-country would like quick and profitable CDM projects, and the investor also wants quick and easy returns. Converting air-conditioners and fitting coal plants with coal-scrubbers, or just ensuring that methane from landfills is burnt rather than released, are all easy and profitable projects.

Meanwhile, LDC countries are hardly seeing any CDM revenues and would be very interested in more carbon forestry, but have trouble attracting investors due to the high risks and poor conditions in those countries as well as the complex rules governing CDM A/R.

Further, all of the players are aware that there is a high potential for cheating in the forestry carbon game. The threat is not only theoretical, given the estimation that perhaps 15 percent of the global timber trade is connected with illegal harvesting. (Contreras-Hermosilla, 2002) Forests are still essentially open access—it is hard to protect forests from illegal logging, from overuse by local peoples, from accidental forest fires and storms etcetera.

There is also a high potential for forestry projects to become another way to subsidize timber and paper industries. It is easy to deduce that timber and paper companies make decent returns already, since they have large operations around the world, and also that they are not particularly interested in sustainable forest management for its own sake. Since all of the projects have a limited commitment period of 20 to 30 years, it is easy to imagine a timber company getting carbon subsidies for creating a plantation that they would have been interested in planting anyway, knowing that they can harvest as soon as the trees are mature and get carbon revenues in the meantime. They also have little incentive to replant after harvesting at the end of the crediting period—first because they would need to rework the land, and secondly because they would have to re-develop their project methodology, and thirdly because their may be no CDM twenty years from now. The case for the paper industry using the CDM to subsidize plantations of short rotation pulp trees that they would have planted anyway is even stronger. Paper companies have been clearing forest and planting eucalyptus in Asia for several years with no expectation of qualifying for carbon revues. (Greenpeace 2004a and 2004b, Qin and Wu, 2004)

Industrial subsidization was even addressed directly in two Brazilian Eucalyptus projects in which the project developers developed immense tracts of Eucalyptus to use as fuel for the pig iron industry. The most famous of these, the Plantar project, was eventually resubmitted as an alternative fuel project rather than a forestry project, however the main fear, that the CDM is used to subsidize unsustainable practices, remains. (UNFCCC CDM, 2005b, 2006a; Rainforest Foundation et al, 2005)

Conclusion: What to Do

If forestry carbon projects are going to be able to fulfill the goal of sequestering significant amounts of CO_2 and supporting sustainable development, then the framework for these programs has to be reworked substantially. Further, this reworking must happen rapidly, as the goals and rules for the period after 2012 are already being hammered out in the European Union and will hopefully soon be addressed in the UNFCCC. This analysis of the development of CDM forestry projects and the hurdles they face highlights the fact that there is too much risk, that the returns are too delayed and too small, and that the transaction costs are much too high to make forestry projects attractive to the private sector. They are not even very attractive to governments or NGOs unless they have another strong reason for pursuing forestry projects. This is a great pity because forests are crucial to environmental health and are the basis for livelihoods for poor and marginalized peoples all around the globe—and they are very large and important carbon sinks that could be expanded to absorb nearly all the emissions required to meet the Kyoto criteria if that goal were pursued aggressively.

The root problem is the classical environmental problem: The resource is still essentially open access for many, and the positive external benefits provided by forests are not reflected in their market value. The international community has provided a framework in which the carbon sequestration is valued minimally, but they have not captured the value of the other ecosystem and livelihood services that the forests provide.

Absent a new international regime that will somehow value these services, the best solution is to acknowledge that public action is needed to pay for these public goods. Currently, market oriented forestry projects will do little beyond providing monocultures of tree crops, which may be somewhat more beneficial to the environment than agricultural crops, but they will not compare the value of healthy natural forests, plantations for sustainable livelihood development, or small-scale planting for livelihood purposes such as tools, food, fodder, building materials and fuel wood.

