KEYNOTES

New Generation Bamboo Plantations

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Cecilia Alcoreza L., Lead, Sustainable Paper and Packaging
WWF International
cecilia.alcoreza@wwf.cl

Abstract

Bamboo plantations have the potential to be a promising part of the solution to face the booming demand for fiber. Extremely fast growing, bamboo also plays an important role supplying high yields of fibre in a relatively small area, providing ecosystem services like carbon sequestration and erosion control, supporting rural development and offering opportunities for farmers and rural communities.

Embedding sustainability in the bamboo core business might contribute to the development of areas, which are productive, competitive with the principles of social justice and environmental protection. Therefore, responsible bamboo production could play an important role in healthy, diverse and multi-functional and sectorial landscapes which are compatible with biodiversity conservation and human needs. Additionally, the bamboo production is an important source to contribute the economic growth and to generate employment.

A business philosophy that has gained considerable traction within New Generation Plantation (NGP) is it goes beyond traditional approaches to corporate social responsibility by building social and environmental values into the business strategy: addressing risks and challenges becomes an opportunity that enables the sector to reduce costs, increase revenue or enhance competitiveness.

The NGP concept is premised that well-managed and well-designed plantations in the right places can help conserve biodiversity and meet human needs, while contributing to sustainable economic growth and local livelihoods. In other words, it is maintaining ecosystem integrity**,** protecting high-conservation-value areas, and building relationships with stakeholders, talking and listening to them, and empowering them to meet their needs and achieve their aspirations.

Keywords: Bamboo, new generation plantation; landscape approach

Introduction

By the year 2050, the world's population will reach 9.8 billion, 29 percent higher than today, most of the global increase is attributable to a small number of developing countries (United Nations, 2017). At the same time, economic growth, urbanization and increasing prosperity are driving greater consumption. Meeting the needs and the growing demands of nearly 10 billion people will increase the already huge pressure on the world's natural resources and food and wood-based products are absolutely no exception.

Over the coming decades, demand of food will double by 2050 (WWF Food, 2019), and wood-based products will grow to unprecedented levels. WWF's Living Forest model projects wood harvesting will more than double by 2030 (7,553 million cubic meters), and almost double quadruple by 2050 (13,802 million cubic meters). There are various measures that societies could, and should, employ to reduce the need to produce more food and fiber – including sustainable intensification production, more efficient technologies, use of alternative fibers, greater recycling and re-use and less wasteful consumption.

These facts have revived the interest in alternative fibers among both producers, companies and consumers. These fibers are being explored as alternatives to paper and solid wood products made from trees. In theory, these alternative fibers could complement wood fiber from responsible forest sources, taking pressure off of natural forests, in some cases utilizing other agricultural residue such as bamboo, and contributing to future industrial fiber supply (WWF, 2014).

Bamboo is being hailed as a new super material, with uses ranging from textiles to construction. Bamboo is the fastest growing wood resource on earth and it is a viable substitute for timber and tropical hardwoods. About 18 million Ha. of bamboo are distributed in world forest ecosystems, in Asia, Africa, and America, with over 1,200 different species worldwide (Plantation International, 2017). The multiple uses, resilience of the plant, its extraordinary fast growth rates and possibility of multiple harvests are great advantages that bamboo has over other forestry species. The diversity of uses that it has been traditionally used and the new uses as an industrial raw material that it has found in recent times has led to an interest in promoting bamboo species as an ideal candidate for planted forests (BTSG – KFRI, 2015).

Bamboo plantations have an important role to play in taking pressure off forests elsewhere in the world. They also provide an important source of income for smallholders in rural areas, and have great potential to mitigate climate change by sequestering carbon. At the same time, new technologies are opening up new markets for bamboo, including as a greener alternative to steel and plastics (Jeffries, 2015). The global demand for bamboo is however already growing faster than supply can allow. The need for man-made bamboo plantations opens great possibilities for business in the agriculture and forestry sectors. There is a great industrial demand for it and interest in bamboo production is increasing throughout Asia, Africa, and America (FAO , 2015).

Unlike most timber, bamboo is a self-regenerating natural resource; new shoots that appear annually ensure future raw material after mature culms are harvested. Bamboo provides considerable environmental benefits. In many countries, it is used for ecological purposes such as soil stabilization and erosion prevention on hill slopes and verges (Plantations International, 2018).

Bamboo silviculture is an option for conserving and protecting tropical forests while creating enduring supplies for the textile, wood and cellulose industries. However, there are growing concerns around the development of alternative fibers such as bamboo at scale due of their potential "unintended consequences". According with WWF study on responsible alternative fibers, poor site selection and management could create the need for additional water use, cause pollution from excess chemical or fertilizer use, and even result in the conversion of natural forests. This means, among other issues, it is necessary to ensure the inclusion of environment, socio-economic, cultural and governance criteria

that allow the bamboo sector contributing and enhancing natural resources and ecosystem conservation and protection, while improving the livelihood and well-being of people and social groups.

An ideal alternative fiber feedstock coming from bamboo plantations is one that (WWF, 2014):

- is derived from a renewable feedstock that was selected to improve production compared with traditional sources - including the greenhouse gas footprint-, minimize spread of unwanted species, and provide for environmental and economic resilience under a changing climate and other future conditions;
- is produced on land selected to minimize negative impacts and enhance biodiversity wherever possible by balancing biodiversity conservation between the site and the landscape;
- is land selected after careful consideration of implications for neighboring communities (including free, prior, and informed consent and collaborative operation design and management with local people and/or indigenous communities where appropriate);
- is produced in a way that minimizes overall resource use and on-site and downstream negative impacts to people and nature;
- is produced in a way that maintains or improves the function of ecosystem services and the social and economic conditions in producing communities, while not adversely impacting food or water security and affordability; and
- is legally sourced and produced in a safe and healthy way for workers and surrounding communities that respects human and labor rights.

The New Generation Plantation Approach to the Bamboo Sector

The factors motivating bamboo sector to embark upon sustainable development include social responsibility, environmental aspects, government regulations and international standards, and increased customer consciousness.

To achieve the greater of productivity required, standards must ensure a governance framework that provides social safeguards, achieves inclusive local economic development, provides effective ecosystem stewardship, and stimulates preferential procurement and increased consumer awareness.

It is within this new paradigm that the principles of the “new generation plantations” (NGP) concept carry particular significance (Neves, 2016) (Figure No. 1). Well-managed bamboo plantations stablished and managed in the right places can help conserve biodiversity and meet human needs while contributing to sustainable economic growth and local livelihoods if they (Jeffries, 2017):

- **Maintain ecosystem integrity** for ecosystems to continue to provide the servicies that human beings depend on, key ecological processes need to be able to funtion. These include natural cycles of water, nutrients, carbon and biodibersity. Well designed bamboo plantations can be part of healthy, resilient landscapes, and can strengthen ecosytem services in productive landscapes.

- **Protect and enhance hight conservation values** – biological, ecological, social and cultural values of outstanding significance or critical importance. These might include rare or threatened species, crucial ecosystem services, or sacred and historial sites. By doing this the bamboo sector could contribute to conservation work on a significant scale.

- **Stakeholder involvement**, having a social licence to operate is fundamental to a long term productive sector success. The basis of stakeholder involvement is consultation; this involment is also inherent to worker’s rights and employment conditions, indigenous peoples’ rights and community relationes, among other areas.

- **Economic growth**, bamboo plantations often operate in rural areas with high levels of poverty and unemployment. By bringing jobs and investments into these areas, the sector has the potential to make a significant contribution to economic growth supporting local people to develop forestry and other business, building local people's skills and opportunities, improving health and safety and working conditions.

Figure 1. New generation plantation principles.

Source NGP platform 2011

The NGP Process

How can the bamboo sector begin a process where, little by little, it is inspired by the New Generation Plantations concept and principles? Discussion will not be easy. Even then, promote multistakeholder dialogue and strengthen management systems will require bamboo sector leaders, they can be small and medium sized enterprises or bamboo plantations owners with the appetite of achieve the goals of the business in terms of profitability and growth, but also social and environmental impact.

There is now a substantial momentum towards engagement with the New Generation Plantation concept. Just as the use and uses of bamboo fiber are rapidly expanding, so are the opportunities for bamboo plantations to contribute to important social, environmental and development challenges.

NGP is a learning and influencing platform lead by WWF, and set up with the private sector and government agencies to promote dialogue and co-construct sustainable solutions for tree plantation management. Nevertheless, the NGP concept may be adopted by the bamboo sector and could advocates for bamboo better plantation practices in key regions, showing and sharing practical examples of better bamboo plantation management and the environmental, social and economic benefits. The NGP platform also leverages the engagement with local communities and stakeholders in meaningful processes which goes beyond consultation into processes of empowering communities to achieve their aspirations (Neves, 2014), which is compliant with the essence of this particular sector.

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NGP aspires to an ideal form of plantation that maintains ecosystem integrity, protects high conservation values and is developed through effective stakeholder participation, while contributing to inclusive economic growth. The platform participants share a vision, where well-managed plantations, particularly used to restore currently degraded land and ecosystems, will play an increasingly important role in multifunctional landscapes contributing towards sustainable development goals.

The NGP concept brings together people with different viewpoints, backgrounds and interests in an environment that fosters listening, sharing and collaboration. In encourage people to reflect on and question their own views, attitudes and actions (Jeffries, 2017). Trust, respect and honesty are essential. That is, by recognizing and appreciating the bamboo sector diversity, divergent views can bring alternatives or new insights and new forward.

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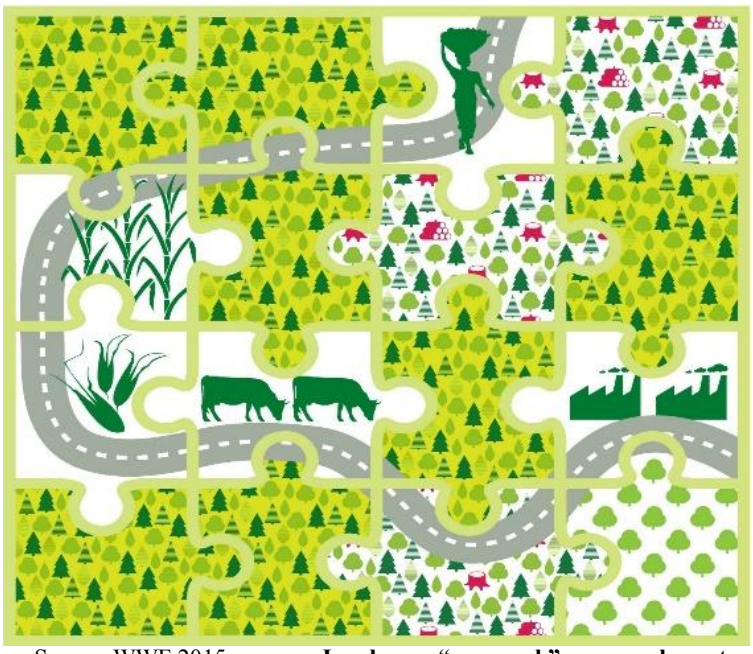
A NGP field visit, focused on practical tasks, discussions and the exchange of ideals

Discussion

Despite its importance, bamboo plantations have not been used to its full potential. This is due to a number of factors, including poor management of existing bamboo stands. Now, however, bamboo is experiencing a real growth period, with good chance of becoming a bio-raw material of the future. It is because of this promise and as it becomes an increasingly lucrative cash crop, that bamboo plantations will be established on a commercial scale and starting to grow as a mono-crop. With unsupportive policy and regulatory frameworks, it could trigger of unregulated expansion of bamboo production and leaving behind the virtues of this plant.

The proposal is well-placed, well-managed bamboo plantations as important components of sustainable and climate – smart landscapes and poverty alleviation. adding the specifics of local governance regimes, ecological dynamics and the rights, needs and aspirations of local people at landscape approach.

In addition, for an expansion productive sector, it is fundamental to incorporate cross-sectorial planning and zoning in mosaics designs to ensure that there is sufficient land for other uses, such as food and fiber production and biodiversity conservation, while also diminishing logging pressure on natural forest and their associated communities, ecosystem services and biodiversity (FAO, 2016).



Source: WWF 2015

Landscape "approach" means coherent intervention at a landscape scale to secure food, fibre and energy production, improvements in social welfare, water security and ecosystem

In an increasingly complex world of limited resources and volatility, fundamental changes are required in production models, business paradigms and governance. Isolated efforts will not be enough. Organizations and productive sectors must develop a strong ecosystem of partners stretching across their stakeholders landscape, and develop creative strategies to harness and leverage interested outsiders. Developing relationships, cross-cultural, cross-sectorial empathy and building networks are important for NGP visionaries.

Conclusion

The NGP concept is aspirational, suggesting plantations can achieve positive environmental and social impacts through continuous improvement. It is based on premises of transparency and cooperation across sectors of society through mutual learning and co-construction of solutions. NGP provides opportunities for dialogue, insights and understanding, and leverage with policymakers and the private sector to advocate environmentally sound, socially responsible and economically viable land-use planning and management practices.

NGP can help to catalyze ambitious systemic changes in the bamboo sector. This will help to avoid the risks and optimize the full potential value of bamboo plantations in meeting the world's fibre needs

sustainably. One way of achieving this would be to envisage aligned agendas for change, so the sector can find a place in relation to larger goals and frameworks, and will allow to make the most significant contributions that the sector can. Flexibility is important to actively experiment and adapt to a continuous changing circumstances. Practicality and collaboration will make the difference on the ground, collaborations should demonstrate collective leadership, foster deep reflection, and help shift focus towards positive visions of the future and the means to get there.

ACKNOWLEDGEMENTS

The author thanks WWF and the NGP Platform participants – the State Forest Administration of China, The Forestry Commission of Great Britain, Governo Estadual do Acre of Brazil, APSD, Arauco, CMPC, Fibria, Kimberly – Clark, Mondi, Portucel/The Navigator Company, Stora Enso, Suzano, The New Forest Company and UPM –who have co-construct the NGP concept. Special thanks to Luis Neves Silvia for his perseverance and determination to influence positively the plantations sector.

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Nueva Generación de Plantaciones de Bambú

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Cecilia Alcoreza L., Líder en Sustentabilidad en Papel y Embalaje
WWF Internacional
cecilia.alcoreza@wwf.cl

Resumen

Las plantaciones de bambú tienen el potencial de ser una parte prometedora de la solución frente al auge de la demanda por fibras. De crecimiento rápido en extremo, el bambú también juega un importante rol suministrando altos rendimientos de fibra en un área relativamente pequeña, proveyendo servicios ecosistémicos como la retención de carbono y control de erosión, apoyando el desarrollo rural y ofreciendo oportunidades a los agricultores y comunidades rurales.

La incorporación del concepto de sustentabilidad en la actividad medular de la producción de bambú puede contribuir al desarrollo de áreas que son productivas y competitivas, con los principios de justicia social y protección ambiental. Por lo tanto, la producción responsable de bambú puede jugar un importante rol en paisajes sectoriales y multifuncionales saludables y diversos, que son compatibles con la conservación de la biodiversidad y las necesidades humanas. Adicionalmente, la producción de bambú es un importante recurso para contribuir con el crecimiento económico y con la generación empleo.

La construcción de valores sociales y ambientales en la estrategia de negocios es una filosofía comercial que ha ganado considerable atracción dentro la plataforma de Plantaciones de Nueva Generación (NGP por sus siglas en inglés) ya que va más allá de las tradicionales estrategias de responsabilidad social corporativa, abordando riesgos y desafíos que resulten una oportunidad que permita al sector reducir costos, incrementar ingresos o aumentar la competitividad.

El concepto de NGP está basado en el buen manejo y buen diseño de las plantaciones en lugares adecuados donde éstas pueden ayudar a conservar la biodiversidad y satisfacer las necesidades humanas, contribuyendo a su vez con un crecimiento económico sustentable y los medios de subsistencia locales.

En otras palabras, manteniendo la integridad del ecosistema, protegiendo áreas de alto valor de conservación y construyendo relaciones con las partes interesadas, escuchándoles, explicándoles y empoderándoles para satisfacer sus necesidades y lograr sus aspiraciones.

Palabras clave: Bambú, plantaciones de nueva generación, enfoque de paisaje

Introducción

Para el año 2050, la población mundial alcanzará los 9.8 billones de habitantes, 29 por ciento más alta que la población actual, la mayoría de este crecimiento global es atribuible a un pequeño número de países en desarrollo (Naciones Unidas 2017). Al mismo tiempo el crecimiento económico, la urbanización y el incremento de la prosperidad están conduciendo a un mayor consumo. Satisfacer las necesidades y las demandas crecientes de cerca de 10 billones de personas incrementará la ya enorme presión sobre los recursos naturales, y los productos alimenticios y basados en madera no son una excepción.

En las próximas décadas, la demanda de alimentos se duplicará en el 2050 (WWF Food, 2019) y la demanda de productos basados en madera crecerá a niveles sin precedente. Según las proyecciones del modelo Bosques Vivos de WWF, el volumen de madera cosechada será más del doble del actual para el año 2030 (7.553 millones de metros cúbicos) y casi se cuadriplicará para el año 2050 (13.802 millones de metros cúbicos). Existen varias medidas que la sociedad puede y debe emplear para reducir la necesidad de producir más alimentos y más fibra – incluyendo la intensificación sustentable de la producción, tecnologías más eficientes, uso de fibras alternativas, más reciclaje y reutilización y menos consumo innecesario.

Los hechos anteriores han revivido el interés por fibras alternativas tanto en productores, empresas y consumidores. Estas fibras están siendo exploradas como alternativa para la producción de papel y productos de madera provenientes de los árboles. En teoría, estas fibras alternativas pueden complementar la fibra de madera producida en forma responsable, reduciendo la presión sobre los bosques naturales y en algunos casos utilizado otros residuos agricolas tal como el bambú y contribuyendo al suministro de fibra industrial en el futuro (WWF, 2014).

El bambú está siendo aclamado como un nuevo súper material, con usos que van desde los textiles hasta la construcción. El bambú es el recurso maderero de más rápido crecimiento en la tierra y es un sustituto viable a la madera como las maderas duras tropicales. Alrededor de 18 millones de hectáreas de bambú se distribuyen en los ecosistemas forestales mundiales, Asia, África y América, con más de 1.200 especies diferentes en todo el mundo (Plantation International, 2017). Los usos múltiples, la capacidad de resilencia de la planta, sus tasas de crecimiento extraordinarias y la posibilidad de cosechas múltiples son grandes ventajas que tiene el bambú sobre otras especies forestales. La diversidad de usos tradicionalmente y el descubrimiento de nuevos usos como materia prima industrial en los últimos tiempos ha despertado un interés en promover las especies de bambú como un candidato ideal para el establecimiento de plantaciones (BTSG - KFRI, 2015).

Las plantaciones de bambú tienen un papel importante que desempeñar para reducir la presión sobre los bosques en otras partes del mundo. También proporcionan una importante fuente de ingresos para pequeños agricultores en las zonas rurales, y tienen un gran potencial para mitigar el cambio climático a través de la captura de carbono. Al mismo tiempo, las nuevas tecnologías están abriendo nuevos mercados para el bambú, incluso como una alternativa más ecológica al acero y los plásticos (Jeffries, 2015). Sin embargo, la demanda mundial de bambú ya está creciendo más rápido de lo que la oferta puede permitir. La necesidad de plantaciones de bambú crea grandes posibilidades para los negocios en los sectores de la agricultura y la silvicultura. Existe una gran demanda industrial y el interés en la producción de bambú está aumentando en toda Asia, África y América (FAO, 2015).

A diferencia de la mayoría de la madera, el bambú es un recurso natural que se regenera a sí mismo; los nuevos brotes que aparecen anualmente garantizan la futura materia prima después de la cosecha de los tallos maduros. El bambú proporciona considerables beneficios medioambientales. En muchos países, se utiliza con fines ecológicos, como la estabilización del suelo y la prevención de la erosión en bordes y la laderas de las colinas (Plantations International, 2018).

La silvicultura de bambú es una opción para conservar y proteger los bosques tropicales mientras se crean insumos duraderos para las industrias textil, maderera y de celulosa. Sin embargo, existen preocupaciones crecientes en torno al desarrollo de fibras alternativas como el bambú a escala debido a sus posibles "consecuencias imprevistas". De acuerdo con el estudio de WWF sobre fibras alternativas responsables, la selección y gestión de sitios deficientes podría crear la necesidad de un uso adicional de agua, causar contaminación por el uso excesivo de químicos o fertilizantes, e incluso resultar en la conversión de bosques naturales. Esto significa, entre otros aspectos, la necesidad de garantizar la inclusión de criterios medioambientales, socioeconómicos, culturales y de gobernanza que permitan al sector del bambú contribuir y mejorar los recursos naturales, y la conservación y protección de los ecosistemas, al tiempo que se mejoran los medios de subsistencia y el bienestar de los seres humanos y grupos sociales.

Una fibra alternativa ideal proveniente de plantaciones de bambú es una que (WWF, 2014):

- se deriva de una materia prima renovable que se seleccionó para mejorar la producción en comparación con fuentes tradicionales, incluida la huella de gases de efecto invernadero, minimizar la propagación de especies no deseadas y proporcionar resiliencia ambiental y económica bajo un clima cambiante y otras condiciones futuras;

- se produce en tierras seleccionadas para minimizar los impactos negativos y mejorar la biodiversidad siempre que sea posible equilibrando la conservación de la biodiversidad entre el sitio y el paisaje;

- se selecciona la tierra después de una cuidadosa consideración de las implicaciones para las comunidades vecinas (incluido el consentimiento libre, previo e informado y el diseño y gestión de la operación colaborativa con la población local y/o las comunidades indígenas, según corresponda);

- se produce de una manera que minimiza el uso general de los recursos y los impactos negativos en el sitio y agua abajo para las personas y la naturaleza;

- se produce de una manera que mantiene o mejora la función de los servicios de los ecosistemas y las condiciones sociales y económicas en las comunidades productoras, sin afectar negativamente la seguridad y asequibilidad de los alimentos o el agua; y

- tiene origen legal y se produce de manera segura y saludable para los trabajadores y las comunidades aledañas que respetan los derechos humanos y laborales.

Enfoque de Plantaciones de Nueva Generacion para el sector de Bambu

Los factores que motivan al sector del bambú a embarcarse en el desarrollo sustentable incluyen la responsabilidad social, los aspectos ambientales, las reglamentaciones gubernamentales y las normas internacionales, y una mayor conciencia del comprador.

Para lograr la mayor productividad requerida, las normas deben garantizar un marco de gobernanza que proporcione salvaguardas sociales, logre un desarrollo económico local inclusivo, proporcione una administración eficiente de los ecosistemas y estimule la adquisición preferencial y una mayor conciencia del consumidor.

Es dentro de este nuevo paradigma que los principios del concepto de "Plantaciones de Nueva Generación" (NGP) tienen un significado particular (Neves, 2016) (Figura No. 1). Las plantaciones de bambú bien establecidas y gestionadas en los lugares adecuados, pueden ayudar a conservar la biodiversidad y satisfacer las necesidades humanas, al tiempo que contribuyen al crecimiento económico sustentable y a los medios de subsistencia locales si (Jeffries, 2017):

- **Mantener la integridad del ecosistema** para que continúen proporcionando los servicios ecosistémicos de los que dependen los seres humanos, los procesos ecológicos clave deben poder funcionar. Estos incluyen ciclos naturales de agua, nutrientes, carbono y biodiversidad. Las plantaciones de bambú bien diseñadas pueden ser parte de paisajes saludables y resilientes, y pueden fortalecer los servicios ecosistémicos en paisajes productivos.

- **Proteger y mejorar los altos valores de conservación** - valores biológicos, ecológicos, sociales y culturales de gran importancia o importancia crítica. Estos pueden incluir especies raras o amenazadas, servicios ecosistémicos cruciales o sitios sagrados e históricos. Al hacer esto, el sector del bambú podría contribuir al trabajo de conservación a una escala significativa.

- La **participación de las partes interesados**, tener una licencia social para operar es fundamental para el éxito del sector productivo a largo plazo. La base de la participación de las partes interesadas es la consulta; esta participación también es inherente a los derechos de los trabajadores y las condiciones de empleo, los derechos de los pueblos indígenas y las relaciones comunitarias, entre otras áreas.

- **Crecimiento económico**, las plantaciones de bambú a menudo operan en áreas rurales con altos niveles de pobreza y desempleo. Al traer puestos de trabajo e inversiones a estas áreas, el sector tiene el potencial de hacer una contribución significativa al crecimiento económico apoyando a la población local a desarrollar actividades forestales y de otro tipo, desarrollando habilidades y oportunidades locales, mejorando la salud y la seguridad y las condiciones de trabajo.

Figure 1. Principios de Nueva Generacion de Plantaciones

Fuente: Plataforma de NGP, 2011

El proceso de NGP

¿Cómo puede el sector del bambú comenzar un proceso donde, poco a poco, se inspira en el concepto y los principios de Plantaciones de Nueva Generación? La discusión no será fácil. Incluso entonces, promover el diálogo de múltiples partes interesadas y fortalecer los sistemas de gestión requerirá líderes

del sector de bambú, pueden ser pequeñas y medianas empresas o propietarios de plantaciones de bambú, con ganas de lograr los objetivos del negocio en términos de rentabilidad y crecimiento, pero también generando impacto social y ambiental positivo.

Ahora existe impulso sustancial hacia el compromiso con el concepto de Plantaciones de Nueva Generación. Así como el uso y los usos de la fibra de bambú se están expandiendo rápidamente, también lo están las oportunidades para que las plantaciones de bambú contribuyan a importantes desafíos sociales, ambientales y de desarrollo.

NGP es una plataforma de aprendizaje e influencia liderada por WWF y establecida con el sector privado y agencias gubernamentales para promover el diálogo y la construcción conjunta de soluciones sustentables para la gestión de plantaciones. Sin embargo, el concepto de NGP puede ser adoptado por el sector del bambú y podría abogar por mejores prácticas en plantaciones de bambú en regiones clave, mostrando y compartiendo ejemplos prácticos de una mejor gestión de plantaciones de bambú y los beneficios ambientales, sociales y económicos que genera. La plataforma NGP también aprovecha el compromiso con las comunidades locales y las partes interesadas en procesos significativos que van más allá de la consulta, hacia procesos de empoderamiento de las comunidades para alcanzar sus aspiraciones (Neves, 2014), que cumple con la esencia de este sector en particular.

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NGP aspira a una forma ideal de plantaciones que mantenga la integridad del ecosistema, proteja los altos valores de conservación y se desarrolle a través de la participación efectiva de las partes interesadas, al tiempo que contribuye al crecimiento económico inclusivo. Los participantes de la plataforma comparten una visión, donde las plantaciones bien administradas, particularmente usadas para restaurar tierras y ecosistemas actualmente degradados, jugarán un papel cada vez más importante en paisajes multifuncionales que contribuyan a los objetivos de desarrollo sustentable.

El concepto NGP reúne a personas con diferentes puntos de vista, antecedentes e intereses en un entorno que fomenta el escuchar, el intercambio y la colaboración. Alienta a las personas a reflexionar y cuestionar sus propios puntos de vista, actitudes y acciones (Jeffries, 2017). La confianza, el respeto y la honestidad son esenciales. Es decir, al reconocer y apreciar la diversidad del sector del bambú, las opiniones divergentes pueden brindar alternativas o nuevos conocimientos y nuevos avances.

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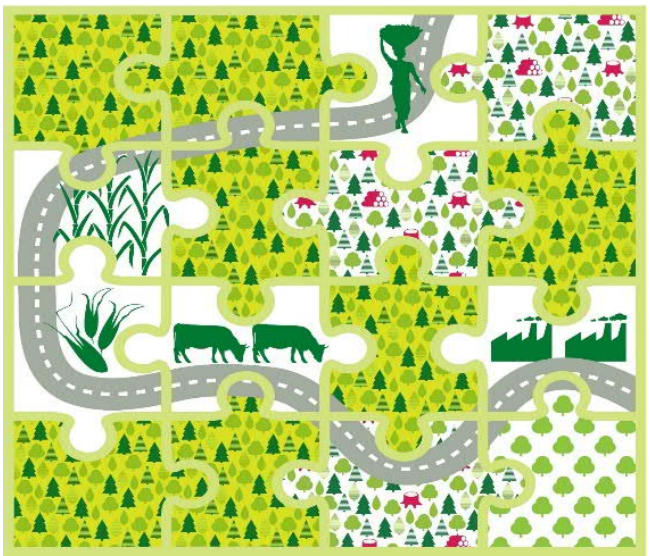
Visita de campo NGP, enfocada en trabajo practico, discusion e intercambio de ideales

Discusión

A pesar de su importancia, las plantaciones de bambú no se han utilizado en todo su potencial. Esto se debe a una serie de factores, incluida la gestión deficiente de los rodales de bambú existentes. Ahora, sin embargo, el bambú está experimentando un período de crecimiento real, con buenas posibilidades de convertirse en la materia prima biológica del futuro. Debido a esta promesa y al convertirse en un cultivo comercial cada vez más lucrativo, las plantaciones de bambú se establecerán a escala comercial y comenzarán a crecer como monocultivo. Con políticas y marcos regulatorios no comprensivos, podrían desencadenar una expansión no regulada de la producción de bambú y dejar atrás las virtudes de esta planta.

La propuesta consiste en plantaciones de bambú bien establecidas y bien manejadas como componente importante de paisajes sustentables y climáticamente inteligentes, además de aliviar la pobreza. Agregando los detalles de los regímenes de gobernabilidad local, la dinámica ecológica y los derechos, necesidades y aspiraciones de la gente local dentro del enfoque de paisaje.

Además, para un sector productivo de expansión, es fundamental incorporar la planificación y zonificación intersectorial en diseños de mosaicos para garantizar que haya suficiente tierra para otros usos, como la producción de alimentos y fibras y la conservación de la biodiversidad, al tiempo que disminuye la presión maderera sobre bosque natural y sus comunidades asociadas, servicios de los ecosistemas y biodiversidad (FAO, 2016).



Fuente: WWF 2015

El "enfoque" del paisaje significa una intervención coherente a escala de paisaje para garantizar la producción de alimentos, fibras y energía, mejoras en el bienestar social, la seguridad del agua y el ecosistema.

En un mundo cada vez más complejo con recursos limitados y volatilidad, se requieren cambios fundamentales en los modelos de producción, paradigmas de negocios y la gobernanza. Los esfuerzos aislados no serán suficientes. Las organizaciones y los sectores productivos deben desarrollar un ecosistema sólido y fortalecido de sus socios y sus partes interesadas a escala de paisaje, y desarrollar estrategias creativas para motivar y potenciar interesados externos. Desarrollar relaciones, empatía transcultural, intersectorial y construir redes son importantes para los visionarios de NGP.

Conclusión

El concepto de NGP es ambicioso, lo que sugiere que las plantaciones pueden lograr impactos ambientales y sociales positivos a través de la mejora continua. Se basa en premisas de transparencia y cooperación en todos los sectores de la sociedad a través del aprendizaje mutuo y la co-construcción de soluciones. NGP brinda oportunidades para el diálogo, el intercambio de conocimientos y la comprensión, y el apalancamiento junto con los responsables de formular políticas y del sector privado para abogar por prácticas de gestión y planificación del uso de la tierra ambientalmente racionales, socialmente responsables y económicamente viables.

NGP puede ayudar a catalizar ambiciosos cambios sistémicos en el sector del bambú. Esto ayudará a evitar los riesgos y optimizar el valor potencial total de las plantaciones de bambú para satisfacer las necesidades mundiales de fibra de manera sustentable. Una forma de lograr esto sería contemplar agendas alineadas para el cambio, de modo que el sector pueda encontrar un lugar en relación con objetivos y marcos más amplios, permitiendo hacer contribuciones más significativas por parte del sector. La flexibilidad es importante para experimentar activamente y adaptarse a un cambio continuo de circunstancias. La practicidad y la colaboración marcarán la diferencia sobre el terreno, las colaboraciones deben demostrar liderazgo colectivo, fomentar una reflexión profunda y ayudar a cambiar el enfoque hacia visiones positivas del futuro y los medios para llegar allí.

EXPRESIONES DE AGRADECIMIENTO

La autora agradece a WWF y los participantes de la Plataforma de NGP: la Administración Forestal del Estado de China, la Comisión Forestal de Gran Bretaña, el Gobierno Estadual de Acre de Brasil, APSD, Arauco, CMPC, Fibria, Kimberly - Clark, Mondi, Portucel / The Navigator Company , Stora Enso, Suzano, The New Forest Company y UPM, quienes han compartido el concepto de NGP. Un agradecimiento especial a Luis Neves Silvia por su perseverancia y determinación para influir positivamente en el sector de plantaciones.

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Keynote Lecture / Conferencia Majestral

BAMBÚ EN URBANIZACIONES: ENTRE LA TRADICIÓN Y EL FUTURO

Autores:
Lucy Amparo Bastidas Passos & Edgar Flores Borja, Arquitectos.
Dirección: Carrera 6ª No. 5N- 17. Of. 122. Popayán, Colombia.
Institución: Vivo Arquitectura SAS. Página WEB: www.vivoarquitectura.co
Correo e.: vivoarquitecturasas@gmail.com; amparobastidas@yahoo.com
Teléfono: 2- 8200777- Popayán, Col. cel: 318 5874535
Colaboración: Constanza Lucía y Camilo Flores Bastidas
Palabras clave: Guadua, urbanizaciones, entrepisos, tradición, futuro.

Resumen
Como arquitectos y constructores corresponde asumir compromisos locales y globales. En tal razón cabe iniciar con el reconocimiento de la cultura de la región que habitamos: su naturaleza, el paisaje natural y el paisaje urbano; sus fisonomías culturales y del afecto. Las tradiciones obligan una responsabilidad con los vientos que en Colombia desde la infancia mecieron bambúes, salpicando paisajes de guaduales en la dimensión donde se contrae y expande el alma humana. En tal escenario con un pie en la tradición y otro en el futuro, abrimos ventanas al progreso, indagando en ocasionar un menor detrimento ambiental en el entorno de la construcción de urbanizaciones. Estudiamos así, La *Guadua angustifolia* como material de construcción que ha sido usada ancestralmente por los nativos, y que presenta buena resistencia en las edificaciones a saber: a la compresión y tracción, convirtiéndose en material idóneo para reemplazar el acero, en nuestro caso, en placas de entrepiso, debidamente apoyadas sobre estructuras de concreto reforzado, a modo de técnicas mixtas. Este sistema lo empleamos desde hace 28 años en la construcción de 340 viviendas unifamiliares en Popayán – Colombia, obteniendo óptimos resultados en la resistencia estructural y durabilidad del material. Construimos dos tipos de entrepisos: Uno, con la guadua a la vista. Dos, con la guadua inmersa en el concreto. Las dos técnicas abaratan aproximadamente un 35% el costo comparativo con el de las losas convencionales. Sistema que resulta competitivo económicamente en urbanizaciones de vivienda. Además mitiga de manera importante el impacto ambiental en la construcción.

Introducción

La abundante existencia de guadua en Colombia, su uso en la arquitectura tradicional y sostenible, y la relación íntima con la cultura local y los afectos, han determinado el diseño

Fotografías. 1 y 2.
Guadua en Popayán.

y la edificación de nuestras viviendas y otras construcciones. Fotografías 1 y 2.
Los autores hacemos equipo de trabajo en un grupo familiar con labor profesional ejercida desde hace más de 30 años. El objetivo es aplicar tecnologías propias de la región, usando bambú guadua con tecnologías mixtas, donde la guadua es usada principalmente en losas de entrepiso sin acero de refuerzo, (Bastidas y Flores 2000), cumpliendo con las Normas colombianas de sismo resistencia, NSR- 10. Pueden emplearse en otras construcciones de similares características, resultando competitiva en vivienda masiva al bajar los costos de construcción, con un objetivo de fondo: disminuir el impacto ambiental en la actividad constructora además de fomentar la tradición del uso ancestral de la guadua en la región.

1. Aspectos de innovación en losas de entrepiso usando guadua con técnicas mixtas.

Las técnicas mixtas propuestas consisten en edificar estructuras de concreto reforzado con acero, sea en pórticos o confinada con muros de ladrillo, o estructuras de madera, sobre las que se construyen losas de entrepiso con guadua rolliza utilizada como refuerzo estructural.

Tipos de entrepisos

Se construyen dos tipos de entrepiso con guadua rolliza como material de resistencia, sin refuerzo de acero. Se disponen simplemente apoyadas sobre estructura de concreto o de madera.

Losa de entrepiso Tipo I

La guadua va simplemente apoyada sobre las vigas de concreto, separadas entre ellas 5cms. Debajo se arma un encofrado temporal. Sobre las guaduas se vierte concreto simple, quedando embebidas dentro de la placa de concreto. Ésta técnica fue ideada en Popayán en los años de 1990. Fotografías 3, 4, 5 y 6.




Fotografías. 3, 4, 5 y 6. Losas en viviendas barrio Guayacanes, Popayán, 1994.

Losa de entrepiso Tipo II.

Losa de entrepiso Tipo II.
Las guaduas van apoyadas sobre las vigas y se separan entre ejes 40cms. Sobre éstas y al través se clava esterilla de guadua y encima se funde el concreto. Es un sistema usado en Colombia hace más de un siglo. En ocasiones la guadua queda expuesta a la vista. Fotografías 7 y 8.

Fotografías 7 y 8. Losa en vivienda particular, 2000.

En los dos tipos de entrepiso comprobamos empíricamente su resistencia con ensayos de carga en obra, sobrepasando 600Kg/m2, que rebasan las Normas de Ingeniería exigidas para vivienda en Colombia que es de 180 Kg/m2.

No obstante, la incredulidad de algunas personas en un sistema 'nuevo', nos condujo a realizar ensayos de carga en laboratorio. La arquitecta Constanza Flores, efectuó en 2010 su tesis de Maestría en construcción en la Universidad Nacional de Bogotá, sobre este tipo de entrepisos, dirigida por la ingeniera, Caori Takeuchi, en las viviendas construidas en Popayán, Fotografía 9, y en 12 losas de prueba elaboradas en el Campus de esa universidad, (Flores 2012). En los dos tipos de entrepisos se demostró que no solamente cumplen con las normas colombinas NSR- 10, sino que sobrepasan dichas exigencias. «Después de realizar la carga de 600Kg en las placas, se tomó la medida con el equipo topográfico sin detectar deformaciones, fallas, ni fisuras, antes, durante, ni después de la carga,

Fotografía. 9. Urbanización Guayacanes, Popayán 1994.

demostrando la eficiencia del sistema.» (Flores, Flores, Giorgos y Takeuchi 2011).

2. Aspectos de sustentabilidad en losas de entrepiso usando guadua con técnicas mixtas.

La guadua para la construcción de losas no requiere transformación, ni cortes especiales o aditivos químicos para cumplir su función, pero debe estar seca e inmunizada. Fotografía 15.

