Bamboo and sustainable development in Viet Nam

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Summary

Sustainable development is essential for humans to survive on earth indefinitely, and in this context, Viet Nam has work to do to reduce its ecological footprint to a sustainable level. Since the Earth Summit in Rio in 1992, there has been a slow but steady global implementation of initiatives to achieve sustainable development, even though climate change has emerged as the de facto proxy for addressing sustainable development issues. Carbon trading has developed through different mechanisms as a means to control excessive CO_2 emissions, and the establishment of bamboo forests, if they meet the qualifying criteria, could be a source of revenue to support the industry, and to improve the livelihoods of rural poor people in Viet Nam. Viet Nam has developed strategies for sustainable development, and has been a benefactor of carbon trading with the development of Clean Development Mechanism (CDM), REDD+ and Payment for Ecosystem Services (PFES) programmes. So far however, none of these pro,grammes have included bamboo.

Bamboo is a unique material in that it is very fast-growing, has a myriad of traditional uses and an ever-increasing range of contemporary uses, and bamboo is as good as, or better, than other forest types in terms of providing ecosystem services and locking-up carbon. It is critical for the development of a bamboo industry in Viet Nam to include a high level of participation by local communities, to build a sense of ownership in, and commitment to, the industry. The industry also needs to be very carefully designed, in terms of every aspect of its function – farming, production, marketing and waste minimization. To achieve sustainability, bamboo farming practices need to be technically of a high standard, achievable through training via highly trained bamboo forestry extension officers. Best practice for treatment of bamboo against insect and fungal attack needs to be part of a bamboo industry program, and research into improved methods of treating bamboo should be encouraged and supported.

The establishment of a bamboo industry in Viet Nam could form part of a strategic planning approach for protecting national biodiversity, through adopting a species-rich planting philosophy and striving to connect habitat patches in the landscape for movement of animals and plants and building ecosystem resilience, particularly in the context of climate change. There is considerable knowledge available on all aspects of the bamboo industry, and perhaps China and the International Network for Bamboo and Rattan (INBAR) are two sources which could be approached to help set up a high standard bamboo industry in Viet Nam. Historically, the Vietnamese government has offered assistance in the development of bamboo plantations. With a continuation of this support, together with financial incentives associated with carbon trading, there surely is a bright future for a bamboo industry in Viet Nam if there is commitment at a high level to pursue it.

Vietnammosasa spp – Vietnamese name“Vau” - at Phu An Bamboo Village and collected from Yokdon in Daklak Province (photo Paul Bourne).

I. Introduction

For countries around the world, there are many challenges as to how to manage an increasing human population and an increasing demand for energy and natural resources, in a way that does not negatively impact on future generations. This means that with development, there is also a necessity to protect natural systems – catchments and water quality, oceans, the atmosphere and biodiversity – as humans are dependent on these systems one way or another.

For Viet Nam, its ecological footprint has been increasing rapidly since 2001, and is currently exceeding its biocapacity by 42% (Global Footprint Network, 2015, Attachment 1). For a sustainable future, the nation's ecological footprint should not exceed its biocapacity.

Population pressure and economic development is leading to increasing pressure on Viet Nam's forests, with flow-on impacts on biodiversity. Bamboo is a resource which has the potential to reduce this pressure, and in so doing, make a significant contribution towards the achievement of sustainable development for the nation.

II. Sustainable development

In 1987, the *Report of the World Commission on Environment and Development: Our Common Future* (Brundtland, 1987), was presented to the United Nations. The report defined sustainable development as:

> *development that meets the needs of the present without compromising the ability of future generations to meet their own needs*

The Brundtland report provided direction to the countries of the world on what was necessary for humans to live on earth sustainably, and in 1992, at the United Nations Earth Summit in Rio, served as the catalyst for the adoption of ground-breaking global documents on sustainability: Agenda 21, the Rio Declaration on Environment and Development, the Statement of Forest Principles, the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention on Biological Diversity (United Nations, 1997). Viet Nam was one of the 172 countries attending the Summit and a signatory to the documents (Socialist Republic of Viet Nam, 2012).

The Earth Summit in Rio started a process, and in September 2000, at the Millennium Summit, world leaders adopted the UN Millennium Declaration, committing their nations to eight targets, with a deadline of 2015, that have become known as the Millennium Development Goals (MDGs). Although the MDGs are strongly focused on social challenges, Goal 7 aimed to ensure environmental sustainability (Millennium Project, 2006).

To address sustainability beyond the MDGs, the June 2012 United Nations Conference on Sustainable Development, known as Rio+20, launched a process to develop a set of Sustainable Development Goals (SDGs), to come in to effect in January 2016 (United Nations, 2015a). From a science perspective, the SDGs are a major improvement over the MDGs, by offering better coverage of, and balance between, the three dimensions of sustainable development – social, economic and environmental – the institutional/governance aspects and their applicability to all countries (ICSU, ISSC, 2015). Of the 17 SDGs, those of particular relevance to bamboo and sustainable development are:

- Goal 13. Take urgent action to combat climate change and its impacts
- Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Each SDG has a set of targets, and those for Goal 15 appear in Attachment 2.

Despite its efforts to achieve sustainability, the UN General Assembly noted at the 1997 Earth Summit+5 in New York that “the overall trends with respect to sustainable development are worse today than they were in 1992”, and at the 2002 World Summit on Sustainable Development in Johannesburg, in his report on Agenda 21, the UN Secretary-General confirmed that “progress towards reaching the goals set at Rio has been slower than anticipated” and “there is undoubtedly a gap in implementation (Drexhage, & Murphy, 2010).

The implementation of sustainable development has been, and is, hindered by the reigning policy orientation of development as purely economic growth. A successful country is perceived as one that is expanding its economy and has a healthy, long-living population who become ever richer. The concept of sustaining economic growth, rather than sustaining the global ecosystem has prevailed, and sustainable development has been subsumed under the globalization paradigm. Since the Earth Summit in Rio, the notion of sustainable development has lost traction because of the dominance of the economic growth agenda (Drexhage, & Murphy, 2010).

While sustainable development was supposed to have an institutional home in the Commission for Sustainable Development, it has not been harnessed effectively by national governments as a vehicle for implementation. As a result, climate change has emerged as the de facto proxy for addressing sustainable development issues (Drexhage, & Murphy, 2010).

III. Sustainable development and climate change

The first World Climate Conference (WCC) in 1979 informed the world that climate change was a major global issue. In response to increasing evidence, in 1988 the Inter-governmental Panel on Climate Change (IPCC) was established, which, in 1990, together with the second WCC, called for the establishment of a global treaty on climate change. In 1991 government representatives adopted the UNFCCC, and in 1992 at the Rio Earth Summit, the Convention was opened for signature. In 1997 the third Conference of Parties (known as COP 3) was held in Kyoto, Japan, which resulted in the adoption of the Kyoto Protocol. In 2001 COP 7 was held in Marrakesh, Morocco, and signing of the Marrakesh Accords took place (UNFCCC, 2003).

The adoption of the 1997 Kyoto Protocol legally bound developed countries (*Parties*) to CO_2 emission reduction targets. There are currently 192 Parties to the Kyoto Protocol, with Viet Nam signing in December 1998, and accepting and ratifying it in September 2002. The Protocol’s first commitment period started in 2008 and ended in 2012, with the second commitment period beginning on 1 January 2013, which will end in 2020. Under the Protocol, countries must meet their targets primarily through national measures, however there are additional market-based mechanisms to meet their targets, which are:

- *International Emissions Trading*
- *Clean Development Mechanism* (CDM)
- *Joint implementation* (JI)

The mechanisms help to stimulate green investment and help Parties meet their emission targets in a cost-effective way UNFCCC (2003).

International emissions trading, as set out in Article 17 of the Kyoto Protocol, allows countries which have spare permitted emission units to sell them to countries which are over their targets, thus creating a new commodity in the form of emission reductions or removals. Since carbon dioxide (CO_2) is the principal greenhouse gas, people refer to “trading in carbon”. Carbon is now tracked and traded like any other commodity, which is referred to as the "carbon market”. More than actual emissions units can be traded and sold, and the other units which may be transferred under the scheme, each equal to one tonne of CO_2, may be in the form of:

- A removal unit (RMU) on the basis of *land use land-use change and forestry* (LULUCF) activities such as reforestation
- An emission reduction unit (ERU) generated by a JI project
- A certified emission reduction (CER) generated from a CDM project activity

The CDM, defined in Article 12 of the Protocol, allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Such projects can earn saleable certified CER credits, which can be counted towards meeting Kyoto targets. The CDM is expected to generate investment in developing countries, especially from the private sector, enhance the transfer of environmentally friendly technologies and promote sustainable development in general. The CDM also allows Annex I Parties to implement sustainable development project activities that reduce emissions in non-Annex I Parties. As well as helping non-Annex I Parties work towards sustainable development, and so to contribute to the ultimate objective of the Convention, the CERs generated by such projects can be used by Annex I Parties to help meet their own emissions targets. The Protocol’s compliance system, agreed to as part of the Marrakesh Accords, gives added legal muscle to the process of holding Parties to their commitments. The Compliance Committee’s facilitative branch aims to provide advice and assistance to Parties, including an ‘early warning’ if a Party appears to be in danger of not complying with its target, whereas the enforcement branch has powers to apply certain measures if a Party does not meet its target. If a Party fails to meet its emissions target, it must make up the difference, plus a penalty of 30 percent in the second commitment period. It must also develop a compliance action plan and its eligibility to ‘sell’ credits under emissions trading will be suspended (UNFCCC, 2003).