The fundamental purposes of government are, at a minimum, to provide stability and a level playing field. Part of this is the provision of public goods. The UNFCCC has not managed to provide a level playing field or stability for forest project developers. Since it has a very limited capacity, the next best solution is to focus on a framework to finance the provision of public goods through subsidies rather than semi-market mechanisms. As it now stands, the only projects that meet the goals of the CDM are already those that are financed heavily by public entities or by non-profits with environmental or development missions. Thus, if more projects that meet the goals of the CDM should be realized, the UNFCCC and international community needs to admit that they need public funds to provide public goods because they are not capable of capturing the value of the externalities in the framework they have set up.

The problem with subsidies is the debate over additionality and the hope that the CDM projects could be driven by markets. The markets are not fully developed, and the playing field is not level, so insisting that the market will pick the best projects is rather ridiculous at this point. As regarding additionality, it may be time for proponents of additionality to recognize that insistence on it—in its financial and carbon manifestations—is counter-productive because it is creating towering barriers to entry. Loosening the rigor and exactness of the carbon sequestration proofs, particularly in the requirements for measuring the baseline and additional sequestration every five years, would encourage many more projects and much more sequestration overall. Striking the requirement that the CDM not be supported by official development aid would also be a really good idea. In fact, perhaps it should be a requirement that the project is funded partly by governments or public-interest organizations.

Development institutions like the World Bank and Asian Development Bank have the most capacity to foster these programs and have already had the largest impacts on the existing pool of projects. Opening the ODA and bilateral development aid purses would allow synergies between "regular" sustainable development and land-management programs and carbon land-management and sustainable development programs. Finally, public agencies may be the only actors willing to sponsor carbon forestry projects in the most remote and poorest regions that would benefit most from them. Many Africans, in particular, would thank the rest of the global community for opening a channel for attracting CDM revenues in which they have a competitive advantage.

This means that the global governance function of the UNFCCC, must be strengthened to let bamboo win, and more importantly to let the goals of the CDM be fulfilled. Government must provide stability and predictability and also intervene in the market to provide incentives for internalizing social and environmental externalities. The CDM is a not a market mechanism, but a sustainable development mechanism—and the rules should be changed to acknowledge this and allow real progress towards sustainable development so long as the market is not capable of valuing the public goods that sustainable projects provide.

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Annexes:

1. Bamboo Products: Uses and Potential

Bamboo is currently used in a large array of products and industries. The products can be grouped into construction and reinforcing fibers; paper textiles and boards, food and fuel. (Scurlock 2000):

Construction materials: Housing and scaffolding

Housing is a major field for bamboo utilization, in combination with other materials or on its own and in a large variety of styles. The houses can be developed very cheaply for poor areas, disaster management etcetera or be made into luxurious bungalows, villas and resorts. Bamboo houses are also traditional in many Asian countries and even in Ethiopia. In Ecuador *Guadua angustifolia* is a major and traditional construction material for housing and has also been demonstrated for construction of bridges and other large structures. Moso bamboo is the most common construction material in China, although sympodial species with even larger culms may be more useful in the future. Experts estimate that over one billion people on the planet live in the traditional bamboo houses. These buildings are usually cheap, light, strong and earthquake resistant unlike break or cement constructions. The new types of pre-fabricated bamboo houses made of engineered bamboo are easier and cheaper to transport, well-designed for modern living and environmentally friendly. (Lobovikov,et al, in press)

Bamboo pulp and paper and cloth

Several bamboo producing countries, such as China and India, have traditionally used bamboo for producing pulp and paper and now also have developed bamboo fabrics. Bamboo paper has very similar qualities to wood papers and its brightness and other optical properties also remain stable over time while wood papers tend to deteriorate. Morphological characteristics of bamboo fibers allow bamboo paper to have a high tear index similar to hardwood paper. (Lobovikov et al., 2006) The tensile stiffness is somewhat lower compared to the softwood paper, and the strain strength of bamboo paper is between that of hardwood and softwood paper. Cloth produced with bamboo is very soft and flexible and also has desirable qualities such as softness, elasticity, moisture absorption and antibacterial and deodorant performance. (Fu 2003)