Guadua angustifolia especie nativa:
- Se desarrolla más rápido que otras especies maderables, siendo idónea para absorber la demanda maderera. (Castaño y Moreno 2004).
- La silvicultura de guadua responde con un mínimo de inversión. (Londoño 2000).
- Contrarresta la deforestación de especies nativas.
- Cumple un rol concluyente en el ecosistema.
- No requiere gastos mayores de transporte.
- Disminuye la contaminación en la construcción al no utilizar acero en las losas, ni recorrer largas distancias en transporte con combustible proveniente de hidrocarburos. (Flores 2011).

Fotografía. 10. Casa particular, Popayán 2000.

3. Aspectos de negocio en losas de entrepiso usando guadua con técnicas mixtas.
Sistema competitivo económicamente en urbanizaciones de vivienda:
Características:
Reemplaza al acero, a la vez que es material de aligeramiento
Es una placa aligerada de alta resistencia
Es más liviana
En relación a la placa convencional reforzada con acero, es un 35% más económica.
Cuando la guadua queda a la vista agrega valor estético a la vivienda.

Fotografía. 11. Urbanización Guayacanes del Río, 124 viviendas, Popayán 1997.

Ejercicio:
En un conjunto de 60 viviendas de dos pisos, se construye por casa 30M2 de losa de entrepiso. Con un total de 1800M2 de losa en las 60 casas. Si la losa convencional cuesta en Colombia, 50 dólares por M2, en total las losas importan: 90.000 dólares. Si ese valor tiene una disminución de costo del 35% correspondiente al entrepiso con guadua, equivale a 31.500 dólares menos. Ahorro que permite bajar un poco el valor final de la vivienda, resultando competitivo en el mercado inmobiliario de viviendas del mismo tipo con la losa convencional.

Fotografías 12 ,13 y 14. Casa del guadual, Popayán 2000.

Fotografía. 15. Edificio Bambú Vivo, Popayán 2014.

Edificio Bambú Vivo

Edificio de cuatro pisos, se construyó con el sistema de entrepisos con guadua como refuerzo estructural en 2014. Bambú Vivo es el primer edificio en Colombia en el que se emplea este sistema de técnicas mixtas, resultando competitivo en el mercado de apartamentos.

Fotografía.16. Casa Sánchez. Pance. Cali, 2017 Fotografía. 17. Urbanización El Mango. Popayán 2017- 2018

Conclusiones

Los resultados logrados al utilizar *Guadua angustifolia* Kunth, en losas de entrepiso son eficaces, en durabilidad, sismo resistencia, disminución del impacto ambiental y sostenibilidad económica. El sistema constructivo se puede utilizar en otras construcciones de análogas características. Sin duda, es un aporte en la promoción de las tradiciones constructivas de la región, al tiempo que se abren puertas para urbanizaciones y viviendas futuras.

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Keynote Lecture

PELLETS: BIO-ENERGY BUSINESS IN MEXICO

Alberto Bustamante Alcazar /

The purpose of the presentation will be to disseminate information about biomass as an alternative source of fossil fuel, using the Mexican market as an example, and the socio-economic impact produced in the regions where this market develops.

Initially, we will make an introduction situating the context of the fight against climate change and the potential contribution of biomass processed in the form of pellets, including the international market and the main actors.

I will explain the technique of pelletization from a technical point of view and the virtues against unprocessed biomasses, application technologies in the industrial, hotel and domestic spheres. Giving examples of use in the Mexican Republic. Rapid implementation of burner technology.

Potential of bamboo as a raw material in the pellet sector. Through an example of a plant located in Huatusco, Veracruz profitability and potential.
We will finish with calculations of avoided emissions of CO2 and calculation methodology.

PELLET: NEGOCIO DE LA BIOENERGIA EN MEXICO

Alberto Bustamante Alcazar /

La conferencia impartida tendrá como objeto la divulgación de la biomasa como fuente alternativa de combustible fósil poniendo como ejemplo el mercado mexicano. El impacto socioeconómico producido en las regiones donde se desarrolla este mercado.
En primer lugar, realizaremos una introducción situando el contexto de la lucha contra el cambio climático y el potencial de contribución de la biomasa procesada en forma de pellet. El mercado internacional y los principales actores.

Expondré la técnica de la pelletización desde un punto de vista técnico y las virtudes frente a biomasas no procesadas.

Las tecnologías de aplicación en el ámbito industrial, hotelero y doméstico. Dando ejemplos de uso en la república mexicana. Tecnología de quemadores de rápida implementación.

Potencial del bambú como materia prima dentro del sector del pellet. Mediante un ejemplo de planta situada en Huatusco, Veracruz rentabilidades y potencial.

Finalizaremos con cálculos de emisiones evitadas de CO2 y metodología de cálculo.

Keynote Lecture

THE HEALING TOUCH OF BAMBOO: SOUL, MIND AND BODY

Nirmala Chongtham / cnirmala10@gmail.com
Department of Botany
Panjab University, Chandigarh, India

Bamboo is a plant that is intricately associated with humans from time immemorial fulfilling all human needs, particularly in East and South East Asian region. It is a plant which is revered as God, teacher, friend, soul mate to food and medicine for body, weapon for hunting and protection from enemies, shelters and utensils for cooking and eating. Since centuries, bamboos are intermingled deeply with the daily life of rural and tribal populations and are an indispensable part of their cultural, traditional, social, and economic requirements (Tiwari 1988; Madhab 2003; Liese and Kohl, 2015). People often consider bamboo as a good luck charm bestowing populace with youth, flexibility and love (Piper 1992). Bamboo became a symbol for consistency and integrity because it grows straight and upright and is green every season. In days of yore, writers wrote about nature and enjoyed the bamboo, and poets used it in their poems. Bamboo makes us feel invigorated and refreshed through the clean warm wind. It also looks commanding and dignified, and so it was popular with painters.

It is a common belief in several Asian cultures that humanity emerged from a bamboo stem. In some parts of India, bamboo is also called Kalpavirksha (divine tree in Indian mythology fulfilling all the needs and desires) due to its numerous uses in daily life in physical as well as in spiritual form. First direct reference to bamboo Indian literature is in “Rig Veda” (5000 BC) “Bestow upon us a hundred bamboo clumps”. Bamboos are symbolic of constancy, fidelity, integrity, and purity (Farrelly 1984) and also inspire the emotional and spiritual life of many people. In China, bamboo is considered friend of the people symbolizing gentleness, modesty

and serenity and the people consider it as one of the four noble plants along with plum, orchid and chrysanthemum. There are several folk tales, stories, dramas, cultural activities, myths, beliefs and even superstitions associated with bamboo highlighting the intricate relation of this wonderful plant with the culture and tradition of several Asian societies. Bamboo has always been an emotional, motivational and inspirational plant for poets and writers. Some feel peace and tranquility in writing on bamboo, whereas many others like to write and sing about bamboo. Bamboo painting and calligraphy are the oldest art forms in China, Korea and Japan to express the thoughts, feelings and artistry of a person, where bamboo has played a very significant role right from providing pens for writing on bamboo strips and paper to the inspiration and ideas for art and calligraphy. Drawing of nodes, internodes and leaves in black ink gave artists a deep satisfaction and mental peace. There was a time in these countries when bamboo painting and calligraphy flourished to its highest level. Wen Tong (1018-1079), Wang Fu (1362 – 1416), Guan Daosheng (1262-1319), Hasegawa Tohaku, Katsushika Hokusai, Yi Chong , Yu Tok Chang and Sin Wi are some of the famous bamboo painters and calligraphers of the region. Sakutaro Hagiwara (1886-1942) who is known as father of modern colloquial poetry in Japan has written many beautiful poems on bamboo.

The importance of bamboo in Chinese culture is reflected in the words of Su Dongpo, a revered literary figure of Song Dynasty (960-1270) who said that without bamboo, people of China would lose their serenity as well as culture (Yang *et al.* 2008). Chinese were the first to appreciate the beauty and utility of bamboo with poets extolling this versatile plant and artists painting it, cherishing its grace and beauty (Tom 1989). Oriental scholars, artists, and epicures have praised admirable qualities of bamboo in painting, rhymed couplets, and lyrical tributes. Bamboo is intricately associated with the social, cultural and religious life of the Karbis, a hill tribe of the state of Assam in India where bamboo is an indispensable part of the Karbi society of North East India and there is a popular proverb which says “A Karbi is born with bamboo in his hand and leaves the world holding a bamboo (Teron and Borthakur 2012a). In Karbi society, when a mother conceives, the family performs certain rituals in honor of the unborn baby using rice grains wrapped with banana leaves and tied with bamboo. During the life time of the

person, he/she uses bamboo mat tied to a bamboo culm with bamboo and taken to the cremation ground. Hence, for the Karbis, life begins with bamboo and ends with bamboo. In Meetei community of Manipur, India planting of bamboo plant in the court yard is considered lucky, a symbol of prosperity (Singh *et al.* 2003). At Karang, an isolated island in Loktak lake Manipur, people used to put up tall straight bamboo poles with a lovely cluster of small branches and leaves at the tip in their courtyard (Ghosh 2008). These totems signify that the marriageable daughter in the family is engaged to her future husband. Bamboo has also remained a fascinating material for artists, writers and poets particularly in countries like China, Korea and Japan. There are books like "The Book of Songs" from China "Leaves Collection", "Taketori Monogatri" from Japan and "Bamboo Window" "Bamboo Forest" from Korea written on bamboo or about bamboo describing it in many ways like symbol of a gentleman and person of noble virtue (Jia Yan 2014).

Bamboo is gaining increased attention as an evergreen plant with multiple functions and benefits; and has the brightest prospect and potential in the 21st century. Today, bamboo is recognized as an important asset in eradication of poverty, economic and environmental development and remains highly important as a basic livelihood crop and material for rural people living in Asia, Latin America and Africa, as well as a growing number of higher income people who purchase green bamboo products throughout the world.

Bamboo shoots for good health

Bamboo shoots have been frequently assessed for various bioactivities due to their nutritional and therapeutic importance and overall application in food and pharmaceutical industry. In traditional cultures of Chinese, Tibetan, Korean and Japanese, bamboo is considered as healthy food and medicine. In Japan bamboo shoot is called "King of Forest Vegetables" and in China it is a treasure dish and it was considered that, "there is no banquet without bamboo". Presently, bamboo shoots have taken the status of health food as they are low in calories, have negligible fats and have more minerals, bioactive compounds and

dietary fibers. The juvenile bamboo shoots are rich in nutrients, health promoting bioactive compounds (phenols, phytosterols, dietary fiber), vitamins (vitamin A, vitamin B1, vitamin B3,vitamin B6, vitamin C, vitamin E), amino acids, and minerals, hence, play a significant role in maintaining good health and projected as health food (Kumbhare and Bhargava 2007; Hiromichi 2007; Park and Jhon 2009; Nirmala *et al.* 2011). Bamboo shoots are rich source of minerals like silica, potassium, calcium, magnesium, selenium, etc. Calcium and silica are essential for making of bones, hairs, ligaments, nails and skin. Bamboo shoots have around 17 amino acids including all the essential ones. It contains arginine and tyrosine as the major amino acids that otherwise is a minor component in common fruits and vegetables (Kozukue *et al.* 1999). Arginine plays a key role in the synthesis of glycoproteins, and tyrosine is a major precursor of several neurotransmitters and may directly affect processes in the brain including cognitive function. Bamboo shoot also contains selenium, an important antioxidant in trace amount (Nirmala *et al.* 2018), and lysine which lacks in cereals, plays an important role in growth and development. Fresh bamboo shoots have also been found to be rich in potassium which helps to prevent blockage of blood vessels. Dietary fiber from bamboo shoots is a common ingredient in bakery, dairy, and meat products. Bamboo shoot fibers are used to make pills and tablets for sliming and weight loss. Young shoots are rich in phytosterols which help in preventing of the absorption of cholesterol due to similar structures and thus protects from various cardio-vascular diseases. Bamboo is one of the richest source potassium which called as heart protecting mineral. Bamboo leaf tea is famous in South Korea, considered as the store house of antioxidants. The Korean people also produce a type of salt called ‘bamboo salt’ rich in minerals extracted from bamboo.

Bamboo as medicine

It is known that a sound mind lives in sound body and importance of bamboo for keeping healthy body is known since centuries in East and South East countries. Bamboo plays a significant role in traditional Asian medicine and their therapeutic applications have been well described in all the ancient Pharmacopoeias of the world. The medicinal applications of bamboo were first mentioned around 500 AD wherein the therapeutic applications of bamboo

sap and stem shavings were described (Berky and Borolet 1990; Huang and Wang 1993). In ancient literatures of India (Bhavprakashinghantu) it is written that, “Bamboo by nature is laxative, frigid seminal curative, palatable, bladder purifier and full of astringent juice. It splits cough, subsides bile and cures leprosy, flux, wounds and swellings” (Tiwari 1992). Bamboo medicinal applications were first mentioned in India around 10,000 years ago for preparing Chyawanprash, a health tonic prepared from a number of herbs, including bamboo manna to impart youth, beauty and longevity. "Chyawanprash" is named after Rishi, or a sage by the name of Chyawan, who was the first person to prepare this tonic and he regained his youthfulness and vitality with the use of this herbal tonic. It is now famous in the world for its anti-stress and anti-aging properties.

All parts of the bamboo plant such as rhizomes, culms and bark shavings, resin, shoots, leaves, and seeds have clinical applications (Wang *et al*. 2002; Zhang *et al*. 2005a; Tripathi *et al*. 2009). On the basis of the knowledge of their therapeutic applications, bamboo has been used for medicinal purposes and many beneficial effects of bamboo leaves, shoots, shaving and oils on metabolic disorders and cardiovascular diseases have been reported. In ancient Chinese medicine, leaves are used as a component to reduce the energy of “fire” (related to inflammation) and treat hypertension, arteriosclerosis and cardiovascular disease (Yaun 1983). Bamboo is considered cooling, calming and phlegm resolving and is used for epilepsy, fainting and loss of consciousness in feverish diseases and a variety of mental disorders that develop with aging. Bamboo shoot decoction is used for treating infections, cleaning wounds, maggot infected sores and ulcers. In Java, sap from shoots is used for curing jaundice. Culm shaving of *Bambusa breviflora* is used to clear phlegm and heat in the lungs with thick sputum, a stifling sensation in the chest. Following traditional practices, there was continuous usage of bamboo in modernized Chinese medicine such as “Zhu Li Kou Fu Ye”, an extract of bamboo leaves inhibiting inflammation in the throat. The important biological and therapeutic properties of bamboo leaf extracts including anti-oxidant, anti-microbial, anti-inflammatory, anti-helmintic, anti-diabetic and anti-ulcer have been confirmed by several *in-vitro* and *in-vivo* experiments (Tripathi *et al.* 2015; Daswad *et al.* 2017). According to Chinese medicinal books such as “Ben

Chao Qui Zheng", "Ben Jing Feng Yuan", "Yao Pin Hua Yi" and "Jing Yue", bamboo shoots are beneficial to human health notably by promoting the peristalsis of the stomach and the intestine, helping digestion, preventing and curing cardiovascular disease and cancer and promoting the excretion of urine (Lu *et al.* 2010).

Ayurveda, the ancient Indian system of medicine recommends bamboo and its products such as Banslochan, Tabasheer and Sitopaladi Churna for treatment of various ailments. Tabasheer or banslochan has been used since ancient times as a cooling tonic and aphrodisiac and in asthma, cough and other debilitating diseases. It is a siliceous secretion found in the culms of bamboos and occurs is fragments or masses, about an inch thick. A bamboo derived Ayurvedic remedy, Sitopaladi Churna is prescribed for pleurodynia, intercostal neuralgia, cold cough associated with bronchitis, pneumonia, tuberculosis, viral respiratory infection, digestive impairment and pharyngeal or chest congestion (Makhija *et al*. 2012). In Tibet, it is used for treatment of various lung diseases. It is a powder made with tabasheer as the main ingredient, plus small amounts of long pepper, cardamom, and cinnamon in a base of sugar. In Chinese traditional medicine, bamboo is generally considered cooling, calming, and phlegm resolving and is incorporated in many traditional formulas to treat lung and stomach heat, febrile disease and correct up flowing qi (qi is a fundamental concept in traditional Chinese medicine referring to the energy flow in a living being). Leaves are the part of the plant which is triggering the most intensive interest possible because the leaves comprise a significant portion of the total biomass of the plant, are easy to harvest and process and can be obtained as a waste of bamboo timber industry. Studies have revealed that bamboo is a rich source of antioxidants and regular consumption of bamboo-based products may reduce the risk of age-related chronic diseases including cardiovascular diseases, Alzheimer's disease, Parkinson's disease, cancer and diabetes. The main antioxidants in bamboo leaves and shoots are phenols, vitamin C & E and mineral elements such as selenium, copper, zinc, iron and manganese. At present, natural antioxidants are in great demand as synthetic antioxidants being used in food and pharmaceuticals may be deleterious to health. Bamboo a fast growing plant with huge biomass can serve as an alternative for the production of natural antioxidants.

Supporting traditional practices, modern research has scientifically validated most of the health claims of bamboos and it is still attracting huge interest from researchers to unearth even more potential health benefits (Panee, 2015; Gong *et al*., 2016; Nirmala and Bisht, 2017; Ying *et al*., 2017). Biomedical investigations on health beneficial effects of different parts and species of bamboos have been carried out since 1960s and a wide range of protective effects of bamboo derived products have been documented such as protection against oxidative stress, inflammation, lipotoxicity, cancer and cardiovascular disease. Several *in vitro* and *in vivo* experiments on animals have confirmed important biological and medicinal properties of bamboo extracts such as antioxidant, anticancer, antimicrobial, anti-inflammatory, anti-ulcer, anti-helminthic and anti-diabetic (Muniappan and Sundararaj 2003; Lu et al. 2005, 2010). Thus, bamboo is a plant that not only caters to the need of more than 1.2 billion people for their livelihood but also provides a healing touch to the soul, mind and body of humans.

Acknowledgment: Financial assistance provided by Ned Jaquith Foundation and American Bamboo Society, USA is gratefully acknowledged.

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Keynote Lecture

DIVERSITY AND EVOLUTION OF THE NEW WORLD BAMBOOS
(Poaceae: Bambusoideae: Bambuseae, Olyreae)

Lynn G. Clark, Ph.D.
Dept. of Ecology, Evolution, and Organismal Biology
Iowa State University
Ames, IA 50011-4009
lgclark@iastate.edu

R. Patricia de Oliveira, Ph.D.
Universidade Estadual de Feira de Santana / DCBIO
Programa de Pós-graduação em Botânica
Laboratório de Sistemática Molecular de Plantas
Av. Transnordestina, s/n
44036-900 - Feira de Santana, Bahia, Brasil
rpatricia@uefs.br

Abstract
Bambusoideae (bamboos), comprising 1,680+ species, is one of 12 subfamilies within the Poaceae representing the only one to diversify primarily in association with forests. Bamboos are classified into three tribes: Arundinarieae (temperate woody bamboos, 581 species), Bambuseae (tropical woody bamboos, 976 species) and the Olyreae (herbaceous bamboos, 123 species). The Arundinarieae is primarily of eastern Asia and has no native species in the American tropics. Bambuseae consists of two major clades, the Paleotropical (PWB, 554 species) and the Neotropical woody bamboos (NWB, 422 species), and is distributed broadly in the tropics and subtropics with a few taxa in subtemperate regions, and extensive diversity in montane systems. Except for 1 genus endemic to New Guinea, and 1 species occurring in both the Neotropics and Africa, the rest of the Olyreae is restricted to the Neotropics. Olyreae typically inhabit the understory, with some adapted to gaps and edges, but the woody bamboos mostly occupy gaps and edges or open habitats. Recent bamboo studies are based on both floristics and molecular phylogenomics using both plastid and nuclear DNA sequence data. In the usual absence of flowering material, complete vegetative collections are essential for discovery and identification. Previously reported relationships of subtribes within the NWB clade and the Olyreae continue to be supported, but molecular data suggest some generic realignments and new species continue to be described. Brazil has the greatest diversity of both NWB and Olyreae, but the Andes, Panama/Costa Rica, Mexico and the West Indies also harbor significant diversity and endemism. In the Neotropics, *Chusquea*, *Guadua*, *Merostachys* and *Pariana* still require significant taxonomic attention. Phylogenetic hypotheses require additional sampling of critical taxa before biogeographic patterns can be fully explored and classification stabilized; bamboo ecology and reproductive biology remain understudied.

Keywords: Arundinarieae, bamboo, bamboo diversity, bamboo evolution, Neotropical bamboos

Introduction

The bamboos (Bambusoideae) form one of the 12 subfamilies recognized within the grass family (Poaceae) (Kellogg 2015; Soreng et al. 2017). Although the grass family itself originated in forests, the Bambusoideae is the only major lineage within the family to diversify primarily in association with forests (Clark et al. 2015; Kellogg 2015). Molecular sequence data strongly support the Bambusoideae as a distinct lineage (Kelchner & BPG 2013; Saarela et al. 2018), and anatomically bamboos are characterized by the presence of well developed, asymmetrically strongly infolded arm cells in the leaf mesophyll as seen in cross section (Clark et al. 2015; Leandro et al. 2016, 2017). Reflecting their general adaptation to forest habitats, bamboos also usually exhibit relatively broad, pseudopetiolate leaf blades, with intercellular cavities often referred to as fusoid cells flanking the vascular bundles, although these may be lacking in sun plants or sun leaves (March & Clark 2011; Leandro et al. 2018). Bamboos include 1680+ species grouped into approximately 127 genera, and comprise three lineages recognized formally as tribes: Arundinarieae (temperate woody bamboos, 581 species in 31 genera), Bambuseae (tropical woody bamboos, 976 species in 74 genera), and Olyreae (herbaceous bamboos, 123 species in 22 genera) (Table 1) (Vorontsova et al. 2016; Soreng et al. 2017). Herbaceous bamboos are often important elements of the understory in tropical forests, and woody bamboos are conspicuous in gaps or along margins in tropical or temperate forests or they may form bamboo forests at lower elevations or bamboo-dominated grasslands above the treeline (Clark et al. 2015 and references cited therein).

Since the Proceedings of the 9th World Bamboo Congress, which had bamboo science as a major focus, were published (Gielis & Potters 2012), a number of important advances in bamboo systematics and evolution have appeared in the literature (see below). Some of these were incorporated into Chapter 1 of Liese & Köhl (2015) or in the bamboo treatments presented in Kellogg (2015) and Soreng et al. (2017), but we wanted to make this information more accessible to a broader bamboo audience. Although the temperate woody bamboos (Arundinarieae) are extremely important, our expertise lies with the tropical bamboos (Bambuseae and Olyreae), so we have chosen to focus on these two tribes in this paper. We here present a review of recent work and updates in our understanding of the diversity, evolution and classification of the tropical bamboos, with a particular focus on the Neotropical taxa.

RECENT LANDMARKS IN BAMBOO SYSTEMATICS

Molecular phylogenetic analyses continue to confirm unambiguously that the Bambusoideae as a whole is monophyletic, that is, that this lineage had a single origin, but these data also indicate that the bamboos have had a complex evolutionary history including hybridization and allopolyploidy (Goh et al. 2013; Fisher et al. 2014; Oliveira et al. 2014; Triplett et al. 2014; Wysocki et al. 2015; Wysocki et al. 2016; Zhang et al. 2016; Zhou et al. 2017; Saarela et al. 2018; Ferreira et al. in press). Analyses based on plastid DNA markers or, increasingly, whole plastid genomes (plastomes) consistently support a sister relationship between the Bambuseae and Olyreae (the tropical bamboos), with the Arundinarieae sister to that clade (Kelchner & BPG 2013; Ma et al. 2014; Wysocki et al. 2015; Attigala et al. 2016; Zhang et al. 2016; Saarela et al. 2018). In contrast, analyses based

on sequencing of nuclear markers or other genome-wide techniques support monophyly of the woody bamboos or do not recover the same groups within tribes as obtained in plastid analyses (Fisher et al. 2014; Triplett et al. 2014; Wysocki et al. 2016; Wang et al. 2017).

The availability of evolutionary trees derived from molecular data, as well as additional bamboo fossils (e.g., Brea et al. 2013; Wang et al. 2014), have enabled studies of bamboo evolution and biogeography. For example, Ruiz-Sanchez & Sosa (2015) examined the origin and evolution of fleshy fruit in woody bamboos using a plastid phylogeny and molecular dating. They showed that fleshy fruits evolved independently at least seven times within Arundinarieae and Bambuseae, but that neither current climatic conditions nor soil parameters could explain this pattern. Veller et al. (2015) focused on the well-known flowering cycles in woody bamboos, proposing a simple mathematical model to explain the evolution of these remarkable cycles as part of a two-step process. Zhang et al. (2016) used a plastid phylogeny and molecular dating to establish an origin of the Arundinarieae 12-14 mya with a rapid radiation in some of its lineages beginning 7-8 mya. The pattern of relationships within the tribe allowed them to infer that the Arundinarieae originated in Eastern Asia, with later dispersals to North America (*Arundinaria*) and tropical montane locations in Africa (e.g., *Oldeania*) or elsewhere in the Paleotropics (e.g., *Kuruna* in southern India and Sri Lanka).

Two major works (Kellogg 2015; Vorontsova et al. 2016) have contributed to identification resources for bamboos and documentation of their species diversity. Both of these books were influenced by some of the phylogenetic studies cited above, but their objectives were to provide an updated generic level treatment of the grasses, including bamboos (Kellogg 2015), and a peer-reviewed worldwide checklist of bamboo species (Vorontsova et al. 2016). The bamboo treatment by Kellogg (2015) includes a brief synopsis of each genus (whether presumed monophyletic or not), as well as a key to these taxonomic entities. Subsequently, some of the non-monophyletic genera have been formally described as new genera [e.g., not "*Nastus*" has been published as two genera by Wong & Dransfield (2016) and the remainder placed in the resurrected *Chloothamnus* by Widjaja & Wong (2016)] and the status of some generic names is still under study (e.g., *Parodiolyra* and *Raddiella* by RPO and her research group), but this still remains the only available modern key to the genera of the Bambusoideae. We also note that additional national- or regional-level treatments of bamboo diversity are beginning to appear [e.g., Ruiz-Sanchez et al. (2015) for Mexican bamboos, Wong et al. (2016) for Malesian bamboos, Rúgolo de Agrasar (2017) for Argentinian bamboos, and bamboo contributions for the Brazilian Flora 2020 project].

The global checklist of bamboos in Vorontsova et al. (2016) was prepared from the nomenclatural data base at the Royal Botanic Gardens, Kew, and subjected to review by a number of bamboo taxonomists. In addition to accepted names, synonymy, and geographic distribution, the checklist includes a list of all of the synonyms with their currently accepted names for easy reference. BPG (2012) estimated that there were 1,482 species of bamboo, but the Vorontsova et al. (2016) checklist documents 1,642 species, a significant increase. In part this is due to the continued description of new species, but it also represents a more accurate genus by genus estimate with input from specialists. Soreng et al. (2017) incorporated additional new species published since the checklist, and provided an estimate of 1,670 bamboo species; we have included species published or in press in the

last year to arrive at our estimate of 1,680 bamboo species (Table 1).

Table 1. Diversity of Bambusoideae by tribe (Arundinarieae, Bambuseae, Olyreae) and subtribe within the tropical bamboos (Bambuseae, Olyreae).

Taxon	Number of genera	Number of species
Arundinarieae	**31**	**581**
Bambuseae	**74**	**976**
Neotropical (NWB)	21	422
Arthrostylidiinae	15	186
Chusqueinae	1	181
Guaduinae	5	55
Paleotropical (PWB)	53	554
Bambusinae	18	324
Dinochloinae	7	56
Greslaniinae	1	2
Hickeliinae	9	32
Holttumochloinae	3	6
Melocanninae	9	99
Racemobambosinae	3	31
Temburongiinae	2	3
Incertae Sedis	1	1
Olyreae	**22**	**123**
Buergersiochloinae	1	1
Parianinae	3	34
Olyrinae	18	88
Total for tropical bamboos	**96**	**1,099**
Total for Bambusoideae	**127**	**1,680**

BAMBUSEAE

Recent phylogenetic analyses of the Bambuseae have been based primarily on individual plastid markers or whole plastomes (Kelchner & BPG 2013; Chokthaweepanich 2014; Ruiz-Sanchez & Sosa 2015; Wysocki et al. 2015; Zhou et al. 2017). Support values for both the Bambuseae and the Paleotropical woody bamboo (PWB) clade in these studies are consistently very strong, with more moderate support for the Neotropical woody bamboo (NWB) clade. A summary of the current estimate of phylogenetic relationships within the tropical woody bamboos (Bambuseae and Olyreae) based on plastid data is shown in Figure 1. The Bambuseae exhibit aerial branch development from the base of the culm to the apex (acropetal) or from the middle toward both ends (bidirectional) [vs. from the apex toward the base (basipetal) in Arundinarieae], but there are no morphological features that define either the PWB or NWB clades (Clark et al. 2015).

[insert Figure 1 here]

The sister relationship of Melocanninae to the rest of the PWB clade was already well established (Sungkaew et al. 2009; Kelchner & BPG 2013), but until recently, relationships among the Bambusinae, Hickeliinae and Racemobambosinae were not well understood. Although much more work remains to be done, Goh et al. (2013), Chokthaweepanich (2014) and Zhou et al. (2017) improved sampling and support within the PWB clade, with the resolution of several lineages. As shown in Figure 1, Holttumochloinae is supported as sister to the Bambusinae and the Dinochloiinae is sister to the Greslaniinae (this group was previously known as the DGMNS assemblage or clade), and these two lineages form a polytomy with the Racemobambosinae, Hickeliinae and Temburongiinae. The classification of the Paleotropical woody bamboos has been refined based on these results, including the description of two new genera (*Widjajachloa* and *Ruhooglandia*) for two Asian species of *Nastus* (Wong & Dransfield 2016), the resurrection of *Chloothamnus* for the remaining Asian species of *Nastus* (Widjaja & Wong 2016), and the emendation of Racemobambosinae along with the description of four new subtribes (Wong et al. 2016) (Table 2). In addition, *Sokinochloa* (the hedgehog bamboo, named for its dense, spiky-looking inflorescences) was described in the Hickeliinae to accommodate three species from Madagascar formerly classified in *Cephalostachyum*, and an additional four new species in this genus were also described (Dransfield 2016). The results of Zhou et al. (2017) clearly indicate that *Temochloa*, which was treated as of uncertain placement (Incertae Sedis) in Soreng et al. (2017), belongs in the Bambusinae, so we here make this change (Table 2).

Within the NWB clade, the relationship of Chusqueinae + (Arthrostylidiinae + Guaduinae) is consistently and strongly supported in molecular phylogenetic analyses (Kelchner & BPG 2013; Soreng et al. 2017) (Figure 1). The Arthrostylidiinae + Guaduinae clade may be defined by the presence of refractive papillae on the leaf epidermises, but these papillae apparently also occur in the Melocanninae (PWB) and their structure and evolutionary history within the Bambuseae are poorly understood (Soderstrom & Ellis 1987; BPG 2012; Kellogg 2015). The description of new species within all three subtribes continues, especially within *Chusquea* (Chusqueinae) and *Merostachys* (Arthrostylidiinae) (e.g., Viníciuis-Silva et al. 2016; Attigala et al. 2017; Ruiz-Sanchez et al. 2018; Pianissola Machado et al., in press;). In these two genera, the number of species has increased by 5% and 6%, respectively, in just the past three years (since the compilation of Clark et al. 2015), and a number of new species in both genera are in preparation. Molecular phylogenetic analyses combined with anatomical studies are also leading to generic realignments (e.g., Jesus-Costa et al., in press, in which a species of *Atractantha* is being transferred to *Athroostachys*), but a number of these studies are still in progress. A revision of *Chusquea* sect. *Tenellae* was published last year (Attigala et al. 2017) and a revision of *Colanthelia* is forthcoming (Santos-Gonçalves et al., in press); additional revisions or monographs are in progress. Within the Neotropics, Brazil has the greatest diversity of both NWB and Olyreae, but the Andes, Panama/Costa Rica, Mexico and the West Indies also harbor significant diversity and endemism (Clark et al. 2015).

Table 2. Summary of tropical bamboo classification by tribe (Bambuseae, Olyreae) and subtribe. Numbers in parentheses indicate the number of species currently recognized in each genus.

Bambuseae—Neotropical

Arthrostylidiinae: *Actinocladum* (1), *Alvimia* (3), *Arthrostylidium* (31), *Athroostachys* (2), *Atractantha* (5), *Aulonemia* (47), *Cambajuva* (1), *Colanthelia* (7), *Didymogonyx* (2), *Elytrostachys* (2), *Filgueirasia* (2), *Glaziophyton* (1), *Merostachys* (51), *Myriocladus* (12), *Rhipidocladum* (19).

Chusqueinae: *Chusquea* (181).

Guaduinae: *Apoclada* (1), *Eremocaulon* (4), *Guadua* (33), *Olmeca* (5), *Otatea* (12).

Bambuseae—Paleotropical

Bambusinae: *Bambusa* (153), *Bonia* (5), *Cochinchinochloa* (1), *Dendrocalamus* (66), ×*Gigantocalamus* (1), *Gigantochloa* (63), *Maclurochloa* (3), *Melocalamus* (14), *Neomicrocalamus* (3), *Oreobambos* (1), *Oxytenanthera* (1), *Phuphanochloa* (1), *Pseudoxytenanthera* (4), *Soejatmia* (1), *Temochloa* (1), *Thyrsostachys* (2), *Vietnamosasa* (3), *Yersinochloa* (1).

Dinochloinae: *Cyrtochloa* (7), *Dinochloa* (38), *Mullerochloa* (1), *Neololeba* (5), *Parabambusa* (1), *Pinga* (1), *Sphaerobambos* (3).

Greslaniinae: *Greslania* (2).

Hickeliinae: *Cathariostachys* (2), *Decaryochloa* (1), *Hickelia* (4), *Hitchcockella* (1), *Nastus* (12), *Perrierbambus* (2), *Sirochloa* (1), *Sokinochloa* (7), *Valiha* (2).

Holttumochloinae: *Holttumochloa* (3), *Kinabaluchloa* (2), *Nianhochloa* (1).

Melocanninae: *Annamocalamus* (1), *Cephalostachyum* (13), *Davidsea* (1), *Melocanna* (3), *Neohouzeaua* (6), *Ochlandra* (10), *Pseudostachyum* (1), *Schizostachyum* (62), *Stapletonia* (2).

Racemobambosinae: *Chloothamnus* (11), *Racemobambos* (19), *Widjajachloa* (1).

Temburongiinae: *Fimbribambusa* (2), *Temburongia* (1).

Incertae Sedis: *Ruhooglandia* (1).

Olyreae

Buergersiochloinae: *Buergersiochloa* (1)

Parianinae: *Eremitis* (5), *Pariana* (27), *Parianella* (2)

Olyrinae: *Agnesia* (1), *Arberella* (7), *Cryptochloa* (9), *Diandrolyra* (3), *Ekmanochloa* (2), *Froesiochloa* (1), *Lithachne* (4), *Maclurolyra* (1), *Mniochloa* (1), *Olyra* (25), *Parodiolyra* (6), *Piresia* (5), *Piresiella* (1), *Raddia* (9), *Raddiella* (8), *Rehia* (1), *Reitzia* (1), *Sucrea* (3).

OLYREAE

This tribe is easily distinguished from the two tribes of woody bamboos based on its relatively weakly lignified culms, lack of well differentiated culm leaves, restricted vegetative branching, lack of an outer ligule on the foliage leaves, and unisexual, often dimorphic spikelets (Clark et al. 2015). Virtually all Olyreae exhibit pluri-annual (seasonal) flowering, although there are a few, mostly anecdotal reports of possible gregarious flowering on longer cycles in the tribe (Judziewicz et al. 1999). All Olyreae except for *Buergersiochloa* apparently have epidermal silica cells containing cross-shaped or crenate (olyroid) silica bodies, the latter type unique to the tribe (Soderstrom & Ellis 1987; Clark et

al. 2015). Molecular phylogenetic analyses consistently support monophyly of the Olyreae, and the three subtribes are related in the following way: Buergersiochloinae + (Parianinae + Olyrinae) (Kelchner & BPG 2013; Oliveira et al. 2014) (Figure 1). Within the Parianinae, *Parianella* (from the Atlantic forest) is sister to a lineage consisting of *Eremitis* (also from the Atlantic forest) + *Pariana* (from Central America and northern South America) (Ferreira et al., in press). Within the Olyrinae, Oliveira et al. (2014) recovered at least four main lineages, including one consisting of *Sucrea* and *Raddia* but without strong support, and they also demonstrated the non-monophyly of both *Olyra* and *Parodiolyra*. More comprehensive molecular analyses of the subtribe by RPO and her research group are in progress, and generic realignments are to be expected based on these data and also supported by pollen morphology (Dórea et al. 2017). The currently accepted genera, with species numbers, in Olyreae are summarized by subtribe in Table 2.

Although it appears that the number of species in Olyreae has remained relatively stable in recent years [122 in BPG (2012), 124 in Clark et al. (2015) and 121 in Vorontsova et al. (2016)], in fact several new species and even a new genus have been described within the last five years (e.g., Ferreira et al. 2013a, b; Baldini & Ortiz 2015; Ferreira et al. 2016), and the description of several new taxa is in progress. Most of the difficulty in obtaining an accurate estimate of species diversity within the tribe is due to the problematic taxonomy of *Pariana* [Clark et al. (2015) estimated 33 species, whereas Vorontsova et al. (2016) accepted only 27].

CONCLUSIONS

The current estimate of bamboo diversity stands at 1,680 species, but at least in the Neotropics, a large number remain to be described, and we predict that the total number of species will easily exceed 1,700 in the near future. While most of the new species are recognized based on morphology and anatomy, better sampling and advances in molecular techniques have provided a much more detailed overview of bamboo relationships and the complex evolutionary history of the bamboos. Although much more work remains to be done, especially with the nuclear genome and with the inclusion of critical taxa, phylogenetic studies to date have produced an intriguing set of testable hypotheses regarding the broad picture of bamboo evolution. In turn, revised classifications at the subtribal and generic levels have emerged based on these molecular phylogenetic results. We emphasize the need for continued fieldwork for bamboos generally, to better document their distributions for ecological and biogeographic studies as well as for conservation purposes, and to provide material for ongoing molecular work. Better and more complete collections are also critical for documenting woody bamboos in the vegetative condition, which will facilitate better identification resources for bamboos. In the Neotropics, *Chusquea*, *Guadua*, *Merostachys* and *Pariana* still require significant taxonomic attention. We also strongly recommend further study of bamboo ecology and bamboo reproductive biology, as these areas lag behind the recent advances in bamboo systematics.