The mechanism known as JI, defined in Article 6 of the Kyoto Protocol, allows an Annex B Party to earn ERUs from an emission-reduction or emission removal project in another Annex B Party, which can be counted towards meeting its Kyoto target (UNFCCC, 2014).

Non-Annex 1 countries, and Viet Nam is one of them, are mostly developing countries and those recognized by the Convention as being specially vulnerable to the adverse impacts of climate change, and as such, do not have binding emission reduction targets to meet (UNFCCC, 2003). All Parties to the Convention, however, are subject to general commitments to respond to climate change. They agree to compile an inventory of their greenhouse gas emissions, and submit reports, known as national communications, on actions they are taking to implement the Convention (UNFCCC, 2003).

Historically, bamboo forests have been overlooked in the climate change regime. They were missing in the forests definitions of the Marrakech Accords (MA) and the Clean Development Mechanism (CDM). They have been disregarded in IPCC Assessment Reports and in IPCC guidelines for Greenhouse Gas Emission Inventories. That bamboos are botanically not trees but grasses, and that they have traditionally been considered “the poor man’s timber” may help explain these omissions (Lobokov *et al*., 2009).

The CDM is a market-based mechanism, driven by demand for CER carbon offsets from private or public entities in developed countries and by supply from carbon offset projects in host countries. CDM projects which reduce emissions from sources can be carried out in many sectors, particularly energy, including wood energy. Only afforestation / reafforestation (A/R) projects which remove carbon from the atmosphere qualify as CDM projects. Carbon sequestration in agricultural crops and soils is not eligible for sale under the CDM in the first commitment period (CP) 2008-2012. To qualify for CDM, the land being utilized must not have been forested for at least 50 years (“afforestation”) or converted to other uses before 31.12.1989 (“reforestation”), and has not been a “forest” since then. A/R projects can consist of assisted natural succession to trees, productive and protective plantations, agroforestry, as well as urban tree plantings and parks. Enrichment planting or forest rehabilitation in degraded forests will not usually qualify as “reforestation”, because the prior land cover was forest. Carbon sequestration via A/R projects must be *additional* to what would have occurred without the project. The additionality criterion, rigorously applied in the interest of environmental integrity of the CDM, has doomed many proposed projects (Lobovikov *et al*., 2009)

Carbon farming involves improving the rate at which CO_2 is removed from the atmosphere and converted to plant material and/or soil organic matter. Carbon trading is a voluntary and mandatory emission trading market (Nath *et al*., 2015). Reforestation, afforestation and reducing deforestation and forest degradation (REDD) are eligible for carbon trading. To date, most of the studies have been done on the carbon trading potential of trees, but little on woody bamboo species. The CDM Executive Board, in its 39th meeting however, decided that palm trees and bamboos are equivalent to “trees” in the context of afforestation and reforestation’’. The Food and Trees for Africa’s (FTFA) Bamboo for Africa programme has subsequently been certified under the verified carbon standard (VCS), and is the first accreditation for bamboo in the world. The Gold Standard Foundation, which closely cooperates with the Forest Stewardship Council (FSC), verifies and sells premium carbon credits as an internationally recognized benchmark for quality and rigor in both the compliance and voluntary carbon markets. The Gold Standard has now included bamboo forest in their definition of forest, to enable reforestation projects of this valuable ecotype. This allows project developers to choose between a range of methodologies when designing bamboo carbon projects (INBAR, 2013). For the REDD programme however, bamboo ecosystems remain to be recognised (Nath *et al*., 2015).

REDD+ stands for *reducing emissions from deforestation and forest degradation,* and includes *sustainable forest management* and *conservation and enhancement of forest carbon*. It is an initiative within the framework of the UNFCCC, in order to provide financial and technical assistance to developing countries to implement activities to reduce emissions of greenhouse gases through forest protection and development. Deforestation is defined by the Marrakech Accords as the direct human-induced conversion of forested land to non-forested land (with less than 10% crown cover) (UN-REDD Viet Nam, 2015).

To really help bamboo take a place in carbon sequestration initiatives, tree-like bamboo stands need to be considered as forests in the REDD process, for not to do so neglects significant carbon stores, highly effective carbon sinks, and proven pillars of rural livelihoods. It invites destruction of bamboo forests, or their replacement by rubber plantations in Viet Nam's case. If encouraged, new bamboo plantations could reduce deforestation by serving as wood substitutes and as a means to curb the spread of slash-and-burn agriculture. Bamboo could thus become an important component of a REDD strategy (Lobovikov *et al*., 2009).

Countries have acknowledged that there is an urgent need for them to exist sustainably, and there are incentives and guidelines on how to do it, so let us examine what it might be with bamboo, which can help a country such as Viet Nam, achieve a sustainable future.

IV. Bamboo and its uses

Bamboo and culture

Bamboo has been described as the fastest-growing woody plant on earth (Karoshi & Nadagoudar, 2012), and a study of the well-known Chinese *Moso* bamboo reported culms reaching full height of more than 10 m in two to four months (Cui *et al*., 2012). The classification of bamboos is complex, and to date there are some 1,000 or so species of bamboo in 70~80 genera, which have worldwide acceptance from the majority of scholars (Yuming and Chaomao, 2010, p.33). It can be asked however: Is bamboo a grass or a tree? Taxonomically it is a *grass* (INBAR, 2014). In China, *Moso* is considered a valuable *hardwood*, under Forest Stewardship Council (FSC) certification bamboo is a NTFP (non-timber forest product), and under carbon trading schemes such as CDM (Clean Development Mechanism) bamboo is considered a *tree* (Buckingham, 2009). The International Network for Bamboo and Rattan (INBAR) regards bamboo as a NTFP, but strongly advocates for it, and other NTFPs, to be regarded as tools for climate change mitigation and adaptation (Nadkarni & Kuehl, 2013). In Viet Nam's Forest Development Strategy (Socialist Republic of Viet Nam, 2015b) bamboo is regarded as a NTFP, but in Viet Nam's REDD documentation it is separate from NTFPs and listed as *bamboo forest* or *mixed timber-bamboo forest* (UN-REDD Viet Nam, 2013).

The speed of growth of bamboo, its light-weight cylindrical beam-like form (mostly hollow, but not always), its great strength, its ability to be easily divided into strips, its long fibres, its ability to grow in many situations and its ability to be beneficial in terms of climate change mitigation and to provide products sustainably, make bamboo an enduring, versatile and highly renewable resource. The yield of bamboo is high compared to most other wood species and the yield of bamboo for production of biofuel is extremely high (Vogtländer *et al*., 2010). Bamboo is resilient, and can recover quickly from natural disasters (Xua *et al*., 2013), and with more than 1,500 documented uses, ranging from fuelwood to light bulbs, medicine, poison and toys to aircraft manufacturing (Jamatia, 2012), and of course boats (Fig. 1) it is a truly unique resource.

Figure 1. Traditional Vietnamese bamboo coracle (thúng chai) (photo Paul Bourne).

In the countries where bamboo mainly occurs, Asia and Central and South America, the range of species and its usefulness have led to an extensive range of traditions and customs, and Japanese, Chinese and Indonesian legends abound in stories symbolizing bamboo as energy, sexuality and fertility, prosperity and longevity (Cusack, 1999, p.211). In Viet Nam, bamboo is known as "brother", and symbolizes the spirit of Voviram (a Vietnamese martial art) and also the Vietnamese soul- the gentleman-like straight forwardness, hard-working, optimism, unity and adaptation (Basumatary *et al*., 2015). Bamboo has a special cultural significance to the Chinese, and is regarded as one of four special plants, along with the orchid, chrysanthemum and plum (Brenner, 2008). Bamboo culture in China is rich and profound, and bamboo exerts a tremendous influence on Chinese history and culture, literature and art, poetry and painting, craft, horticulture, music, religion and folk customs, and is a spiritual treasure in which the Chinese people take great pride (Yuming & Chaomao, 2010). With Viet Nam's historical connection with China, it is likely that bamboo will be just as significant to Vietnamese.