Bamboo Based Panels

China started producing bamboo panels in the early 19th century and currently more than 20 different types of panels are produced in Asia. Since the bamboo fiber is longer than wooden fiber, bamboo has some technological advantages. The panels are widely used in elements of modern construction such as structural elements and in monolith concrete moldings. They are also used for flooring, roofing, partitions, doors, and window frames. Some new uses for veneers include Styrofoam substitutes and surfboard manufacture. (Lobovikov et al., 2006; Fu, 2003)

Bamboo flooring

Bamboo flooring is a high quality product of growing popularity in developed countries. Its advantages to wood floors are its smoothness, brightness, stability, high resistance, insulation qualities and flexibility. The estimated annual production of bamboo flooring in China is 17.5 million sq. m 2004 of which 65 percent was for export. (Lobovikov and Hong, 2005)

Bamboo Furniture

Most traditional bamboo furniture uses round or spitted bamboo. Recently, "pack-flat" or “knock-down" bamboo furniture had been developed using bamboo glue-laminated panels. Unlike the traditional design, this furniture may be shipped in compact flat packs and be assembled on site. The new design overcomes many of the problems of the traditional bamboo furniture such as high labor and transportation costs, instability, varied quality and susceptibility to insects and fungi; while retaining practical and aesthetic features of bamboo. (Lobovikov et al., 2006)

Bamboo weaving products and crafts

Bamboo handicrafts and woven mats are traditional products in China, Malaysia, Philippines, India and Thailand. The techniques are often several thousand years old and the products are diverse and practical. Bamboo woven products in Asia have nearly twenty categories, such as fruit-baskets, trays, bottles, jars, boxes, cases, bowls, fans, screens, curtains, cushions, lamp-shades, lanterns etc. (Lobovikov et al., 2006)

Bamboo Shoots

About 200 species of bamboo can provide edible vegetables (bamboo shoots). Bamboo shoots are very popular in Asian cuisines and are considered healthy for their high fiber content. The crispy vegetables are easy to package and can be shipped easily. Many communities collect shoots from natural forests, but cultivation of bamboo for shoots and the processing of shoots has become an important source of income for many farmers in China. (Lobovikov et al., 2006)

Bamboo Charcoal

Bamboo charcoal is a fairly new product that has become increasingly popular, particularly in Japan, South Korea, and Taiwan. Its main uses are for purification of air and water, making medical instruments, barbeque briquettes, and handicrafts. Bamboo charcoal is attractive for filtration because of its micro-holed structure and adsorption and electromagnetic shield properties. The absorption capacity of bamboo charcoal is six times better than that of wood charcoal of the same weight. The properties of bamboo charcoal are similar to those of charcoal from hardwoods, (Lobovikov and Hong, 2005) so it may be an increasing substitute for other charcoal sources.

Figures: Bamboo Diversity and Extent

Figure 1: Bambusae Species in the Asia-Pacific

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Table 1. Numbers of species of Bambuseae occurring in the countries of the Asia-Pacific region (Ohrnberger 1999).

Country	Number of naturally occurring species
Australia	3
Bangladesh	18
Bhutan	21
Brunei	6
Cambodia	4
China	626
Hong Kong	9
India	102
Indonesia	56
Japan	84
Laos	13
Malaysia	50
Myanmar	75
Nepal	25
North Korea	2
Pakistan	3
Papua New Guinea	22
Philippines	26
Russia (Sakhalin and Kuril Islands)	1
Singapore	3
South Korea	6
Sri Lanka	11
Thailand	36
Vietnam	69
Total species in all countries	1012

(Source: Bystriakova et al, 2003b)