ACKNOWLEDGEMENTS

LGC thanks the U.S. National Science Foundation for grants BSR-8906340, DEB-0515712, DEB-1120750 and the National Geographic Society for two grants that supported field or

laboratory work on bamboos during the last 30 years. The Academia Mexicana de Ciencias, Programa de visitas de profesores distinguidos, AMC-FUMEC, 2013-2014, provided a fellowship to LGC that greatly assisted recent bamboo work in that country. RPO thanks the Fundação de Amparo à Pesquisa do Estado da Bahia (FAPESB, grant PNX0014/2009) and Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brazil (CNPq, grants 478901/2008-9, 562349/2010-3, 563558/2010-5 and 401526/2014-3) for financial support. We also thank the CNPq and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brazil, the Bamboos of the Americas (BOTA) Student Assistance Program, and the Ned Jaquith Foundation for a number of student fellowships/grants.

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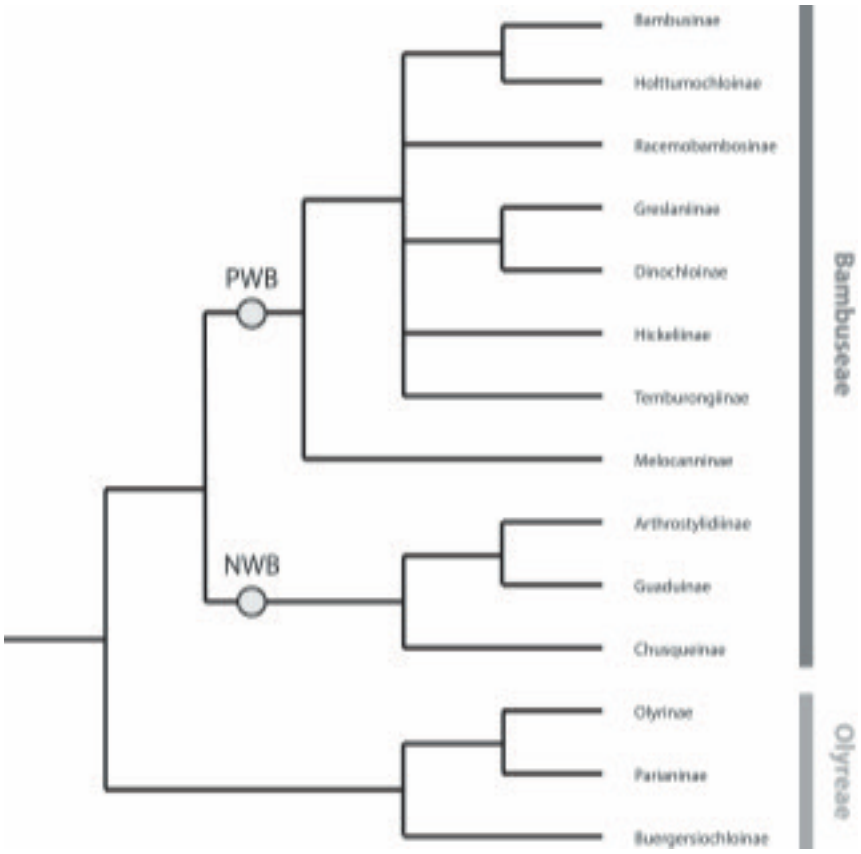
LIST OF FIGURES

Figure 1. Summary of the evolutionary relationships of subtribes within the tropical bamboo clade (Bambuseae and Olyreae). NWB = Neotropical woody bamboos; PWB = Paleotropical woody bamboos.

LIST OF CHARACTERS

mya is million years ago


Bambusinae
Holttumochloinae
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Hickelinae
Temburongiinae
Melocanninae
Arthrostylidinae
Guaduinae
Chusqueinae
Olyrinae
Parianinae
Buergersiochloinae
PWB
NWB
Bambuseae
Olyreae

Keynote Lecture

SURBAMBÚ: A PRACTICAL CASE OF BUSINESS INTEGRATION BETWEEN PLANTATIONS AND INDUSTRY

Hormilson Cruz Ríos
Surbambú
Carretera Mexico Toluca # 50 – 50
México DF. México. CP: 05320
hormilson@surbambu.mx

Abstract

In Mexico bamboo grows in many aspects; forestry, plantations, propagation, evaluation not only in native but also in exotic bamboo species with high economical potential, construction, biomass production, charcoal, clean energy, engineered wood and cellulose.

Surbambú, the most powerful Mexican company of the current times was created for six partners who believed in the properties of bamboo and the potential to make large projects with them in a sustainable way.

This conference shows the principles or philosophy and the way how Surbambú became the leading bamboo company in Mexico and one of the most important in America.

Introduction

I feel if we continue saying and writing that bamboo is a wonderful plant that traps large amounts of carbon dioxide, regulates water currents, controls erosion and hosts flora and fauna, they will be continue admired but not important.

I feel that use bamboo poles in construction, bicycles, handicrafts, little houses, is very important, but with that kind of uses the bamboos will be continue admire but not important.

In the examples mentioned above, the amount of stems harvested in the field is very small, with the sad aggravating factor that the cut is made only once. Under such circumstances, the bamboo will continue to remain in the forests, without use, because the market for them is very limited. It is not known what to cut them, their use under such considerations is very low, and therefore the people of the field do not see, nor will see in the bamboo a plant that will generate wealth, large amounts of labor and therefore elevation of the level of life, which represents an important social impact.

It is industrialization and large projects that can be made with bamboo that will bring it to its true level. In these, hundreds of thousands are used, and maybe millions of stems a year, but most decisively, continuously because a company needs raw material not only one year, but all the years of its existence. When we do that, the bamboo will be loved, admired and respected.

After being a researcher, I went to the natural forests, then I entered into commercial plantations, and now my struggle is that in America we move on to the realization of large industrial projects that revolutionize bamboo in all its facets, but let the rural people begin to improve their standard of living.

I was one of the pioneers of the laminates in Colombia where I actively participate personally investing money, but now with the advance of the industry in the East of the hemisphere, I have dedicated myself to follow this process that we can replicate and adjust for our countries in America.

To achieve it countless trips and deep studies have been made that show that this is the step that is needed and that we must arrive quickly. The detailed studies already exist and as a consequence, Mexico has just initiated big plantations linked to the industrial processes.

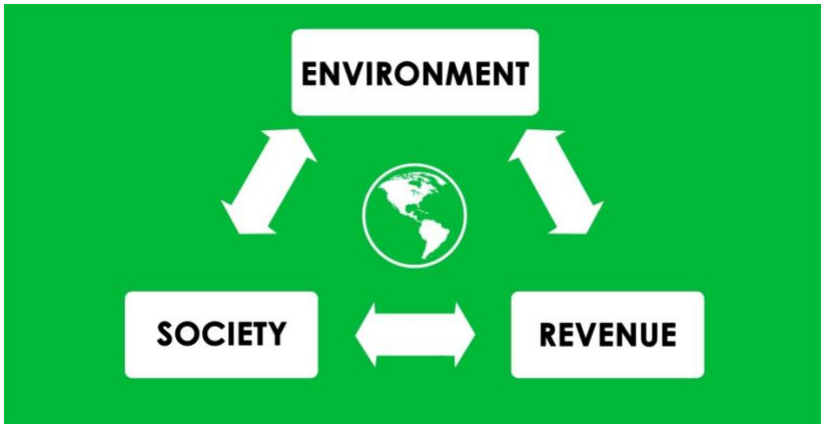
Surbambu has now plantations, a bamboo strips factory producing to export to United States and is establishing a pilot factory to produce bamboo pellets.

Philosophy of Surbambú.

In Mexico, bamboos are studied and working for only 25 years. However, in only that short period of time has been possible to make great development. Now, Mexico becoming one of the most outstanding countries in the Americas, with the firm vision of being one of the most important in the world in a few more years.

In Mexico, Surbambú is the most important bamboo company and was created with five important principles where all the projects carried out must consider.

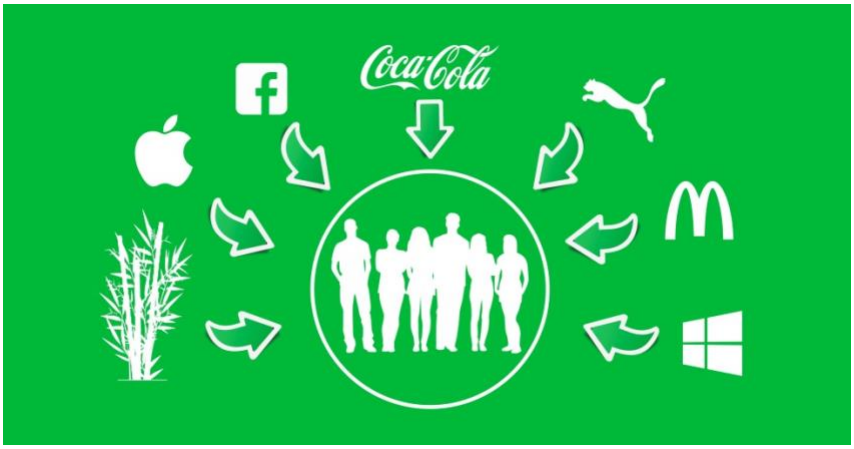
Sustainability.



Sustainability is not just planting bamboo for its environmental properties

A project is sustainable when it joins the improvement of the environment, helps the society and generates money. When those three aspects are united, any project is really sustainable and can be replicated several times.

Massiveness



Massiveness means that one product reaches the masses, thousands of customers on permanent basis. For bamboo to be really important, the products generated must be massive.

If a bamboo project arises as the generation of something massive, there will be always people working in the field every day, every month and every year. Similarly, people who work in the industry producing massive products will also work every day, months and years.

For a bamboo project to be successful it must be massive. It must reach the masses and should be sold products all the days.

Sow the appropriate bamboo species according to industrial objective

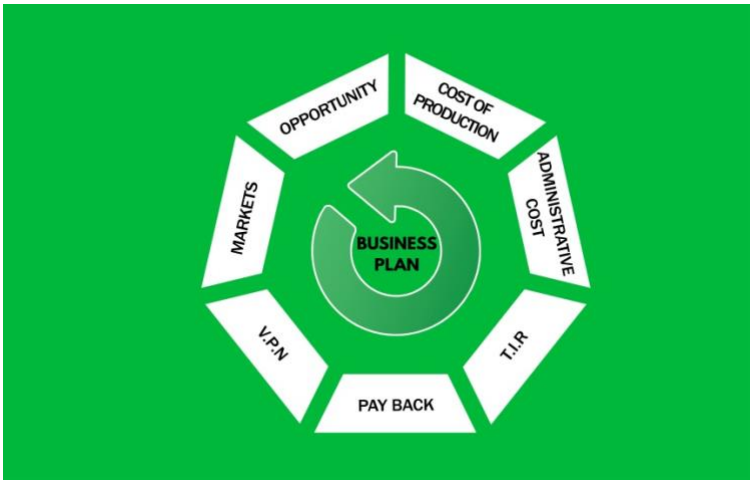
It is necessary to know what kind of bamboo should be planted as a producer of the correct raw material for an industrial project. It is incorrect sow only one kind of bamboo and with it wants to do everything in the industrial process. Sow an incorrect bamboo for a special industrial project is a big mistake.

Plantations linked to industries

A high degree of success is ensured when the bamboo plantation is linked with an industrial process.

That does not mean that a large plantation has to do it. A small plantation can be made and linked as a raw material producer to an industrial process as a social housing or charcoal production. Or make a medium plantation linked to a factory that produces engineered wood. It is possible to make a bigger plantation and linked it to a pellet production plant or bioethanol. A large one can be done making to produce raw material for a factory generating cellulose and long fiber paper.

Business plan



Before to start a project, always, the business plan must be done. Writing a business plan is very important because it brings so much value to the project. The business plan is not just a tool to raise capital or to appear before institutions that support entrepreneurial activity; It is a process that helps entrepreneurs get more knowledge of their business ideas. The discipline of the planning process, if well done, helps to evaluate the opportunity and allows to shape a business model to exploit it.
The strength and success of Surbambú is the human team

The success of a company like Surbambú is due to the fact that a team of expert professionals joined in each of its strengths.

There is a person highly specialized in international management, another person is specialized in all bamboo aspects bamboo, another is specialized in industrial process, another in administrative and finance aspects. The union of strengths created a strong team that made investors believe in Surbambú.

Results

In two years of work the Surbambú company has created.

Bought a 2,200 ha in Campeche State where the company is planting 900 ha of bamboo. The other 1,300 ha are intended for the conservation of native vegetation and wild animals, including the jaguar.

Created a plant of production of strips with high quality to export to the United States for the realization of engineered wood.

It is establishing a bamboo pellets factory.

It is close in union with investors from the United States to purchase 6,300 hectares for the planting of bamboo as a raw material producer for an engineered wood production.

Keynote Lecture

THE EVOLUTION OF BAMBOO IN MEXICO

Ing. Eduardo D' Esezarte Lara

Contributor: Ing. Wiliams Lagunes Castro

Bambues Edel S of P.R, of R.L.- km 1.5 road Atoyaquillo-Cañada Blanca, Municipality of Amatlan de los Reyes, Ver. - edel_03@hotmail.com

Summary

This paper shows in a summarized way the historical evolution that has preceded the current knowledge of bamboo as a Renewable Natural Resource in Mexico; Emphasis is placed on the current perspectives of their use and exploitation, as well as on the importance of conserving natural ecosystems. Likewise, reference is made to the recommended actions to obtain more and better results in the commercialization and industrialization of bamboo from the point of view of the social and economic conditions of the country. In general, the guidelines that Mexico must follow to take advantage of this resource are proposed, since it is reaching the exact point where a true culture can be unleashed in the cultivation, industrialization and uses of bamboo that can improve the quality of life in rural communities fighting poverty without compromising the environmental balance and achieving Sustainability.

Keywords: evolution, historical transition, bamboo, renewable natural resource, conservation, industrialization.

Abstract: In this paper, the historical evolution that advanced the current knowledge of bamboo as a Renewable Natural Resource in Mexico was presented in a summarized manner; Emphasis is placed on the current perspectives of their use and exploitation, as well as on the importance of conserving natural ecosystems. In the same way, reference is made to the recommended actions to obtain more and better results in the commercialization and industrialization of bamboo from the point of view of the social and economic conditions of the country. In general, the guidelines that Mexico must have to use this resource are proposed, which can be obtained by reaching the exact point where you can find a true bamboo culture that can improve the quality of life in rural communities by combating poverty without compromising the environmental balance and achieving Sustainability.

Keywords: evolution, historical transition, bamboo, renewable natural resource, conservation industrializations.

Introduction

The presence and evolution of this grass in the world has been important for the development of human beings. The transcendental contribution, in the beginnings of the industry very recognized and cited, is to be one of the first primary materials used in the production of paper, this grass has changed and contributed to the evolution of humanity by bringing man to improve communication and education on the planet.

This and other uses, which exceed one thousand, are attributed to the different species of bamboo and their adaptability, grasses form, without doubt, one of the most important plant groups from the economic point of view. In the history of the human being, grasses have been a fundamental factor in the formation and evolution of great civilizations since they have been used as primary food. Several of the great cultures supported their feeding in some grass. Thus, New Guinea used sugarcane, the civilizations of Asia and the Middle East based their subsistence and development on crops of sorghum, barley, oats, rice, etc. Europe based its development on wheat cultivation and in Mesoamerica corn played a major role in most pre-Columbian cultures.

In addition to its use as food and fodder, grasses are used by man in the production of medical products, crafts and also in industry. Likewise, they are used for construction, recreation, and religious ceremonies. Some representatives of this family are important elements of the conservation and regeneration of soils and play a fundamental ecological role and their commercial development has also taken centuries.

This plant resource has a wide geographic distribution, appear as important constituents of the natural flora of many parts of the tropical, subtropical, and temperate-middle regions of the world, from sea level to the snow limit. The distribution of the Bamboo in the World goes from the 51 degrees of North latitude (Japan) to the 45 degrees of South latitude (Chile) and from the level of the sea, to the 4300 meters of height reported in the equatorial Andes in the known formation as Páramo. (Londoño 2002).

The use of bamboo in Mexico has a pre-Hispanic background: the Totonacs in Veracruz, the Huastecos in Hidalgo and Tamaulipas, the Aztecs and Teotihuacans in central Mexico, the Maya-Chontales in Tabasco, have built bamboo houses and continue to do so today. day (Cortes, s / f on bambumex.org).

With the arrival of the Spaniards, new construction techniques were added to the American systems, such as the quincha, the bahareque, the brick, the tile, together with the raw earth in the form of adobe or mud, adapted to the stone and cancahua giving place to the colonial architecture that left footprints in all the American countries. (Valdiviezo & Castillo, 2011)

In our country. Two species are particularly important from the Ethnobotanical point of view: ***Guadua aculeata*** and ***Otatea acuminata***; the first commonly known as - tarro - is an important species used in the construction of houses in the Huasteca region of Mexico, mainly comprising the states of Puebla and Veracruz, as well as being used at present for different activities of people living in the field, is a fact that is and has been an important element in the construction of houses, under the system known as Bahareque. The - otate -, the second species cited, is probably the most widely distributed bamboo in Mexico, particularly in the states of Veracruz, Nayarit, Colima and Jalisco is very abundant and used for multiple activities. The two species have been used in the construction of traditional houses by many indigenous populations.

To the 54 recognized native species in our days, esteem a thirty of introduced species that have diversified, in much, the traditional and economic use that today is contemplated as much in rural communities as in the environs of the big cities of the country

The use of bamboo is very old, but little known. From this species we obtain multiple benefits, among which we can mention some: housing construction, furniture, handicrafts, food, paper production, canes, kitchen utensils, baskets, garrochas, cattle feed, toys, arrows, construction material of housing, ornamental, medicinal, scaffolding, carbon capture, reforestation, production of water and oxygen, are just some of them. (Moreno & Jakob, 2012)

In the present work, some of the historical considerations that have preceded the current knowledge of bamboo as a Renewable Natural Resource in Mexico are shown; Emphasis is placed on the current perspectives of its use and exploitation, emphasizing the development that this plant has taken today, in our vast territory.

The relationship between the Industrial Design career of FES Aragón and bamboo began in 1980 when the opportunity was presented, within the framework of the Technical and Scientific Cooperation Program with the People's Republic of China, to request the stay of a specialized technician in bamboo technology in the faculty to teach a course aimed at designers.

In 1981 Professors Gabriel Simón Sol and José Manuel López López moved to the People's Republic of China and visited the bamboo furniture workshops Hunan Bamboo Wares in the Yi Yang Municipality of Hunan Province. The stay of the Chinese technician took a little longer and it was not until 1984 that he was received in the faculty, that same year they started working relationships with artisans from Monte Blanco, Ver., Where the furniture was made for the National Fund for Development to the Crafts (FONART).

These works led to a line of research since the National Autonomous University of Mexico (UNAM), studied the causes of cracks and moth attacks that presented the bamboo furniture that they commercialized, as well as reviewing their design as they were not very

comfortable furniture. This project, gave us the opportunity to enter the world of bamboo, a world that we did not imagine so big and important.

From 1998 when the company Bambuver, A.C. begins its activities, the knowledge and commercial use of bamboo has a remarkable increase, because this company is dedicated to promoting its use and transformation, as well as to propagate mainly species with a high productive potential.

Currently in the state of Veracruz, there are organized groups of producers, artisans and micro-companies that are working with bamboo. A region well known for the production of furniture and craftsmanship with bamboo is the region of Coatepec-Teocelo-Monte Blanco-Huatusco-Orizaba which have been strengthened with the support of the National Forestry Commission (CONAFOR) to adopt knowledge and the technologies generated by the Institute of Ecology (INECOL), the Training Unit for Rural Development (UNCADER), the Veracruzana University (UV), the Center for Agricultural and Forestry Training (CECAF) and the National Institute of Agricultural Forestry Research and Cattle (INIFAP). This agricultural and artisanal activity has allowed them to generate sources of income and the generation of jobs through the production and commercialization of bamboo as a non-timber forest resource.

Based on the above and as a sectoral development strategy. The Veracruzan Council of Bamboo was created on August 5, 2005 to "promote the development of the productive activities of bamboo cultivation, as well as the organizations of producers and the exploitation of this resource in the different regions of the Veracruzana entity" (http://portal.veracruz.gob.mx/pls/portal/docs/PAGE/SEDARPA1INICIO/COVERBAMBU/MANUALES%20DE%20ORGANIZACION/REGLAMENTO%20INTERIOR.PDF of July 3, 2011), being imitated by other states of the country.

In addition to this great achievement, in 2005 the 1st Mexican Bamboo Congress was held in the city of Xalapa, Veracruz, with an international character that brought together personalities such as Arq. Jorge Morán, Arq. Simón Veles, Ing. Ximena Londoño, Ing. Francisco Castaño, Dr. Lynn Clark, among others, and on behalf of Mexico, Mr. Eduardo D'Esezarte Lara, who served as Executive President and Gilberto Cortés on Bamboo in Mexico, the latter the president of the Mexican Association of Bamboo (AMEB) (Bambumex.org).

In 2008, it is the city of Puebla that houses the 2nd Mexican Bamboo Congress, which also brought together specialists from around the world and was organized by representatives of INBAR, the international body that promotes the use of bamboo and rattan, AMEB (Mexican Bamboo Association), and the Government of the State of Puebla in addition to the Produce Puebla Foundation, AC.

In 2012 the INECOL held the 1st Bamboo State Forum: current situation and perspectives ". Being the center of the state of Veracruz one of the most important regions for the

cultivation of this plant, these events can be retaken as the great achievements, to publicize the actions that were taking place in the country.

In the year 2016, the 3rd Mexican Bamboo Congress was held in the City of Huatusco. See, in this congress the vanguard in Innovation, the potential of the Sustainability, the exponential development of the Industry and the benefit of the Businesses around the bamboo, in favor of the society and the care to the environment were illustrated.

Currently, some of the most important organizations, agencies and educational institutions dedicated to the dissemination of bamboo in Mexico are: Conafor, Sedema, Bambuver, Kaltia, Bambuterra, Morbambu, Bamboolife, Bamboo Business, Bambusec, Bambas, Agromod, Inecol, Uncader, Universidad Veracruzana, UNAM, Bambumex, Bambúes Edel, Bambú Cid, Bambúes y Forestales de México, Bambú Guadua premier, Sur Bambú, Bambusa, Dicma Trade, Bambú Maya, Bambú Jal, Ojtat, Red Mexicana del Bambú, Bambú Rain, between many others, have served as motivators for those who could venture into the use of this noble plant material, which began several years ago, the introduction of exotic species with various uses, such as: specific scientific studies, academic exchanges, tours in countries dedicated to the cultivation and industrialization, development of commercial nurseries, reforestation, establishment of commercial plantations, training of personnel, design and construction among many other structures, in order to contribute to improving the quality of life of many people involved in this area.

In several states of the Mexican Republic the cultivation and use of bamboo emerges as a potential alternative for development and production, (in Veracruz there are 54 native species and some 30 introduced, currently have estimated about 15 000 hectares, already established and 5,000 hectares in the process of development), the future for this species is very promising, since its cultivation and exploitation is possible to be carried out satisfactorily, granting a socio-economic and environmental benefit, leading us to a sustainable development.

Mexico through CONAFOR contributes to reducing the effects of climate change by establishing hydroregulating curtains in rivers and streams and supporting the establishment of commercial forest plantations with bamboo plants, as well as preventing the deforestation of those forests and forests that still exist, a negative effect that normally takes place in countries with less industrial development, this forces us to turn to see a material that replaces the great use of wood that exists today.

At present, for the aforementioned and with the purpose of promoting schemes that strengthen the productivity and competitiveness of the agricultural and forestry sector, as well as to know the work of producers, businessmen, professionals and researchers, thanks to the support of the Wold Congres Bambú organizes the 11th World Bamboo Congress in Mexico: Sustainability - Environment - Society - Economy. With transfer in the City of Xalapa, Ver. From August 14 to 18, 2018.

In this 11th world congress, the exchange of experiences will be promoted, where great specialists in the subject will present the latest technological and scientific advances, where they will undoubtedly bring knowledge, thus benefiting all of us who are directly or indirectly involved with this resource called bamboo.

The evolution and future of bamboo in Mexico for all the benefits that it offers, will have to generate that the institutions of education and investigation consider it like subject of studies, this crop could be the way to foment the rural work and the programs of reforestation in lands infertile or baldías, that when increasing the surface of plantations, we will be able to have:

- Large plantations to generate stems for construction, biomass, edible shoots
- Creation of companies that produce charcoal
- Large companies that produce ecological wood that replaces the wood that is obtained from the trees and thereby reduce the pressure of the forests.
- Large companies that produce engineered wood that compete in the hardwood market.
- Large companies that produce pellets as fuel to generate clean energy
- Large companies that produce long fiber cellulose, paper, and cardboard.

Conclusion

Due to its natural climate and soil conditions, the benefits of this wonderful plant should continue to be promoted. Collaboration is the key to making this crop a true development alternative. Bamboo plays an important role and it is crucial to reach important advances in several segments. of the value chain compared to the previous decade: the mastery of propagation techniques, new actors with greater knowledge about the different processes, innovative industrial processes, contact of a greater number of actors with internal and external markets, several universities conducting research for to study the markets for bamboo and its respective products and by-products and, a government with political will and decision to support the processes concerning the improvement of the bamboo sector in the country. However, the aforementioned, actions that consolidate the landscape of bamboo cultivation are required

Among these are: the realization of a national inventory to know the exact surface covered with bamboo, improve the institutional framework, strengthen the technical aspects of silvicultural management, develop strategies to reduce production costs and improve marketing, look for financial incentives to expand the surface planted with bamboo, contribute to improve ongoing industrial processes and other value added, perform a specific study to know the marketing dynamics in other countries.

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Keynote Lecture

LA EVOLUCIÓN DEL BAMBÚ EN MÉXICO

Ing. Eduardo D´ Esezarte Lara

Colaborador: Ing. Wiliams lagunes castro

Bambues Edel S de P.R, de R.L.- km 1.5 carretera Atoyaquillo-Cañada Blanca, Municipio de Amatlan de los Reyes, Ver. – edel_03@hotmail.com

Resumen

En este escrito se muestra de manera resumida la evolución histórica que ha antecedido a los conocimientos actuales del bambú como Recurso Natural Renovable en México; se enfatizan las perspectivas actuales de su uso y aprovechamiento, además de la importancia en la conservación de los ecosistemas naturales. De igual forma, se hace referencia a las acciones recomendadas para obtener más y mejores resultados en la comercialización e industrialización del bambú desde el punto de vista de las condiciones sociales y económicas del país. Se proponen, de manera general, los lineamientos que México debe de seguir para aprovechar convenientemente este recurso, ya que se está logrando llegar al punto exacto en donde pueda desatarse una verdadera cultura en el cultivo, industrialización y usos del bambú que podrá mejorar la calidad de vida en las comunidades rurales combatiendo la pobreza sin comprometer el equilibrio ambiental y logrando la Sustentabilidad.

Palabras clave: evolución, transición histórica, bambú, recurso natural renovable, conservación, industrialización.

Abstract: In this paper, the historical evolution that advanced the current knowledge of bamboo as a Renewable Natural Resource in Mexico was presented in a summarized manner; Emphasis is placed on the current perspectives of their use and exploitation, as well as on the importance of conserving natural ecosystems. In the same way, reference is made to the recommended actions to obtain more and better results in the commercialization and industrialization of bamboo from the point of view of the social and economic conditions of the country. In general, the guidelines that Mexico must have to conveniently use this resource are proposed, which can be obtained by reaching the exact point where you can find a true bamboo culture that can improve the quality of life in rural communities by combating poverty without compromising the environmental balance and achieving Sustainability.

Keywords: evolution, historical transition, bamboo, renewable natural resource, conservation industrializations.

Introducción

La presencia y evolución que ha tenido esta gramínea en el mundo ha sido importante para el desarrollo de los seres humanos. La contribución trascendental, en los inicios de la industria muy reconocida y citada, es ser uno de los primeros materiales primarios utilizados en la elaboración de papel, esta gramínea ha cambiado y contribuido a la evolución de la humanidad al arrimar al hombre a mejorar la comunicación y educación en el planeta.

Este y otros usos, que superan el millar, son atribuidos a las diferentes especies de bambú y a su adaptabilidad, las gramíneas forman, sin lugar a duda, uno de los grupos vegetales más importantes desde el punto de vista económico. En la historia del ser humano las gramíneas han sido un factor fundamental en la formación y evolución de las grandes civilizaciones, pues se han usado como alimento primario. Varias de las grandes culturas sustentaron su alimentación en alguna gramínea. Así, Nueva Guinea utilizó la caña de azúcar, las civilizaciones de Asia y Medio Oriente basaron su subsistencia y desarrollo en cultivos de sorgo, cebada, avena, arroz, etc. Europa basó su desarrollo en el cultivo del trigo y en Mesoamérica el maíz jugó un papel primordial en la mayoría de las culturas precolombinas.

Además de su utilización como alimento y forraje, las gramíneas son empleadas por el hombre en la elaboración de productos médicos, artesanales y también en la industria. Igualmente, se utilizan para la construcción, recreación y en ceremonias religiosas. Algunos representantes de esta familia son elementos importantes de la conservación y regeneración de suelos y desempeñan un papel ecológico fundamental y su desarrollo comercial igualmente ha tomado siglos.

Este recurso vegetal presenta una amplia distribución geográfica, aparecen como constituyentes importantes de la flora natural de muchas partes de las regiones tropical, subtropical y templado-medio del mundo, desde el nivel del mar hasta el límite de las nieves. La distribución del Bambú en el Mundo va desde los 51 grados de latitud Norte (Japón) hasta los 45 grados de latitud Sur (Chile) y desde el nivel del mar, hasta los 4300 metros de altura reportada en los Andes ecuatoriales en la formación conocida como Páramo. (Londoño 2002).

El uso del bambú en México tiene antecedentes prehispánicos: los totonacas en Veracruz, los huastecos en Hidalgo y Tamaulipas, los aztecas y teotihuacanos en el centro de México, los maya-chontales en Tabasco, han construido casas de bambú y lo siguen haciendo hoy en día (Cortes, s/f en bambumex.org).

Con la llegada de los españoles, llegaron nuevas técnicas de construcción que se sumaron a los sistemas americanos, como la quincha, el bahareque, el ladrillo cocido, la teja, junto con la tierra cruda en forma de adobe o tapia, se adaptaron a la piedra y cancahua dando lugar a la arquitectura colonial que dejó huellas en todos los países americanos. (Valdiviezo & Castillo, 2011)

En nuestro país. Dos especies son particularmente importantes desde el punto de vista Etnobotánico: ***Guadua aculeata*** y ***Otatea acuminata***; la primera conocida comúnmente como -tarro - es una importante especie utilizada en la construcción de viviendas en la región Huasteca de México, comprendiendo principalmente los estados de Puebla y Veracruz, además de ser usada en la actualidad para diferentes actividades de las personas que viven en el campo, es un hecho que es y ha sido un elemento importante en la construcción de viviendas, bajo el sistema conocido como Bahareque. El – otate -, la segunda especie citada, es seguramente el bambú más ampliamente distribuido en México, en particular en los estados de Veracruz, Nayarit, Colima y Jalisco es muy abundante y aprovechado para múltiples actividades. Las dos especies, han sido usadas en la construcción de viviendas tradicionales por muchas poblaciones indígenas.

A las 54 especies nativas reconocidas en nuestros días, se estima una treintena de especies introducidas que han diversificado, en mucho, el aprovechamiento tradicional y económico que hoy se contempla tanto en comunidades rurales como en las inmediaciones de las grandes ciudades del país

La utilización del bambú es muy antigua, pero poco conocida. De esta especie obtenemos múltiples beneficios, entre los que podemos citar algunos: construcción de viviendas, muebles, artesanías, alimento, producción de papel, bastones, utensilios de cocina, cestos, garrochas, alimento para el ganado, juguetes, flechas, material de construcción de viviendas, ornamentales, medicinales, andamios, captura de carbono, reforestación, producción de agua y oxígeno, son solo algunos de ellos.(Moreno & Jakob, 2012)

En el presente trabajo, se muestran algunas de las consideraciones históricas que han precedido a los conocimientos actuales del bambú como Recurso Natural Renovable en México; se enfatizan las perspectivas actuales de su uso y aprovechamiento, haciendo énfasis en el desarrollo que esta planta ha tomado hoy en día, en nuestro vasto territorio.

La relación de la carrera de Diseño Industrial de la FES Aragón con el bambú se inició en 1980 cuando se presentó la oportunidad, dentro del marco del Programa de Cooperación Técnica y Científica con la República Popular China, de solicitar la estancia de un técnico especializado en tecnología del bambú en la facultad para impartir un curso dirigido a diseñadores.

En 1981 Los profesores Gabriel Simón Sol y José Manuel López López se trasladaron a la República Popular China y visitaron los talleres artesanales de muebles de bambú Hunan

Bamboo Wares en el Municipio Yi Yang de la Provincia de Hunan. La estancia del técnico chino tardó un poco más y no fue hasta 1984 que lo recibieron en la facultad, ese mismo año se iniciaron relaciones de trabajo con artesanos de Monte Blanco, Ver., donde se elaboraban los muebles para el Fondo Nacional Para el Fomento a las Artesanías (FONART).

Estos trabajos llevaron a una línea de investigación ya que la Universidad Nacional Autónoma de México (UNAM), estudio las causas de rajaduras y ataques de polilla que presentaban los muebles de bambú que comercializaban, así como revisar su diseño pues no eran muebles muy cómodos. Este proyecto, dio la oportunidad de adentrarnos en el mundo del bambú, un mundo que no imaginábamos tan grande e importante.

A partir de 1998 cuando la empresa Bambuver, A.C. inicia sus actividades, el conocimiento y uso comercial del bambú tiene un aumento notable, pues esta empresa se dedica a promocionar su uso y transformación, así como a propagar principalmente especies con un alto potencial productivo.

En la actualidad en el estado de Veracruz, existen grupos organizados de productores, artesanos y microempresas que están trabajando con bambú. Una región muy conocida por la producción de muebles y elaboración de artesanías con bambú es la región de Coatepec-Teocelo-Monte Blanco- Huatusco-Orizaba los cuales se han visto fortalecidos con los apoyos de la Comisión Nacional Forestal (CONAFOR) para adoptar conocimientos y las tecnologías generadas por el Instituto de Ecología (INECOL) , la Unidad de Capacitación para el Desarrollo Rural (UNCADER), la Universidad Veracruzana (UV), el Centro de Capacitación Agropecuaria y Forestal (CECAF) y el Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuaria (INIFAP). Esta actividad agrícola y artesanal les ha permitido generar fuentes de ingresos y la generación de empleos mediante la producción y la comercialización del bambú como un recurso forestal no maderable.

Con base en lo anterior y como una estrategia de desarrollo sectorial. Se crea el 5 de agosto de 2005 el Consejo Veracruzano del Bambú para “impulsar el desarrollo de las actividades productivas del cultivo del bambú, así como de las organizaciones de productores y la explotación de este recurso en las distintas regiones de la entidad Veracruzana” (http://portal.veracruz.gob.mx/pls/portal/docs/PAGE/SEDARPA1INICIO/COVERBAMBU/MANUALES%20DE%20ORGANIZACION/REGLAMENTO% 20INTERIOR.PDF del 3 de julio del 2011), siendo imitada por otros estados del país.

Aunado a este gran logro, en el año 2005 se realizó el 1º Congreso Mexicano del Bambú en la ciudad de Xalapa, Veracruz, con un carácter internacional que reunió a personalidades como Arq. Jorge Morán, Arq. Simón Veles, Ing. Ximena Londoño, Ing. Francisco Castaño, Dra Lynn Clark, entre otros, y por parte de México, el Ing. Eduardo D´ Esezarte Lara, que se desempeñó como Presidente Ejecutivo y Gilberto Cortés sobre el

Bambú en México, este último el presidente de la Asociación Mexicana del Bambú (AMEB) (Bambumex.org).

En el 2008, es la ciudad de Puebla la que alberga el 2º Congreso Mexicano del Bambú, que igualmente reunió a especialistas de todo el mundo y estuvo organizado por representantes del INBAR, el organismo internacional que promociona el uso del bambú y del ratán, del AMEB (Asociación Mexicana del Bambú), y del propio Gobierno del Estado de Puebla además de la Fundación Produce Puebla, A.C..

En el año 2012 el en INECOL se realizó el 1° Foro Estatal del Bambú: situación actual y perspectivas". Siendo el centro del estado de Veracruz una de las regiones de mayor importancia para el cultivo de esta planta, de estos eventos se pueden retomar como los grandes logros, el dar a conocer las acciones que se estaban llevando a cabo en el país.

En el año 2016 se efectuó el 3 ° Congreso Mexicano del Bambú en la Ciudad de Huatusco. Ver, en este congreso se ilustraron la vanguardia en Innovación, el potencial de la Sustentabilidad, el desarrollo exponencial de la Industria y el beneficio de los Negocios entorno al bambú, en favor de la sociedad y el cuidado al medio ambiente.

En la actualidad algunas de las organizaciones, dependencias e instituciones educativas más importantes dedicadas a la difusión del bambú en México son: Conafor, Sedema, , Bambuver, Kaltia, Bambuterra, Morbambu, Bamboolife, Bamboo Business, Bambusec, Bambas, Agromod, Inecol, Uncader, Universidad Veracruzana, UNAM, Bambumex, Bambúes Edel, Bambú Cid, Bambúes y Forestales de México, Bambú Guadua premier, Sur Bambú, Bambusa, Dicma Trade, Bambú Maya, Bambú Jal, Ojtat, Red Mexicana del Bambú, Bambú Rain, entre otras muchas más, han servido como motivadores para aquellos que pudieran incursionar en el uso de este noble material vegetal, mismas que iniciaron hace ya varios años, la introducción de especies exóticas con diversos usos, tales como: estudios científicos específicos, intercambios académicos, giras en países dedicados al cultivo e industrialización, desarrollo de viveros comerciales, reforestación, establecimiento de plantaciones comerciales, capacitación de personal, diseño y construcción entre muchas otras estructuras, con el fin de contribuir a mejorar la calidad de vida de muchas personas involucradas en este rubro.

En varios estados de la República Mexicana el cultivo y aprovechamiento del bambú surge como una alternativa potencial de desarrollo y de producción, (en Veracruz existen 54 especies nativas y unas 30 introducidas, actualmente se tienen estimadas alrededor de 15 000 has., ya establecidas y 5 000 has en vías de desarrollo), el futuro para esta especie es muy promisorio, ya que su cultivo y aprovechamiento es posible realizarse satisfactoriamente otorgando un beneficio socio-económico y ambiental llevándonos a un desarrollo sustentable.