Climate change mitigation

Bamboo is a high-value resource which can be used in many ways to provide climate smart mitigation and adaption solutions - cheap and renewable local energy sources, renewable components for affordable housing, rapid regeneration of soils and rangelands, the basis for new types of small and large industries, new sources of animal fodder and reforestation to sequester carbon (INBAR, 2014). INBAR (2014) recommends that the UNFCCC should include bamboo-based carbon accounting methodologies for afforestation and reforestation projects in the convention agreements on carbon market mechanisms, as well as supporting the development of new methodologies to incorporate bamboo into REDD+ programmes and national greenhouse inventory accounting for Harvested Wood Products. A recent assessment of studies on the subject supports this view, and concluded that bamboo can generate tradable amounts of carbon under CDM and REDD schemes (Nath *et al*., 2015).

Present climate change is considered to be caused by a human-induced increase in atmospheric CO_2. To combat this increase, there are two principle approaches: to reduce CO_2 emissions, and to increase CO_2 uptake and storage. In a forest context, the vegetation sequests CO_2 from the atmosphere and stores it. Falling leaves and branches, and the death of a plant, marks the beginning of a CO_2-release phase, as the organic material is broken down via natural processes. If timber is harvested, and is turned into long-lasting products, the CO_2 remains stored (INBAR, 2014).

The high annual rate of carbon accumulation of bamboo forests means that they are one of the most efficient types of forest vegetation for carbon fixation (Song *et al*., 2011) and certainly comparable with agroforestry and forest ecosystems (Nath *et al*., 2015). Net primary productivity (NPP), which is the balance between carbon inputs (photosynthesis) and outputs (respiration), was assessed for 28 genera/species in 252 data sets, and bamboo (five data sets) was recorded as having the highest average NPP value (Karoshi & Nadagoudar, 2012).

Ecosystem services

Ecosystem services are the benefits people obtain from ecosystems, and include provisioning services such as food, fuel, fibre and water; regulating services such as regulation of floods, climate, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, aesthetic, spiritual, religious and other nonmaterial benefits (Millennium Ecosystem Assessment, 2003). A very important, but indirect supply of ecosystem services, are those provided by forests that remain standing, because bamboo has been able to provide the timber which those forests would otherwise have provided (INBAR, 2014.

A Chinese study of ecosystem services and their values, in the Qinba mountain area in Shaanxi Province in China, and the annual value of the vegetation's primary productivity, soil and fertility conservation, water conservation, carbon fixation, and oxygen supply concluded that the economic value of services of the forest ecosystems in the study area were huge (Li *et al.*, 2006), even though the researchers could not assess the economic value of every forest ecosystem service, such as air purification, noise dampening, protection of the ozone layer, etc., nor species shelter, rest and recreation values. A simple calculation was performed on the data in Table 1 of the study, which revealed that on an ecosystem service value per unit area by forest type, *subtropical bamboo forest* had the greatest value, of the 20 forest types listed.

Bamboo forests are responsible for unique nutrient-cycling functions. A study of *moso* bamboo in Japan (Umemura & Takenaka, 2014) found that a huge biogenic silicon (Si) pool derived from bamboo plants exists in the floor of bamboo forests - Si has various biogeochemical functions, such as regulating soil formation and species composition. One study suggested that the environment downstream of bamboo forests could be altered by the physiological activity of bamboo, thereby increasing the concentration of dissolved salts, which may eventually affect the local fishery as well as agriculture (Akagi *et al*., 2012). The researchers, in referring to Isagi and Torii (1998), also described the invasion of significant areas of forest in Japan by bamboo as an important environmental problem. Whilst the caution by Akagi *et al*. (2012) should be noted, there is much work to be done to understand interactions between plant Si metabolism and whole ecosystem Si cycling (Schoelynck *et al*., 2014).

In a study of the biomass, litterfall, and soil organic matter dynamics during a complete bamboo talun-kebun rotation cycle in West Java, Indonesia, it was found that the historical sustained success of the system, with minimal external inputs of fertilizer, appears to be closely related to the growth habit and biogeochemical characteristics of the bamboo - that is, its rapid biomass accumulation, the accumulation of its litter, and the extremely high biomass of fine roots. The study provided scientific support for the traditional saying of the local farmers: "without bamboo, the land dies (Christanty *et al*., 1996).

Researchers studying *Phyllostachys pubescens* in southern China found that intensive management practices, such as fertilization, weeding and deep tilling, are extensively utilized, and generally had a negative influence on soil biological properties. To minimize these detrimental effects, an improved intensive management practice, which reduces mineral fertilizer application and increases organic fertilizer application, was recommended, so that both high bamboo yield and soil quality can be sustained over a long period (Xu *et al*., 2008). An Indian study examined the possible use of bio-fertilizers for bamboo production, as an alternative to chemical fertilizers, because of the latter's potential to degrade soil, however the study concluded that more work was required on the subject (Hazarika *et al*., 2006).

Phytoremediation

Phytoremediation is a process whereby plants offer a permanent, in situ, non-intrusive, self-sustaining method of soil and water contaminant removal. Potential risks may exist however, for animals and humans who live in the areas in which phytoremediators grow, especially if they feed on the plants. Phytoremediation should therefore involve the use of plants which are not consumed as food, and bamboo is a likely candidate (Bosire, 2014).

A study of dwarf bamboo (*Sasa*) in mountainous areas of Japan found that *Sasa* communities may have a significant role in preventing soil acidification because of recycling elements in the soil-*Sasa* ecosystem (Takamatsu *et al*., 1997). A Chinese study of two bamboo species, *Phyllostachys auresulcata* and *Pleioblastus chino*, found that both bamboo species have the potential to be developed in Cu-polluted areas of China as bioenergy resources and phytoremediation plants (Jiang *et al*., 2013). Acid-treated bamboo root could be a good adsorbent for the removal of Cu^{2+} and Zn^{2+} ions from industrial effluents (Babatunde *et al*., 2009). Acid-treated bamboo powder effectively adsorbs Cd II ions, which is significant in the context of being able to remove Cd from aquatic environments for protection of human health (Luo *et al*., 2011). Bamboo leaves have also been found to be excellent for Cd(II) removal from aqueous solution (Pandey *et al*., 2015).

While phytoremediation using bamboo may have great potential, the ultimate fate of any contaminants taken-up by bamboo needs to be assessed, and in the case of persistent contaminants, a rigorous management plan for bamboo harvesting, use and/or disposal, must be developed, implemented and monitored, to protect the health of potentially affected humans and animals. For example, if a phytoremediation project involved capture and storage of persistent contaminants, the bamboo species selected should be those which do not produce edible shoots.

Fuel

Bamboo can produce both wood fuel and charcoal (Fig. 2) for cooking and heating, and can generate electricity using biomass gasification technology, which takes pressure off other forest resources (INBAR, 2014). As a wood fuel, bamboo shares a number of desirable fuel characteristics with certain other bioenergy feedstocks, such as low ash content and alkali index. Bamboo's heating value is lower than many woody biomass feedstocks but higher than most agricultural residues, grasses and straws (Scurlock *et al*., 2000).

Figure 2. Bamboo charcoal (photo Paul Bourne).

The relatively high cellulose and low lignin content of bamboo makes it suitable for bioethanol production, and one study found that it has the potential to generate 143 L of ethanol per dry ton of bamboo process waste (Kuttiraja *et al.*, 2013).

Charcoal purifiers

Activated charcoal made from bamboo is used as a deodorant, purifier, disinfectant, medicine, agricultural chemical and absorbent of pollution and excessive moisture (Troya & Xu, 2014). A Nigerian study into the effectiveness of charcoal made from waste bamboo (*Bambusa vulgaris*) collected from a construction site concluded that the charcoal had a maximum adsorptive capacity within 24 hours of use and could effectively reduce most organic and inorganic contaminants found in surface water (Ijaola *et al*., 2013).

Affordable housing and contemporary design

Bamboo has been used in Vietnamese traditional housing for a very long time, and still is being used for housing in many parts of the country, and in particular by minority ethnic groups (California State University, 2015; Vietnam Culture, 2015). Climate-smart housing using bamboo has been underway in South America over the last few years. The designs provide houses which are of low cost, disaster-resistant, quick to build and comfortable to live in (INBAR, 2014). The bamboo *bahareque* house construction traditions from the *Guadua* culture region of Colombia and Ecuador, which consist of bamboo plastered with cement mortar, are functional, earthquake resistant and are being taken-up by other countries in Latin America (Gutiérrez, 2000). In Viet Nam, Vo Trong Nghia Architects and H & P Architects (Fig. 3) have come up with very interesting low-cost housing designs (Williams, 2014 and Jebiga, 2015). Bamboo is also finding its way into contemporary design, with some spectacular results (Ecofriend, 2012).

Figure 3. Floating bamboo low-cost house by H & P Architects (courtesy www.jebiga.com).