Figure 2:Distribution map of bamboo biodiversity in the Asia-Pacific

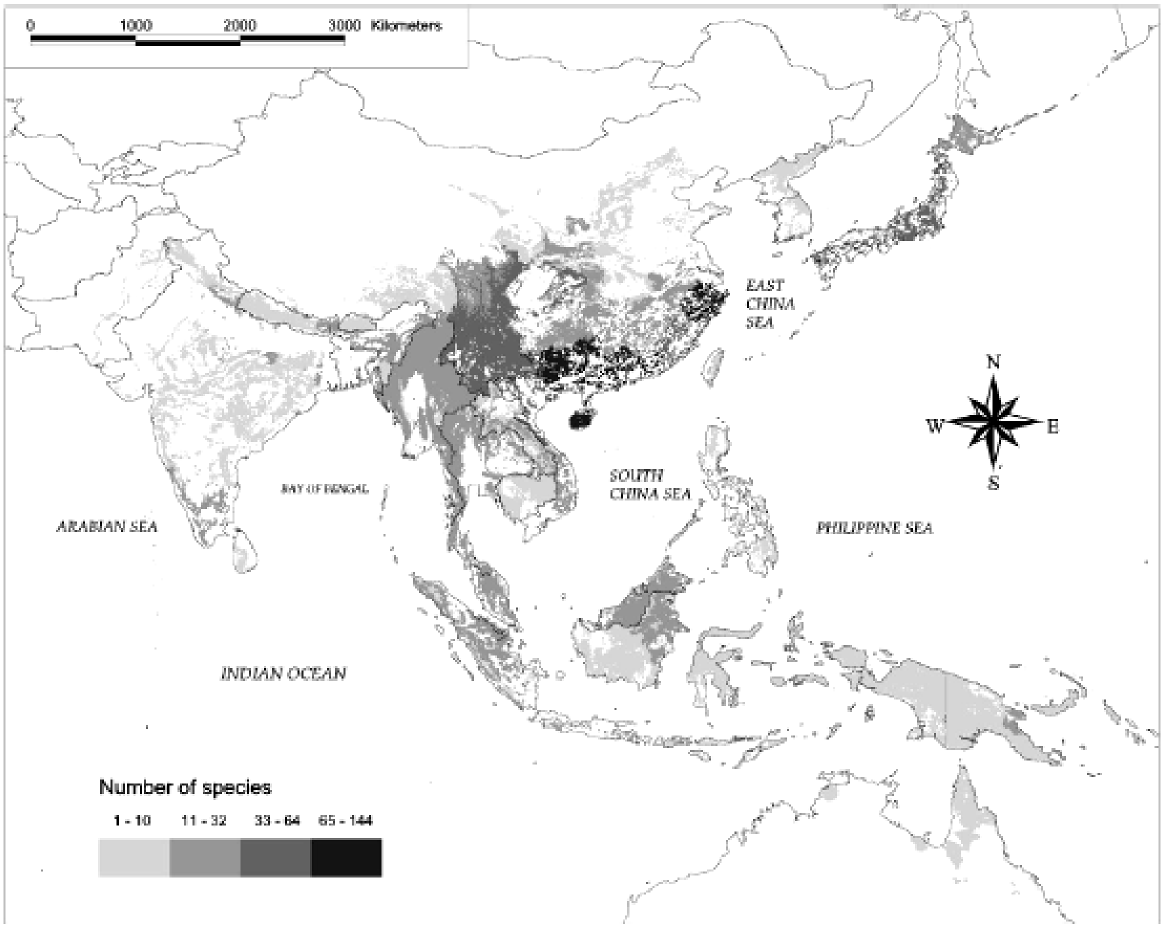

Figure 2. Map showing the potential distribution of total species richness of woody bamboos in forests of the Asia-Pacific region. The map was compiled by overlaying distribution maps for 998 individual species. These were derived for each species using bibliographic information on political units, elevation and ecological preferences, mapping these and using UNEP-WCMC data on forest cover to eliminate all non-forest areas.

(Source: Bystriakova et al, 2003b)