México a través de la CONAFOR contribuye a la reducción de los efectos del cambio climático estableciendo cortinas hidroreguladoras en ríos y arroyos y el apoyo para el establecimiento de plantaciones forestales comerciales con plantas de bambú, así como evitar que se sigan desforestando aquellos bosques y selvas que aún existen, efecto negativo que normalmente se lleva a cabo en los países de menor desarrollo industrial, esto nos obliga a voltear a ver un material que sustituya la gran utilización de madera que existe hoy en día.

En la actualidad, por lo anteriormente citado y con el propósito de promover esquemas que fortalezcan la productividad y competitividad del sector agropecuario y forestal, así como conocer trabajos de productores, empresarios, profesionales e investigadores, gracias al apoyo del Wold Congres Bambú se organiza el **11 Congreso Mundial del Bambú en México: Sustentabilidad – Medio Ambiente – Sociedad - Economía.** Con cede en la Ciudad de Xalapa, Ver. del 14 al 18 de agosto del 201**8.**

En este 11 congreso mundial se promoverá el intercambio de experiencias en donde grandes especialistas en el tema expondrán los últimos avances tecnológicos y científicos, donde sin duda traerán conocimiento siendo así un beneficio para todos los que estamos involucrados directa o indirectamente con este recurso llamado bambú.

La evolución y futuro del bambú en México por todas las bondades que ofrece, habrá de generar que las instituciones de enseñanza e investigación lo consideren como tema de estudios, este cultivo podría ser la vía para fomentar el trabajo rural y los programas de reforestación en tierras infértiles o baldías, que al incrementar la superficie de plantaciones podremos tener:

- Grandes Plantaciones para generar tallos para construcción, biomasa, brotes comestibles
- Creación de empresas que produzcan carbón vegetal
- Grandes empresas que produzcan madera ecológica que reemplace la madera que se obtiene de los árboles y con ello restar la presión de los bosques.
- Grandes empresas que produzcan madera ingenierizada que compitan en el mercado de las maderas duras.
- Grandes empresas que produzcan pellets como combustible para generar energías limpia
- Grandes empresas que produzcan celulosa de fibra larga, papel y cartulina

Conclusión

Por sus condiciones naturales de clima y suelo se deberá continuar promoviendo las bondades de esta maravillosa planta la colaboración es la clave para hacer de este cultivo una verdadera alternativa de desarrollo, el bambú juega un papel importante y es

determinante llegar a avances importantes en varios segmentos de la cadena de valor frente a la década anterior: el dominio de técnicas de propagación, nuevos actores con mayor conocimiento sobre los diferentes procesos, procesos industriales innovadores, contacto de un número mayor de actores con mercados internos y externos, varias universidades realizando investigaciones para estudiar los mercados para el bambú y sus respectivos productos y subproductos y, un gobierno con voluntad y decisión política para apoyar los procesos concernientes a mejorar el sector del bambú en el país. No obstante, lo ya mencionado, se requieren acciones que consoliden el panorama del cultivo del bambú.

Entre estas están: la realización de un inventario nacional para conocer la superficie exacta cubierta con bambú, mejorar el marco institucional, fortalecer los aspectos técnicos de manejo silvicultural, desarrollar estrategias para disminuir costos de producción y mejorar la comercialización, buscar incentivos financieros para ampliar la superficie plantada con bambú, aportar a mejorar los procesos industriales en marcha y otros agregados de valor, realizar un estudio específico para conocer la dinámica de comercialización en otros países.

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Introducción

La presencia y evolución que ha tenido esta gramínea en el mundo ha sido importante para el desarrollo de los seres humanos. La contribución trascendental, en los inicios de la industria muy reconocida y citada, es ser uno de los primeros materiales primarios utilizados en la elaboración de papel, esta gramínea ha cambiado y contribuido a la evolución de la humanidad al arrimar al hombre a mejorar la comunicación y educación en el planeta.

Este y otros usos, que superan el millar, son atribuidos a las diferentes especies de bambú y a su adaptabilidad, las gramíneas forman, sin lugar a duda, uno de los grupos vegetales más importantes desde el punto de vista económico. En la historia del ser humano las gramíneas han sido un factor fundamental en la formación y evolución de las grandes civilizaciones, pues se han usado como alimento primario. Varias de las grandes culturas sustentaron su alimentación en alguna gramínea. Así, Nueva Guinea utilizó la caña de azúcar, las civilizaciones de Asia y Medio Oriente basaron su subsistencia y desarrollo en cultivos de sorgo, cebada, avena, arroz, etc. Europa basó su desarrollo en el cultivo del trigo y en Mesoamérica el maíz jugó un papel primordial en la mayoría de las culturas precolombinas.

Además de su utilización como alimento y forraje, las gramíneas son empleadas por el hombre en la elaboración de productos médicos, artesanales y también en la industria. Igualmente, se utilizan para la construcción, recreación y en ceremonias religiosas. Algunos representantes de esta familia son elementos importantes de la conservación y regeneración de suelos y desempeñan un papel ecológico fundamental y su desarrollo comercial igualmente ha tomado siglos.

Este recurso vegetal presenta una amplia distribución geográfica, aparecen como constituyentes importantes de la flora natural de muchas partes de las regiones tropical, subtropical y templado-medio del mundo, desde el nivel del mar hasta el límite de las nieves. La distribución del Bambú en el Mundo va desde los 51 grados de latitud Norte (Japón) hasta los 45 grados de latitud Sur (Chile) y desde el nivel del mar, hasta los 4300 metros de altura reportada en los Andes ecuatoriales en la formación conocida como Páramo. (Londoño 2002).

El uso del bambú en México tiene antecedentes prehispánicos: los totonacas en Veracruz, los huastecos en Hidalgo y Tamaulipas, los aztecas y teotihuacanos en el centro de México, los maya-chontales en Tabasco, han construido casas de bambú y lo siguen haciendo hoy en día (Cortes, s/f en bambumex.org).

Con la llegada de los españoles, llegaron nuevas técnicas de construcción que se sumaron a los sistemas americanos, como la quincha, el bahareque, el ladrillo cocido, la teja, junto con la tierra cruda en forma de adobe o tapia, se adaptaron a la piedra y cancahua dando lugar a la arquitectura colonial que dejó huellas en todos los países americanos. (Valdiviezo & Castillo, 2011)

En nuestro país. Dos especies son particularmente importantes desde el punto de vista Etnobotánico: ***Guadua aculeata*** y ***Otatea acuminata***; la primera conocida comúnmente como -tarro - es una importante especie utilizada en la construcción de viviendas en la región Huasteca de México, comprendiendo principalmente los estados de Puebla y Veracruz, además de ser usada en la actualidad para diferentes actividades de las personas que viven en el campo, es un hecho que es y ha sido un elemento importante en la construcción de viviendas, bajo el sistema conocido como Bahareque. El – otate -, la segunda especie citada, es seguramente el bambú más ampliamente distribuido en México, en particular en los estados de Veracruz, Nayarit, Colima y Jalisco es muy abundante y aprovechado para múltiples actividades. Las dos especies, han sido usadas en la construcción de viviendas tradicionales por muchas poblaciones indígenas.

A las 54 especies nativas reconocidas en nuestros días, se estima una treintena de especies introducidas que han diversificado, en mucho, el aprovechamiento tradicional y económico que hoy se contempla tanto en comunidades rurales como en las inmediaciones de las grandes ciudades del país

La utilización del bambú es muy antigua, pero poco conocida. De esta especie obtenemos múltiples beneficios, entre los que podemos citar algunos: construcción de viviendas, muebles, artesanías, alimento, producción de papel, bastones, utensilios de cocina, cestos, garrochas, alimento para el ganado, juguetes, flechas, material de construcción de viviendas, ornamentales, medicinales, andamios, captura de carbono, reforestación, producción de agua y oxígeno, son solo algunos de ellos.(Moreno & Jakob, 2012)

En el presente trabajo, se muestran algunas de las consideraciones históricas que han precedido a los conocimientos actuales del bambú como Recurso Natural Renovable en México; se enfatizan las perspectivas actuales de su uso y aprovechamiento, haciendo énfasis en el desarrollo que esta planta ha tomado hoy en día, en nuestro vasto territorio.

La relación de la carrera de Diseño Industrial de la FES Aragón con el bambú se inició en 1980 cuando se presentó la oportunidad, dentro del marco del Programa de Cooperación Técnica y Científica con la República Popular China, de solicitar la estancia de un técnico especializado en tecnología del bambú en la facultad para impartir un curso dirigido a diseñadores.

En 1981 Los profesores Gabriel Simón Sol y José Manuel López López se trasladaron a la República Popular China y visitaron los talleres artesanales de muebles de bambú Hunan

Bamboo Wares en el Municipio Yi Yang de la Provincia de Hunan. La estancia del técnico chino tardó un poco más y no fue hasta 1984 que lo recibieron en la facultad, ese mismo año se iniciaron relaciones de trabajo con artesanos de Monte Blanco, Ver., donde se elaboraban los muebles para el Fondo Nacional Para el Fomento a las Artesanías (FONART).

Estos trabajos llevaron a una línea de investigación ya que la Universidad Nacional Autónoma de México (UNAM), estudio las causas de rajaduras y ataques de polilla que presentaban los muebles de bambú que comercializaban, así como revisar su diseño pues no eran muebles muy cómodos. Este proyecto, dio la oportunidad de adentrarnos en el mundo del bambú, un mundo que no imaginábamos tan grande e importante.

A partir de 1998 cuando la empresa Bambuver, A.C. inicia sus actividades, el conocimiento y uso comercial del bambú tiene un aumento notable, pues esta empresa se dedica a promocionar su uso y transformación, así como a propagar principalmente especies con un alto potencial productivo.

En la actualidad en el estado de Veracruz, existen grupos organizados de productores, artesanos y microempresas que están trabajando con bambú. Una región muy conocida por la producción de muebles y elaboración de artesanías con bambú es la región de Coatepec-Teocelo-Monte Blanco- Huatusco-Orizaba los cuales se han visto fortalecidos con los apoyos de la Comisión Nacional Forestal (CONAFOR) para adoptar conocimientos y las tecnologías generadas por el Instituto de Ecología (INECOL) , la Unidad de Capacitación para el Desarrollo Rural (UNCADER), la Universidad Veracruzana (UV), el Centro de Capacitación Agropecuaria y Forestal (CECAF) y el Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuaria (INIFAP). Esta actividad agrícola y artesanal les ha permitido generar fuentes de ingresos y la generación de empleos mediante la producción y la comercialización del bambú como un recurso forestal no maderable.

Con base en lo anterior y como una estrategia de desarrollo sectorial. Se crea el 5 de agosto de 2005 el Consejo Veracruzano del Bambú para “impulsar el desarrollo de las actividades productivas del cultivo del bambú, así como de las organizaciones de productores y la explotación de este recurso en las distintas regiones de la entidad Veracruzana” (http://portal.veracruz.gob.mx/pls/portal/docs/PAGE/SEDARPA1INICIO/COVERBAMBU/MANUALES%20DE%20ORGANIZACION/REGLAMENTO% 20INTERIOR.PDF del 3 de julio del 2011), siendo imitada por otros estados del país.

Aunado a este gran logro, en el año 2005 se realizó el 1º Congreso Mexicano del Bambú en la ciudad de Xalapa, Veracruz, con un carácter internacional que reunió a personalidades como Arq. Jorge Morán, Arq. Simón Veles, Ing. Ximena Londoño, Ing. Francisco Castaño, Dra Lynn Clark, entre otros, y por parte de México, el Ing. Eduardo D´ Esezarte Lara, que se desempeñó como Presidente Ejecutivo y Gilberto Cortés sobre el

Bambú en México, este último el presidente de la Asociación Mexicana del Bambú (AMEB) (Bambumex.org).

En el 2008, es la ciudad de Puebla la que alberga el 2º Congreso Mexicano del Bambú, que igualmente reunió a especialistas de todo el mundo y estuvo organizado por representantes del INBAR, el organismo internacional que promociona el uso del bambú y del ratán, del AMEB (Asociación Mexicana del Bambú), y del propio Gobierno del Estado de Puebla además de la Fundación Produce Puebla, A.C..

En el año 2012 el en INECOL se realizó el 1° Foro Estatal del Bambú: situación actual y perspectivas". Siendo el centro del estado de Veracruz una de las regiones de mayor importancia para el cultivo de esta planta, de estos eventos se pueden retomar como los grandes logros, el dar a conocer las acciones que se estaban llevando a cabo en el país.

En el año 2016 se efectuó el 3 ° Congreso Mexicano del Bambú en la Ciudad de Huatusco. Ver, en este congreso se ilustraron la vanguardia en Innovación, el potencial de la Sustentabilidad, el desarrollo exponencial de la Industria y el beneficio de los Negocios entorno al bambú, en favor de la sociedad y el cuidado al medio ambiente.

En la actualidad algunas de las organizaciones, dependencias e instituciones educativas más importantes dedicadas a la difusión del bambú en México son: Conafor, Sedema, , Bambuver, Kaltia, Bambuterra, Morbambu, Bamboolife, Bamboo Business, Bambusec, Bambas, Agromod, Inecol, Uncader, Universidad Veracruzana, UNAM, Bambumex, Bambúes Edel, Bambú Cid, Bambúes y Forestales de México, Bambú Guadua premier, Sur Bambú, Bambusa, Dicma Trade, Bambú Maya, Bambú Jal, Ojtat, Red Mexicana del Bambú, Bambú Rain, entre otras muchas más, han servido como motivadores para aquellos que pudieran incursionar en el uso de este noble material vegetal, mismas que iniciaron hace ya varios años, la introducción de especies exóticas con diversos usos, tales como: estudios científicos específicos, intercambios académicos, giras en países dedicados al cultivo e industrialización, desarrollo de viveros comerciales, reforestación, establecimiento de plantaciones comerciales, capacitación de personal, diseño y construcción entre muchas otras estructuras, con el fin de contribuir a mejorar la calidad de vida de muchas personas involucradas en este rubro.

En varios estados de la República Mexicana el cultivo y aprovechamiento del bambú surge como una alternativa potencial de desarrollo y de producción, (en Veracruz existen 54 especies nativas y unas 30 introducidas, actualmente se tienen estimadas alrededor de 15 000 has., ya establecidas y 5 000 has en vías de desarrollo), el futuro para esta especie es muy promisorio, ya que su cultivo y aprovechamiento es posible realizarse satisfactoriamente otorgando un beneficio socio-económico y ambiental llevándonos a un desarrollo sustentable.

México a través de la CONAFOR contribuye a la reducción de los efectos del cambio climático estableciendo cortinas hidroreguladoras en ríos y arroyos y el apoyo para el establecimiento de plantaciones forestales comerciales con plantas de bambú, así como evitar que se sigan desforestando aquellos bosques y selvas que aún existen, efecto negativo que normalmente se lleva a cabo en los países de menor desarrollo industrial, esto nos obliga a voltear a ver un material que sustituya la gran utilización de madera que existe hoy en día.

En la actualidad, por lo anteriormente citado y con el propósito de promover esquemas que fortalezcan la productividad y competitividad del sector agropecuario y forestal, así como conocer trabajos de productores, empresarios, profesionales e investigadores, gracias al apoyo del Wold Congres Bambú se organiza el **11 Congreso Mundial del Bambú en México: Sustentabilidad – Medio Ambiente – Sociedad - Economía.** Con cede en la Ciudad de Xalapa, Ver. del 14 al 18 de agosto del 201**8.**

En este 11 congreso mundial se promoverá el intercambio de experiencias en donde grandes especialistas en el tema expondrán los últimos avances tecnológicos y científicos, donde sin duda traerán conocimiento siendo así un beneficio para todos los que estamos involucrados directa o indirectamente con este recurso llamado bambú.

La evolución y futuro del bambú en México por todas las bondades que ofrece, habrá de generar que las instituciones de enseñanza e investigación lo consideren como tema de estudios, este cultivo podría ser la vía para fomentar el trabajo rural y los programas de reforestación en tierras infértiles o baldías, que al incrementar la superficie de plantaciones podremos tener:

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Conclusión

Por sus condiciones naturales de clima y suelo se deberá continuar promoviendo las bondades de esta maravillosa planta la colaboración es la clave para hacer de este cultivo una verdadera alternativa de desarrollo, el bambú juega un papel importante y es

determinante llegar a avances importantes en varios segmentos de la cadena de valor frente a la década anterior: el dominio de técnicas de propagación, nuevos actores con mayor conocimiento sobre los diferentes procesos, procesos industriales innovadores, contacto de un número mayor de actores con mercados internos y externos, varias universidades realizando investigaciones para estudiar los mercados para el bambú y sus respectivos productos y subproductos y, un gobierno con voluntad y decisión política para apoyar los procesos concernientes a mejorar el sector del bambú en el país. No obstante, lo ya mencionado, se requieren acciones que consoliden el panorama del cultivo del bambú.

Entre estas están: la realización de un inventario nacional para conocer la superficie exacta cubierta con bambú, mejorar el marco institucional, fortalecer los aspectos técnicos de manejo silvicultural, desarrollar estrategias para disminuir costos de producción y mejorar la comercialización, buscar incentivos financieros para ampliar la superficie plantada con bambú, aportar a mejorar los procesos industriales en marcha y otros agregados de valor, realizar un estudio específico para conocer la dinámica de comercialización en otros países.

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Cortes, s/f en bambumex.org

Keynote Lecture

RESOURCE FIBER LLC. BAMBOO FIBER FOR INDUSTRY

David M. Knight / dknight@resource-fiber.com

David will describe Resource Fiber LLC, its objectives and goals. He will explain the Resource Fiber business model and share his thoughts on the development of the bamboo industry.

Resource Fiber LLC is the only vertically integrated bamboo fiber products company in the United States growing bamboo and manufacturing high-performing bamboo industrial products while developing bamboo bio-composites for plastics, carbon fiber and polymers for 3-D printing. The company's bamboo nursery is the largest in the U.S.

Currently, *Phyllostachys edulis* and *Phyllostachys rubromarginata* are growing at the Company's in-field nursery located in rural Alabama, one of the poorest and undeveloped regions of the U.S. While domestic supply reaches maturity, Resource Fiber is sourcing, preprocessing and importing bamboo from other countries to begin production.

For more information, visit resource-fiber.com.

David M. Knight, CBI
Co-Founder
President / Chief Executive Officer
Resource Fiber LLC
Cell: 206.390.8289
Ofc: 205.747.2832 x701
Skype: david_knight1

RESOURCE FIBER LLC
Bamboo Fiber for Industry
www.resource-fiber.com

Conferencia magistral

RESOURCE FIBER LLC. FIBRA DE BAMBÚ PARA LA INDUSTRIA

David M. Knight / dknight@resource-fiber.com

David describirá Resource Fiber, sus objetivos y sus metas. Explicará el modelo de negocios de Resource Fiber y compartirá sus ideas sobre el desarrollo de la industria del bambú.

Resource Fiber LLC es la única empresa de productos de fibra de bambú integrada verticalmente en los Estados Unidos (EE.UU.) que cultiva bambú y fabrica productos industriales de bambú de alto rendimiento, mientras que desarrolla biocompuestos de bambú para plásticos, fibra de carbono y polímeros para impresión tridimensional. El vivero de bambú de esta compañía es el más grande de EE. UU.

Actualmente, *Phyllostachys edulis* y *Phyllostachys rubromarginata* están creciendo en el vivero de campo de la Compañía ubicado en la zona rural de Alabama, una de las regiones más pobres y subdesarrolladas de los EE. UU. Mientras la provisión doméstica alcanza su madurez, Resource Fiber está abasteciendo, preprocesando e importando bambú de otros países para comenzar la producción.

Para más información, visita resource-fiber.com.

David M. Knight, CBI
Co-Foundeador
Presidente / Director ejecutivo
Resource Fiber LLC
Celular: 206.390.8289
Oficina: 205.747.2832 x701
Skype: david_knight1

RESOURCE FIBER LLC
Fibra de bamboo para la industria
www.resource-fiber.com

Keynote Lecture

THE PARADISE OF BAMBOO AND GUADUA– AN AGRICULTURAL AND EDUCATION TOURISTIC DESTINATION

Ximena Londoño / ximelondo@gmail.com

The Paradise of Bamboo and Guadua is a company devoted to conveying a life´s passion for Guadua and other bamboos through agri-environmental tours, training workshops and the sales of plantlets and specialized bamboo handcrafts.

HOW WAS IT BORN?

In the Coffee Growing Area of Colombia where this destination is located, *Guadua angustifolia* Kunth is a notable main actor of the evolution and history of the culture of the central west area of the country, where it has been used since prehistoric times by the communities to build housing, bridges, rafts, tools, musical instruments and hunting and fishing tools.

When the Spaniards arrived to this region they found the native population amidst the Guadua stands, their homes, fortresses and fenced enclosure were built with thick Guadua or "fat" Guadua as the chroniclers called them.

This Guadua producing region, made up at present by the states of Caldas, Quindío, Risaralda and the northern area of Valle del Cauca, remained "invisible" for many years, without settlers and with a dense forest. It was at the end of the XIX and the beginning of the XX century when farmers from Antioquia rediscovered it when searching for the archeological wealth – gold- left by the Quimbaya Indians. These new settlers did not know the Guadua plant. But it was thanks to it , an abundant, low cost, strong and light material that the settlers from Antioquia were able to undertake this harsh adventure of colonizing the land and solve the problems of a very steep and rough topography that has strong seismic activity.

At the beginning of the XX century, one of the main characters of The Paradise of Bamboo and Guadua appeared. Don José Ramón de la Pava, who, in January 1908 bought the property of the Finca La Esmeralda. In 1949, when don José Ramón died, the Esmeralda farm was inherited by his 7 children, who through public deed 538 of December 1949, and by mutual agreement divided it into 7 properties. In 2001, I, Ximena Londoño de la Pava, grandchild of Don José Ramón inherited from my mother an area of 16.7 hectares, the place where this agro-touristic destination specialized in bamboo is located. The title of the land is then the first step to be able to develop and materialize The Paradise of Bamboo and Guadua.

The second component is the education given to me by my parents, Héctor and Sophy, who taught me from a very early age to love the rural areas and to love and respect their inhabitants. This contact with the fields from such a young age marked me for the rest of my life. It made me aware of the issues of agriculture and inspired in me a great passion for Guadua. A plant I always admired because of its versatility, fast growth and beauty, and because of its contribution to the protection and preservation of water and biodiversity in our territory.

In 1977 I enrolled in the faculty of agronomy in the National University of Colombia, campus of Palmira and chose as my graduation thesis to make a comparative study of the vegetation associated to the Guaduales of Valle del Cauca and Quindío. In 1984 I travelled to Washington, D.C., where I devoted myself to the study of the taxonomy botanic of bamboos with emphasis on the *Guadua* genus at the Smithsonian Institute under the mentorship of Dr. Thomas R. Soderstrom and was fortunate to meet my friends Lynn G. Clark and Emmet Judziewics, who have been my colleagues, teaches and coworkers in this scientific journey on the bamboos of the neo-tropics. With them and with other research colleagues such as Gerrit Davidse, Paul Peterson, Tarciso Filgueiras Eduardo Ruiz-Sánchez, Francisca Ely, Jaime Eduardo Muñoz, Juan Carlos Camargo, Ramona Oviedo and Chris Tyrrel among others, we have been able to make a significant contribution to the knowledge of biodiversity and ecology of the Latin American Bamboos. To all of them a million thanks!

The third component arises from my awareness of my duties as a daughter, and it is from this act of love that life leads me to make the decision of sharing experiences and knowledge with others.

In 2012 I move from Cali to La Esmeralda for good, with the only purpose of accompanying my mother during the last 4 years of her life. While I was there I was visited by two journalists from the Avianca magazine, to write a report where they were promoting the touristic areas in the coffee growing area. Obviously, at that time my farm was not a touristic destination, but it was a beautiful place that I had been building since 1984. To my surprise, when the Avianca magazine was published in November 2012, the cover was a picture taken in the bamboo stands of the wetland. And this is the publication that induces me to open to the public what had been built over so many years, with the purpose of becoming an agritourism cultural option in this coffee growing area that would contribute, in a significant manner, to the environmental, cultural and socioeconomic valuing of bamboos.

The fourth and final component is the entrepreneurship unit of SENA the National Learning Service, an agency of the Colombian government that provides support to business initiative or innovative ideas through resources from the Financial Fund for Development Projects -FONADE.

After deciding to open my life´s project to the public, I turned to the Quindío branch of SENA and prepare a business plan with the professional support of the entrepreneurship promotors, and compete at the national level for funding from FONADE:

In August 2013 the Board of Directors at SENA gave a favorable vote to fund business plan No. 50062: The Paradise of Bamboo and Guadua, and approved financing for an amount of 73 million Colombian Pesos. The business plan had to be completed within one year. By meeting the performance indicators and with the outcome of the year, the Board of Directors at SENA decided to write off the debt of the funding allocated.
And from these 4 components the company Bambú Turismo Verde Esmeralda SAS was born, having as its business name " El Paraíso del Bambú y la Guadua" (The Paradise of Bamboo and Guadua).

WHAT DOES THE PARADISE HAVE AND WHAT IT OFFERS

The Paradise of Bamboo and Guadua offers educational tours through ecological pathways and around the Coffee Growing Cultural Landscape. It offers training workshops every 2 or 3 months. It sells specialized bamboo handcrafts, Guadua and bamboo plantlets, and of organic coffee. It is model of harmony between agriculture and the environment.

1. **BAMBOO COLLECTION**

Thirty years ago, in 1988, the largest bamboo collection of Colombia is born, thanks to Lynn Clark´s gift of the *Gigantochloa atter* specie. Afterwards Kim Higbie & Paul Smith sent me a gift, *Gigantochloa atroviolacea* y *Schizostachyum brachycladum*, bamboos that are mainly ornamental from Indonesia. In this way friends like Gerald Bold, Gert van Delf, Eduardo Ruiz-Sanchez, Rogelio Macias, Francisca Ely, among others through gifts or by exchanging species have allowed us to have at present 75 species of native and exotic bamboos. I must highlight that we also have the largest collection of the *Guadua* genus species, with a total of 9 species and 3 varieties.

Bamboos are plants with prolonged flowering cycles and an important function of the *ex situ* collections which is to be observing and recording the exact time of flowering. With the *ex situ* collection at The Paradise of Bamboo and Guadua we have contributed towards the identification and knowledge about native species such as the *Otate colombiana* Ruiz-Sanchez & Londoño that flowered after 23 years of having collected it in its natural habitat.

This collection of bamboos allows the visitor to have a wider spectrum of the diversity of these plants and its multiple benefits. We also provide scientific information unknown to most people, that enriches the visitor.

2. WETLAND AND WATER SPRING

The estate was received on a wetland, which began to be transformed in 2002. The methodology used for its recuperation was to make a trough or central axis to drain the wetland in the least wet part and guide the water from the water springs located there to the Tres Palitos creek.

As the land was drained, we planted the bamboos using an organic culture system for the crops neighboring the wetland.

After 16 years of intervention of the wetland, the visitor will be able to see the consolidation of a small creeck with a flow volume of 2 liters per second during the rainy season called Quebrada Ticor in honor of my father. The visitor may also watch the close relationship of bamboos with water, how to create a creek using the bamboos as elements to bioremediate, and how with their fast growth they prevent the evaporation of water from the water springs, and how its efficiency in water consumption contributes to maintain the flow volume, its rhizome network helps to purify the spring water, and how the water we produce here contribute to enrich the water system of the country and to generate a local , regional, national and international impact because these waters, at the end, flow out to the Atlantic Ocean. Because of all of these benefits and positive outcomes, the bamboos may receive the name of "Water Sowers"

3. WILDLIFE CONNECTIVE CORRIDORS

The cultural landscape of the coffee area is fragmented due to the agricultural activities of its inhabitants.

At the El Bambusal farm, the specie *Guadua angustifolia,* abundant in the banks of the Tres Palitos creek does not tolerate the extreme moisture conditions in the soil and interrupts its growth when it gets to the wetland area of El Bambusal.

An ecological restauration process has been taking place in these wetlands for the past 16 years, selecting and establishing species such as bory (*Alocasia macrorhiza*), pizamo (*Erythrina poeppigiana*), wild banana (*Musa velutina*) and *Guadua uncinata* which tolerate that kind of ecosystem, reestablishing connectivity between the Guadua stands that were separated at Tres Palitos creek.

Attaining this connectivity implies conserving biodiversity and allowing for the circulation of native fauna and flora. The wetlands at the El Bambusal farm became fauna and flora sanctuaries, where the species from the river La Vieja such as the snapping turtle *Chelydra acutirostris*, Hoffman´s two towed sloth (*Choloepus hoffmanni*), the kinkajou (*Potos flavus*), the Agouti (*Dasyprocta punctata*), the armadillo (*Dasypus novemcinctus*), and diverse herpetofauna are preserved. It is also a habitat of multiple birds such as the

spectacled owl (Pulsatrix *perspicillata*), the buffed- necked Ibis(*Theristicus caudatus*), and the cattle egret (*Bubulcus ibis*).

In the table below you can note the biological diversity that exists in this small 16.7 hectare site.

BIOLOGICAL GROUP	**Number of species**
PLANTS	128
BIRDS	124.
HERPETOS	18

The wetland has been operational for work done together with institutions such as the CIPAV Foundation for the conservation of endangered plants such as *Sanchezia macrocnemis,* and to test the adaptability of bamboo species from other regions of Colombia and other countries in the process of ecological restoration and connectivity in the Cultural Landscape of the Coffee Growing Area.

The wetlands and the connectivity corridors at The Paradise of Bamboo and Guadua are a unique encounter with nature where the visitors may evidence the close relationship that bamboos have with that vital element called water and to perceive, through their various senses the other environmental benefits offered by these plants: lowering temperature, conserving biodiversity, erosion control, and sequestration of CO_2 among others. Visitors are also witnesses of the integral role played by these plants in the economic, social and cultural, and environmental fields.

4. NATURE AND THE TUNNEL OF LOVE

After visiting the bamboo forest of Arashiyama in Japan- an art of nature- in 2008 with members from Japan´s Bamboo Society, I became interested in doing something aesthetically similar in the tropics, a harmonious and shadowed path that could connect the house at El Bambusal with the wetlands.

Afterwards I was fortunate to be a guest speaker at the VIII World Bamboo Congress in Bangkok, Thailand, where each speaker was given seeds of the *Thrysostachys siamensis* specie. When these seeds arrived to Colombia, they were planted in the nursery obtaining 8 plantlets of a sexual origin.

In 2010 the first 8 plants of this bamboo were planted amidst the coffee plantation of the El Bambusal farm. The plants underwent vegetative propagation until achieving a marvelous 350 linear meter tunneled path, devoted to love and to nature.

5. OUR FRIEND *Guadua angustifolia* Kunth

During the partition process of the La Esmeralda farm only 0.6 hectares of natural Guadua stands , representing 3.6% of the total area, were allocated to El Bambusal. This small fragments of Guadua stands are a benchmark of the importance these ecosystems have in the conservation of biodiversity and in the production of the water volume flow. In them you can observe the long neck pachymorph rhizomes that differentiates them from most of the tropical woody bamboos, the various stages of development of the culm, and the amazing speed of growth of this specie, achieving averages of 21 cm per day and 25 mts height in six months. These Guadua stands have allowed undergraduate, master degree and doctorate candidates to do research on diversity and genetics, being able to make an inventory of over 150 plant species, 115 bird species, and to demonstrate the existence of a high genetic diversity in the region and a population structure associated to the geographic location.

In addition, the Guadua stands at the El Bambusal farm are part of the associative initiative of the Nucleo Forestal de Guadua La Esmeralda, which seeks to attain common benefits in the management, social, commercial and environmental areas and to work together towards productive Guadua plantations with good cultural practices.

Because of the small area planted in Guadua at El Bambusal, a plan was started to substitute commercial crops such as coffee, plantain and banana for *Guadua angustifolia* and other bamboo species. After 17 years we were able to achieve a reforested area of 2.6 ha, equivalent to 15.5% of the total farm area vs the initial area of 3.6%.

6. THE EL CEDRO LOOKOUT POINT

In 2003, a bolt of lighting, from an electrical storm killed an approximately 180-year-old *Cedrela odorata L*. tree. This tree, which was a parental tree stopped performing its functions and began to die. In 2004, the lifeless tree is exploited thanks to the advise of friends from the lumber world: Marcelo Villegas, Gabriel Germán Londoño and Carlos Jaramillo, producing a volume of lumber of 12,000 inches. The logged wood was protected and stowed, and 10 years later, when The Paradise of Bamboo and Guadua opened, this cedar tree provided the raw material to manufacture furniture and other household fittings. It has not only covered the needs of the new project, but also generated much satisfaction as well as income.

After 13 years of being logged, we decided to protect its base right in the place where it met its honorable death. To do so we uncovered its root, excavating around it, and we designed and built a structure with Guadua to protect it from moisture and sunshine. This place allows to appreciate the magnificence of the tree, enjoy the butterflies and hummingbirds that feed from the nectar of the honey plants sown around it, as well as to

visualize the canopy of the bamboos planted during the restoration process of the Tres Palitos creek.

As friend Gabriel Nass says: this is the story *of a tree that walked in the night to remain in the living side of the border, to then fight with a lightning bolt and to grow old forever giving so much and giving it all.*

7. RURAL INFRASTRUCTURE

Guadua was decisive in the settlement of this land: it was everything in rural life. The ease to harvest, transport, polish and handle it facilitated its use in rural infrastructure.

The house that was allocated to El Bambusal is called the "Alimentadero" (feeding site) because it was the place where the workers lived and had their meals. This house, with 8 rooms, a kitchen and bathroom facilities are approximately 100 years old. It is a typical construction of the Antioqueña architecture, where the structure is done with round Guadua, the walls with bamboo mats esterilla, coated with plaster, the columns made of stout Guadua and the roof with visible Guadua beams without a ceiling.

The concept of poverty linked to Guadua was deeply rooted in the new inhabitants, and that is why Guadua was never seen in the principal house of the owners, only fine woods were showcased in the pillars of the corridors and in the support structure. At that time Guadua became a social status indicator and was only see in low income housing or in the houses built for the workers. It was also used to build the processing plant for coffee beans, the chicken coop, for the hogs and the cattle. It was also used to bring water from the water intake to the kitchen and as a fence for the pastures and for the farm.

The dining room at El Bambusal, a 40 m2 guadua structure was built after the earthquake of 1999, when the wooden structure erected at the site collapsed. This new building, designed and built with Guadua by our friend, engineer Jairo Velásquez Echeverri in 2001 houses a wooden dining table that is unique and majestic.

In November 2014 when The Paradise of Bamboo and Guadua opened to the public there was no icon or portal that provided an identity to the site. In a trip to Guayaquil, Ecuador, to participate in the I International Bamboo Congress, I spoke with the architect and friend Simón Vélez, who offered to design for me a Guadua structure as an entry point into the theme park. The "caseta" or gatehouse as it is known today was designed and built by that great architect of Guadua in 2015. This gatehouse teaches two important things: 1) that Guadua with a good design and labor quality competes at the highest level and cannot be stigmatized as the lumber of the poor; and 2) that bamboos are plants that grow so quickly that in a period of 13 years you are able to get, from plantlets, mature culms with the optimal age and diameter for construction purposes. Here we were able to fulfill our dream of "planting my own house", since the Guadua used in the gatepost was taken from

plantlets established in 2002 where one hectare of coffee was substituted by *Guadua angustifolia.*

The eco-builders of the world have in Guadua a natural material, that can be used without needing any type of industrial process. And, as architect Simón Vélez says, "a structural material like Guadua, and our very own construction techniques in the periphery of the tropical third world, open the doors to enrichening proposals doing away with any inferiority complex.

8. SPECIALIZED NURSERY

Our main motivation for the tours offered at The Paradise of Bamboo and Guadua is to educate and change the "chip" of our visitors, motivating them to make the decision of planting bamboos to recover the watersheds of their territory.

For this reason, we decided to set up a specialized bamboo nursery where we offer native and exotic species. We also care for and reproduce the best clones of *Guadua angustifolia* selected in the Coffee Growing Area as part of the research work funded by the Ministry of Agriculture and led by the National University of Colombia- Palmira campus. For a period of 3 years the genetic wealth of the region was studied under an agrobusiness perspective, and 5 clones were selected for the construction industry, 2 for the industry of laminates, and 2 for the furniture and handcrafts sector.

Visitors who require it are advised on the bamboo specie to plant according to the soil and climatic conditions of their site, as well as the silvicultural management needed in the new plantation.

9. TRAINING WORKSHOP

Workshops are a specialized informal training lasting from 2 – 3 days, usually held over the weekend, where the participants learn specific topics related to Guadua and other bamboos through conferences and on-hand learning. The workshops are done every 2 months and include topics such as handcrafts, construction, the botanics of bamboo, and silviculture. Hiring national and international experts to dictate the workshops allow offering innovative training sessions that captivate the public in general.

The participants have the possibility of lodging at El Bamusal that has a hostal which is able to house up to 16 people.

10. SOCIAL ASPECTS

We offer decent employment to farmers of the sector and their oldest children. They receive training for the various jobs of the company aiming to stop rural migration to the cities and to encourage rural sustainability. Employment generation has a favorable impact on the goals to reduce rates of unemployment in the State of Quindío, which at present occupies the second place in unemployment of the country.

Artisans who produce furniture and handcrafts from Guadua/bamboo also benefit from being commercial partners of the company.

In February 2018 we signed a contract with artisan Víctor Martínez to promote the conservation of the Guadua culture and to allow visitors to see and get to know the traditional processes used to produce handcrafts and manufacture furniture with Guadua, improving the touristic offering at The Paradise of Bamboo and Guadua and of the area in general.

For the past two years we have been working with a group of women from the Once Casas township located in Pueblo Tapao, Municipality of Montenegro, contributing to their organizational dynamics and helping them improve their earnings through training in production systems related to bamboo and Guadua.

El Bambusal farm is part of the Núcleo Forestal de Guadua La Esmeralda founded in March 2007 with the purpose of: a) protect the Guadua stands that are being cut down to the pressure exerted over them by more profitable crops and housing projects in the rural area; b) protect the watersheds of the Tres Palitos and La Esmeralda creeks affected by the deforestation of their banks; c) have the Guadua stand owners receive fair payment for their raw materials; d) guarantee the sustainability of Guadua stands through the sustainable management of the Guadua ecosystem; e) assist other institutions in creating forests nuclei, a pioneering experience, that could be replicated at other sites; and f) provide high quality raw materials.

Businesswise, our company seeks to establish a strong relationship with the neighboring communities, who benefit from an increase in jobs; learn about specialized agricultural tourism in bamboo/Guadua and directly benefit from it; learn about new association and cultural dynamics, and increase their economic possibilities.

At present we are lobbying for the passing of bill of law No. 043 of 2016 in the Chamber of Representatives. It has already been approved in two debates at the Senate. This law would allow the Guadua plantations to become an agroforestry and agrobusiness resource regulated by the Ministry of Agriculture, from its present status of a protected forestry resource regulated by the Ministry of the Environment and the Regional Environmental Authorities.