Construction materials

Bamboo has been used in construction from times immemorial (Yuming & Chaomao, 2010), and still is, and in areas where it does not naturally occur, it is becoming ever more popular as an attractive and ecological building material for product and interior design (Uffelen, 2015). With technical advancement, new bamboo products are available: bamboo panels, knock-down bamboo furniture, processed bamboo flooring, pulp and paper and bamboo textiles (INBAR, 2014) (Fig. 4). Bamboo is also used for fencing, slats and plywood (Brenner, 2008). Industries based on replacing wood with bamboo have already taken shape in China. To replace wood with bamboo, the major approach is to mass produce bamboo based panels as substitutes for various wood based panels. At present the main products include woven bamboo plywood, bamboo laminated plywood, bamboo veneer panels, over-laid decorative boards, bamboo parquet flooring, bamboo wood composite panels,

Figure 4. Moulded bamboo structural components - box-beam and splint-column made from bamboo laminated panels (fig. 2 from Wang & Guo, 2014).

bamboo flakeboard, bamboo shaveboard, corrugated bamboo board, and bamboo fiberboard (Yuming & Chaomao, 2010, p.170).

Reinforcement in concrete and composites

Bamboo can be used as a means to reinforce cement for making concrete products, such as low-cost roofing sheets (Alade & Olutoge, 2004), and for concrete structural elements generally (Ghavami, 2005; Brink & Rush, 1966; Sevalia, 2013). Bamboo is currently being used to make composite panels and a wide range of moulded products (Khalil *et al*., 2012) (Fig. 5), and research is on-going into the possibilities of bamboo fibre reinforcement for epoxy and polyester resins (Kushwaha & Kumar, 2009; Kushwaha *et al*., 2012; Gupta, 2014)

Composite Decking

Composite Fencing

Composite Deck Tiles

Composite Railing

Figure 5. Various applications of bamboo fibre composites from China (source: www.composite-deck.com/bamboo-plastic-composite.html - accessed 23 October 2015.

Pipelines, erosion-control structures and soil surface stabilization

Bambusa vulgaris has been found to have high potential as a means to pipe water, however the health risk from bamboo treatment is a challenge, unless a "pipe-within-a-pipe" approach is taken (Lippert, 1976). There is also the potential for bamboo to be used in small-scale irrigation systems (Awe & Ogedengbe, 2010) and low-cost wells (Shakya *et al*., 2009).

Bamboo can be used to make wave attenuation structures to reduce coastal erosion (Halide *et al*., 2004), to form a bed on soft muds for rubble coastal protection works (Kamali & Hashim, 2010) and to stabilize riverbanks (Rahman *et al*., 2011). Because of its shallow root system (Kleinhenz & Midmore, 2001), bamboo does not pose a piping threat if it were to be planted along coastal dykes (Cusack, 1999, p.50) as a source of material for coastal protections works, however species would need to be selected carefully, as bamboo generally prefers soil with pH values between 5 and 6.5 and grows poorly on saline-sodic soil and coastal solonchak soil conditions (Yuming & Chaomao, 2010).

The fibrous nature of the root system of bamboo means that it will hold soil together against surface runoff induced erosion. Whilst this may be a useful attribute for flat and gently-sloping lands, the shallow root system of bamboo may render it unsuitable for stabilizing sloping ground (Lin *et al*., 2011; Stokes *et al*., 2007).

Bamboo crafts

Figure 6. Bamboo weaving in Bao La Village has helped to raise people out of poverty by providing them with extra income (photo VNA/VNS Photo Nguyen Thuy).

Bamboo is used to make an array of craft and domestic items, such as furniture, mats, baskets, tools and tool handles, hats, traditional toys, musical instruments, trays, bottles, jars, boxes, cases, bowls, fans, screens, curtains, cushions, lampshades, lanterns and toothpicks (INBAR, 2014; Patel, 2005). Non-timber forestry, and particularly bamboo, is closely attached to almost 24 million mountainous ethnic people in Viet Nam, and in 2010 the country had more than 2,000 traditional craft villages, with 723 of them involved in traditional bamboo and rattan weaving (VietNamNewsToday.com, 2010). Good examples of such craft villages are Thai My village in Cu Chi District (Vietnam Pictorial, 2012), Thu Hong Bamboo and Rattan Craft Village (Vietnam Pictorial, 2012a) and Bao La craft village in central Thua Thien (Fig. 6) and Hue Province's Quang Dien District (Viet Nam News, 2012).

Textiles and paper

Figure 7. Paper from a Chinese factory from Kaiyuan, Yunnan (photo Chaomao, from Yuming & Chaomao, 2010, p.173).

Using bamboo for textile manufacture is a form of engineering for sustainable development (Waite, 2009). The advantages of bamboo fabric are its very soft feel (chemically manufactured), or ramie-like feel (mechanically manufactured), its anti-microbial properties, its moisture-wicking capabilities and its anti-static nature. The main constraints for bamboo are costs, and those typical of the textile industry – energy, water and chemical requirements - which could be addressed through closed-loop manufacturing, eco-chemicals, water-recycling, and economic tools such as full pricing (Waite, 2009).

The relatively long and wide fibers of bamboo make it a very acceptable material for paper and rayon making (Fig. 7), however the species used have to be adaptable to the ecological environment of the site (such as an indigenous species with a strong adaptation), they need to produce straight and large culms with moderate wall thickness, and they should have a high content of long fibres but a low content of lignin and silica (Yuming & Chaomao, 2010). India ranks first in the world for producing bamboo paper, and as of 1982, bamboo accounted for 60%-65% of India's total raw material for paper making (Yuming & Chaomao, 2010, p.171).

Bamboo shoots

Bamboo shoots are a major source of food in many parts of the world, and the bamboo-shoot industry is extensive (Fig. 8). The main constituents of bamboo shoots include protein, amino acids, fat, saccharides, and minerals, and bamboo shoots rank highest among vegetables in protein content (Yuming & Chaomao, 2010, p.149). Growing bamboo for shoot supply may be part of the answer in providing food security to those communities which are struggling to obtain sufficient food to eat (Basumatary, *et al.*, 2015). Bamboo shoot harvesting however, as with culms, is seasonal, and harvesting of shoots while underground can yield higher protein and amino acid content (Troya & Xu, 2014). Bamboo shoots are now processed into many kinds of food, including fresh shoots, dry shoots, and canned shoots, and are sold around the world, and some new products, such as bamboo candy, bamboo chutney, bamboo canned juice and bamboo beer are also available (Troya & Xu, 2014).

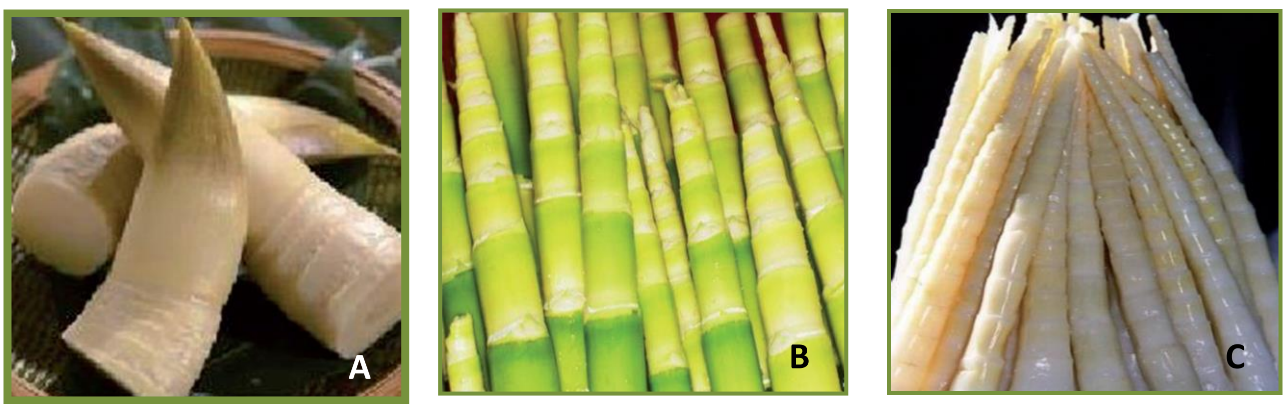

Figure 8. Bamboo shoots for food: *Sinocalamus latiflorus* (A), *Pleioblastus sp*. (B and C) (from Troya and Xu, 2014, p.9).

Medicinal properties

In Chinese culture, many parts of the bamboo – leaf, seed, root, tabasheer, associated fungus, chips of fine inner skin and juice from bamboo culms - are all efficacious medicines for many diseases (Yuming & Chaomao, 2010, p.10). It has been found that bamboo vinegar could be used as a potential additive in animal production as an antibiotic (Wang *et al*., 2012), that polysaccharides extracted from *Moso* bamboo-leaf could possibly be effectively employed as ingredients in health or functional food to alleviate oxidative stress (Maoa *et al*., 2013). There is pharmacological evidence to

Figure 9. Bamboo silica as a health product (source: www.vitexnutrition.com).

support the clinical application of bamboo leaf flavonoids, because of their remarkable protective effects on acute liver injury, which is related to its strong antioxidant capacity to reduce damage in the liver caused by oxidative stress and cell apoptosis (Zhang *et al*., 2014).