11. ECONOMIC ASPECTS

People who come to The Paradise of Bamboo and Guadua must make an appointment earlier and they must have selected the touristic package they want to do. Two packages are offered: 1) The conquest of the wetlands: with a cost of $40,000 pesos, that has a duration of 3 hours, for a minimum of two people, and includes and environmental interpreter and a snack; and 2) Our friend the Guadua, for a cost of $60,000 pesos , that has a duration of 5 hours, for a minimum of 4 people, and includes and environmental interpreter and lunch. The load capacity at our site is of maximum 60 people/day.

Partnerships are being done on a permanent basis with tourism companies so they promote the site.

Universities and schools have differential tariffs depending on the number of students who are to be trained.

Despite being a rural company, we have a marketing strategy based on IT through our web page(www.bambuturismo.com), facebook (/elparaisodelbambuylaguadua/), instagram (/paraisobambuyguadua/), and twitter (/bambuturismo/). We are also on the Trip adviser platform.

Since it was opened to the public in 2014, the number of people visiting The Paradise of Bamboo and Guadua have increased by 300%. This has been achieved through a word of mouth marketing strategy and through advertising.

Ultimately, it is in this social, cultural, environmental and economic context that our Company: The Paradise of Bamboo and Guadua becomes relevant. We conform to the Colombian tourism policies; we contribute to the education, knowledge and dissemination of the topic of Guadua/bamboo, a very specialized and strongly rooted subject in our country; we create a multiplying effect generating awareness on the harmonious relationship between nature, men and agriculture; we create a unique offer of an emblematic product of the coffee growing area; we contribute with the economic and sustainable development of the region and the country by generating employment; and we are a domestic and international showcase for the regional culture of Guadua.

Keynote Lecture

EL PARAISO DEL BAMBU Y LA GUADUA – UN DESTINO AGROTURISTICO Y EDIUCATIVO

Ximena Londoño / ximelondo@gmail.com

El Paraíso del Bambú y la Guadua es una empresa dedicada a transmitir una pasión de vida por la guadua y otros bambúes, mediante recorridos agroecológicos, talleres de capacitación y venta de plántulas y artesanías especializadas en bambú.

COMO NACE?

En el Eje Cafetero de Colombia, en donde está ubicado este destino, *Guadua angustifolia* Kunth es una protagonista notable de la evolución e historia de la cultura del centro-occidente del país, donde ha sido utilizada desde las comunidades prehispánicas para la construcción de viviendas, puentes, balsas, herramientas, instrumentos musicales, de caza y de pesca.

Cuando llegaron los españoles a esta región, encontraron a los pobladores nativos en medio de los guaduales, cuyas casas, fortalezas y palizadas estaban construidas con gruesas guaduas o *cañas gordas* como las llamaron los cronistas.

Esta región *guaduera*, que hoy la conforman los departamentos de Caldas, Quindío, Risaralda y norte del Valle del Cauca, se mantuvo "invisible" por muchos años, ausente de pobladores y con una selva densa. Pero fue a finales del siglo XIX y comienzos del siglo XX, que campesinos venidos de Antioquia la re-descubren a raíz de la riqueza arqueológica en oro dejada por los indígenas Quimbaya. Estos nuevos colonizadores no conocían la guadua. Pero fue gracias a la guadua, material abundante, barato, fuerte y liviano, que el hombre antioqueño pudo emprender la dura aventura de colonizar estas tierras y resolver los problemas de una topografía quebrada y empinada, y con una gran actividad sísmica.

Es a comienzos del siglo XX cuando aparece un protagonista esencial de El Paraíso del Bambú y la Guadua, Don José Ramón de la Pava, quien en enero de 1908 adquiere los predios de la Finca La Esmeralda. En 1949, a raíz de la muerte de Don José Ramón, la "La Esmeralda", pasa por sucesión a sus 7 hijos quienes mediante la escritura 538 de diciembre de 1949 y de común acuerdo la parten en 7 predios. En el año 2001, yo, Ximena Londoño de la Pava, nieta de Don José Ramón, recibo en herencia por parte de mi madre, un área de 16.7 hectáreas, lugar en donde se desarrolla este destino agro-turístico especializado en bambú. Se convierte entonces, la tenencia de la tierra, en el primer paso para poder desarrollar y materializar El Paraíso del Bambú y la Guadua.

El segundo componente es la educación brindada por mis padres, Héctor y Sophy, quienes desde muy temprana edad me enseñaron a amar el campo y a querer y respetar a sus moradores. Este contacto con el campo desde tan pequeña me marcó para el resto de mi

vida, me sensibilizó con el tema de la agricultura y me inspiró una gran pasión por la guadua, planta que admire siempre por su versatilidad, rapidez y belleza, y por la contribución a la protección y conservación del agua y la biodiversidad en nuestro territorio.

En el año de 1977 ingresé a estudiar agronomía en la Universidad Nacional de Colombia, Palmira, y escogí como tesis de grado el estudio comparativo de la vegetación asociada a los guaduales del Valle del Cauca y del Quindío. En 1984 viajé a Washington, D.C. en donde me dediqué a estudiar la botánica de los bambúes con énfasis en el género *Guadua* en el Smithsonian Institution bajo la tutoría del Dr. Thomas R. Soderstrom, y tuve la fortuna de conocer a mis amigos Lynn Clark y Emmet Judziewics, quienes han sido mis colegas, maestros y colaboradores en este incursionar científico sobre los bambúes del neotrópico. Con ellos y con otros colegas investigadores como Gerrit Davidse, Paul Peterson, Tarciso Filgueiras Eduardo Ruiz-Sánchez, Francisca Ely, Jaime Eduardo Muñoz, Juan Carlos Camargo, Ramona Oviedo y Chris Tyrrel entre otros, hemos logrado aportar significativamente al conocimiento de la biodiversidad y ecología de los bambúes de América Latina. Para todos ellos un millón de gracias!!.

El tercer componente surge de la toma de conciencia de mis deberes como hija, y es a partir de un gesto de amor, que la vida me conduce a tomar la decisión de compartir experiencias y saberes con los demás.

En el año 2012 me traslado definitivamente de Cali para La Esmeralda, con el único fin de acompañar a mi madre en sus últimos 4 años de vida. Estando allí me visitan dos periodistas de la revista AVIANCA con el propósito de elaborar un artículo periodístico en donde se promocionarían los lugares turísticos del Eje Cafetero. Obviamente, mi finca no era un destino turístico en ese momento pero si un lugar hermoso que venía construyendo desde el año 1984. Para sorpresa mía, cuando sale la revista Avianca en Noviembre de 2012, la foto de la caratula de la revista era tomada en los bambusales del pantano y es esa publicación la que me induce a abrir al público lo construido durante tantos años, con el objetivo de ser una alternativa agroturística cultural en esta zona cafetera, que contribuyera, de manera significativa, a la valoración ambiental, cultural y socioeconómica de los bambúes.

El cuarto y último componente es la unidad de emprendimiento del Servicio Nacional de Aprendizaje - SENA, institución del estado colombiano que apoya a través de recursos del Fondo Financiero de Proyectos de Desarrollo - FONADE iniciativas empresariales o ideas innovadoras.

Una vez tomada la decisión de abrir al público mi proyecto de vida, acudo al SENA Quindío y elaboro un Plan de Negocio con el apoyo profesional de los gestores de emprendimiento, y concurso a nivel nacional por recursos FONADE.

En agosto del 2013, el consejo Directivo del SENA da el voto favorable para la financiación del plan de negocio No. 50062 – El Paraíso del Bambú y la Guadua, y aprueba un valor de 73 millones de pesos colombianos para ejecutarse en un periodo de un año. Gracias al cumplimiento de los indicadores de gestión y a los resultados obtenidos durante el año, el Consejo Directivo del SENA decide la condonación de los recursos asignados.

Y es después de estos 4 componentes, que nace la empresa Bambú Turismo Verde Esmeralda SAS, con nombre comercial "El Paraíso del bambú y la Guadua".

QUE TIENE EL PARAISO Y QUE OFRECE

El Paraíso del Bambú y la Guadua ofrece recorridos educativos por senderos ecológicos y por el Paisaje Cultural Cafetero, ofrece talleres de capacitación cada 2 o 3 meses, venta de artesanía especializada en bambú, venta de plántulas de guadua y de bambúes, y venta de café orgánico. Es un modelo de armonía entre agricultura y medio ambiente.

1. COLECCIÓN DE BAMBÚES

En el año de 1988, es decir hace 30 años, nace la colección de bambúes más grande de Colombia gracias al obsequio por parte de Lynn Clark de la especie *Gigantochloa atter*. Posteriormente, Kim & Paul (Higgins please last name??) me envian de regalo con Lynn Clark, *Gigantochloa atroviolacea* y *Schizostachyum brachycladum*, bambúes especialmente ornamentales de Indonesia. Así, sucesivamente, amigos como Gerald Bold, Gert van Delf, Eduardo Ruiz-Sanches, Rogelio Macias, Francisca Ely, entre otros, me fueron regalando o intercambiando especies hasta contar hoy con una colección de 75 especies de bambúes nativos y exóticos. Es de resaltar que además se tiene la colección de especies del genero *Guadua* más grande de América, con un total de 9 especies y 3 variedades.

Los bambúes son plantas que tienen ciclos de floración prolongados y una función importante de las colecciones *ex situ* es poder estar observando y registrando el momento exacto de la floración. Con la colección ex situ de El Paraíso del Bambú y la guadua se ha contribuido a la identificación y conocimiento de especies nativas como *Otate colombiana* Ruiz-Sanchez & Londoño, que floreció después de 23 años de haberla recolectado en su hábitat natural.

Esta colección de bambúes le permite al visitante tener un espectro más amplio de la diversidad de estas plantas y de sus múltiples beneficios. Además, se brinda información de carácter científico que enriquece al visitante y que la mayoría de las personas desconocen.

2. PANTANO Y NACIMIENTO DE AGUA

Se recibe en herencia un humedal, el cual se empezó a transformar en el año 2002. La metodología empleada para su recuperación consistió en hacer una zanja o eje central para drenar el humedal en la parte menos húmeda y orientar hacia la Quebrada Tres Palitos el agua que aflora allí procedente de los nacimientos..

A medida que el terreno se fue drenando, se fueron sembrando bambúes y se fue implementando un sistema de manejo orgánico de los cultivos aledaños al pantano.

Después de 16 años de estar interviniendo el pantano, el visitante podrá ver la consolidación de un pequeño riachuelo que afora 2 litros por segundo en época de lluvias y que lleva el nombre de Quebrada Ticor en honor a mi padre. También puede apreciar la relación estrecha de los bambúes con el agua, cómo se puede construir una quebrada utilizando los bambúes como elementos bio-remediadores, cómo con su rápido crecimiento pueden evitar la evaporación del agua que brota de los nacimientos, como su eficiencia en el consumo hídrico contribuye a mantener el caudal, su red de rizomas ayuda a purificar el agua del manantial, y como las aguas que producimos allí contribuyen a enriquecer el sistema hídrico del país, y a generar un impacto local, regional, nacional e internacional, porque esas aguas desembocan finalmente en el Océano Atlántico. Es por todos esos beneficios y resultados positivos que a los bambúes los podemos llamar "SEMBRADORES DE AGUA".

3. CORREDORES DE CONECTIVIDAD

El paisaje cultural cafetero es un paisaje fragmentado por causa de la actividad agrícola de sus moradores.

En la finca El Bambusal, la especie *Guadua angustifolia*, abundante a orilla de la Quebrada Tres Palitos, no tolera condiciones de humedad extrema en el suelo e interrumpe su desarrollo cuando llega a la zona pantanosa de El Bambusal.

En estas áreas pantanosas se ha desarrollado en un periodo de 16 años, un proceso de restauración ecológica, seleccionando y estableciendo especies como bore (*Alocasia macrorhiza*), pizamo (*Erythrina poeppigiana*), banano silvestre (*Musa velutina*) y *Guadua uncinata* Londoño & Clark que toleran este tipo de ecosistema, restableciendo la conectividad entre los guaduales desunidos de la Quebrada Tres Palitos.

Lograr esta conectividad implica la conservación de la biodiversidad y la circulación de la fauna y flora nativa. Los pantanos de la Finca El Bambusal se convierten en santuarios de flora y fauna, en donde se preservan especies de la cuenca del Rio La Vieja, como la tortuga mordedora *Chelydra acutirostris*, el oso perezoso de dos dedos (*Choloepus hoffmanni*), el perro de monte (*Potos flavus*), el guatín (*Dasyprocta punctata*), el armadillo (*Dasypus novemcinctus*), diversa herpetofauna, además sirven de hábitat para múltiples

aves como el búho de anteojos (Pulsatrix *perspicillata*), el cocli (*Theristicus caudatus*), y la garza buellera (*Bubulcus ibis*).

En esta tabla se puede registrar la diversidad biológica que existe en este pequeño lugar de 16.7 ha.

GRUPO BIOLOGICO	**No. de especies**
PLANTAS	128
AVES	124.
HERPETOS	18

El pantano ha servido para trabajar con instituciones como la Fundación CIPAV en la conservación de plantas en vía de extinción como la *Sanchezia macrocnemis*, y probar la adaptabilidad de especies de bambúes procedentes de otras regiones de Colombia y de otros países en los procesos de restauración ecológica y de conectividad del Paisaje Cultural Cafetero.

Los pantanos y los corredores de conectividad en El Paraíso del Bambú y la Guadua son un encuentro único con la naturaleza, en donde el visitante puede evidenciar esa estrecha relación que tienen los bambúes con ese vital elemento llamado agua y a través de sus sentidos, percibir los demás beneficios ambientales que ofrecen estas plantas como son reducción de temperatura, conservación de biodiversidad, control de erosión, captura de CO_2 entre otros. Además, los visitantes son testigos del role integral que juegan estas plantas en lo económico, social cultural y ambiental.

4. EL TUNEL DEL AMOR Y LA NATURALEZA

A raíz de la visita en el 2008 con miembros de la Sociedad Japonesa del Bambú al bosque de bambú de Arashiyama en Japón - un arte de la naturaleza - nace el deseo de realizar en el trópico algo estéticamente parecido, un sendero sombreado y armonioso, que pudiera conectar la casa de El Bambusal con el pantano.

Posteriormente tuve la fortuna de ser invitada como conferencista al VIII Congreso Mundial del Bambú en Bangkok, Tailandia, en donde le entregaron a cada conferencista semillas de la especie *Thrysostachys siamensis*. Estas semillas, al llegar a Colombia se sembraron en vivero y se obtuvieron 8 plántulas de origen sexual.

En el 2010, en medio de los cafetales de la finca El Bambusal, se sembraron las primeras 8 plantas de este bambú, las cuales se fueron multiplicando vegetativamente hasta lograr un sendero-tunel maravilloso de 350 metros lineales, dedicado al amor y a la naturaleza.

5. NUESTRA AMIGA LA *Guadua angustifolia* Kunth

En el proceso de partición de la Finca La Esmeralda solamente 0.6 hectáreas de guaduales naturales que representaban el 3.6% del área total le correspondieron a El Bambusal. Esos pequeños fragmentos de guaduales son un referente de la importancia que ejercen estos ecosistemas en la conservación de la biodiversidad y de la protección del caudal hídrico. En ellos se puede apreciar el tipo de rizoma paquimorfo de cuello largo que hace la diferencia con la mayoría de las especies de bambúes leñosos tropicales, los diferentes estados de desarrollo del culmo, y la increíble velocidad de crecimiento de esa especie, logrando promedios de 21 cm día y 25 metros de altura en 6 meses. Estos guaduales han servido para que estudiantes de pregrado, maestría y doctorado realicen investigaciones sobre diversidad y genética, inventariando más de 150 especies vegetales, 115 especies de aves, y para demostrar que existe una alta diversidad genética en la región y una estructura poblacional asociada a ubicación geográfica.

Además, los guaduales de la Finca El Bambusal forman parte de la iniciativa asociativa Núcleo Forestal de Guadua La Esmeralda, que busca conseguir beneficios comunes en la parte administrativa, social, comercial y ambiental, y trabajar conjuntamente por tener guaduales con buenas prácticas de manejo y a la vez productivos.

A raíz de la poca área en guaduales existente en El Bambusal, se inicia un plan de sustitución de cultivos comerciales como café, plátano y banano, por siembra de *Guadua angustifolia* y de otras especies de bambúes, logrando después de 17 años, un área reforestada de 2.6 ha que equivale al 15.5 % del área total de la finca vs. 3.6% inicial.

5. EL MIRADOR DEL CEDRO

En el año 2003 un rayo, fruto de una tormenta eléctrica, mata un árbol de *Cedrela odorata* L. con edad aproximada de 180 años. Ese árbol que era un árbol parental deja de cumplir sus funciones y empieza a morirse. En el 2004, el árbol ya sin vida, es aprovechado gracias a la asesoría de amigos del mundo de la madera como Marcelo Villegas, Gabriel Germán Londoño y Carlos Jaramillo, y produce un volumen de madera de 12.000 pulgadas. Después de aserrado, la madera se protege y se guarda, y 10 años más tarde, cuando nace El Paraíso del Bambú y la Guadua, este cedro provee la materia prima para la fabricación de muebles y enseres. No solamente ha servido para suplir las necesidades del nuevo proyecto sino que me ha generado múltiples satisfacciones e ingresos.

Después de 13 años de haberse aserrado, se toma la decisión de proteger la base del mismo en el lugar donde dignamente murió. Para ello, se desentierra la raíz excavando a su alrededor, se diseña y construye una estructura en guadua para aislarla de la humedad y de los rayos del sol. Este lugar permite apreciar la magnificencia del árbol, disfrutar de mariposas y colibríes que nectan las plantas melíferas sembradas a su alrededor, y

visualizar el dosel de los bambúes sembrados durante el proceso de restauración de la Quebrada Tres Palitos.

Como dice el amigo Gabriel Nass, esta es la historia *de un árbol que caminó de noche para quedarse del lado vivo de la frontera, para luego pelear con un rayo y envejecer para siempre dando tanto y todo.*

6. INFRAESTRUCTURA RURAL

La guadua fue decisiva para la colonización de esta tierra, ya que fue todo en la vida rural. La facilidad de cortarla, trasportarla, pulirla y manejarla facilitó su uso en la infraestructura rural.

A El Bambusal le correspondió la casa llamada el "Alimentadero", porque en ella se alimentaban y vivían los trabajadores. Esta casa, con 8 cuartos, cocina y batería de baños, tiene una edad aproximada de 100 años. Es una construcción típica de la arquitectura antioqueña, en donde la estructura es hecha con guadua gruesa, las paredes con esterilla revocada, las columnas de guadua rolliza y el techo con guadua a la vista y sin cielorraso.

El concepto de pobreza ligado a la guadua estaba arraigado en los nuevos pobladores y es por ello que en la casa de los abuelos nunca se veía la guadua, pero si se exhibían maderas finas en las columnas de los corredores y en la estructura de soporte. La guadua paso entonces a ser un indicador de clase social, utilizándose únicamente en las construcciones populares o en las casas para los trabajadores. Además sirvió para edificar el beneficiadero de café, el corral para las gallinas, para los cerdos, para el ganado, sirvió para conducir el agua de la boca toma a la cocina y para cercar los potreros y la propiedad.

El comedor de El Bambusal, estructura en guadua de 40 $m^{2,}$ nace a raíz del terremoto de 1999, después de que colapsa la estructura en madera que había en ese sitio. Esta nueva construcción, diseñada y construida en guadua por el amigo ingeniero Jairo Velásquez Echeverri en el año 2001, alberga un comedor en madera único y majestuoso.

En el 2014 cuando se habré al público El Paraíso del Bambú y la Guadua no existía un icono ni una portería que le diera identidad al lugar. En un viaje a Guayaquil Ecuador para participar del I Congreso Internacional del Bambú en noviembre del 2014 compartí con el Arquitecto y amigo Simón Vélez quien se ofreció diseñarme una estructura en guadua para ingresar al parque temático. La caseta, como se conoce hoy día, fue diseñada y construida por el gran arquitecto de la guadua en el 2015. Esta caseta enseña dos cosas importantes: 1. Que la guadua con buen diseño y calidad de mano de obra compite al más alto nivel y no se puede estigmatizar como la madera de los pobres; y 2. Que los bambúes son plantas tan rápidas en su crecimiento, que en un periodo de 13 años se puede obtener, a partir de siembra de chusquines, culmos maduros en edad y diámetro óptimos para construcción. Aquí, se logró cumplir el sueño de "sembrar mi propia casa" ya que la

guadua utilizada en la construcción de la caseta vino de un cultivo establecido en el 2002, en donde se sustituyó una hectárea de café por *Guadua angustifolia.*

Los eco-constructores del mundo tiene en la guadua un material natural, capaz de ser utilizado sin requerir ningún tipo de proceso industrial. Y como dice el Arq. Vélez "un material estructural como la guadua, y unas técnicas constructivas muy nuestras, nos abre las puertas para que desde la periferia del tercer mundo tropical, apoyados en nuestra bio-etno diversidad, se den propuestas enriquecedoras sin complejos de inferioridad".

7. VIVERO ESPECIALIZADO

Nuestra principal motivación con los recorridos por El Paraíso del Bambú y la Guadua es educar y cambiarle el "chip" al visitante, motivándolo para que tome la decisión de sembrar bambúes y recuperar cuencas hídricas en su territorio.

Es por esto que decidimos establecer un vivero especializado en bambú en donde ofrecemos especies nativas y especies exóticas. Además, cuidamos y reproducimos los clones superiores de *Guadua angustifolia* seleccionados en el Eje Cafetero dentro del trabajo de investigación financiado por el Ministerio de Agricultura y liderado por la Universidad Nacional de Colombia sede Palmira. Durante un periodo de 3 años se logró darle una mirada agroindustrial a la riqueza genética que tenemos en esta región y se seleccionaron 5 clones para la industria de la construcción, 2 para la industria de laminados y 2 para el sector de muebles y artesanías.

A los visitantes que lo requiera se le asesora sobre que especie de bambú sembrar según las condiciones edafoclimaticas del lugar, y sobre el manejo silvicultural que le debe realizar a la nueva siembra.

8. TALLERES DE CAPACITACION

Los talleres son un tipo de formación informal especializada, en donde el participante durante dos o tres días - generalmente fines de semana - aprende temas puntuales alusivos a la guadua y a otros bambúes a través de clases magistrales y de ejercicios prácticos. Los talleres se ofrecen cada 2 meses en temas como artesanía, construcción, botánica de los bambúes y silvicultura. La contratación de expertos nacionales e internacionales para dictar los diversos temas permite que se oferten capacitaciones siempre innovadoras que cautivan al público en general.

A los participantes se les ofrece la posibilidad de alojarse en el Bambusal ya que se cuenta con un hostal con capacidad para 16 personas.

9. ASPECTOS SOCIALES

Ofrecemos una propuestas de empleabilidad digna para campesinos e hijos mayores de campesinos del sector, donde estos son capacitados para los diferentes cargos de la empresa con el fin de detener la migración del campo a la ciudad e incentivar la sostenibilidad rural. La generación de empleo repercute favorablemente en las metas de disminución de la tasa de desempleo del Departamento del Quindío el cual ocupa actualmente el segundo puesto en desempleo a nivel nacional.

Se beneficia a la población de artesanos dedicados a la producción de artesanías y muebles a base de guadua/bambú, quienes con sus singulares productos son aliados comerciales de la empresa.

En febrero del 2018 se firma un contrato con el artesano Víctor Alonso Martínez para impulsar la conservación de la cultura de la guadua y darle a conocer al visitante los procesos tradicionales utilizados en la artesanía y fabricación de muebles con guadua, mejorando de esta manera la oferta turística de El Paraíso del Bambú y la Guadua y de la zona.

Desde hace 2 años se viene trabajando con un grupo de mujeres del caserío de Once Casas, ubicado en Pueblo Tapao, Municipio de Montenegro, con el fin de contribuir al fortalecimiento de su dinámica organizativa y de su mejoramiento económico, a través de la capacitación en sistemas productivos alrededor del bambú y la guadua.

La Finca El Bambusal forma parte del Núcleo Forestal de Guadua La Esmeralda, el cual se crea en marzo de 2007 con el propósito de: a) proteger los guaduales que están en detrimento por la presión que ejercen sobre ellos cultivos más rentables y procesos de urbanismo del área rural; b) proteger las cuencas hídricas de las Quebradas Tres Palitos y La Esmeralda, afectadas por la deforestación de sus márgenes; c) pretender que los dueños de los guaduales reciban un pago más justo por la materia prima; d) garantizar la sostenibilidad de los guaduales mediante un manejo sostenible del ecosistema guadual; e) realizar mediante el acompañamiento de otras instituciones una experiencia pionera en la conformación de Núcleos Forestales, que pueda ser replicable en otros sitios; f) proveer materia prima de calidad.

Socialmente, a través de esta empresa, se propicia un vínculo estrecho con la comunidad del entorno ya que se ve directamente beneficiada con puestos de trabajo, además recibe una influencia directa de lo que significa el agroturismo cultural especializado en bambú/guadua, proporcionándoles saberes, posibilidades económicas, culturales y nuevas dinámicas de asociatividad.

Actualmente, estamos luchando por que el proyecto de Ley Número 043 de 2016 que ya paso dos debates en el Senado, sea aprobado en la Cámara de Representantes, y los

guaduales dejen de ser un recurso forestal protegido, bajo la sombrilla del Ministerio del Medio Ambiente y de las Corporaciones Autónomas Regionales, y se conviertan en un recurso agroforestal y agroindustrial que lo cobije el Ministerio de Agricultura.

9. ASPECTOS ECONOMICOS

Las personas que ingresan a El Paraiso del Bambú y la Guadua se reciben únicamente con cita previa y con la selección del paquete turístico que desean realizar. Se ofrecen 2 paquetes: a) *La conquista del Pantano*, por un valor de $40.000 pesos, duración 3 horas, mínimo 2 personas, incluye intérprete ambiental y refrigerio; 2) *Nuestra amiga la Guadua*, por un valor de $60.000 pesos, duración 5 horas, mínimo 4 personas e incluye interprete ambiental y almuerzo. La capacidad de carga del sitio es de máximo 60 personas días.

Permanentemente se realizan alianzas con empresas de turismo para que ellos den a conocer el sitio y rediman clientes ofreciéndoles una comisión por venta.

Con las universidades y colegios se pactan tarifas diferenciales según el número de estudiantes a capacitar.

A pesar de ser una empresa rural se cuenta con una estrategia de mercadeo basada en las tecnologías TIC. Tenemos página web (www.bambuturismo.com), facebook (/elparaisodelbambuylaguadua/), instagrand (/paraisobambuyguadua/), y twitter (/bambuturismo/). También estamos en plataformas de turismo como Trip adviser.

Desde que se abrió al público en el año 2014, el número de personas que ha ingresado a El Paraíso del Bambú y la Guadua se ha incrementado en un 300%, en donde la estrategia del *voz a voz* y los anuncios publicitarios han contribuido mucho a su difusión.

Finalmente, es en este contexto social, cultural, ambiental y económico, que esta empresa denominada EL PARAISO DEL BAMBU Y LA GUADUA adquiere relevancia porque cumple con los principios de la política turística Colombiana, aporta a la formación, al conocimiento y a la difusión de un tema tan especializado y arraigado como es el de la guadua/bambú en nuestro país, crea un efecto multiplicador en la toma de conciencia sobre la relación armoniosa entre la naturaleza, el hombre y la agricultura, crea una oferta única de un producto emblemático de la zona cafetera, contribuye con el desarrollo económico y sostenible de la región y el país, genera empleo, y se convierte en una vitrina nacional e internacional de la cultura regional de la guadua.

Keynote Lecture

THE GLOBAL BAMBOO COLLECTIVE

Mr Jed Long
Cave Urban, Sydney, Australia
School of Technology, Environments and Design, University of Tasmania, Australia
Email: jed@caveurban.com;

Abstract
Bamboo's recent emergence as a renewable resource of great potential is the continuation of a long and diverse tradition of vernacular construction globally. Ongoing developments in construction technology have expanded the capacity of bamboo beyond the traditional value chain that encompasses cultivation to construction. Additionally, bamboo has also been recognized as a means to create new livelihoods and restore degraded landscape.

Different approaches to working with bamboo as a construction material are explored through a series of case studies that range from impermanent interventions to permanent construction. By examining the multitude of ways bamboo is employed in the buildings, attention is drawn to the social, cultural and environmental factors that determine how bamboo may be utilized to appropriately respond to particular contexts. This is achieved through a holistic understanding of the implications of utilizing low tech or high tech, short or long-term solutions in design. The diversity of techniques can be understood as a complementary set of approaches that form part of a larger narrative that is the global bamboo collective.

Introduction
Bamboo has been utilised as a building material for thousands of years. Despite this long vernacular tradition, bamboo has only recently gained widespread attention as a potential contemporary construction material. The environmental benefits and unique structural properties of bamboo suggest that it is a renewable resource with great potential. However there has been little discussion of how bamboo fits into a wider architectural discourse.

There is no single answer to the current challenges facing the global community. Overreliance upon non-renewable resources and increasing urbanization highlight the advantages and opportunities of exploring how bamboo can be utilized as a contemporary building material with strong environmental and social credentials. Both the benefits and challenges of working with bamboo can be understood in a number of different ways, depending on the context of the project.

This paper explores the multitude of ways different organisations are working with bamboo in response to the particular challenges of their own cultural context. The relevance of different design and construction systems, directly relates to the particular demands of site, culture and context. The case studies presented describe different ways of utilising bamboo in buildings, demonstrating a diversity of approaches that form part of a broader narrative of bamboo's relevance to the contemporary built environment.

The Global Bamboo Collective

The ready availability and affordability of steel, glass, concrete and brick is leading to the disappearance of traditional building practices and the depletion of finite resources and the environment. This process is particularly prevalent in developing countries where rapid urbanisation is shifting agrarian based economies into industrialised and globalised economies within a single generation (The World Bank; Fenson, 2016). Urbanization, coupled with a growing global population, is driving an increasing consumption of non-renewable resources with a multitude of environmental consequences. With the onset of the Anthropocene, the building industry stands out as one of the major contributors to human induced climate change.

Globalisation and urbanisation is not only causing degradation to the environment but is also responsible for an erosion of culture and context (Relph 2008). The result is homogenised and placeless cityscapes that stand in direct contrast to vernacular practice. As such, some architects see the notion of the contemporary vernacular as a means to design buildings suitable to place and responding directly to the cultural context in which they are working.

Bamboo has been identified as a material with great potential for application within the built environment. The social and ecological narrative of bamboo from cultivation to construction highlights a value chain with multiple benefits at all stages, some of which include;

-Fast growth rate
-Annual harvest
-High capacity for CO_2 mitigation when managed
-Restores degraded soil
-Shallow binding root system to stop erosion
-Multiple uses of the culm as a building material and also for food, paper, textiles, fuel, furniture etc
-Prevalent across the developing countries throughout the worlds equatorial region
-Sympodial bamboo is non-invasive
-Unique structural properties
-Long history of craft
-Lightweight

However, there are also challenges involved in using bamboo in buildings, including;

-Round section
-Non-uniform shape
-Labour intensive
-Requires unique skill set to craft (Artisan knowledge)
-Treatment critical to longevity
-Non-homogenous structural properties
-Variation in species dependent upon site and climate
-Harvest requires specialised knowledge to select correct culms
-Monopodial bamboo is invasive
-Very little research available relative to other building products

-Challenging to standardise
-Public perception

Both the benefits and challenges are dependent upon context. The ability to address and overcome each potential challenge is relative to the way in which bamboo is being used. The context of working with bamboo in Australia is vastly different to Mexico, just as the context of building a resort in Vietnam is different to constructing post-disaster shelter in Indonesia. Thus, there are a variety of best practice solution for working with bamboo that are specific to the cultural, social and environmental factors of the site.

The following case studies, identify different ways of utilising bamboo that are neither better nor worse, but are simply different form other ways in which the material may be utilised. Each organisation is engaging with bamboo and exploring its material properties relative to their own context. Through an environment of collaboration rather than competition, these stories can be seen as complimentary to each other.

Architecture of Impermanence

Traditional methods of bamboo construction made use of various systems of preservation to ensure longevity. Despite this, bamboo has obtained a reputation as a low value material with a short lifespan. The rapid rate of growth of bamboo has traditionally compensated for this concern by providing an abundant of supply of material to replace decaying elements.

The pursuit of material permanence is crucial to challenge preconceptions of bamboo as a temporal material. However, by removing the constraints of permanence, bamboo can be utilised as a tool for education, experimentation and expression. Cave Urban and Wang Wen Chih take advantage of the properties of green bamboo to construct spatial experiences that are temporal and align with a cycle of growth, life and decay. It is a process that reframes the constraints of working with bamboo and encourages community participation as a means of education and empowerment. As such the process of construction is of equal importance as the built outcome.

Cave Urban - Australia

Cave Urban was founded in 2010 to investigate vernacular architecture and its relevance to contemporary design. Vernacular architecture derives from the specific context of a site and the patterns of use over time. The construction methodology is often directly responding to climate, material availability and cultural context. It often is representative of an architecture of use, rather than aesthetics. Bamboo has been employed as a construction material by many different vernacular societies. The forms and methods of working with bamboo hold lessons that can be applied to contemporary practice. Because of this Cave Urban was encouraged to explore how it could be developed as a lightweight, temporary construction material.

Australia is a country with no tradition of bamboo craft. High labour costs and regulation, cultural preconceptions and only a small handful of people with knowledge about bamboo creates a challenging environment for working with the material.

When Cave Urban first began learning about bamboo, it was a challenge to gain access to information. This necessitated a number of research trips internationally, visiting buildings and participating in workshops, gaining knowledge through direct hands on experience. This information was documented through a research folio which is shared as open source information in the hope it may aid or inspire those who are also interested in bamboo as a building material.

Through collaborations with bamboo masters, this knowledge continues to grow and be shared to participants in Cave Urban projects, workshops or university courses. Key to this process is the notion of collaboration and the idea that the whole is greater than the sum of its parts (Figure 1). By openly sharing information, it allows others to build upon existing knowledge rather than having to reinvent the wheel every time. Since the bamboo industry is still in its infancy, this is critical to spreading enthusiasm about its potential as a building product.

Figure 1

Cave Urban's work with bamboo is a response to the context of working in Australia, which is covered by Juan Pablo Pinto (2018) in greater depth. For Cave Urban art projects have been utilised as a medium to navigate regulatory restrictions and has been utilised as a means of research and development. High labour costs in Australia have necessitated the involvement of groups of volunteers and students working with Cave Urban in a master/apprentice model that builds capacity and understanding of bamboo construction. The exchange of knowledge for labour serves to expose a larger body of people to the potential of utilising bamboo as a material and emphasises the built form as only part of the final outcome. The design of works responds in part to the process of construction, which takes into account the largely unskilled labour that will help to assist construction. As such there is often a limited number of construction techniques utilised, which can be taught and repeated en masse to great effect (Figure 2). By reducing a complex task down to a set of simple repeatable tasks, large scale works can be created in short time frames through the compilation of small singular elements into a larger more complex whole.

Figure 2

The informal process of research and development was influenced by collaboration with artists such as Wang Wen Chih and has developed Cave Urbans understanding of the potential of bamboo as a building material (Figure 3). Further partnerships with Humanitarian Benchmark Consulting and the Environmental Bamboo Foundation has led to new pathways being explored onsite at Woodfordia, Australia. The Woodford Folk Federation has facilitated the planting of a bamboo forest (Figure 4), new research into bamboo treatment (Figure 5) and the development of training models and typologies for post disaster reconstruction.

Figure 3


Figure 4 + 5

This research has been continued through a Byera Hadley research scholarship and a Churchill Fellowship, enabling Cave Urban to engage with the bamboo community globally. The focus of the research was to engage directly with universities, NGO's, designers and the skilled artisans for whom knowledge is intrinsic rather than formalised, in order to gain a holistic overview of bamboos role in the built environment.

Cave Urban partnered with the University of Tasmania in 2017 to establish the 'Agritecture' program. It is a means of exploring the intersection of architecture and agriculture, encompassing the entire value chain of bamboo cultivation and construction (Norrie et al. 2018). Initially focussing upon communities, organisations and university's in Vietnam, the program is widening its scope to include projects in Cambodia and Indonesia.

Wang Wen Chih - Taiwan

Taiwanese artist Wang Wen Chih is best known for his largescale woven bamboo artworks. Having represented Taiwan at the 2001 Venice Biennale, Master Wang has exhibited globally and has collaborated with Cave Urban on eight occasions (Figure 6). His dynamic woven structures provide profound spatial experiences that utilise the materiality of bamboo. Through the creation of haptic spaces that sensually utilise sound, sight, touch smell and the memory of light to establish a dialogue between the body and nature.

Figure 6

Master Wang's works utilise community engagement and draws upon the traditional weaving techniques of his hometown Chiayi. Designed as temporary forms, Master Wang's structures explore our own temporal existence, resonating with the Japanese concept of *Mono no aware* or the "the awareness of the transient beauty of nature" (Brownell 2011). They are forms designed to be inhabited and remembered, rather than endure. It is an idea that integrates with the growth cycle of bamboo, which regrows another pole in the time it takes his work to decay.

The split and woven bamboo is not treated or is protected from the sun. Rather the work celebrates ephemerality and provides an appropriate solution for creating art for festivals and exhibitions that tend to adhere to short time frames, whilst utilising a sustainable resource that has little environmental impact. Working with recently harvested *Phyllostachys* bamboo, Master Wang utilises the high flexibility of split green bamboo to weave a bamboo membrane that utilises a randomised weaving pattern that is very strong. As the bamboo is not covered with a membrane and left exposed, it allows light to pass through creating spaces that celebrate the interplay of light and shadow (Figure 7).

Figure 7

The Setouchi Triennale has commissioned Master Wang to create an installation for the past three exhibitions. Each exhibition, he returns to the same site situated in the rice fields of Shodoshima. The structural framework of the first work has remained in place over the last nine years providing a foundation from which each subsequent work has been created. Like Ise Jingu, Japan's most famous shrine that is rebuilt every twenty years on adjacent parcels of land (Figure 8), Master Wang's installation follow a cycle of growth, life, decay and rebirth (Figure 9). The three-year life cycle of each work aligns with the three years growth cycle of the bamboo that he harvests locally to create the work. Whilst the more permanent foundations created from steel and concrete remain in place to be utilised time and time again, which is fitting given their large ecological footprint.


Figure 8 + 9
Informal Bamboo Architecture

With roughly one billion people globally living in housing that utilises bamboo construction, the vast majority of bamboo construction is informal (Figure 10). Increasing urbanisation and the aspiration for a secure, durable home is resulting in temporary vernacular housing being replaced by non-renewable building materials and typologies that are often unsuitable for local climatic conditions.

Figure 10

The conflict between humanitarian imperative and long-term ecological and social consequences is a recurring issue that is becoming increasingly prevalent. Over consumption of resources and increasing emissions has led to a rise in extreme weather conditions that disproportionally effect the most vulnerable communities in less developed countries (Eckstein et al. 2018).

Whilst both the Humanitarian Bamboo Project and RAW Impact are focussing on vulnerable communities a distinction must be made as to the difference between the terms ‘humanitarian aid’ and ‘development aid’. Whilst development will look towards the long-term improvement of a community, humanitarian aid responds to the immediate needs of a community.

Whilst seminal, largescale projects lift global awareness of bamboo, the construction techniques utilised are not suitable for application in low tech/unskilled architecture and as such do not address the issue of how to we make informal bamboo architecture more durable. Disaster reconstruction is not a testing ground (Prideaux 2016) and the fragility of the local economy will magnify any failure of novel building solutions or implementation if the local community is not familiar with building techniques. Thus, utilising bamboo within this context requires a nuanced response to existing methods of construction and resource availability.

Humanitarian Bamboo Project – Indonesia

The Humanitarian Bamboo Project was set up by the Indonesian based organisation Humanitarian Benchmark Consulting (HBC) in response to the 2006 Jogjakarta earthquake. During the reconstruction of Jogjakarta over a period of nine months, 70,000 transitional shelters, each 24m^2, were constructed from bamboo at an average cost of US$100-200 (Hodgkin et al. 2009) (Figure 11). The construction of these shelters represented one of the largest and most rapid post-disaster responses in recent history. However, throughout the process it became evident that although bamboo had great potential as a strong, cost effective, readily available and rapidly constructed material, there was a lack of experience and clear guidelines for best practice within the humanitarian community (Hodgkin et al. 2009).

Figure 11

In response, extensive consultation with experts in humanitarian shelter and bamboo construction has led to the formation of the Humanitarian Bamboo guidelines. The guidelines aim to be an open source resource that assist humanitarian workers to make better informed decisions as to when and how to utilise bamboo as part of a post disaster shelter response.

David Hodgkin, one of the founders of HBC talks of how 'shelter is a process not a product' (2016). Contrary to the continuing desire of architects to design innovative one size fits all response to humanitarian shelter, Hodgkin's identifies systemic solutions as more important than design in influencing change. Given that majority of post disaster reconstruction is often undertaken by local inhabitants rather than Non-Governmental Organisations (NGO), agency for self-determination becomes a critical tool in the reconstruction process. This can be achieved through the dissemination of best practice guidelines to the local population that acknowledges the existing informal architecture and how it can be improved rather than replaced (Sharma 2017).

Provided that there is a locally available source, bamboo thus becomes a versatile material for constructing interim shelter that meets the immediate humanitarian imperative (Figure 12). By focussing on appropriate low cost/technological solutions that build upon local

knowledge and skills, communities are able to utilise innovation and effort to counter low fiscal capacity. Given that transitory shelter serves as a placeholder for future construction, considerations such as treatment do not hold as high an importance, as it does in more permanent buildings.

Figure 12

RAW Impact - Cambodia

Raising Awareness Worldwide (RAW) Impact is an NGO based in Phnom Penh, Cambodia. Founded by Australians Troy and Nicole Roberts, RAW Impact works directly with highly vulnerable Cambodian communities focussing on capacity building. The organisation's core principles to sustain, educate and protect, address diverse issues, establishing pathways for families to avoid debt slavery and child sex trafficking by providing education and a sustainable lively hood, as well as providing better housing and more secure land tenure.

Cambodia is an agrarian nation, with a largely rural population, whose people rely upon natural resources for food and income (MoE 2009). Over the last thirty-five years, Cambodia's population has tripled from five million to fifteen million people as it recovers from the atrocities committed by the Khmer Rouge. The exploitation of diminishing resources is being amplified by the growing population, 36% of which is living below the poverty line (MoE 2009).

RAW Impact has identified bamboo as a resource capable of addressing some of the issues confronting Cambodia, providing multiple beneficial outcomes that includes housing, environmental remediation and employment. Working in collaboration with the University of New South Wales, Casey Brown Architects and Cave Urban, the Every Piece Matters program was established to design and construct housing prototypes (Figure 13). The process of building seven housing modules provided a means of educating local workers in bamboo construction, whilst also serving as a means of learning through making for all

participants in the project. A continual process of critical reflection has allowed for the gradual evolution of designs towards an outcome that is suitable for bamboo construction and local ways of living.

Figure 13

Key to this process was the recognition that it was an iterative process that allowed for feedback from those involved and external consultants to guide the evolution of the designs. Troy Roberts (Rebel on a Rainbow 2014) describes innovation as a core value, stating "We're not afraid to fail and learn from it, and we're willing to try out-of-the-box solutions to some huge issues". As a result, over a period of two years there has been distinct improvements in construction knowledge along with social integration with the local community (Figure 14).

Figure 14

The most recent designs reflect a number of improvements that include:
-simplification of the buildings programs that recognises the majority of time is spent on the ground plane beneath the shade of the house and a single room is required for sleeping.
-utilising rope and dowel connections in place of threaded rod.
-concrete footings to raise the bamboo posts above flood water.
-larger eaves to protect the walls from rain and sun

The social context of the project- highlights the longevity of the housing modules, and investment is made in exploring this process. All bamboo is treated onsite to prevent degradation and building design is refined to minimise the effects of weathering.

The construction process has been refined to allow for capacity building of the community. Training young Khmai workers who may not have any building experience requires a system of construction that is repeatable and ensures a level of quality control (Figure 15). A series of jigs have been fabricated which allows for all work to take place on ground and repeated to achieve a higher level of efficiency. Previously work had taken place in-situ and had posed a number of challenges that prefabrication on ground solves. Low-tech innovation such as this is highly suitable to the circumstance and presents a simplified methodology that is an appropriate response and an opportunity for changing perceptions about bamboo as a building material.


Figure 15

The individual buildings are carefully arranged to form a village, allowing an increased permanence for the community. However, the contextual fluidity of the project suggests that housing may only need to last ten to fifteen years before the context in which families are living will have changed and a different housing solution is required. Working with

bamboo allows the material resources to fit the contextual requirements of architectural fluidity.

RAW Impact is working on improving housing for the lowest socio-economic bracket and developing typologies that suit the particular cultural context in which they are working. By creating simple low-tech solutions to bamboo architecture, RAW Impact is going a long way towards demonstrating how bamboo can remain relevant for those seeking a more secure life.

Contemporary Bamboo Architecture

1+1>2 - Vietnam
Vietnam has a long tradition of utilising bamboo as a building material. Vernacular hybrid systems of construction utilised bamboo in combination with hardwood timber and thatch. In the colder northern regions of the country, split bamboo is utilised as a substrate over which mud is applied in a manner similar to wattle and daub or *bahareque* (Norrie et al 2018). Increasingly concrete and masonry has replaced these traditional methods of construction, with bamboo being relegated to the status of 'poor man's material'.

Hoang Thuc Hao, of Vietnamese architectural practice 1+1>2, continues the tradition of utilising bamboo as part of a hybrid system of construction. Working with a broad material pallet, Hao designs community buildings that simultaneously evoke feelings of tradition, whilst sequencing space and program using modernist principles of design. Each of 1+1>2 buildings respond directly to the context in which they are created. Traditional methods of joining bamboo with dowel and rope are utilised and there is a low-tech simplicity to how the buildings are constructed. Yet complexity is established through the highly though out series of spaces and the way in which multiple materials are utilised to optimise their material qualities (Norrie et al 2018) (Figure 16).


Figure 16

The skill in Hoang Thuc Hao's work is that on first inspection, his buildings do not distinctly read as bamboo architecture. Rather they are representative of the notion of contemporary vernacular, where traditional building methodologies are re-contextualised in alignment with modernist aspirations. By separating a material ideology from design, he is able to create work that can be appreciated for its spatial and programmatic qualities alongside the strong social and environmental agenda that is present in his work (Figure 17).

Figure 17

Vo Trong Nghia - Vietnam

The rapid change Vietnam is undertaking from an agrarian economy to a highly connected part of the global community is causing distinct change to its urban landscape. Vernacular building methodologies have been replaced by a taste for new buildings methods, processes and materials (Norrie et al 2018). The loss of cultural character, particularly in urban environments has begun to be recognised and emphasis has been placed on the notion of 'homeland' (a connection to cultural heritage). Bamboo has subsequently emerged as a symbol of Vietnamese culture and often forms part of a nostalgia for a traditional way of life. Subsequently it has begun to be recognised as a high-end material in contemporary architecture that utilised sophisticated methods of construction. However, this has not served to protect traditional low-tech methods of working with bamboo from being replaced by masonry construction.

Vo Trong Nghia (VTN) has developed an international reputation for his iconic bamboo buildings, starting with the first project for the Wind and Water Café in Ho Chi Minh in 2006 (Figure 18). VTN's distinct methods of construction combine the particular structural and material qualities of Vietnamese bamboo with a Japanese architectural education. Traditionally bamboo in Vietnam was constructed on two-dimensional planes, often as a series of frames. The architecture of VTN innovates through the application of a three-dimensional structural systems that utilises bundled and curved elements of bamboo. Utilising small diameter but solid bamboo VTN constructs truss's and arches that form spaces on a monumental scale as can be seen in his design for Naman Retreat or Sen Village Community House (Figure 19).

Figure 18 + 19

The iconic forms of VTN's structure are highly expressive and evoke a nostalgia for the vernacular but utilise high-tech construction techniques (Norrie et al 2018). Through extensive international recognition, VTN has come to represent bamboo architecture in Vietnam. Many derivative organisations have been inspired by the unique method of construction seen in VTN's work, subsequently raising the profile of bamboo as a building material in Vietnam.

VTN's work has become key icons in the global 'iconomy', the imaged based economy of marketing and architoursim (Smith 2005; Norrie et al. 2018). Demand for VTN's work is driven by restaurants and resorts seeking to market themselves utilising bamboo and VTN's distinct architectural style. Similarly works such as Sen Village Community House (Figure 20) and the Diamond Island Community Centre have been commissioned by developers to serve as icons of a narrative that evokes a traditional way of life. The utilisation of bamboo as marketing presents a contradiction that risks bamboo being seen as a fad if it becomes too closely associated with iconography.

Figure 20

Simon Velez - Colombia

Colombia is home to one of the strongest traditions of bamboo architecture. Traditional vernacular construction coalesced with Spanish construction systems, creating bamboo architecture that could last up to 100 years and withstand seismic activity. Early pioneers such as Oscar Hidalgo-Lopez documented the construction methodology of traditional Colombian typologies and evolved these systems to suit contemporary design. Bamboo: Gift of the Gods, by Hidalgo-Lopez, continues to be one the most comprehensive texts on bamboo construction, influencing designers worldwide.

The Colombian architect Simon Velez, a disciple of Hidalgo-Lopez, continued his legacy through the development of mortar reinforced joints and the creation of some the most structurally ambitious bamboo projects worldwide. With the support of Gunther Pauli and ZERI, Velez brought bamboo onto the world stage during the 2000 Hannover Expo (Figure 21). The ZERI Pavilion was a landmark moment for bamboo architecture, proving that largescale bamboo construction could be achieved in a country with a highly regulated construction industry and no history of bamboo craft (Long 2018).

Figure 21

Velez proposes a style of architecture that seeks to amend the imbalance between renewable and non-renewable resources. Although considered one of the great champions of bamboo design, his work utilises concrete, timber and masonry in a hybrid system of construction. Velez's proposal to make architecture 'a bit more vegetarian' (Frey 2013) utilises timber and concrete to accentuate the structural capabilities of bamboo. This is typically done through the construction of a distinctive roof element that is in part influenced by his experiences in south-east Asia. It is a direct response to the tropical climate in which the majority of his work resides and serves to protect the bamboo structure from exposure to wind and rain.

The work of Velez has inspired a generation of designers across Latin America and his influence can be seen in the current bamboo revival taking place in South East Asia. The fluidity of bamboo building technologies to be shared and transposed to different cultural contexts is displayed through the creation of Cross Waters Eco lodge designed by Paul Pholeros in collaboration with Velez (Figure 22). The project utilised organic and recycled

materials found in the immediate vicinity of the project. Clay roof tiles sourced from demolished buildings in the nearby village are paired with rammed earth walls and bamboo construction (Wang 2007). Although constructed utilising Colombian construction methodologies, the buildings feel distinctly Chinese in character and relate strongly to the surrounding landscape.

Figure 22

Standardizing Bamboo

There is a strong narrative that connects the cultivation of bamboo to construction and social development in countries where bamboo is native. Round culm bamboo is often utilised as a building material and the construction methodology is the evolution of traditional vernacular techniques. However, with increasing urbanisation, these methods of construction are not directly relatable to dense urban environments or to standardised systems of construction required for highly regulated building industries. In order for bamboo to be relevant to mainstream construction, these problems must be addressed.

Research by a number of institutions and individuals conclude that engineered bamboo products are critical to providing a pathway for the utilisation of bamboo in a dense urban setting or as building material for highly regulated societies. The processing of raw material into laminated composites allows for standardisation in construction and less inherent variability when compared to the natural material. Research has demonstrated that engineered bamboo products have properties that are comparable or surpass that of timber and timber-based products (Sharma et al. 2015). Whilst there are still a number of limitations to the use of these products in structural design, further research is being undertaken to resolve these issues.

Technical Research

The recent emergence of bamboo as a contemporary building material correlates to research undertaken to establish national building codes for bamboo. The 1999 earthquake in Armenia, Columbia has been directly attributed to the subsequent production of the Colombian Code for Bamboo Construction. As the first building code for bamboo

construction, the Colombian guidelines have subsequently been adapted as the foundation for national codes in Ecuador, Peru, China and India.

ISO Technical Committee 165, Working Group 12 was established to develop an international standard for bamboo structural design. Sitting within ISO/TC 165 Timber Structures, working group 12 drew upon existing national codes and timber guidelines to develop ISO 22156:2004, first published in 2004.

Subsequent research and practical application has led to the understanding that whilst a significant first step, ISO 22156:2004 requires significant revision to maintain relevance. Since only a handful of countries globally have developed a nation code for bamboo construction, the ISO standard has become the benchmark for certification worldwide.

With more than 2000 species of bamboo worldwide, the structural properties of this material vary significantly, posing significant restriction to full culm construction. A major obstacle for mainstream construction is the lack of standardisation in connection and jointing techniques due to bamboo's round and variable section. The application of bamboo as a material for highly regulated building industry has thus centred on the potential of engineered bamboo composites for its environmental credential and standardisation of shape.

Since ISO 22156:2004 is applicable only to full culm bamboo, the need for a similar code for engineered structural bamboo is evident, in order to ensure quality control for products entering the market. A proposed standard for engineered bamboo products has begun to be developed and will be developed over the coming years.

Whilst standardizing bamboo construction system will open up new areas of growth and application to a wider construction industry it does not need to sit in opposition to vernacular methods of bamboo construction. A resilient bamboo industry would utilise both methods dependent upon the context in which one is working. The notion of un-modern as less than only continues to promote a western/academic bias that discounts the wisdom of artisan and vernacular knowledge. Whereas a non-biased agenda that derives from a contextual understanding is critical in obtaining a larger holistic understanding of bamboo's role in the built environment. Thus, research and the drive towards standardisation is of equal but not greater importance than improving pedagogical models that allow for information to be spread through informal channels for the implementation of best practice in informal architecture (Figure 23).


Figure 23

Engineered Bamboo

There is a strong narrative that connects the cultivation of bamboo to construction and social development in countries where bamboo is native. The capacity of bamboo to restore landscape, provide industry for subsistence communities and as a renewable building material has been well established in this context. Vernacular traditions in this region often integrate bamboo as part of the cultural legacy given the multitude of applications that it is capable of.

Outside of this region the argument for utilising unprocessed bamboo diminishes. Scarcity of resource, absence of a bamboo culture and highly regulated building industry are some of the challenges that may need to be overcome.

Engineered bamboo provides an opportunity to open these markets to a different form of bamboo construction. Since the 1990's this industry has grown to a global trade valued at US$60 billion annually (van der Lugt 2017).

A variety of engineered bamboo building products now exist, the majority of which tend to be timber substitute products. The transformation of raw bamboo into an engineered product overcomes challenges in regards to construction knowledge, certification and aesthetic quality (Figure 24). However, it often places it in direct competition with similar timber products that may have equal if not greater environmental credentials.


Figure 24

In comparison to tropical hardwood products that are often uncertified, bamboo has a clear advantage when considering it environmental credentials. However, when comparing it to softwood products that are from sustainably managed forests, (often located closer to the target market) the distinction becomes less clear.

It is not necessary to see these as competing materials, rather it is important to recognise the larger ecological picture. Alternative products with equal or greater environmental credentials, requires us to ask the question of how or why should bamboo be in a particular market.

The largest component of bamboo's ecological footprint is the energy consumed during processing, followed by transport of the material (van der Lugt 2017). Differing products will consume vastly different amounts of energy during processing, resulting in the contextual application of each product bearing a large influence on its ecological suitability.

The round and hollow section of bamboo makes it inefficient to transport. Thus, in order to limit the second largest contributing factor to ecological footprint, manufacturing should take place close to the point of harvest.

The Environmental Bamboo Foundation offers an example of a restoration economy model through the implementation of its '1000 Bamboo Villages' program. Decentralised bamboo plantations are utilised to restore degraded land and managed by individual members within a village cooperative (Rabik 2018). The poles are semi processed into splits before being transported to a centralised manufacturing point. By splitting the bamboo, growers are value-adding to the bamboo as well as maximising the volume of bamboo that can be transported at one time. By decentralising the supply chain, added benefit is provided to local communities and smaller micro-economies are able to be established across the archipelago of Indonesia.

Manufacturing engineered bamboo close to the point of harvest, ensures that largest addition to product value is taking place within the economy where bamboo is grown (most likely a developing country). Through a best practice scenario this leads growing local capacity and provides an ecologically beneficial industry in place of a subsistent reliance on a degrading natural environment. Utilising engineered bamboo locally could reduce the reliance upon uncertified hardwood timber or act as a substitute for non-renewable building materials.

Exporting the material to developed markets provides an opportunity for a higher price point given that the product being manufactured is of significant quality. Moso International has been working closely with their China based factories to improve the quality of output. By setting a benchmark of best practice allows for differentiation from other bamboo competitors. The introduction of an international standard for engineered bamboo may help to ensure a level of quality control across the industry that stops products being undermined by cheaper, less sustainable products of unreliable quality.

Engineered bamboo products can be celebrated as a material that has both social and environmental benefits. The direct connection back to communities in developing countries and the restoration of degraded landscape could become a point of differentiation from competing softwood products.

Engineered bamboo presents the opportunity for expanding bamboo's potential in the built environment. It forms part of the overarching narrative of bamboo but does not need to be seen as competing with raw bamboo. The application of engineered bamboo to the built environment meets a different set of social, cultural and environmental contexts that make it unique in its own right.

Agritecture

The University of Tasmania has been collaborating with Cave Urban in the development of the notion of 'Agritecture', a means to understand the relationship between bamboo as a building material and as part of an ecological and economic supply chain (Norrie et al 2018). Drawing together the different ways in which organisations are utilising bamboo to solve challenges faced by the build environment, the project demonstrates a clear connection between architectural and agricultural considerations.

There is a net positive environmental and social benefit for growing bamboo and creating industry around processing the material to various degrees. This process establishes a narrative in clear juxtaposition to the consumption of non-renewable resources that serve to increase global emissions and cause environmental and social degradation. Through a holistic understanding of bamboo's entire value chain from cultivation to consumption, alternative futures can be imagined, particularly in regards to rural and subsistence communities (Norrie et al. 2018).

Through art, research and practice each of the case studies above utilise different methodologies to integrate ecological and social narratives into the built environment. The suitability of utilizing bamboo in each scenario is determined by the context of the project.

The opportunities and constraints of each project demonstrate that there is no single solution as to how bamboo may be deployed as a building material. Rather an appropriate architectural response is achieved through responding to the client, site and the social and cultural context.

These differing responses can be seen as complimentary to each other regardless of whether one is creating temporary or permanent interventions or making use of low tech or high-tech construction systems. By sharing knowledge and remaining sensitive to the contextual consideration of a project, bamboo can help form part of the collective solution to challenges currently being faced by the built environment and global community.

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Figures
All images by Jed Long, unless otherwise indicated.

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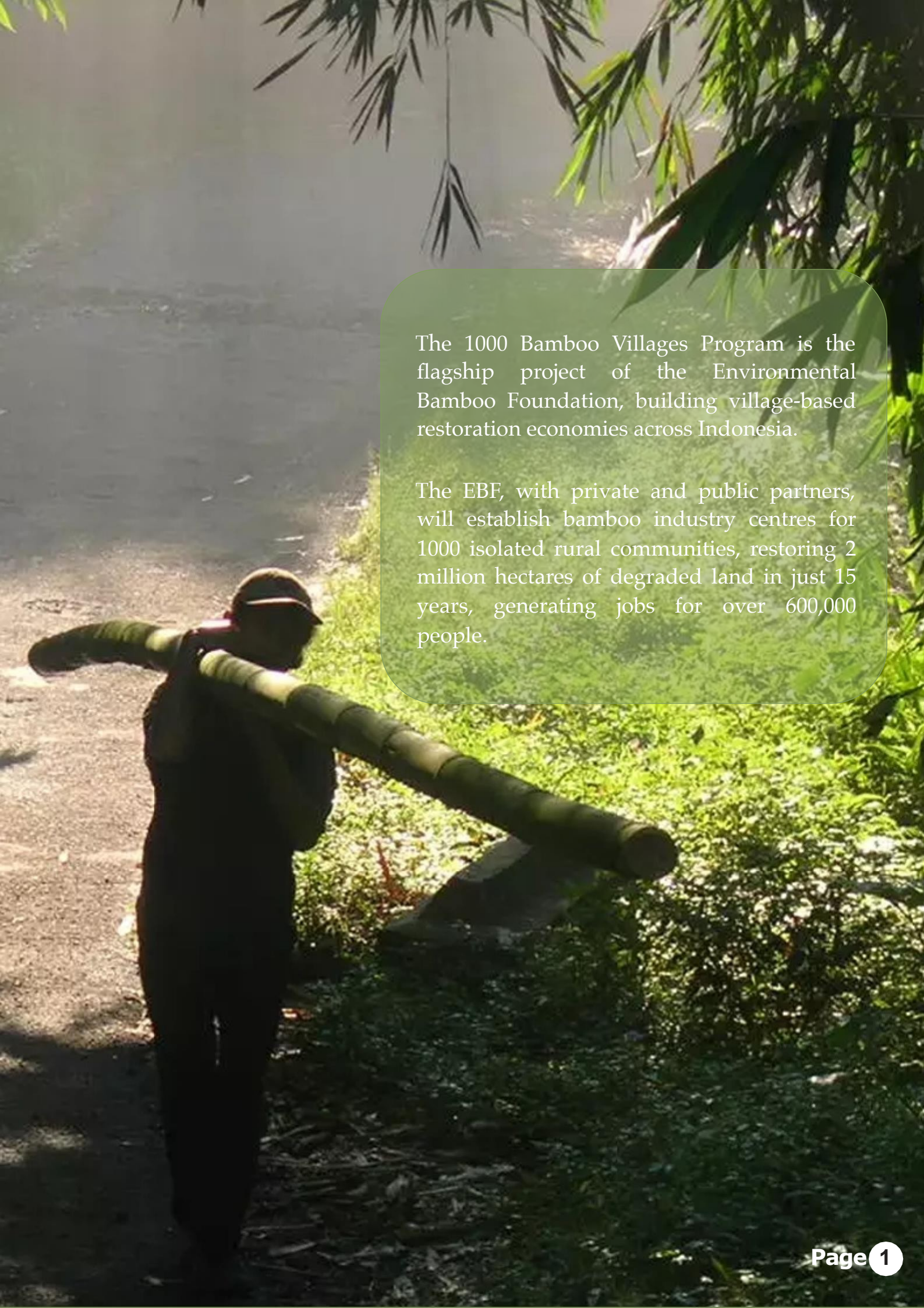
ENVIRONMENTAL BAMBOO FOUNDATION

YAYASAN BAMBU LESTARI

1000 BAMBOO VILLAGES

Empowering village communities across Indonesia to support themselves financially and restore their land with bamboo forests

Jalan Subak Telaga, Banjar Keden, Ketewel, Gianyar-Bali 80582
Telp: 081-236-446-493 Email: yayasanbambulestari.ebf@gmail.com



The 1000 Bamboo Villages Program is the flagship project of the Environmental Bamboo Foundation, building village-based restoration economies across Indonesia.

The EBF, with private and public partners, will establish bamboo industry centres for 1000 isolated rural communities, restoring 2 million hectares of degraded land in just 15 years, generating jobs for over 600,000 people.

INTRODUCTION

The Environmental Bamboo Foundation (EBF) is focusing on implementing its flagship project, the 1,000 Bamboo Villages Program. Our vision is to establish 'restoration economies' in 1,000 communities all over Indonesia, using bamboo as a keystone species for conservation and sustainable livelihood.

We will be working hand-in-hand with village elders and government agents, to empower local people to work with nature, and not against it, using bamboo to stitch back together the canopy coverage and top soil of degraded land. Each village (with an average of 210 households) will be granted rights to be responsible for the restoration, maintenance, management and use of 2,000 hectares of government-owned, degraded forest land to be planted with bamboo. The EBF provides training, guidance and market access for the villagers in this program, guaranteeing a steady income and continuous source of a rapidly renewable building material.

Community-based bamboo industry, in partnership with the industrial sector, will be the catalyst to trigger long term business for farmers and turn the wheel of the local economy. The 1000 Villages Program will directly support almost 1,700,000 people, with an average of eight people per household. This village-based industrial approach will give a very solid foundation to stimulate regional and national economic growth.

Time frame to set up one bamboo village: 5-7 years
We will need:
1. A bamboo cocoon nursery and bamboo field school: USD$20,000
2. To build the village factory and activate it: USD$280,000

We are open to contribution and support from collaborating stakeholders, partners and donors to facilitate and implement this mechanism in 1,000 locations all over Indonesia.

IMPLEMENTATION PHASES

PHASE I

Establishing **Bamboo Cocoon Nursery:**
Area: 10 ha/village
No. of bamboo plantlings: 70,000
Cost: 200 million IDR
Conducting **Bamboo Field School:**
One bamboo village costs: 70 million IDR
Total: 270 million IDR (US **$20,000**)

PHASE II

Planting **The Agroforestry System** (bamboo)
Maintenance of young bamboo forest
Planting appropriate companion plants whilst waiting for first harvest (4-5 years)

Cost: zero. Cooperatives invest in their future for free '(Sweat Equity' investment)

PHASE III

Building **The Village Factory** (to produce useable bamboo laminate planks) and purchase machinery

Cost : US$220,000

PHASE IV

Activating **The Village Industry**:
Machine trials
Sustainable Bamboo Forestry (SBF) system verification and activation.
Signing final off-take agreement with industrial buyer.
Cost : US$10,000

PHASE V

Monitoring the implementation of the SBF system.
Cost: covered by cash flow revenues

LOCATIONS

"Bamboo village distribution in Indonesia: the vision of 1000 Bamboo Villages is to provide an opportunity to remote communities to develop a cost effective supply chain through increasing the level of production."

"Bamboo is the best solution for deforestation and restoration of degraded land in Indonesia."

Linda Garland 1948-2017

THE 1000 BAMBOO VILLAGES PROGRAM

The 1000 Bamboo Villages Program is the most effective solution to restore degraded land and to meet the demand of the manufacturing industry by improving bamboo production and resource management. Many foresters consider bamboo to be 'the alternative to wood and the sustainable building material of the future'.

The core of our program is the empowerment of local farmers, who are trained and mobilized by the EBF to create their own Sustainable Bamboo Forest System, with lasting success. They are guided and helped to organize themselves in a formal legal body, such as a Cooperative or Farmers Group, so as to be able to enter the bamboo-based agro-industry market competitively.

During the facilitation and training process of the SBF System, bamboo farmers are directly involved in applying sustainable community – based agro-forestry techniques to achieve sufficient well-managed bamboo resources. This is an important phase of education and empowerment to ensure that they can meet the quality requirements of the potential buyers.

The incorporation of local wisdom in bamboo management and usage, merged with technological innovation and evolution, sees traditional knowledge and mastery applied in the 1000 Bamboo Villages Program.

The EBF's 1000 Villages Program will contribute 40% of the goal set by 40 nations, who pledged to achieve 5 million hectares of bamboo restoration by 2020.

REINFORCEMENT OF THREE MAJOR COMPONENTS

01

COMMUNITY REINFORCEMENT

The communities involved in this program organize themselves in formal, registered bamboo farmer groups or cooperatives. This process facilitates and strengthens their unity and puts them in a position to work with other stakeholders such as governments and manufacturing sectors. Until now, there have been almost no groups or cooperatives of bamboo farmers in Indonesia. Therefore, community empowerment is one of the central activities in the 1000 Bamboo Villages Program, to build strength, unity and pro-activism, and we achieve this through three enablers:

- Conducting participatory rural appraisal and assessment, as well as socio-economical and geographical surveying
- Building and running a bamboo field school in every village to train and promote 'the best practices and techniques of bamboo management, maintenance and processing'
- Facilitating the establishment of bamboo farmer groups/cooperatives to be legal and operational

FORESTRY REINFORCEMENT

The environmental benefits from the 1000 Bamboo Villages Program can be achieved by restoring land degraded as a result of land slides, erosion, floods, conversion to farming and housing, etc. Forestry reinforcement will be done independently by the well-trained, empowered bamboo farmer cooperatives, who are registered partners of the Environmental Bamboo Foundation.

Forestry reinforcement can be done by implementing the following enablers:

- Facilitating the community to start Bamboo Cocoon Nurseries (for one bamboo village there should be 70,000 plantlings of D. Asper *(Bambu Petung)* or any other species available locally).

These 70,000 plantlings will be planted in an area of 2000 hectares of degraded land belonging to the government with a clear permit and designation to the village. This large number of plantlings will ensure the ability of Bamboo Farmer Groups / Cooperatives to develop a sufficient and sustainable supply of bamboo resources to start cooperating with the manufacturing sector.

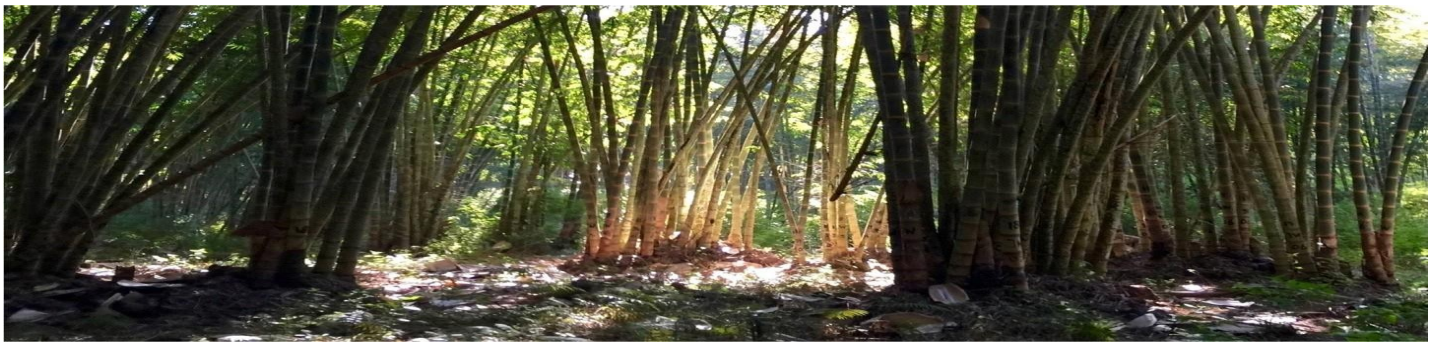
- Implementing the 12 phases of Community-Based Sustainable Bamboo Forest System and following its Standard Operating Procedure

03

VILLAGE-BASED BAMBOO PRODUCTION REINFORCEMENT

One of the goals of the 1000 Bamboo Villages Program is to empower local communities economically, by creating a village-based restoration economy in Indonesia. This is achieved by implementing the effective and productive clump management and a bamboo processing system, making suitable materials for industry. Maintaining the high quality of the expanded bamboo resources will have impact on overall productivity of the villages. In turn, it will improve the quality and quantity of harvested bamboo. It is expected that these two impacts will then increase the income and profit of bamboo farmers and manufacturers, while giving more benefits to the environment. Consistent quality and supply of bamboo will be an ideal factor to be maintained by the bamboo farmer groups and cooperatives for stable cooperation with the purchaser. These farmers can add value to their bamboo by applying the following enablers:

1. Installing a crushing machine to produce semi-processed bamboo material for industry (*pelupuh)*
2. Receiving training in how to use this machine effectively and efficiently
3. Installing a High-Pressure Smoke Preservation System, to preserve the bamboo and reach maximum endurance. This installation should be complemented by the training in the usage of the system to get most benefit out of it.



These three reinforcements will make the Bamboo Farmer Groups /Cooperatives more reliable, and have a stronger position in cooperating with purchasers of bamboo. Both the farmers and the manufacturers will get maximum benefit from their cooperation. Bamboo farmers will get a better price for their semi-processed bamboo, while the manufacturers will benefit from a shorter chain of production with lower risk.

IMPLEMENTATION MECHANISM

FORMATION OF BAMBOO FARMERS GROUPS

Number of members : 30 bamboo farmer families. Total responsibility : 1000 clumps petung eqv. 3000 clumps apus eqv. +-300 ha/cooperative supply responsibility : 3 tons/ day

BAMBOO FIELD SCHOOL (BAMBOO FS)

Learning the bamboo based agroforetry system.
Duration : 8 months

COCOON SEEDLINGS CULTIVATION

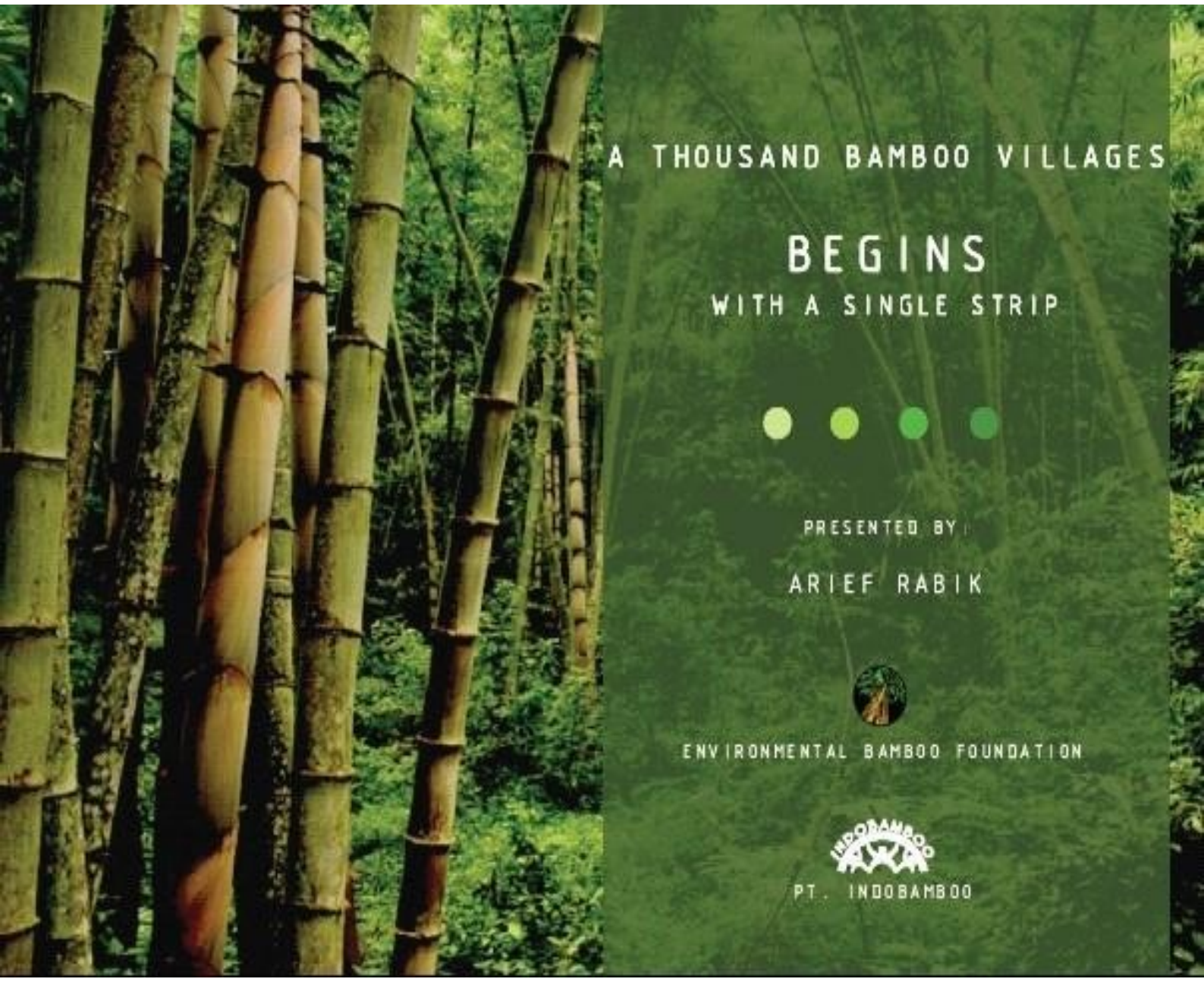
Area needed : 10 ha Bamboo needed : 70,000 plantlings duration: 3 years to mini clump establishment ready for transplant.

SUSTAINABLE HARVEST

The harvest users RBF system, i.e. the clump to be harvested is the clump consisting minimum of 36 culms per clump. The number of culms harvested are 6 culms/ clump

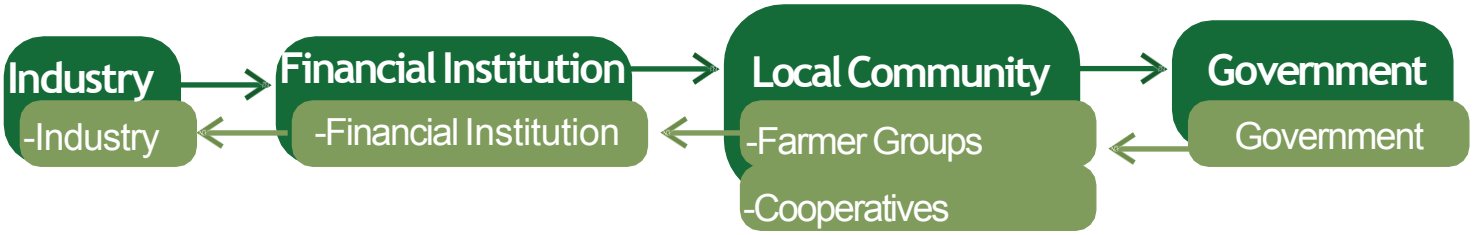
INITIAL PROCESS OF INDUSTRIAL BASIC MATERIAL PROCESSING

Processing of bamboo into semi-processed industrial basic material: bamboo strips, or crushed bamboo mats (*pelupuh*)


A THOUSAND BAMBOO VILLAGES
BEGINS
WITH A SINGLE STRIP
PRESENTED BY :
ARIEF RABIK
ENVIRONMENTAL BAMBOO FOUNDATION
PT. INDOBAMBOO

APPROACH AND STRATEGY

The 1000 Bamboo Villages Program is a groundbreaking innovation from the Environmental Bamboo Foundation to realize the empowerment of a village-based restoration economy in Indonesia. Its unique approach and strategy ensures that the objectives of this program are achieved with the right standard and methodology.