Income generation

With the vast array of uses of bamboo, it has the potential to provide income, particularly for rural households who are struggling to earn an income. A survey was undertaken of 210 farm households and 110 bamboo traders in three upland districts in northwest Thanh Hoa, Viet Nam, into the impact of the industrial bamboo sub-sector. The survey covered an area of 95,000 hectares of luong bamboo (*Dendrocalamus barbatus*), and for the period between 2006 and 2008, it was found that poverty fell by 8 percentage points among households engaged in cultivating, processing or trading luong, but remained unchanged for households without luong incomes (Baulch *et al.*, 2009). Another study of socio-economic and environmental aspects of bamboo production in the mountains of northern Viet Nam, found that bamboo provides the highest return to labor but the lowest land productivity, and that soil carbon under bamboo is 20% higher than that of cultivated land with cassava, although the late income derived from bamboo and low return on land discouraged farmers to grow bamboo (Ly *et al*., 2012). In the case of the latter study area, intercropping food crops with bamboo may offer a satisfactory combination of increased income, food security and better environmental outcomes.

V. Sustainability in Viet Nam and the potential for bamboo

With the global community increasingly developing initiatives to achieve a sustainable future, what has been the part played by Viet Nam? Since signing the 1992 Rio documents, Viet Nam has striven to achieve sustainable development, but as Attachment 1 shows, there is work still to be done. To help address the issue, Prime Minister Nguyen Tan Dung on April 12, 2012 signed Decision No. 432/QD-TTg approving the Viet Nam Sustainable Development Strategy for 2011-2020 (Socialist Republic of Viet Nam, 2015c). The strategy is detailed and comprehensive, and provides a guiding path for the nation to follow for a sustainable future. The Strategy defines sustainable development as:

- the requirement lasting throughout the process of national development; closely, properly and harmoniously combine economic growth with social development, natural resources and environment protection, national security and defense, and social order and safety.
- the common work of the whole Party, people, authorities at all levels, ministries, agencies, localities, enterprises, social organizations, communities and individuals.

Viet Nam has formulated other documents which are aimed at sustainability, including the National Strategy on Environment Protection to 2020 with visions to 2030, the Forest Development Strategy (2006-2020), and, the National strategy on climate change (Socialist Republic of Viet Nam, 2015a, 2015b & 2015).

Viet Nam has also been playing its part in striving to address the issue of climate change. In its 2014 report to the UNFCCC, Viet Nam listed 219 CDM projects as of October 2010, consisting of 179 hydro power, 14 biogas/methane, 13 biomass, 4 wind power, 3 waste management, 2 waste heat recovery, 1 wastewater, 1 fluoro lighting, and 1 expansion of coffee manufacturing (Socialist Republic of Viet Nam, 2014). Forest services, and bamboo, however, are noticeably absent from the list. The proliferation of hydro power projects, whilst directly leading to a reduction in CO_2 emissions, may well have undesirable environmental and social impacts if new dams are constructed, forests are inundated and peoples are displaced.

Since 2009, in line with international-level developments, Viet Nam has taken steps to align its forestry sector with REDD+ and to develop the national capacity and infrastructure for REDD+. REDD+ is becoming a key factor in the ongoing development of the forestry sector, leading to reforms to facilitate the implementation of REDD+ in Viet Nam. With the country's forest functional categories (production, protection and special use forests) and the status of forest management in Viet Nam, all five REDD+ activities are appropriate:

• *Reduction of emissions from deforestation*: relevant to many areas of production and protection forests, which continue to face a threat of deforestation.

• *Reduction of emissions from forest degradation*: relevant to any area of special use, protection and production forest, which continue to face diverse degradation threats.

• *Conservation of forest carbon stocks*: relevant to forests of all functional categories, but in particular to those forest lands that have intact forests.

• *Sustainable management of forests*: relevant to all areas of standing forest and particularly to production forests.

• *Enhancement of forest carbon stocks*: relevant to any forest land where planting or assisted natural regeneration may take place, much of which has been badly degraded or is even barren.

Some of the important institutional and policy steps taken towards REDD+ readiness in Viet Nam include:

• Late 2009 - the National REDD+ Network was established.

• January 2011 - the Prime Minister established the National REDD Steering Committee (NRSC), chaired by MARD, to develop policies, to steer and coordinate government agencies, to oversee the formulation and implementation of a Viet Nam REDD+ Program, and monitoring

• January 2011 - MARD established the Viet Nam REDD+ Office (VRO)

• December 2011 - the National Strategy on Climate Change was approved, which includes Strategic Task 4, the Protection and sustainable development of forest, increasing carbon removals and biodiversity, and increasing forest cover to 47% of the country

• Under MARD instruction, a number of Provincial People's Committees (PPC) are establishing inter-agency REDD+ Task Forces

• June 2012 - the National REDD+ Action Programme (NRAP) was approved through Decision 799/QD-TTg, laying out how Viet Nam will implement the three stages of REDD+ through 2020.

The Viet Nam Administration of Forestry (VNFOREST) within MARD is the lead agency on REDD+, and is responsible for developing and implementing policies and programmes relevant to REDD+ and for coordinating international assistance (UN-REDD Viet Nam, 2013).

Viet Nam's REDD+ Action Plan (NRAP), while beginning to be applied in traditional forest areas, has limited protection for, and promotion of, bamboo. In Lam Dong Province, the PPC gave approval to convert 40,463 ha of mainly bamboo forest and mixed timber-bamboo forests with low standing volume into rubber plantations by 2020. Ha Tinh Province, on the other hand, whilst including a forest conversion program for rubber, also has a bamboo-planting program of 10 million stems/yr. Binh Thuan intends to convert poor forests to plantations (which may include bamboo forests). Bac Kan intends no forest conversion or cutting of natural forests, and aims for 20,000 tons of bamboo production by 2015 (UN-REDD Viet Nam, 2013). There is a lesson to be learned from China, where in the 1960s, plantations of rubber trees were created by opening up virgin soil, which destroyed thousands of hectares of natural *Dendrocalamus membranaceus* bamboo forests, and now the bamboo can only be found in remote areas (Yuming & Chamao, 2010, p.217).

Viet Nam was the first country in Southeast Asia to pilot a scheme of payments for forest ecosystem services (PFES) ("Decision 380"). The scheme focused on watershed protection services in two pilot sites in Lam Dong and Son La Provinces, and based on the success of these pilots, a nation-wide PFES Decree ("Decree 99") came into force on 24 September 2010 (UN-REDD Viet Nam, 2013). A brief overview of the schemes appears in Attachment 3. In time, perhaps bamboo forests too, can be considered eligible for ecosystem service payments and become part of Lam Dong's forestry establishment program, rather than a sacrificial asset.

As of December 2005, Viet Nam's total timber volume was 813.3 million m^3 (94% from natural forest and 6% from plantation forest), and there were around 8.5 billion *bamboo* stems. The average forest area per person in Viet Nam was 0.15 ha, and 9.16 m^3 timber/ person, and Viet Nam belongs to the low group of countries in comparison with the international averages of 0.97 ha of forest/person and 75 m^3 timber/ person. There are 200,000 ha of plantation forests being established each year in Viet Nam, which will take pressure off natural forests for the supply to mining industries, wood chips for export, and fuelwood (Soc. Rep. Viet Nam, 2015b), and there is no reason why bamboo could not be part of the planting program. Attachment 4 provides more detail on Viet Nam's projected demands for forest products, NTFP and environmental Services.

The Viet Nam Prime Minister's Decision No. 177/2007/QĐ-TTg of 20 Nov. 2007 approved the *Master Plan on bio-fuel development until 2015, vision 2025*, which has a target for 2025, for ethanol and vegetable oil output, of 1.8 million tons, which will meet approximately 5% of the country's fuel needs (Soc. Rep. Viet Nam, 2012). Bamboo is a potential source of biofuel, and could become part of the national program.

It is clear that Viet Nam is striving for a sustainable future, and its involvement so far in CDM, REDD+ and PFES indicate the potential for bamboo to be part of the Nation's sustainable future.

VI. Developing a sustainable bamboo industry in Viet Nam

For a bamboo development proposal in rural in Viet Nam to succeed, it is vital that the community is involved. Such involvement can gain traditional knowledge and overcome any negative elements by using a scientific approach to gain community participation in environmental conservation and best practice, as well as achieving socio-economic development of the community (Rao *et al*., 2003). For bamboo enterprises generally, the cultural importance of bamboo to the community should be fully considered, as well as the need to fully explain the proposal to the community (Buckingham, 2009; Brenner, 2008).