The strategy of the Environmental Bamboo Foundation is to facilitate the empowerment of the communities to be able to cooperate with the manufacturing sector. In this strategy, the approach begins with the initiative of the manufacturing sector in collaboration with financial institutions to facilitate and encourage the community, i.e. local farmers, to participate in the program. These two institutions play the role as the pulling factors to attract the communities to join in the program. As farmer organizations (in form the of groups or cooperatives) are established, they are then facilitated to approach local and the central governments to participate in and support this program. It is expected that the government will facilitate the stakeholders with laws and regulations to form the legal base, reference and framework for legal cooperation. It is also expected that the government will facilitate the provision of adequate facilities and infrastructure, so that the cooperation of the stakeholders involved can run smoothly.

The legally operational farmer groups or cooperatives are supported in the creation and development of clear business plans, allowing them to access financial support in the form of loans, and be able to cooperate with the manufacturers from a stronger position. Under this scheme, cooperation between bamboo farmers and the manufacturing sector will last longer, and be more mutually beneficial.

STAKE HOLDERS
(ROLE, COMMITMENT AND NEGOTIATION POSITION)

GOVERNMENT

1. Facilitate funding of Phase 1
2. Creating legal framework
3. Supporting basic infrastructure (road, electricity, etc.)
4. Empowerment through tax subsidies
5. Confirming human resource needs
6. Networking participation of local industrial players
7. Sustainable development

COMMUNITY

1. Creating local bamboo culture
2. Confirming job opportunities
3. Sustainable forestry management
4. Becoming a realiable supplier
5. Engaging government support in Phase 1
6. Embracing technical support and assitance
7. Understanding microfinance

MICROFINANCE (MF)

1. Key to funding of Phase 2 of 1000 Bamboo Villages Program
2. Creating appropriate local forestry system
3. Giving micro credit loan to local cooperatives
4. Enticing government participation
5. Creating clear frameworks for cooperative business process
6. Asset as collateral
7. Contract on absorption or raw material and community work force

INDUSTRIAL PARTNER

1. Committing to industrial investment
2. Signing long term supply contracts with bamboo village cooperatives
3. Employing local and experienced human resources
4. Pioneering a locally appropriate industrial paradigm
5. Setting a “fair value chain” that plans for a development process of more than 50 years
6. Investing in government infrastructures

Why 1000 BAMBOO VILLAGES ?

Why EBF?

The Environmental Bamboo Foundation (EBF) has gathered knowledge and experience from its activities for over thirty years, in developing the Community-Based Bamboo Agro-Forestry System. Through this long learning process, the 1000 Bamboo Village Program finally took shape as a result of the evolution of knowledge and practice in facilitating community empowerment. Participating in this process as an initiator, facilitator, partner and learner, EBF found that there is a key role to be played in the successful implementation of the 1000 Bamboo Villages Program, namely as a ***catalyst collaborator***.

As a catalyst and one of the initiators of the 1000 Bamboo Villages Program, you can work hand-in-hand with EBF to pioneer the paradigm shift in sustainable land restoration, sustainable Community-Based Bamboo Forestry, community empowerment through restoration economy, and the use of bamboo as an alternative, sustainable timber to meet the need of bamboo-based manufactures. The Sustainable Bamboo Forest System *(SBF System)* in the 1000 Bamboo Villages Program is a system designed to accelerate the process of the implementation of this program while giving directions and guidance in good standard practices and management of bamboo resources. In this movement, EBF bridges the interests of all parties involved, with a clear, transparent and accountable management system.

The twelve phases of SBF System and five enablers of the 1000 Bamboo Villages Program are EBFs innovations, based on scientific research and experience for over 30 years. The stages of the program are clearly defined, directed, measured, systemized and presented in simple language so that it is easily understood by all stakeholders. All of these efforts are based on a clear vision, mission and objectives for the successful implementation of the 1000 Bamboo Villages Program in Indonesia towards a strong and resilient Village-Based Bamboo Industry for the prosperity of local communities and the country's ecology.

TIME LINE

1995 — International Bamboo Congress IV (Ubud, Bali)

1997 — National Strategy of Bamboo Conservation and Utilization in Indonesia

2015 — Announcement of 'One Thousand Bamboo Villages' Program at COP 21 (Paris)

2016-2021

Phase 1
NTT : 20 Bamboo Villages

Bali : 5 Bamboo Villages (1 Lamination Factory)

West Java : 15 Bamboo Villages (1 Lamination Factory), (1 Viscose Factory), (1 Paper Factory)

Total : 40 Bamboo Villages
Industrial Revenue: 50 Millions USD/ year

2021-2026

Phase 2
NTT : +25 Bamboo Villages
NTB : 27 Bamboo Villages **Bali** : +35 Bamboo Villages **Java** : 92 Bamboo Villages **Sulawesi** : 62 Bamboo Villages
Kalimantan : 62 Bamboo Villages
Sumatra : 100 Bamboo Villages
Papua : 62 Bamboo Villages

Total : 473 Bamboo Villages (equivalent)
Industrial Revenue: 591.250 Millions USD/ year

2026-2021

Phase 3
NTT : +30 Bamboo Villages **NTB** : +30 Bamboo Villages **Bali** : +35 Bamboo Villages **Java** :+93 Bamboo Villages **Sulawesi** : +63 Bamboo Villages
Kalimantan : +63 Bamboo Villages
Sumatra : +100 Bamboo Villages
Papua : +63 Bamboo Villages

Total : 482 Bamboo Villages (equivalent)
Industrial Revenue: 602.500 Millions USD/ year

OUR PARTNERS

Government Institutions

•Ministry of Environment and Forestry

•Ministry of Industry

•Ministry of Village, Development of Disadvantaged Regions and Transmigration

•Provincial Government of Bali, West Nusa Tenggara, East Nusa Tenggara and South Sulawesi.

Civil Societies/NGOs

•Yayasan Kemitraan (Partnership Foundation)

•Yayasan Kehati (Kehati Foundation)

•World Wildlife Fund

•Cave Urban

International Organizations

•International Tropical Timber Organization (ITTO)

•Inbar

•CBRC

•Asia Pasi c Network for Sustainable Forest Management and Rehabilitation

•Multi-stakeholder Forestry Programme

Private Sector

•PT Indobamboo Lestari

•PT BambooBos

•CIMB Niaga

Association and Community

•Cooperative "Mele Maju" (*Koperasi Mele Maju*) – Central Lombok

•Nusantara Bamboo Community (*Komunitas Bambu Nusantara*)

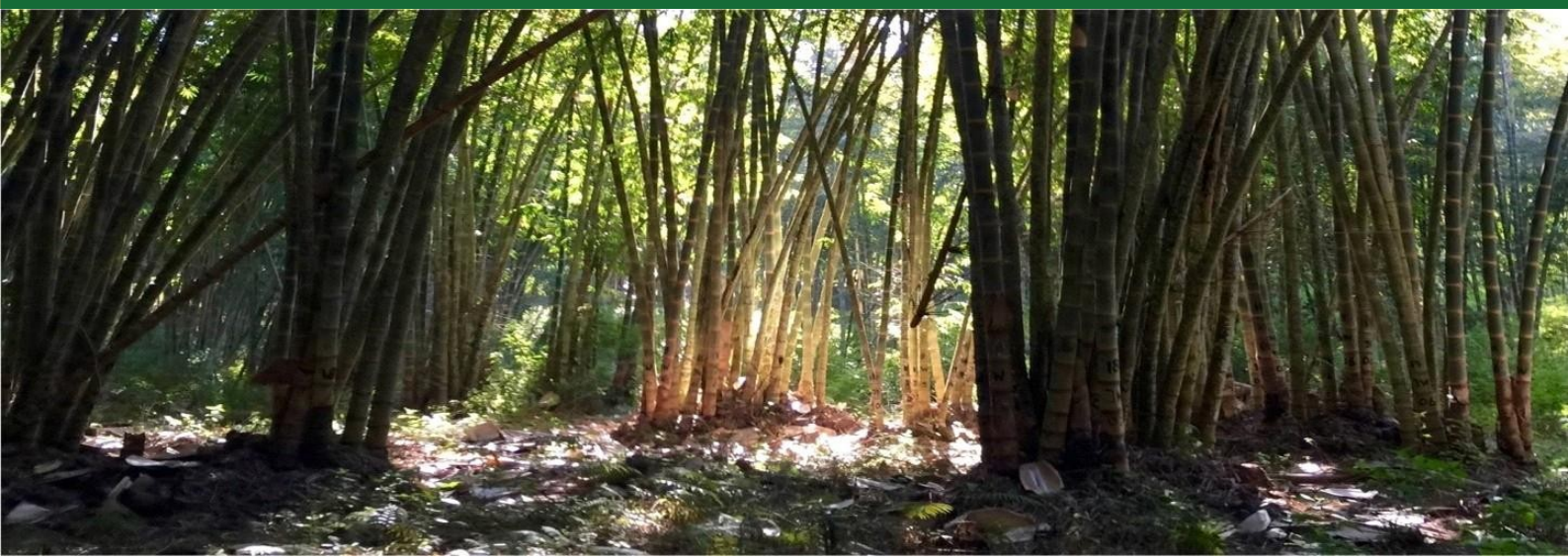
•APHI

•Bambu Nusantara Academi (*Akademi Bambu Nusantara*)

•Community Groups

Universities

•Brawijaya University – Malang, Bogor Agricultural University, Gajah Mada University, Bandung Institute of Technology, University of Helsinki,



PARTNERS FOR BAMBOO COCOON NURSERIES

- P T. Jewelry Design Services – John Hardy, Bali
- Bambu Indah Villa
- Bali ReGreen
- ITTO Bamboo Project
- Kehati Foundation
- MOSO Bamboo Products World Wide
- Gaia Foundation – England

Keynote Lecture

MEXICAN BAMBOOS IN THE XXI CENTURY: DIVERSITY, USEFUL SPECIES AND CONSERVATION

Eduardo Ruiz-Sanchez / ruizsanchez.eduardo@gmail.com

Departamento de Botánica y Zoología, Centro Universitario de Ciencias Biológicas y Agropecuarias, Universidad de Guadalajara. Camino Ing. Ramón Padilla Sánchez 2100, Nextipac, Zapopán, Jalisco 45110, México. ruizsanchez.eduardo@gmail.com

Abstract

Bamboos are giant grasses belonging to the subfamily Bambusoideae, one of the 12 recognized subfamilies in Poaceae. Bambusoideae has more than 1650 described species of bamboos worldwide both of herbaceous bamboos and woody bamboos. Mexico has 56 native bamboos, 52 of them are woody bamboos and four are herbaceous bamboos. Of these 50 species, 35 are endemic to Mexico, that is, they do not live wild in any other part of the world. Two species in Mexico are the most used since pre-Columbian times; *Guadua inermis* and *Otatea acuminata*. Both species have been used for the construction of houses with the technique of "bajereque." Besides these two species, other species have also been used for the same purpose as *Guadua paniculata* and *Otatea fimbriata*. Regionally, other species are used for basketry such as *Chusquea circinata* and *Rhipidocladum racemiflorum*. Finally, the use of the native species of Mexico as ornamental plants has not been exploited and remains an open field. For conservation purposes, only two endemic species of Mexico (*Olmeca recta* and *Ol*. *reflexa*) are listed in Norma Oficial Mexicana (NOM-059-SEMARNAT-2010) as endangered species. New analyzes and results indicate that eight endemic species should be included as critically endangered category and 27 species in the endangered category.

Key words: critically endangered, endangered**,** *Guadua inermis*, endemic, *Otatea acuminata*

Introduction

Bamboo species worldwide account more than 1650 (Vorontsova et al., 2016), which are divided informally into two large groups; woody bamboos that are usually bamboos with lignified culms, have complex rhizomes, well-differentiated culm leaves, develop branching, have bisexual flowers and generally flowering gregariously and are monocarpic. The second group is the herbaceous bamboos do not present complex rhizomes, the culms are not strongly lignified, they do not present culm leaves, they generally do not develop branching, they have unisexual flowers, continuous flowering and they are not monocarpic (Clark et al., 2015).

Bamboos belong to the subfamily Bambusoideae, one of the 12 recognized subfamilies of Poaceae (grass family) (Soreng et al., 2015, 2017). With the exception of Antarctica and Europe, in the rest of the continents we find bamboo growing wild (Clark et al., 2015). Taxonomically bamboos, both herbaceous and woody, are divided into three tribes. The Arundinarieae tribe or temperate woody bamboos have their greatest diversity of species in

Asia, and there are only three species in America, particularly in the United States (Clark et al., 2015). The tribe Bambuseae or tropical woody bamboos, is divided into two large clades or monophyletic groups; the Neotropical bamboos exclusive of America and the Paleotropical bamboo of Africa, Asia and Oceania. Finally, the Olyreae tribe or herbaceous bamboos has practically its entire species in America, and only one *Buergersiochloa bambusoides* is endemic to New Guinea in Asia (Judziewicz et al. 1999; Judziewicz y Clark, 2007; Clark et al. 2015; Wysocki et al. 2015; Soreng et al. 2015, 2017). America has 535 bamboos species, 125 of them are herbaceous bamboos and 410 are woody bamboos (Clark et al., 2015). All countries in the Americas have at least one species of native bamboo, either herbaceous or woody, with the exception of Canada. United States of America has three endemic species of the genus *Arundinaria* (Tripplett et al., 2010), however in the United States there are no tropical bamboos registered in the wild. The rest of the American species belong to the Bambuseae tribe, which in turn is divided into three subtribes that are exclusive to the Americas; Arthrostylidiinae, Chusqueinae, and Guaduinae (Judziewicz et al., 1999, Clark et al., 2015). The country with the largest number of species is Brazil with more than 256, between herbaceous and woody bamboos (Greco et al. 2015).

For Mexico, Ruiz-Sanchez et al. (2015) recorded 54 woody and herbaceous bamboos species. Of those 54 species, 50 are woody bamboos. Seven species of woody bamboos from Mexico belong to the subtribe Arthrostylidiinae. The Chusqueinae subtribe is represented by 21 species and finally, the Guaduinae subtribe has 22 species. The herbaceous bamboos of the Olyreae tribe in Mexico are represented by only four species (Ruiz-Sanchez et al., 2015). 30 woody bamboo species are endemic to Mexico, that is, they do not live anywhere else in the world. The states of the Mexican Republic with the greatest diversity of species are Chiapas with 32 species, Veracruz with 25 species and Oaxaca with 23 species. On the other hand, the states that do not register any native species are Baja California, Baja California Sur, Coahuila and Tlaxcala (Ruiz-Sanchez et al., 2015) (Figure 1).

This study gathers a new list of woody and herbaceous bamboos for Mexico that includes the newly described species. Also, it identifies the species with the greatest potential commercially speaking and compiles a list of species that deserve to be protected to some degree of conservation.

Material and Methods

Data source

A database of Mexican woody and herbaceous bamboo species of georeferenced was gathered (Table 1). The information was obtained from field work, scientific collections of herbarium records from the following herbaria; IBUG, IEB, MEXU and XAL (Thiers 2010) and from the public database GBIF (Global Biodiversity Information Facility) (GBIF 2012). Doubtful records, particularly those that did not have specimens and duplicate records (same species collected multiple times in the same locality) or that did not have enough information to be able to be georeferenced (ambiguous localities) were not taken into account in the final database.

Conservation analysis

To determine the conservation status of each species of woody bamboos present in Mexico, only the geographical distribution was taken into account and the conservation criteria proposed by the IUCN Red List of Endangered Species (IUCN 2012) were considered. For this, the occupation area (AOO) was evaluated, where a cell of 2 x 2 km was calculated for each point of presence of each species (IUCN 2016, Willis et al., 2003). The AOO index was estimated using the GeoCat software (Bachman et al., 2011).

Results and Discussion

The herbaceous bamboos of Mexico are represented by three genera (*Cryptochloa*, *Lithachne*, and *Olyra*) and four species that grow below 1300 m in tropical rainforest, subdeciduos forest and cloud forest (Ruiz-Sanchez et al. 2015). *Cryptochloa strictiflora* is the smallest herbaceous bamboo of Mexico, since it only measures about 20 cm in height and is found exclusively tropical rainforest at an altitude no higher than 900 m (Ruiz-Sanchez and Clark 2018). The woody bamboos of Mexico are represented by eight genera and 52 species. The genera that are only represented by a single species are *Arthrostylidium*, *Aulonemia* and *Merostachys*. *Rhipidoclaum* is represented by four species, *Olmeca* by five species, *Guadua* by seven species, *Otatea* by 11 species, and *Chusquea* by 22 species (Table 1) (Ruiz-Sanchez et al 2015, 2017, 2018a, Ruiz-Sanchez and Castro-Castro 2016).

Ruiz-Sanchez et al. (2015), reported 54 species of native bamboos for Mexico. However, the number increased to 56 species by the description of *Otatea nayeeri* (Ruiz-Sanchez and Castro-Castro 2016) and *Chusquea septentrionalis* (Ruiz-Sanchez et al., 2017). Additionally, *Merostachys mexicana* was described (Ruiz-Sanchez et al., 2018a), however, this new species does not increase the list of species of Mexico, because it had already been considered in the study by Ruiz-Sanchez et al. (2015) as *Merostachys* sp.

From the 1650 bamboo species described to date, only 45 of them are considered economically important (Benton 2015). Of those 45 species, only three are native species of America (*Guadua angustifolia*, *G. amplexifolia* and *G. chacoensis*). Ruiz-Sanchez et al. (2018b) suggest the inclusion of *Guadua inermis* and *Otatea acuminata* to that the list.

Guadua inermis has a geographical distribution on the slope of the Gulf of Mexico, is a medium to large bamboo of 4 to 15 m in height, 4 to 10 cm in diameter, the culms are generally solid or with very thick walls (Cortés-Rodríguez 2000, Londoño and Ruiz 2014). The culms of this species are used mainly for the construction of rural houses, fences, palapas, and furniture (Cortés-Rodríguez 2000). Trabanino and Nuñez (2014) found archaeological evidence of the use of *Guadua* in Mayan graves, possibly it could have been *Guadua inermis*. There is also a record of the use of *Guadua inermis* in Oaxaca in the construction of "bajereque" walls.

Otatea acuminata is the most used species in Mexico, is distributed mainly by the Pacific slope and the central part of Mexico, from Jalisco to Veracruz. It is a small to medium-sized bamboo 2 to 8 m high, 1 to 5 cm in diameter with hollow or solid culms (Ruiz-Sanchez and Sosa 2010, Ruiz-Sanchez et al., 2011, Ruiz-Sanchez 2015). The culms of this species are used to build roofs and walls of rural houses, doors, fences, basketry, "burritas" walking sticks,

tutors for agriculture among other uses (Gúzman et al., 1984, Vázquez-López 1995, Judziewicz et al. 1999, Cortés-Rodríguez 2000, Vázquez-López 2004). There is archaeological evidence that this species was already used by Mesoamerican cultures (800-890 BC) to build houses with the technique of "bajereque" (Júarez and Márquez 1992).

Other species that have been registered uses in the construction of houses is *Guadua aculeata* in the states of Veracruz and Puebla. *Guadua paniculata* and *Otatea fimbriata* were also used in the construction of bajereque walls in Chiapas. It should be noted that *Guadua aculeata* is the largest bamboo species in Mexico, reaching up to 20 meters and 18 cm in diameter. It has qualities very similar to *G. angustifolia*, however, the management of *G. aculeata* is more intense, since it has thorns along the entire culm and the necks of rhizomes that generate new culms are short, making it difficult to extract. Finally, other species registered for different uses are *Rhipidocladum racemiflorum* used in the decoration of bamboo furniture in Veracruz and in the elaboration of decorative curtains, this due to its slim and stylized culms. In Jalisco, this species was used or to make chacaleras (shrimp traps). *Chusquea circinata* is used or was used as a tutor for crops, making baskets and hooks to cut fruits in Jalisco too. Other species of *Otatea* are used as hooks to cut fruits.

Otatea acuminata is known in the United States as "Mexican weeping bamboo" and is widely cultivated as an ornamental species. However, in Mexico, it is not yet cultivated for this purpose. The use of native bamboos from Mexico as ornamental species has not been exploited yet. There are many species that could be used in gardening, such as some species of *Otatea*, *Chusquea* and *Rhipidocladum*. But, it is necessary to start with the propagation, reproduction, and commercialization. Likewise, native species cultivated ornamentally can function as a double purpose: to beautify the cities and capture the CO2 emitted by cars sources mainly.

Of the 56 species of bamboo native to Mexico, 35 are endemic to Mexico (Table 1). These 35 endemic species are all woody bamboos. According to the results of the analysis of AOO to determine the conservation status of endemic species in Mexico, we found that eight of them should be classified as critically endangered (Table 1) and 27 as endangered. Of the 35 species endemic to Mexico, only two of them (*Olmeca recta*and *Ol*. *reflexa*) are in category P (endangered) in the Norma Oficial Mexicana (NOM-059-SEMARNAT-2010), which lists the species of native flora and fauna of Mexico with some conservation status. Our results of AOO that considers the area of occupation, tells us that both species should be remaining in this category. Therefore, 33 more species should be included in NOM-059-SEMARNAT-2010, eight of them in the category of critically endangered and 27 as endangered (Table 1).

Conclusions

Two endemic species of Mexico: *Guadua inermis* and *Otatea acuminata* are the most widely used in the construction of houses with the technique of "bajereque", to make basketry, tutors for crops among other diverse uses. Native people of pre-Columbian in Mexico already used these species in their daily lives. However, traditional uses are being lost little

by little, by the use of other materials that have replaced them. However, the boom of ecological, sustainable and biodegradable materials puts bamboos on the national and global stage. Hence the importance of rescuing the use of our native species. For this, it is necessary to know the diversity of species that we have and know their traditional or potential uses. Finally, a sale of opportunities that have not yet been opened is the use of native bamboos as garden plants. This would put in the houses and cities the native species, embellishing the streets and gardens and capturing CO2. On the other hand, of the 52 species of woody bamboos for Mexico, 35 are endemic and all of them should be protected in NOM-059-SEMARNAT-2010, eight of them in the critically endangered category and 27 of them as endangered.

Acknowledgments
To Dr. Guadalupe Munguía Lino for his help with the AOO analysis.

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Figure 1.
Geographical distribution map of the native bamboo genera of Mexico.

Table 1. Native and endemic bamboo species of Mexico and IUCN categories where some species should be listed.

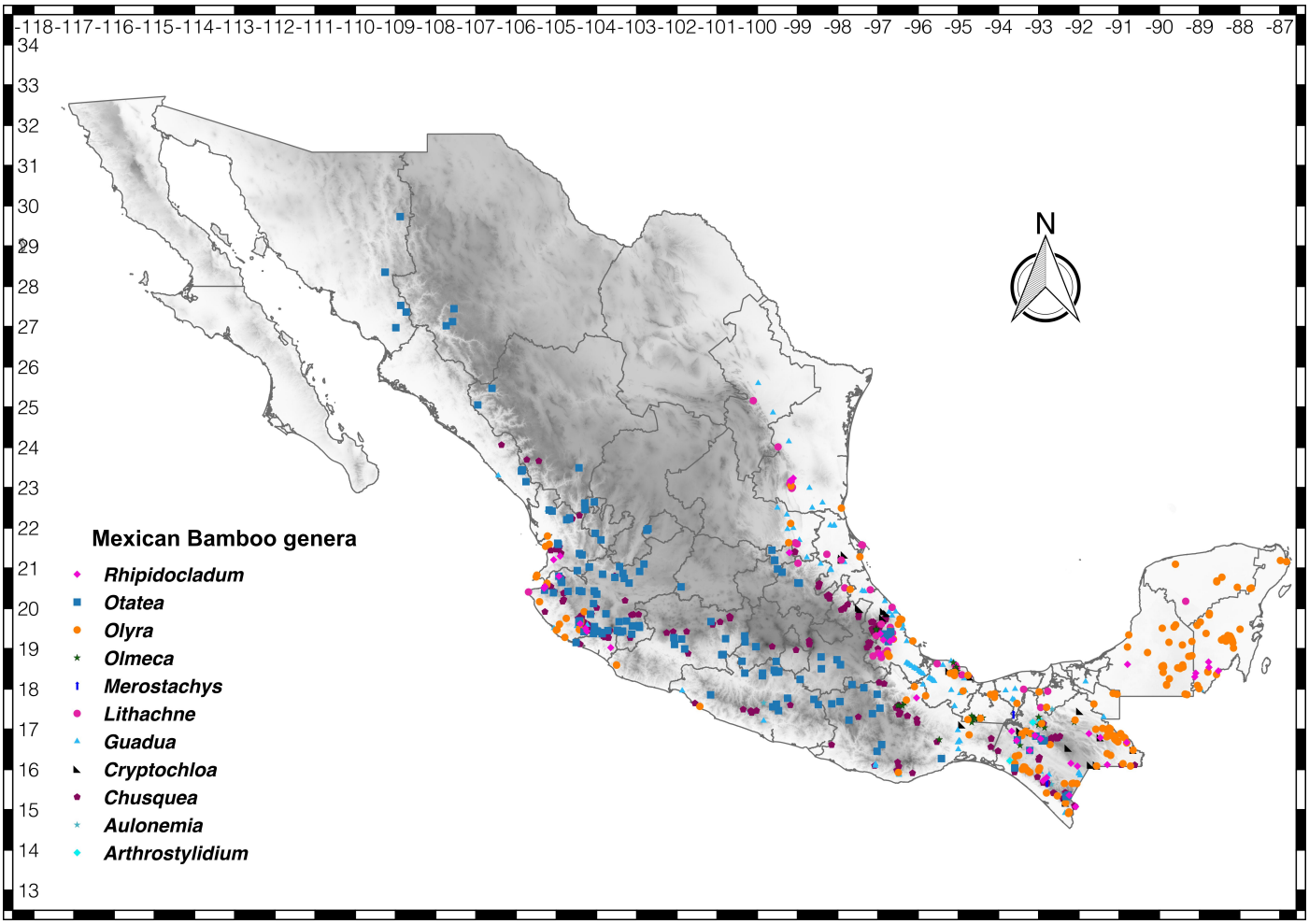
Woody bamboos		**Herbaceous bamboos**
!*Arthrostylidium excelsum* Griseb.	⌘*_C. septentrionalis_ Ruiz-Sanchez, Art. Castro & L. G. Clark	*Cryptochloa strictiflora* (E. Fourn.) Swallen
*!*Aulonemia laxa* (F. Maek.) McClure	*C. simpliciflora* Munro	!*Lithachne pauciflora* (Sw.) P. Beauv.
*!*Merostachys mexicana* Ruiz-Sanchez & L.G. Clark	*C. sulcata* Swallen	*Olyra glaberrima* Raddi
Rhipidocladum bartletii (McClure) McClure	*Guadua aculeata* Rupr. ex E. Fourn.	*O. latifolia* L.
⌘*!*Rhipidocladum martinezii* Davidse & R.W. Pohl	*G. amplexifolia* J. Presl.	
Rhipidocladum pittieri (Hack.) McClure	*!*G. inermis* Rupr. ex E. Fourn	
Rhipidocladum racemiflorum (Steud.) McClure	*G. longifolia* (E. Fourn.) R.W. Pohl	
*!*Chusquea aperta* L.G. Clark	*G. paniculata* Munro	
*!*C. bilimekii* E. Fourn.	*!*G. tuxtlensis* Londoño & Ruiz-Sanchez	
*!*C. circinata* Soderstr.	*!*G. velutina* Londoño & L.G. Clark	
C. coronalis Soderstr.	*Olmeca clarkiae* (Davidse & R.W. Pohl) Ruiz-Sanchez, V. Sosa & Mejía-Saulés	
*!*C. cortesii* L.G.	*!*Ol. fulgor* (Soderstr.)	

Clark & Ruiz-Sanchez	Ruiz-Sanchez, V. Sosa & Mejía-Saulés	
⌘*_C. enigmatica_ Ruiz-Sanchez, Mejía-Saulés & L. G. Clark	*!_Ol. recta_ Soderstr.	
*!_C. galeottiana_ Munro	*!_Ol. reflexa_ Soderstr.	
*!_C. gibcooperi_ Ruiz-Sanchez, Mejía-Saulés, G. Cortés & L. G. Clark	⌘*_Ol. zapotecorum_ Ruiz-Sanchez, V. Sosa & Mejía-Saulés	
*!_C. glauca_ L. G. Clark	*!_Otatea acuminata_ (Munro) C. Calderón & Soderstr.	
C. lanceolata Hitchc.	⌘*_O. carrilloi_ Ruiz-Sanchez, V. Sosa & Mejía-Saulés	
C. liebmannii E. Fourn.	_O. fimbriata_ Soderstr.	
C. longifolia Swallen	⌘*_O. glauca_ L.G. Clark & G. Cortés	
*!_C. matlatzinca_ L. G. Clark & Ruiz-Sanchez	*!_O. nayeeri_ Ruiz-Sanchez	
*!_C. muelleri_ Munro	⌘*_O. ramirezii_ Ruiz-Sanchez	
⌘*_C. nedjaquithii_ Ruiz-Sanchez, Mejía-Saulés & L. G. Clark	*!_O. reynosoana_ Ruiz-Sanchez & L.G. Clark	
*!_C. nelsonii_ Scribn. & J. G. Sm.	*!O. _rzedowskiorum_ Ruiz-Sanchez	
*!_C. perotensis_ L. G. Clark, G. Cortés & Cházaro	*!_O. transvolcanica_ Ruiz-Sanchez & L.G. Clark	
C. pittieri Hack.	*!_O. victoriae_ Ruiz-Sanchez	
*!_C. repens_ L. G. Clark & Londoño	*!_O. ximenae_ Ruiz-Sanchez & L.G. Clark	

* Endemic species of Mexico

⌘ Species to be considered as critically endangered IUCN category

! Species to be included as endangered IUCN category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Mexican Bamboo genera
Rhipidocladum
Otatea
Olyra
Olmeca
Merostachys
Lithachne
Guadua
Cryptochloa
Chusquea
Aulonemia
Arthrostylidium

Keynote Lecture

LOS BAMBÚES DE MÉXICO EN EL SIGLO XXI: DIVERSIDAD, ESPECIES ÚTILES Y CONSERVACIÓN

Eduardo Ruiz-Sanchez
Departamento de Botánica y Zoología, Centro Universitario de Ciencias Biológicas y Agropecuarias, Universidad de Guadalajara. Camino Ing. Ramón Padilla Sánchez 2100, Nextipac, Zapopán, Jalisco 45110, México. ruizsanchez.eduardo@gmail.com

Resumen
Los bambúes son pastos gigantes pertenecientes a la subfamilia Bambusoideae, una de las 12 subfamilias reconocidas en Poaceae. Con más de 1650 especies descritas de bambúes a nivel mundial tanto de bambúes herbáceos como bambúes leñosos, en México solo habitan 56 bambúes nativos. 52 especies son bambúes leñosos y cuatro son bambúes herbáceos. De esos 50 especies, 35 son endémicas para México, es decir no viven de forma silvestre en ninguna otra parte del mundo. Dos especies en México son las mas utilizadas desde tiempo prehispánicos: *Guadua inermis* y *Otatea acuminata*. Ambas especies ha sido utilizadas en la construcción de viviendas con la técnica de "bajereque". Además de estas dos especies también han sido utilizadas para el mismo fin, *Guadua paniculata* y *Otatea fimbriata*. Regionalmente se utilizan otras especies para cestería como *Chusquea circinata* y *Rhipidocladum racemiflorum*. Finalmente, el uso de las especies nativas de México con plantas ornamentales no se ha explotado y sigue siendo un campo abierto. Solo dos especies endémicas de México (*Olmeca recta* y *Ol. reflexa*) están enlistadas de Norma Oficial Mexicana (NOM-059-SEMARNAT-2010) como especies en peligro de extinción. Los nuevos análisis y resultados indican que estas dos especies deberían de estar incluidas como amenazadas y se deberían incluir a ocho especies endémicas en la categoría de estado crítico y 27 especies en la categoría de amenazadas.

Palabras clave: amenazadas**,** *Guadua inermis*, endemismo, estado crítico, *Otatea acuminata*

Introducción

Las especies de bambúes a nivel mundial suman más 1650 (Vorontsova et al. 2016) que están divididas informalmente en dos grandes grupos; los bambúes leñosos que son generalmente bambúes con culmos lignificados, presentan rizomas complejos, vainas caulinares bien diferenciadas, desarrollan ramificación, presentan flores bisexuales y generalmente son de floración gregaria y monocárpicos. El segundo grupo son los bambúes herbáceos no presentan rizomas complejos, los culmos no están fuertemente lignificados, no presentan vainas caulinares, generalmente no desarrollan ramificación, presentan flores unisexuales de floración continua y no son monocárpicos (Clark et al. 2015).

Los bambúes pertenecen a la subfamilia Bambusoideae, una de las 12 subfamilias reconocidas de la familia Poaceae (familia de los pastos) (Soreng et al. 2015, 2017). Con excepción de la Antártica y Europa, en el resto de los continentes encontramos bambúes creciendo de forma silvestre (Clark et al. 2015). Taxonómicamente hablando los bambúes

tanto herbáceos como leñosos están divididos en tres tribus. La tribu Arundinarieae o bambúes leñosos templados tiene su mayor diversidad de especies en Asia, y solo existen tres especies en América, particularmente en Estados Unidos (Clark et al. 2015). La tribu Bambuseae o bambúes leñosos tropicales, está dividida en dos grandes clados o grupos naturales; los bambúes Neotropicales exclusivos de América y los bambués Paleotropicales de África, Asía y Oceanía. Finalmente la tribu Olyreae o bambúes herbáceos, tiene prácticamente todas sus especies en América, y sola una especie *Buergersiochloa bambusoides* es endémica de Nueva Guínea en Asia. (Judziewicz et al. 1999; Judziewicz y Clark, 2007; Clark et al. 2015; Wysocki et al. 2015; Soreng et al. 2015, 2017).

En el continente americano se registran alrededor de 535 especies de bambúes, de las cuales 125 de ellas son bambúes herbáceos y 410 especies de bambúes leñosos. (Clark et al. 2015). Todos los países de América cuentan con al menos una especie de bambú nativo, ya sea herbáceo o leñoso, con excepción de Canadá. Estados Unidos tiene tres especies endémicas del género *Arundinaria* pertenecientes a la tribu Arundinarieae o bambúes templados (Tripplett et al. 2010), sin embargo en Estados Unidos no se registran bambúes tropicales de forma silvestre. El resto de las especies americanas pertenece a la tribu Bambuseae que a su vez está dividida en tres subtribus que son exclusivas de América (Arthrostylidiinae, Chusqueinae y Guaduinae) (Judziewicz et al. 1999; Clark et al. 2015). El país que cuenta con el mayor número de especies es Brasil con más de 256, entre bambúes herbáceos y leñosos (Greco et al 2015).

Para México, Ruiz-Sanchez et al. (2015) registraron 54 especies de bambúes leñosos y herbáceos. De esas 54 especies, 50 son bambúes leñosos. Siete especies de bambúes leñosos de México pertenecen a la subtribu Arthrostylidiinae. La subtribu Chusqueinae esta representada por 21 especies y finalmente, la subtribu Guaduinae cuenta con 22 especies. Los bambúes herbáceos de la tribu Olyreae en México están representados por tan solo cuatro especies (Ruiz-Sanchez et al. 2015). De las 50 especies de bambúes leñosos, 30 de ellas son endémicas para México, es decir no viven en ninguna otra parte del mundo. Los estados de la república Mexicana con la mayor diversidad de especies son: Chiapas con 32 especies, Veracruz con 25 especies y Oaxaca con 23 especies. Por otra parte los estados que no registran ninguna especie nativa son: Baja California, Baja California Sur, Coahuila y Tlaxcala (Ruiz-Sanchez et al. 2015) (Figura 1).

En el presente estudio se pretende hacer un nuevo listado de bambúes leñosos y herbáceos para México, debido a que recientemente se han publicado especies nuevas para el país. Así como identificar a las especies con mayor potencial comercial y determinar a las especies que merecen estar protegidas en algún grado conservación.

Materiales y Métodos

Fuente de datos

Se obtuvo una base de datos de las especies de México de bambúes herbáceos y leñosos georreferenciadas (Cuadro 1). La información fue obtenida de trabajos de campo, colecciones científicas de registros de herbario de los siguientes herbarios: IBUG, IEB, MEXU

y XAL (Thiers 2010) y de la base de datos pública GBIF (Global Biodiversity Information Facility) (GBIF 2012). Registros dudosos, particularmente aquellos que no contaban con especímenes y registros duplicados (misma especie colectada múltiple veces en la misma localidad) o que no contaban con información suficiente para poder ser georreferenciados (localidades ambiguas) no fueron tomados en cuenta en la base de datos final.

Estado de conservación

Para determinar el estado de conservación de cada una de las especies de bambúes leñosos presentes en México, se tomó en cuenta solo la distribución geográfica y se consideraron los criterios de conservación propuestos por la IUCN Lista Roja de las Especies Amenazadas (IUCN 2012). Para lo anterior se evaluó el área de ocupación (AOO), donde se calculó una celda de 2 x 2 km para cada punto de presencia de cada especie (IUCN 2016; Willis et al. 2003). El índice AOO fue estimado utilizando el programa GeoCat (Bachman et al. 2011).

Resultados y Discusión

Los bambúes herbáceos de México están representados por tres géneros (*Cryptochloa*, *Lithachne* y *Olyra*) y cuatro especies, que crecen por debajo de los 1300 m de altitud en selvas altas, selvas medianas y bosques mesófilos de montaña (Ruiz-Sanchez et al. 2015). Siendo *Cryptochloa strictiflora* el bambú herbáceo más pequeño de México, ya que solo mide unos 20 cm de altura y se encuentra exclusivamente en las selvas altas de México a una altitud no mayor a los 900 m (Ruiz-Sanchez y Clark 2018). Los bambúes leñosos de México están representados por ocho géneros y 52 especies. Los géneros que solo están representados por una solo especie son: *Arthrostylidium*, *Aulonemia* y *Merostachys*. *Rhipidoclaum* esta representado por cuatro especies, *Olmeca* por cinco especies, *Guadua* por siete especies, *Otatea* por 11 especies y *Chusquea* por 22 especies (Cuadro 1). (Ruiz-Sanchez et al. 2015, 2017, 2018a, Ruiz-Sanchez y Castro-Castro 2016).