In Africa, there has been concern that the development of the bamboo industry there has not been in the best interests of the people. EcoPlanet Bamboo, a multinational company, has been expanding its operations in Africa while it promotes the industrialisation of bamboo as an environmentally attractive alternative fibre for timber manufacturing industries that currently rely on the harvesting of natural forests for their raw resource. The company believes that bamboo grown in the right way on land that has little value for other uses, and managed under the right sustainable management system, can play a role in restoring highly degraded ecosystems and connecting remnant forest patches, while reducing pressure on remaining natural forests. Currently, bamboo is widely grown in Africa by small farmers for multiple uses who have received international funding in order to create sustainable rural livelihoods and enterprises by using bamboo resources. None-the-less, the concern is that plantations are not owned by the weak in society, but are owned by corporations or rich individuals with strong economic and sometimes political connections, which can lead to displacement of vulnerable farmers, loss of territories and means of livelihoods (IPSNews, 2015). For Viet Nam, to avoid such perceptions, warranted or not, a high level of involvement of all levels of the community in bamboo development projects is essential.

A thorough understanding of all the social relationships and networks that make up local trade relationships will be essential for successful development of a bamboo industry. Research in Viet Nam's Thanh Hoa bamboo-growing area found that luong bamboo is embedded not only in social and economic relationships, but also within local financial networks, as most bamboo is purchased at the farm gate based on credit. The study also found that while farmers have choices in whom to trade with, these are structured by long term relationships that make it difficult for them to move to different buyers (Delaney, 2010).

In assessing the sustainability of a bamboo product, the details of its supply chain life need to be known, so that transport impacts can be calculated as part of the life-cycle cost:benefit assessment. Brenner (2008) provides a simple example of what is involved by describing how Chinese fishing rods are shipped to a locality in the US. Another study found that bamboo products generally have less eco-costs than tropical hardwood (FSC certified), but because of transport costs, bamboo products imported in Europe have more eco-costs than local European softwood (Vogtländer *et al*., 2010). Even though bamboo has such impressive potential, realizing that potential is the challenge. One model for industry development is to set up an economic cluster, such as the IT and electronics cluster in Silicon Valley, California (Nguyen & Martin, 2015). A schematic of a simple cluster model appears in Attachment 5. In the bamboo context, a few of the issues which a cluster will face are:

- upstream in production, there are the problems of degenerated bamboo species, over exploitation and hard competition from construction demands
- in the processing phase, production suffers from low quality equipment, high waste, a high percentage of defective products, weak designs and low-value-added products
- downstream problems concern waste treatment, weak distribution channels, lack of markets for products and hard competition from Chinese products (Nguyen & Martin, 2015)

Essential for success of a bamboo industry is the need to adequately address transport issues, electricity, water and labour supply and treatment of waste and polluted water. To preserve the resource and its environment, and to raise the living standards of the inhabitants, incentives, and a green supply chain management regime, are necessary (Nguyen & Martin, 2015; Collins & Keilar, 2005). A zero waste strategy should be the aim, where crooked or damaged bamboo and industry off-cuts can be used for charcoal production, pulping, splits for flooring, etc.. Branches and leaves can be used as organic fertilizer, manufacturing dust can be used for contaminant filtering or fertilizer, and waste-water can be recycled. Of no lesser importance is the need for respect and protection of the health of workers and the environment. Bamboo outer and inner skins are high in silica and processing dust can lead to silicosis in workers if they are not adequately protected (Cusack, 1999). Treatment chemicals, depending on what they are, can pose serious health risks to workers and the environment, and need to be used in ways to avoid this from happening.

A very important issue is the choice of which bamboo species to farm. There are many species to choose from, so selecting the most appropriate species for the environmental conditions of a site, and the proposed product line, is paramount. As an example, Attachment 6 provides a list of major economic bamboo species in China and their uses (Troya & Xu, 2014).

The bamboo industry needs to be able to provide a properly aged product for industry success. Young culms are weak, and old culms start to lose strength, so it is necessary to harvest culms which are around five years old for temperate species and three years old for tropical species (Yuming & Chaomao, 2010). Real challenges will exist to achieve properly aged bamboo for a successful industry. Research in Thanh Hoa found that very few farmers applied modern farming techniques and supplied aged culms, and there was no “age” factor within the bamboo pricing structure. This has resulted in industries which required high grade bamboo for flooring and not be able to get it, to switch to making products, such as paper pulp, from lower grade bamboo (Delaney, 2010).

A sustainable bamboo industry will need careful planning, for planting, growing and harvesting culms, and respecting the seasonal nature of bamboo cycles. There is a proverb that says "bamboo planting has no specific season, so long as it is done after a rain (Yuming & Chaomao, 2010). There will need to be high level management of farming practices. Intensive management methods, and the use of inorganic fertilizers and pesticides, can lead to soil and water loss, decreased soil fertility, increased water pollution, a simplified forest structure, a decrease in the species richness and biological diversity of the tree, shrub, and herb layers, and can decrease soil microbial activity and biodiversity (Song *et al*., 2011). For sustainable bamboo production, it is very important to manage standing culm density and soil health, particularly by the use of organic fertilisers (Kleinhenz & Midmore, 2001). In Zhejiang province in China, bamboo management involves, amongst other things, top-logging the top third of 1-year old culms and ink-marking of 1-year old culms (Troya & Xu, 2014). A new bamboo forest needs a well-established schedule with specific activities that must be obeyed carefully. In a study of the bamboo industry in the mountains of north Viet Nam, it was found that there was a lack of knowledge on bamboo plantation management, and on processing and utilization of the bamboo, and there was also a need for bamboo research to support intensive bamboo management activities (Tran, 2010).

For bamboo to reach its full potential as a durable product, its susceptibility to attack by insects and fungi must be satisfactorily addressed. The structure of bamboo, whilst imparting it with its unique qualities, ironically renders bamboo difficult to treat with suitable substances. Much research has been done on means to preserve bamboo. There are management strategies which involve cutting bamboo at an appropriate age and time of the year, which can reduce its appeal to insects, but not prevent attack. There are traditional treatment methods involving soaking in water to leach out nutrients, lime-washing, baking and using natural dyes, varnishes and paints. There are a variety of chemical treatments, being either fixing or non-fixing water-borne, oil-based, organic solvent-based or natural toxicants, with varying degrees of effectiveness and toxicity to the environment. Chemicals can be applied by spraying, brushing, dipping, butt-end dipping, pressurized sap-replacement and pressure treatment (National Mission on Bamboo Applications, 2006). There is an on-going need however, for research into improved methods of treating bamboo, which are environmentally friendly, yet effective.

If bamboo projects create monocultures, they are likely to lead to serious environmental problems in the future. In China, the removal of trees and undergrowth from previously biodiversity-rich bamboo forest systems has now led to loss of biodiversity (Buckingham, 2009). In establishing new bamboo plantations, including other plant species of differing structure, will be creating greater habitat niche variety, which in turn will attract fauna assemblages to fill those niches. The more complex the system becomes, the healthier it will be. A study into the protection of bamboo diversity in Yunnan China stressed the need to reinforce scientific knowledge through education, and to develop community economic and cultural outlooks. At the same time, the bad traditional management habits need to be changed (Yuming & Chaomao, 2010, p.220).

Establishing new areas of bamboo can be part of a larger strategy of supporting and increasing biodiversity. Avoiding monocultures of bamboo, and creating species (and niche/habitat) diversity will not only add intrinsic value to planting areas, but could also add resilience to local and regional diversity through the formation of biological corridors, or linkages, through the landscape, whereby other forests and vegetation patches become connected. The process involves *metapopulation dynamics* (Hanski & Gilpin, 1991), whereby habitat patch ecosystems with low biological resilience can be supported by being connected in a biological network, similar to the concept of the internet. In the context of climate change and increasing global temperatures, connections between lowland and upland areas become very important for the movement of organisms. Using drainage systems (creeks, canals, rivers and wetlands) for network establishment can be one approach.

Enriching bamboo forests should ideally be based on the inclusion of other plant species local to the area, and of all structural types (upper storey, mid-storey, shrub layer and ground-cover/grass layer). The publication, China's Bamboo (Yuming & Chaomao, 2010) describes various bamboo communities in China, and a description of one of them, *Dendrocalamus membranaceus,* demonstrates the richness of its floral species. The formation of the *D. membranaceus* community includes 58 families, 132 genera, 165 species of spermatophyte; 6 families, 6 genera, 8 species of ferns; as well as many species of moss (Fig. 10).

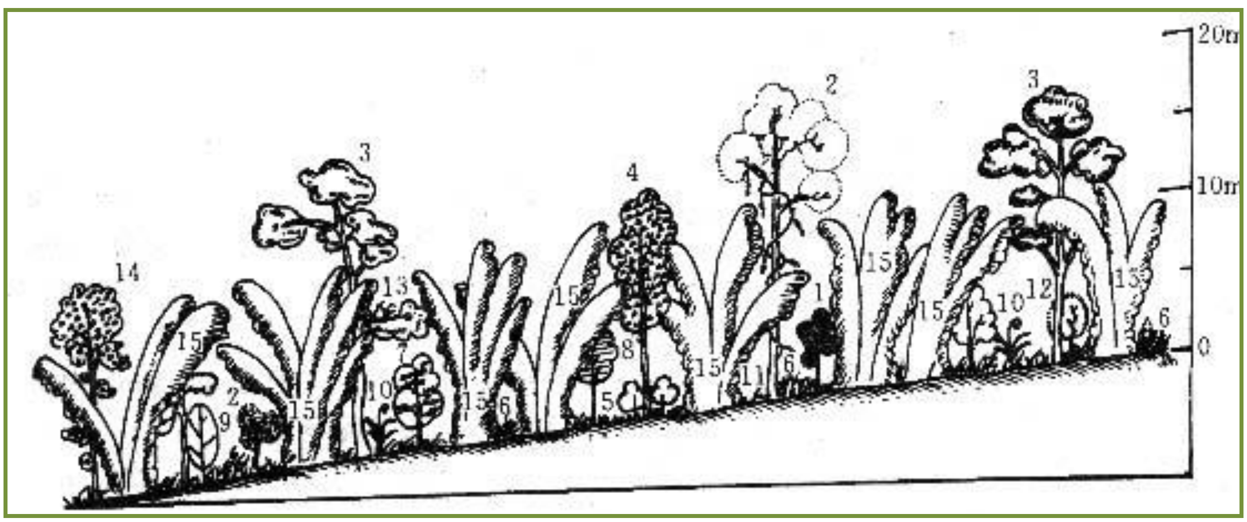

Figure 10. Composition of a natural *D. membranaceus* community: 1. *Bauhinia variegata*; 2. *Dalbergia assamica*; 3. *Stereospermum terragonum*; 4. *Spondias pinnate*; 5. *Ardisia solanacea* ; 6. *Microstegium ciliatum*; 7.*Deospermum gracilentum*; 8. *Aporusa villosa*; 9. *Mallotus philipinensis*; 10. *Cyclosorus molliusalus*; 11. *Milletlia* spp.; 12. *Dendrobium* spp; 13. *Toone sureni*; 14. *Toona ciliata*; 15. *Dendrocalamus membranaceus* (source: Yuming & Chaomao, 2010, p.70).

Other countries, including Viet Nam, could learn from relevant management techniques of Chinese bamboo plantations, to make more use of bamboo resources as a tool for poverty alleviation, and as an alternative for carbon sequestration, taking into consideration social and ecological aspects respectively (Troya & Xu, 2014). The development of bamboo in Viet Nam could also gain much assistance from INBAR, as the latter seeks to find and demonstrate innovative ways of using bamboo and rattan to protect environments and biodiversity, alleviate poverty, and facilitates fairer pro-poor trade. INBAR connects a global network of partners from the government, private, and not-for-profit sectors in over 50 countries to define and implement a global agenda for sustainable development through bamboo and rattan (Yuming & Chaomao, 2010).

Historically, the Viet Nam government has helped bamboo plantation development, and large scale plantations of bamboo (either household or collective) have not been established without some form of state subsidy (Delaney, 2010). In a November 2010 seminar on the development of Viet Nam's bamboo and rattan, the Deputy Minister of Agriculture and Rural Development (MARD), Ho Xuan Hung, stated that MARD will provide seedlings and investment capital to bamboo and rattan growers and apply measures to protect bamboo and rattan forests (VietNamNewsToday.com, 2010).

VII. Conclusion

The world is striving to achieve sustainable development, however financial and economic imperatives associated with development have tended to override environmental needs. The seriousness of human-induced climate change seems to be a more tangible challenge for nations, and means to reduce CO_2 emissions have tended to become the means to achieve sustainability. Bamboo has the potential to play a significant role in reducing CO_2 in the atmosphere, and to become an important component in the global carbon trading market.

For a bamboo industry to succeed, there needs to be a high level of expertise at all levels – on farm, processing, logistics and marketing. For example, there is a need for less use of chemical fertilizers and an increased use of organic fertilizers, and the development of effective, and safe, methods of treatment, so that bamboo can increasingly fulfil many of the building industry functions currently provided for by forest timber.

To maximize the concept of sustainability for a bamboo industry, there must be vision at a high level of government to offer inspiration, direction, encouragement, incentives and support. A close relationship with MARD is essential, to gain financial benefits for communities through the various carbon trading mechanisms available. Potential planting areas need to be identified, communities need to be provided with preliminary planning concepts, technical information and livelihood prospects and invited to provide feedback. The development of a sense of ownership in a proposal will endear the community to it, which will motivate a caring, nurturing and protective element to bamboo development. Industry proposals should embody every aspect of the bamboo industry, with a view to achieving an energy-efficient and zero waste system. Government support via the provision of highly trained forestry extension officers, or an industry-provided equivalent, is essential, to achieve a high level of quality control and efficient, effective and sustainable on-farm bamboo management. All aspects of a bamboo industry need to respect and protect workers and the environment. Social surveyors, economists and market researchers need to be involved to analyse every component of a proposal, including community traditions, relationships and needs, and to determine market potential, which will provide feedback for the development, nature and phases of production.

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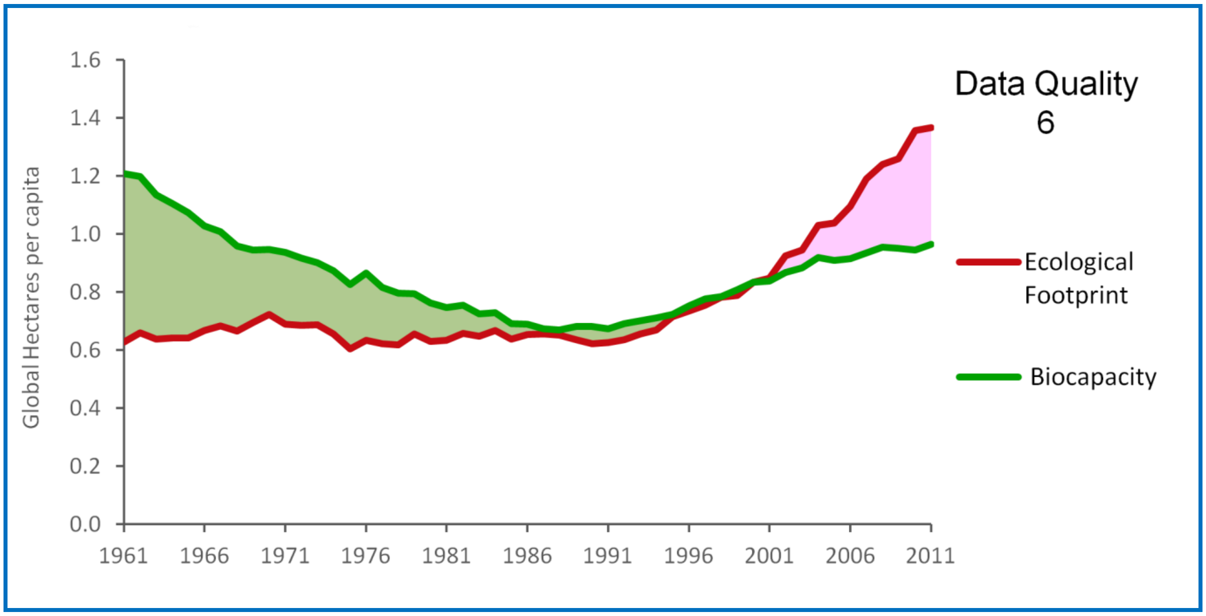
Attachment 1. A comparison of Viet Nam's ecological footprint and biocapacity for the years 1961 to 2011 (Source: Global Footprint Network, 2015).



Note: The data quality value of 6 indicates a high level of reliability.

Attachment 2. Targets under SDG 15 (Source: United Nations, 2015).

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally

15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

lS.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development

15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

15.6 Promote fair and equitable sharing of the benefits arising fi'om the utilization of genetic resources and promote appropriate access to such resources, as intemationally agreed

15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products

15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species

15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts

15.10 Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems

15.11 Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation

15.12 Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities

Attachment 3. Payment for ecosystem services in Lam Dong and Son La provinces (Source: UN-REDD Viet Nam, 2013).

The payment for ecosystem services schemes in Lam Dong and Son La provinces are different. The Son La scheme envisions distributing benefits to all forest owners in the two pilot districts, whereas the Lam Dong scheme pays villagers for the protection of natural forests to which they have no legal rights. In both schemes however, the absence of voluntariness is likely to lead to inefficient use of forest protection funds. To avoid problems, it is important that marginalized people be included in payment schemes.

The Lam Dong scheme pays groups of households to protect forests. They receive the payments on the basis of contracts signed with Protected Area Management Boards, which hold legal titles to a large share of protection forestland in the province. The contracts require the groups to patrol the contracted forest on a regular basis. In return, they receive 90 % of the total revenue collected for the provision of environmental services. This amounts to an average of VND 270,000 (US$15) per year in the Da Nhim watershed, which is significantly more than the VND 100,000 (US$5) paid annually under the 661 Programme.

Both provinces highlight the need to resolve critical issues surrounding forestland tenure. The key issue in Lam Dong is forestland distribution, i.e. the transfer of forestland from state entities to households and village communities. The key issue in Son La is the resolution of disputes over forestland. Disputes between migrants and new settlers are frequent in Son La, as the province has been the location of numerous small and two large hydropower projects in recent years. In addition, conflicts between entities holding legal titles and villagers claiming customary rights to forests are as common in Son La as in other provinces.

Distribution of PFES funds under Lam Dong FPDF in 2009

The total 47.3 billion VND (to be) collected as PFES fees will be distributed as follows:

10% of the total or 4.731 billion VND is retained by (provincial) FPDF to cover its expenses

10% of the remaining fund (9% of the total) or 4.258 billion VND goes to 13 forest owners to cover their management costs

the remaining 90% (81% of the total) or 38.326 billion VND is used to pay for the costs of forest protection; of which 20.8 billion VND is to pay local households for protecting 114,866.3 ha of forest in the pilot sites (four districts of Lac Duong, Don Duong, DucTrong, Da Teh and Da Lat city)

17.526 billion VND is kept as reserve fund

Source: Decision 2091/QD-UBND of Lam Dong PPC, dated 19 August 2009. (UN-REDD Viet Nam, 2013)

Overall, both PFES schemes are highly innovative within the Vietnamese context and promise to yield valuable lessons for the design of Viet Nam's REDD+ programme. Independent evaluation of the initial experiences made in the two provinces however, is critical.

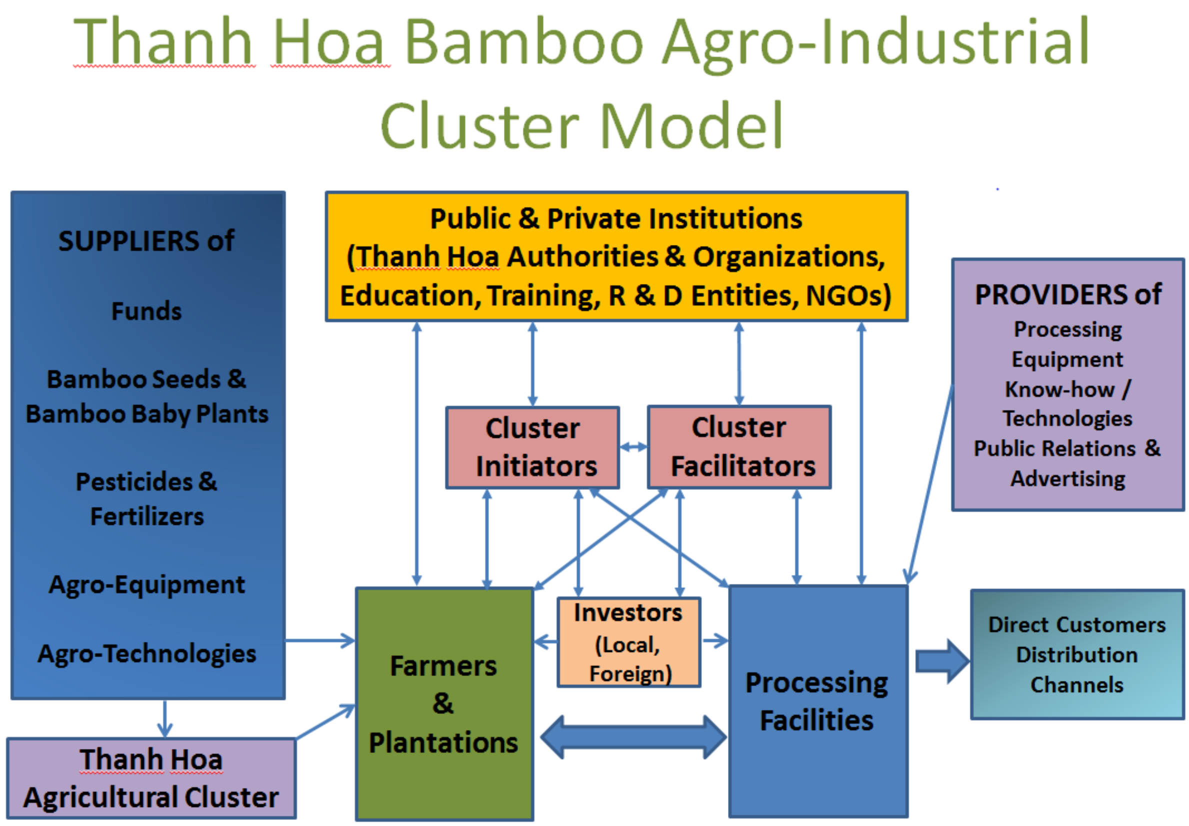
The insights from Son La and Lam Dong are much too preliminary to provide firm lessons on how REDD+ payments may be linked to performance in the future. The Son La scheme may indicate how a future institutional structure can look like, yet it also requires further testing and thorough assessment.

Attachment 4. Projection on demands of forest products, NTFP and environmental Services (Source: Soc. Rep. Viet Nam, 2015b).

	2003	**2005**	**2010**	**2015**	**2020**
I. Domestic and export timber (1,000 m3)	**7,420**	**10,063**	**14,004**	**18,620**	**22,160**
1. Large timber for industry and civil construction.	4,561	5,373	8,030	10,266	11,993
2. Small timber used for export wood-based panels & wood chips	1,649	2,032	2,464	2,922	1,682
3. Small timber for pulp production	1,150	2,568	3,388	5,271	8,283
4. Pit-props	60	90	120	160	200
II. Forest products & NTFP (mil. USD)	**721**	**1.700**	**3,700**	**4,800**	**7,800**
1. Timber products	567	1,500	3,400	4,200	7,000
2. NTFPs	154	200	300	600	800
III. Environmental services (mil. USD)	**0**	**0**	**250**	**900**	**2,000**
1. Clean development mechanism	0	0		400	800
2. Protection in watershed, coastal and urban area	0	0	200	300	800
3. Eco – tourism			50	200	400
IV. Fuelwood (mil m3)	**25**	**25**	**25.7**	**26**	**26**

** Only possible collected values of environmental services are calculated. Total environmental value is not yet calculated*

Attachment 5. Thanh Hoa Bamboo Agro-Industrial Cluster Model (Source: Nguyen & Martin, 2015)



Attachment 6. Major economic bamboo species in China (Source: Troya & Xu, 2014)

Scientific name	Rhizome type	Main Uses			
		Timber	Food	Ornamental	Paper
Bambusa lapidea	Sympodial	x			
Bambusa sinospinosa	Sympodial	x			
Bambusa rigida	Sympodial	x			
Bambusa intermedia	Sympodial	x			
Bambusa vulgaris	Sympodial			x	
Bambusa tuldoides	Sympodial			x	
Bambusa multiplex	Sympodial			x	
Cephalostachyum pergracile	Sympodial			x	
Chimonobambusa quadrangularis	Amphipodial			x	
Chimonobambusa szechuanensis	Amphipodial			x	
Chimonobambusa utilis	Amphipodial				x
Chimonobambusa yunnanensis	Sympodial				x
Chimonobambusa tumidissinoda	Sympodial		x		
Chimonocalamus delicatus	Sympodial	x	x		
Chimonocalamus fimbriatus	Sympodial	x	x		
Chimonocalamus pallens	Sympodial	x	x		
Chimonocalamus makunensis	Sympodial	x	x		
Dendrocalamus giganteus	Sympodial	x	x		
Dendrocalamus sinicus	Sympodial	x	x		
Dendrocalamus latiflorus	Sympodial		x		
Dendrocalamus hamiltonii	Sympodial		x		
Dendrocalamus membranaceus	Sympodial	x	x		x
Fargesia denudata	Sympodial		x		x
Fargesia robusta	Sympodial		x		x
Fargesia nitida	Sympodial		x		x
Fargesia yunnanensis	Sympodial	x	x		x
Indosasa sinica	Monopodial	x			
Phyllostachys edulis	Monopodial	x	x		
Phyllostachys nigra	Monopodial			x	
Phyllostachys aurea	Monopodial			x	
Phyllostachys dulcis	Monopodial		x		
Phyllostachys elegans	Monopodial		x		
Phyllostachys vivax	Monopodial		x		
Schizostachyum funghomii	Sympodial	x	x		

Source: Yuming & Chaomao (2010) China's bamboo.