Ruiz-Sanchez et al. (2015), reportaron para México 54 especies de bambúes nativos, sin embargo la cifra aumentó a 56 especies, por la descripción de *Otatea nayeeri* (Ruiz-Sanchez y Castro-Castro 2016) y *Chusquea septentrionalis* (Ruiz-Sanchez et al. 2017). Adicionalmente se describió *Merostachys mexicana* (Ruiz-Sanchez et al. 2018a), sin embargo esta nueva especie no aumenta la lista de especies de México, porque ya había sido considerada en el estudio de Ruiz-Sanchez et al. (2015) como *Merostachys* sp.

De las 1650 especies de bambúes descritas hasta la fecha, tan solo 45 de ellas son consideradas de importancia económica (Benton 2015). De esas 45 especies, solo tres son especies nativas de América (*Guadua angustifolia*, *G. amplexifolia* y *G. chacoensis*). Ruiz-Sanchez et al. (2018b) sugieren la inclusión en el listado de especies de importancia económica a *Guadua inermis* y *Otatea acuminata*.

Guadua inermis, tiene una distribución geográfica principalmente por la vertiente del Golfo de México, es un bambú de tamaño mediano a grande de 4 a 15 m de altura, por 4 a 10 cm de diámetro, los culmos son generalmente sólidos o de paredes muy gruesas (Cortés-Rodríguez 2000, Londoño y Ruiz 2014). Los culmos de esta especie son utilizados principalmente para la construcción de casas rurales, cercas, palapas y muebles (Cortés-

Rodríguez 2000). Trabanino y Nuñez (2014) encontraron evidencias arqueológicas del uso de *Guadua* en sepulturas mayas, posiblemente podría haber sido *Guadua inermis*. Asimismo se tiene registro del uso de *Guadua inermis* en Oaxaca en la construcción de muros de "bajereque."

*Otatea acuminat*a, es la especie más utilizada en México, se distribuye principalmente por la vertiente del Pacífico y la parte central de México hasta Veracruz. Es un bambú pequeño a mediano de 2 a 8 m de altura, por 1 a 5 cm de diámetro con culmos huecos o sólidos (Ruiz-Sanchez y Sosa 2010, Ruiz-Sanchez et al. 2011, Ruiz-Sanchez 2015). Los culmos de esta especie son utilizados para construir techos y paredes de casas rurales, puertas, cercos, cestería, bastones "burritas", tutores para la agricultura entre otros usos (Gúzman et al. 1984, Vázquez-López 1995, Judziewicz et al. 1999, Cortés-Rodríguez 2000, Vázquez-López 2004). Existe evidencia arqueológica de que esta especie ya era utilizada por culturas mesoamericanas (800-890 AC) para construir casas con la técnica de "bajereque" (Júarez y Márquez 1992).

Otras especies que se han registrado usos en la construcción de casas, es *Guadua aculeata* en los estados de Veracruz y Puebla. *Guadua paniculata* y *Otatea fimbriata* también fueron usadas en la construcción de muros de bajereque. Cabe destacar que Guadua aculeata es la especie de bambú más grande de México, llegando a medir hasta 20 metros, por 18 cm de diámetro. Tiene cualidades muy similares a *G. angustifolia*, sin embargo el manejo de *G. aculeata* es más intenso, ya que presenta espinas a lo largo de todo el culmo y los cuellos de rizomas que generan nuevos culmos son cortos, por lo que dificulta su extracción. Finalmente otras especies registradas para diversos usos son; *Rhipidocladum racemiflorum* es utilizado en la decoración de muebles de bambú en Veracruz y en la elaboración de cortinas decorativas, esto debido a sus culmos delgados y estilizados. En Jalisco, se utilizan o utilizaban para hacer chacaleras. *Chusquea circinata* se utiliza o utilizaba como tutor para cultivos, elaboración de canastos y ganchos para cortar fruta, esto en el estado de Jalisco. Otras especies de *Otatea*, se utilizan como ganchos para cortar fruta.

Otatea acuminata es conocida en Estados Unidos es conocida como "Mexican weeping bamboo" y es ampliamente cultivada como una especie ornamental. Sin embargo en México aún no se cultiva para este fin. El uso de bambúes nativos de México como especies ornamentales no ha sido explotado aún. Existen muchas especies que podrían ser utilizadas en jardinería, como algunas especies de *Otatea*, *Chusquea* y *Rhipidocladum*. Sin embargo es necesario iniciar con la propagación, reproducción y comercialización. Así mismo las especies nativas cultivadas de forma ornamental pueden funcionar como un doble propósito: embellecer a las ciudades y capturar el CO2 emitido por fuentes automotrices principalmente.

De las 56 especies de bambúes nativas para México, 35 son endémicas para México (cuadro 1), es decir solo habitan en este país. Esas 35 especies endémicas son todas ellas de bambúes leñosos. De acuerdo a los resultados del análisis de AOO para determinar el estado de conservación de las especies endémicas de México encontramos que ocho de ellas deberían de estar clasificadas en estado crítico (cuadro 1) y 27 en amenazadas. De las 35 especie endémicas para México, solo dos de ellas (*Olmeca recta* y *O. reflexa*) se encuentran en la categoría P (en peligro de extinción) en la Norma Oficial Mexicana (NOM-

059-SEMARNAT-2010), que enlista a las especies de flora y fauna nativa de México con algún estatus de conservación. Nuestros resultados de AOO que considera el área de ocupación, nos dice que ambas especies deberían de incluirse como especies amenazadas y no en peligro de extinción. Por lo tanto se deberían de incluir en la NOM-059-SEMARNAT-2010, 33 especies más, 9 de ellas en la categoría de estado crítico y 27 como amenazadas (cuadro 1).

Conclusiones

Dos especies endémicas a México: *Guadua inermis* y *Otatea acuminata* son las más ampliamente utilizadas en la construcción de casas con la técnica de "bajereque", para hacer cestería, tutores para cultivos entre otros diversos usos. Pobladores nativos de México pre-colombinos ya utilizaban estas especies en su vida cotidiana. Sin embargo, los usos tradicionales se están perdiendo poco a poco, por el uso de otros materiales que los han sustituido. Sin embargo, el auge de materiales ecológicos, sustentables y biodegradables, pone a los bambúes en el escenario nacional y mundial. De ahí la importancia de rescatar el uso de nuestras especies nativas. Para esto es necesario conocer la diversidad de especies que tenemos y conocer sus usos tradicionales o potenciales. Finalmente un venta de oportunidades que aún no se ha abierto, es el uso de bambúes nativos como plantas de jardinería. Esto pondría en las casas y ciudades a las especies nativas, embelleciendo las calles y jardines y capturando CO_2. Por otra parte de las 50 especies de bambúes leñosas para México, 35 son endémicas y todas ellas deberían de estar protegidas en NOM-059-SEMARNAT-2010. Ocho de ellas en estado crítico y 27 como amenazadas.

Agradecimientos

Mis sinceros agradecimientos a Guadalupe Munguía Lino por la ayuda con los análisis de AOO.

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Figure 1.
Mapa de la distribución geográfica a nivel de géneros de bambúes nativos de México.

Cuadro 1. Lista de especie de bambues nativos y endémicos de México.

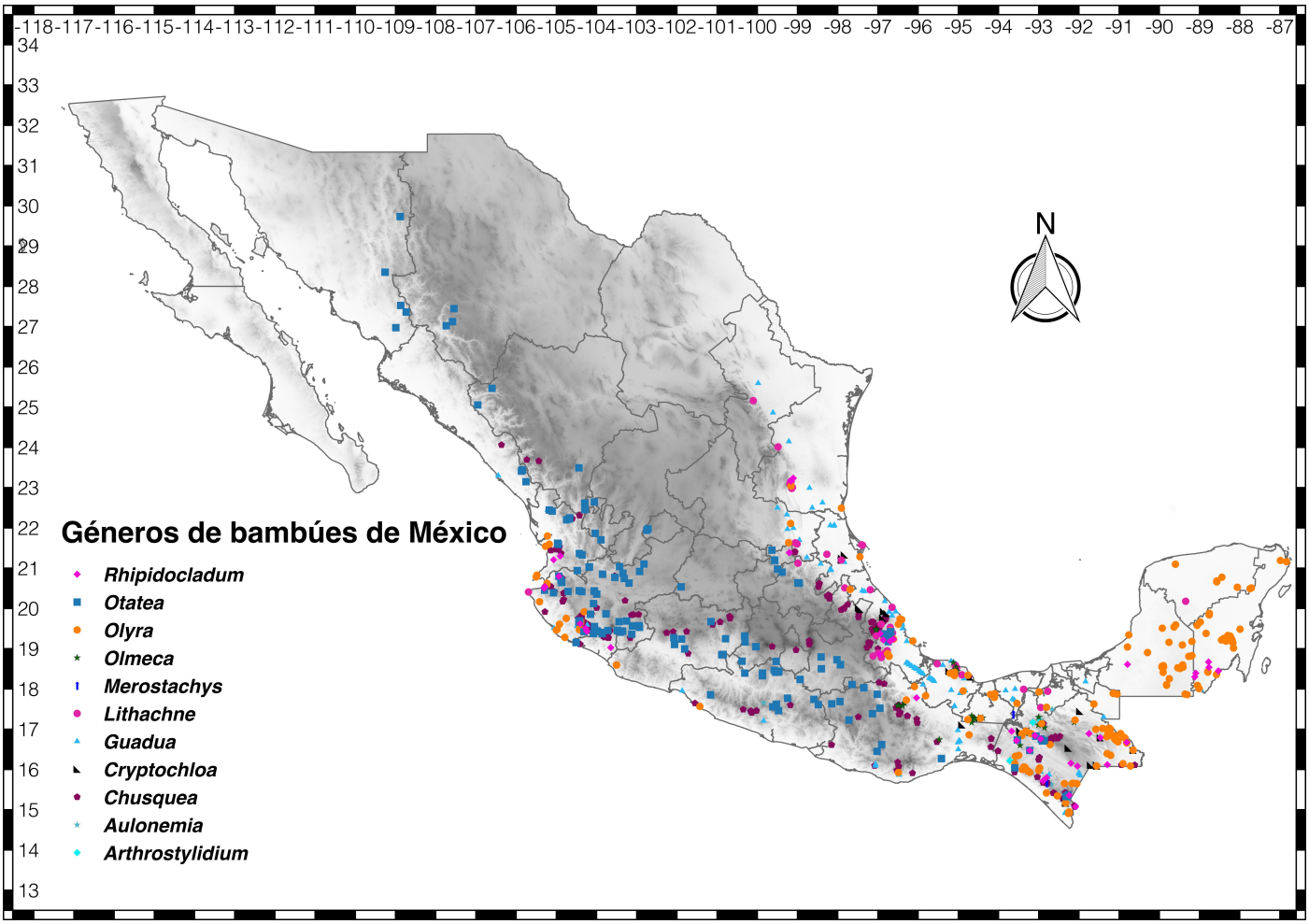
Bambúes leñosos		**Bambúes herbáceos**
!*Arthrostylidium excelsum* Griseb.	⌘**C. septentrionalis* Ruiz-Sanchez, Art. Castro & L. G. Clark	*Cryptochloa strictiflora* (E. Fourn.) Swallen
*!*Aulonemia laxa* (F. Maek.) McClure	*C. simpliciflora* Munro	!*Lithachne pauciflora* (Sw.) P. Beauv.
*!*Merostachys mexicana* Ruiz-Sanchez & L.G. Clark	*C. sulcata* Swallen	*Olyra glaberrima* Raddi
Rhipidocladum bartletii (McClure) McClure	*Guadua aculeata* Rupr. ex E. Fourn.	*O. latifolia* L.
⌘*!*Rhipidocladum martinezii* Davidse & R.W. Pohl	*G. amplexifolia* J. Presl.	
Rhipidocladum pittieri (Hack.) McClure	*!*G. inermis* Rupr. ex E. Fourn	
Rhipidocladum racemiflorum (Steud.) McClure	*G. longifolia* (E. Fourn.) R.W. Pohl	
*!*Chusquea aperta* L.G. Clark	*G. paniculata* Munro	
*!*C. bilimekii* E. Fourn.	*!*G. tuxtlensis* Londoño & Ruiz-Sanchez	
**!*C. circinata* Soderstr.	*!*G. velutina* Londoño & L.G. Clark	
C. coronalis Soderstr.	*Olmeca clarkiae* (Davidse & R.W. Pohl)	

	Ruiz-Sanchez, V. Sosa & Mejía-Saulés	
*!*C. cortesii* L.G. Clark & Ruiz-Sanchez	*!*Ol. fulgor* (Soderstr.) Ruiz-Sanchez, V. Sosa & Mejía-Saulés	
⌘**C. enigmatica* Ruiz-Sanchez, Mejía-Saulés & L. G. Clark	*!*Ol. recta* Soderstr.	
*!*C. galeottiana* Munro	*!*Ol. reflexa* Soderstr.	
*!*C. gibcooperi* Ruiz-Sanchez, Mejía-Saulés, G. Cortés & L. G. Clark	⌘**Ol. zapotecorum* Ruiz-Sanchez, V. Sosa & Mejía-Saulés	
*!*C. glauca* L. G. Clark	*!*Otatea acuminata* (Munro) C. Calderón & Soderstr.	
C. lanceolata Hitchc.	⌘**O. carrilloi* Ruiz-Sanchez, V. Sosa & Mejía-Saulés	
C. liebmannii E. Fourn.	*O. fimbriata* Soderstr.	
C. longifolia Swallen	⌘**O. glauca* L.G. Clark & G. Cortés	
*!*C. matlatzinca* L. G. Clark & Ruiz-Sanchez	*!*O. nayeeri* Ruiz-Sanchez	
*!*C. muelleri* Munro	⌘**O. ramirezii* Ruiz-Sanchez	
⌘**C. nedjaquithii* Ruiz-Sanchez, Mejía-Saulés & L. G. Clark	*!*O. reynosoana* Ruiz-Sanchez & L.G. Clark	
*!*C. nelsonii* Scribn. & J. G. Sm.	*!O. *rzedowskiorum* Ruiz-Sanchez	
*!*C. perotensis* L. G. Clark, G. Cortés & Cházaro	**!*O. transvolcanica* Ruiz-Sanchez & L.G. Clark	
C. pittieri Hack.	*!*O. victoriae* Ruiz-Sanchez	
*!*C. repens* L. G. Clark & Londoño	*!*O. ximenae* Ruiz-Sanchez & L.G. Clark	

* Especie endémica de México

⌘ Especie propuesta para incluirla en la categoría de estado crítico

! Especie propuesta para incluirla en la categoría de amenazada


-118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107 -106 -105 -104 -103 -102 -101 -100 -99 -98 -97 -96 -95 -94 -93 -92 -91 -90 -89 -88 -87
34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13
N
Géneros de bambúes de México
Rhipidocladum
Otatea
Olyra
Olmeca
Merostachys
Lithachne
Guadua
Cryptochloa
Chusquea
Aulonemia
Arthrostylidium

Keynote Speaker

DEVELOPMENTS IN STRUCTURAL DESIGN STANDARDS WITH BAMBOO

David Trujillo, MSc DIC CEng MIstructE
Senior Lecturer (School of Energy, Construction and Environment, Coventry University, UK)
david.trujillo@coventry.ac.uk (corresponding author)

Abstract
Structural design standards and codes emerged over 100 years ago. Their development has been supported by multi-billion dollar industries. Efforts to develop codes and standards for bamboo started in the late 20th century, but only until the early 21st century did the first design codes emerge. Most of these have quite limited application. Two codes stand out in this field: chapters E.7 and G.12 to the Colombian design code. More recent efforts within ISO and supported by INBAR have taken place, these include a revised ISO 22157 and the new ISO 19624. Development of standards and codes is a slow and costly process, efforts need to be coordinated and pooled in order to make the best use of limited resources.
Keywords: standards, codes, bamboo, INBAR, ISO

The origin of standards

Structural design standards, or codes (either term will be used interchangeably in this paper), emerged at the beginning of the 20th century (Addis, 2007) when countries developed the need to standardise the design procedures for steel-frames and reinforced concrete structures. According to Addis (2007), national standards collected three types of information:

- *"Properties of materials, including the quality of their manufacture*
- *The various loads that building structures should be designed to carry*
- *Codes of design practice that provided suitable methods for designing the various structural elements of buildings – columns, beams, floors and shear walls – and the connections between them."*

In the case of the UK, the birth of the *Institution of Structural Engineers* is directly linked to the process of trying to standardise the procedures for the design of reinforced concrete (Addis, 2007). The development of standards permitted breaking the monopoly over reinforced concrete that the first inventors had, allowing any engineer to design with it, and allowed the authorities to check the designs to ensure their safety (Bussell, 1996).

It is important to note that these standards emerge as a need to address the technological developments of framed structures that were much taller than anything that preceded them. Prior to the emergence of standards, designs were done on the basis of published material (e.g. textbooks). Committees of code writers have typically consisted of representatives of the product manufacturers, representatives of the structural designers and researchers (Addis, 2007). Development of codes and standards is a slow and lengthy process, it requires a compromise between the parties and needs to be underpinned by extensive experimental research, which is expensive.

It is worthwhile remembering that the industries behind steel, concrete, and even timber, are gigantic. In 2016, the global market for steel was USD 807 billion (grandviewresearch.com), whereas for cement it was USD 395 billion (statista.com), and for forest products it was USD 227 billion (FAO). Bearing in mind the size of these industries, it is evident that they have had, and continue to have, the financial capacity and political influence to ensure that the research required to develop the standards was funded. Structural and material researchers all over the world still remain committed to further improving these materials and the design methods that ensure their economical use.
In contrast, according to INBAR (2012), the export of industrialized bamboo products in 2012 was USD 539 million (roughly 1500, 700 and 400 times smaller than the steel, concrete and timber industries respectively). Research into the structural properties of bamboo is also much younger and more sparsely undertaken. Bearing this in mind, it is quite remarkable that any progress has been made in the process of development of standards and codes for the structural use of bamboo.

Code and standard development of bamboo: a brief history

The first standard aimed at understanding the mechanical properties of bamboo was 'IS:6874 – Methods of tests for round bamboos' which was introduced by the Bureau of Indian Standards in 1973 (BIS, 1973). In the late 1990s, Dr Jules Janssen from Eindhoven University of Technology led the development of a series of test standards for round bamboo in the name of the International Network for Bamboo and Rattan (INBAR). These INBAR 'standards', as they would become known, were based on IS:6874 and formed the basis of 'ISO 22157-1 Bamboo – Determination of physical and mechanical properties – Part 1: Requirements', and 'ISO 22157-2 Bamboo – Determination of physical and mechanical properties – Part 2: Laboratory manual', which were published in 2004 by the International Organization for Standardization (ISO). Another strand in bamboo testing emerged from China under the name of JG/T 199-2007 'Testing methods for physical and mechanical properties of bamboo used in buildings'.

To the author's knowledge the first document enabling the use of bamboo as a structural material is the International Conference of Building Officials' "AC 162 - Acceptance for Structural Bamboo" published in California in 2000. The document contains the skeleton of a standard, providing even factors of safety to be used to derive Allowable Stresses. In terms of derivation of mechanical properties, it refers the user to the INBAR 'standards' and numerous ASTM standards. In reality, a standard that requires the user to undertake numerous tests is of very little value to most applications.
Arguably the first fully fledged standard that provided guidance and design values for the use of bamboo as a structural member was Colombia's chapter E.7 of the national seismic design code NSR-98, which was published as an addendum in 2002. The name of this chapter roughly translates "cement-rendered *bahareque* one and two storey houses". "*Bahareque*" is the name given to a broad range of wall construction techniques that combine a bamboo (and/or timber) stud wall with a cladding product. Traditionally the cladding consisted of flattened bamboo rendered with a mixture containing soil and horse-dung. Variations to the technique included infilling the wall with more soil. The technique is not too dissimilar to wattle-and-daub. The adoption of *bahareque* in the Coffee-growing region of Colombia obeyed to the high seismicity of the region (Robledo, 1996). Eventually,

with the arrival of cement in the early 20th century, cement mortar was used as the cladding product of choice for its superior performance and durability.

The 1999 Coffee-growing region earthquake of Colombia, acted as a reminder of the superior performance of both traditional and modern *bahareque*, in terms of earthquake resistance, particularly when compared to unreinforced masonry (Macdonald, 1999). During the reconstruction of the Coffee-region several national and international NGOs selected modern *bahareque* as the structural system of choice. Similarly, the Fund for the Reconstruction of the Coffee-growing Region (FOREC) commissioned the development of a code and a handbook to promote and enable its further adoption. The essence of the work is contained in (López and Silva, 2000; and Farbiarz, 2001).
This standard has acted as the template for Peru's E.100, Ecuador's NEC – SE – GUADÚA and the Andean standard (INBAR, 2015). It has also influenced similar developments taking place in Mexico and the Philippines. However, the 2002 version of chapter E.7 limits the role of bamboo to that of a component within a system. It contains no guidance on beam design, and very limited and prescriptive values for column and connection design. Chapter E.7 is a standard that enables the use of bamboo in structures, provided it is part of a modern *bahareque* system.

In 2004 ISO also published 'ISO 22156 Bamboo – Structural', which has the merit of being the first international standard and as such drew from the experience of numerous experts from across the world. In a similar manner to AC 162, it provides factors of safety, procedures to determine characteristic values and discusses design philosophy and precautions. However, it does contains barely any design equations and no mechanical properties. In a similar manner to AC 162, a user is required to undertake significant testing in order to obtain design values. Also in 2004, the Bureau of Indian Standards published Part 6, Section 3B – Bamboo within the National Building Code of India, which contains some important developments such as proposing a grading system, containing some mechanical properties for 20 species of bamboo, and Safe Working Stresses for 16 species – although only compressive strength, modulus of rupture and modulus of elasticity are listed. However, it does not contain any connection design values or specific procedures to design columns, shear walls, or beams, and bizarrely for a code, it contains very few equations. A user would struggle to design anything more complex than a simply supported beam.

In 2010 arguably the most comprehensive and developed standard for structural design with bamboo was published as chapter G.12 within the Colombian NSR-10. This code contains some visual grading guidance, factors of safety, a process to derive characteristic values, mechanical properties (albeit only for Colombian *Guadua angustifolia Kunth*), design procedures for beams and columns, some design values for connections, and, by linking it to chapter E.7, shear wall strength values. Chapter G.12 is not without fault or omission, for example, the procedure for the determination of connection design values is opaque and the listed moduli of elasticity values are peculiar, nevertheless, it is arguably the first standard in the world that would allow a user to undertake the complete structural design of a bamboo building.

Current developments within ISO and INBAR Task Force

In September 2013 INBAR attended the annual meeting of ISO Technical Committee 165 in Stuttgart, with the purpose of reactivating the ISO standards work that had delivered ISO 22156 and ISO 22157 nearly a decade earlier. At this meeting 'Working Group 12 – Structural Use of Bamboo (WG12)' was created. WG12 contains experts from Colombia, the United Kingdom, the United States of America, China, the Netherlands and Ecuador, amongst others. WG12 started with two proposals, revising ISO 22157-1, so that it contained a test to determine the tensile strength perpendicular to the fibres for bamboo, and writing a brand new standard for the grading of bamboo.

In parallel to this development, INBAR launched in 2015 the Bamboo Construction Task Force. The INBAR website states that the Task Force "*coordinates the activities of international research institutes and commercial companies interested in the structural uses of bamboo"* (INBAR, 2018), and it does so by linking individuals who are experts in the field. The intention is to pool and coordinate the isolated and disparate efforts occurring throughout the world. The objectives of the Task Force are:

- *"Help drive and refine the development of new international standards on the structural uses of bamboo and review and update existing international standards*
- *Support global coordination and knowledge dissemination on sustainable bamboo construction*
- *Facilitate the development of pro-poor methodologies for designing and constructing sustainable bamboo housing*
- *Strengthen the capacity of construction sector stakeholders in sustainable bamboo housing*
- *Raise awareness and advocate for bamboo construction being mainstreamed in national housing policies and regulations."*

(INBAR, 2018)

As noted in the first objective, the Task Force engages itself with the development of standards, and as such it has acted as the incubator for the new generation of ISO bamboo standards.

ISO 19624 Bamboo structures — Grading of bamboo culms — Basic principles and procedures

What is grading? ISO 19624 defines grading as:
"(…) the process of sorting every piece of bamboo in a sample into grades according to defined selection criteria. The criteria identify dimensional, visual, geometric, mechanical and/or physical properties that reflect the bamboo's mechanical strength or structural capacity and may affect the utility of the product."

In timber, grading is frequently referred to as strength, or stress, grading, which alludes to the fact that grading is done on the basis of the material's strength. Because bamboo does not come in regularised sizes, it may be necessary to adopt alternative grading procedures. ISO 19624 is not prescriptive about what these procedures should be it simply acts as a framework under which grading procedures could be developed. Grading can be aligned to the source material (i.e. the bamboo species and plantation) or the end application i.e. what do we want to use it for. Grading in timber is typically undertaken either visually or

mechanically (machine grading). ISO 19624 proposes a framework for either of these methods. INBAR's Working Paper 79 (Trujillo and Jangra, 2016) and Trujillo et al. (2017) expand on the work behind this standard.

ISO 22157 Bamboo structures — Determination of physical and mechanical properties of bamboo culms — Test methods

During the aforementioned process of revising ISO 22157, it was decided that it was probably best to rewrite the whole document. In the process it was greatly simplified, two mechanical tests were added, one physical test was removed (shrinkage) and greater consideration was given to the procedures to ensure adequate accuracy and precision. Consideration was also given to the process of homogenisation, which is that all ISO standards are similar. The outcome is a standard that is more closely aligned to modern timber testing standards, yet making allowance for technological limitations that some bamboo researchers may have, and is written in such a way that it complements well ISO 19624.

ISO 22156 Bamboo – Structural Design

In many developing countries steel, concrete and timber codes are a straight adoption or adaptation of codes written in developed economies. Code drafting is an expensive and slow process. Awaiting for every country to develop their own standards will slow the adoption of bamboo. As outlined earlier, since the first version of ISO 22156 was published in 2004, significant developments have taken place in terms of code development and research throughout the world. It was therefore deemed necessary to update ISO 22156, and change it from a code about design philosophy to a template standard that could be adopted by different countries according to their species and practices.

The new version of ISO 22156 will aligned to the new ISO bamboo standards ISO 19624 and ISO 221577, but will continue to borrow from timber standards in terms of derivation of characteristic values, connection testing and shear wall testing. These standards are well suited for the testing of any natural ligno-cellulosic material and are not prescriptive in terms of element shapes or sizes.

In many other respects, ISO 22156 will pick up where G.12 left off.

ISO/NP 23478 – Bamboo structures — Glued laminated bamboo — Test methods for determination of physical and mechanical properties

It is important to note that due to its circular hollow section and range of available sizes, the scope of possible structural applications for bamboo culms is limited. Instead, the scope for Engineered Bamboo Products (EBPs) is much larger. EBPs are a regularised and standardised product that can be engineered to be more durable and fire resistant than bamboo culms. EBPs also hold the promise of job creation in rural communities.

Members of the INBAR Task Force deliberated about the best way to promote the development of structural EBPs, and concluded that standardisation was needed at an international level, and that the starting point was the development of a testing standard for laminated bamboo elements for structural applications. The alternative of simply adopting timber testing standards was studied deemed inappropriate. As from September 2018 a new standard was been initiated within TC 165 with this purpose.

Final thoughts

Standards need to be supported by reliable and verifiable data. Structural testing is expensive because it requires undertaking numerous tests of full-scale elements. Structural testing of a natural material has the added requirement of undertaking large number of repetitions to account for variability. Testing facilities in developed countries are far away from the resource, which increases transport costs and may result in limiting sample size. It also limits experimental work with bamboo to dry specimens and may affect controlling for origin i.e. it is difficult to know how the material was sourced and where. Testing facilities in middle-income countries are mostly adequate and close to the resource, but all too often there is little know-how about timber engineering research, so technology transfer is hindered. This tends to hinder the implementation of processes such as conditioning, control of moisture content, loading rates, etc. Testing facilities in low-income countries, are frequently inadequate for the rigours of modern data generation, it may well be too that researchers are not familiar with timber engineering or recent developments. These set of circumstances result in insufficient good quality data to underpin the development of standards.

The normal path towards acceptance of data is academic publishing, which is time consuming and requires a great deal of effort and expertise. Without peer-reviewed publication of the experimental work, it is unlikely that bamboo research will be taken seriously.

Development of standards is expensive, particularly ISO standards, as they require a lot of travel, and we have no large multinational to bank-roll our efforts. National standards may result in isolated efforts that do not necessarily reflect the technological advances made elsewhere in the planet, or the latest thinking. To an extent it is analogous to returning to the early 20th century.

Structural engineering is a profession with a very large social responsibility: an error could be fatal. Most structural engineers are understandably risk averse. Young generations of engineers are educated to expect standards and codes to meet a certain set of requirements. If bamboo standards do not meet their expectations or require an engineer to make a lot of judgements, it is likely that they will not be implemented.

The solution to these problems is cooperation. Future structural research needs to be rigorous, planned and coordinated, and centred around the needs of standardisation.

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Keynote Lecture

ECOPLANET BAMBOO

Troy Wiseman, CEO and Co-Founder/ twiseman@ecoplanetbamboo.com

Founded in 2010 and with current operations spanning six countries, EcoPlanet Bamboo's mission and vision is for bamboo to be a tool for reducing deforestation of the world's remaining natural forests, while restoring thousands of hectares of degraded land in some of the poorest parts of the planet. Seven years on, EcoPlanet Bamboo's commercial reforestation projects have laid a framework for bamboo to truly become the first plant whose industrialization leads to reforestation and a regeneration of degraded land, rather than contributing towards a loss of natural resources.

During this keynote session EcoPlanet Bamboo CEO Troy Wiseman will provide a snapshot of the company's steps towards achieving this goal, and its pioneer role in industrializing bamboo outside of China and as a viable alternative fiber for major timber and wood based industries. Utilizing examples from the company's models in operation across Latin America and Africa, the range of barriers to the commercialization of bamboo will be highlighted, as well as the mechanisms employed by EcoPlanet Bamboo in overcoming them.

EcoPlanet Bamboo's projects have followed the strictest of sustainability frameworks. The company has internal policies restricting its use of land to the most degraded within each country of choice, despite the significantly increased cost of operations to achieve this, as well as the extended time for the bamboo to achieve maturity. The long-term nature of these projects has provided ample opportunity to gather rigorous scientifically backed data on the silviculture and ecology of the species under production.

Following the origination and implementation of commercial bamboo reforestation projects in Nicaragua and South Africa, the company expanded its scope to technology development, following a desire to ensure that any manufacturing process that absorbed its sustainable and certified raw fiber. Tech development has spanned multiple markets and products, from activated carbon to biofuels, but EcoPlanet Bamboo has settled on pulp and paper as being the core market within which it believes its network of decentralized and integrated facilities can have the most significant impact in disrupting a current global industry.

This bamboo bio-economy model allows the targeted region or nation to gain independence on a key market sector that experiences high growth during periods of high economic development, reducing spending on foreign imports and driving truly green growth.

With the frameworks, knowledge, and experience on both the bamboo reforestation and the technology and manufacturing sides now secure, EcoPlanet Bamboo has spent the past 12 months putting in place a pipeline of additional projects, expected to generate an additional 22,000 acres of high yielding, sustainably managed bamboo resource during the next five-year period.

Conferencia magistral

ECOPLANET BAMBOO
Troy Wiseman, CEO y Co-Fundador/ twiseman@ecoplanetbamboo.com

Fundada en 2010 y con operaciones actuales en seis países, la misión y visión de EcoPlanet Bamboo es que el bambú sea una herramienta para reducir la deforestación de los bosques naturales restantes del mundo, mientras restaura miles de hectáreas de tierras degradadas en algunas de las partes más pobres del planeta. A siete años, los proyectos de reforestación comercial de EcoPlanet Bamboo han establecido un marco para que el bambú se convierta verdaderamente en la primera planta cuya industrialización conduzca a la reforestación y a la regeneración de tierras degradadas, en lugar de contribuir a la pérdida de recursos naturales.

Durante esta sesión magistral, el CEO de EcoPlanet Bamboo, Troy Wiseman, proporcionará una visión instantánea de los pasos de la compañía hacia este objetivo y su papel pionero en la industrialización del bambú fuera de China y como fibra alternativa viable para las principales industrias de madera y madera para construcción. Utilizando como ejemplo los modelos de compañías que operan en América Latina y África, se resaltará la gama de barreras para la comercialización de bambú, así como los mecanismos empleados por EcoPlanet Bamboo para superarlas.

Los proyectos de EcoPlanet Bamboo han seguido los más estrictos marcos de sostenibilidad. La compañía tiene políticas internas que la restringen de hacer un uso degradado de la tierra dentro de cada país de su elección, a pesar de que esto represente un costo significativamente mayor de las operaciones, así como una prolongación del tiempo necesario para que el bambú alcance su madurez. La naturaleza de estos proyectos a largo plazo ha brindado amplias oportunidades de recopilar datos con un respaldo rigurosamente científico sobre la silvicultura y la ecología de las especies en producción.

Siguiendo el origen e implementación de proyectos de reforestación de bambú en Nicaragua y Sudáfrica, la empresa extendió su alcance al desarrollo tecnológico, con el deseo de garantizar a cualquier proceso de manufactura, que absorba su fibra cruda sostenible y certificada. El desarrollo tecnológico ha abarcado múltiples mercados y productos, desde carbón activado hasta biocombustibles, pero EcoPlanet Bamboo ha establecido a la pulpa y el papel como el mercado central, cuya red de instalaciones descentralizadas e integradas, cree que puede tener el impacto más significativo para la disrupción de una corriente industria global.

Este modelo de bioeconomía de bambú permite a la región o nación objetivo ganar independencia en un sector clave del mercado que experimenta un alto crecimiento durante los períodos de alto desarrollo económico, reduciendo el gasto en importaciones extranjeras e impulsando un crecimiento verdaderamente ecológico.

Con los marcos de trabajo, el conocimiento y la experiencia, tanto de la reforestación de bambú como de la tecnología y la fabricación, ahora seguras, EcoPlanet Bamboo ha pasado los últimos 12 meses implementando una serie de proyectos adicionales, que se espera generen 22,000

acres adicionales de alto rendimiento, recurso de bambú sosteniblemente manejado, durante el próximo período de cinco años.

Keynote Lecture

100 YEARS OF TIGER BAMBOO
- THE UTILIZATION OF SUSTAINABLE LOCAL RESOURCES

Yoshihiro Yamagishi / yondaime@taketora.co.jp

Good afternoon. I am Yoshihiro Yamagishi from Japan, the president of a Japanese bamboo product company. I am truly grateful for this opportunity to talk to you today.
First, I would like to tell you about my company, Taketora. Founded in 1894, the company has been specializing in tiger bamboo crafts for 124 years. I am the fourth generation of this family business. We are the sole trader dealing with tiger bamboo in Japan.

A unique form of Japanese bamboo - Toratake
Distinct from wood or grass, bamboo has the special advantage of being strong but flexible. Since bamboo is available nearby and easy to process, it has been used for daily goods, tools, crafts, building materials, and as food. Bamboo is found in regions with a mild, humid climate, such as Southeast Asia, Australia, Latin America and Africa. It is said that there are 1,300 species of bamboo in the world and some 600 of them grow in Japan. Nevertheless, only three species are widely utilised. The three most commonly-used species are moso bamboo, madake bamboo and hachiku bamboo. Tiger bamboo, the one we deal with, is extremely rare.

Tiger bamboo is officially called “Tosa torahu take”. It is (thought to be) a variety of hachiku bamboo. An unusual characteristic of tiger bamboo is the mottled, tiger –like pattern on its surface. It grows only in a valley in my hometown, Awa, part of Susaki city, in Kochi prefecture. With a width of 1.5 kilometres, it naturally grows from the foot to the top of the mountain valley. Strangely enough, however, not a single tiger bamboo is seen beyond the peak. The world-famous botanist from Kochi, Tomitaro Makino, named the bamboo “Toratake” in 1916. However, the bamboo was well-known among locals long before it was given the official name. Historical documentation says that, in the Edo era, tiger bamboos were presented to the feudal lord of Tosa as the land tax payment instead of rice.

The colours and patterns of tiger bamboo are entirely natural; therefore, they can be quite different from one another. Some have patterns all over, and others have no clear patterns and look like normal hachiku bamboo.
The cutting period of tiger bamboo is from early September to the end of January. This period is fixed for the purpose of quality control. We cut them only during this period. After

cutting we sort the bamboos carefully, checking their colours one by one as each one of them is distinctive.
Why does tiger bamboo have such patterns in the first place? Some university researchers suggest that it could be the work of fungus in the soil peculiar to this area. A definitive answer has yet to be found. Some mountain specialists who have been cutting tiger bamboo for many years say that it may be a result of the combination of sea breeze, sunshine and temperature. We have a botanical garden named after Dr Tomitaro Makino in Kochi. There, I saw a map of Kochi prefecture's geological features. The colour was different where tiger bamboo grows, showing that the soil there was unique. This unique soil may have something to do with the unusual quality of tiger bamboo.
Personally, I feel that it is the miraculous result of various natural factors. Whatever the cause may be, the tiger patterns on the bamboo are curiously absent when it is transplanted elsewhere.

As tiger bamboo is a kind of hachiku, the surface looks powder-coated. Contrary to its appearance, bamboo is, in fact, an oil-rich plant; therefore, when heated by a gas burner at 700 degrees Celsius, oil comes to the surface. After the oil is wiped away by cloth, tiger patterns clearly emerge along with a beautiful gloss. Our customers sometimes ask if some sort of paint is applied, but the shine is entirely natural, caused by the oil from the bamboo itself.

It is nearly 30 years ago that the BBC came to Awa for footage. In addition to some attention from foreign media, we have made some collaborative products with a famous fashion brand. This is not only because tiger bamboo is rare and beautiful. It is part of a long history in bamboo crafts and reaches people nationwide. Tiger bamboo is interwoven with people's lives, in the form of indispensable everyday goods.

2. Our challenges
In general, moso bamboo blooms at the same time once every 60 years, and the madake and hachiku bamboos bloom every 120 years. However, a small-scale partial blooming of bamboo can be seen occasionally. The flowers are just like rice flowers, and so we can clearly see that bamboo is part of the rice family. Rice farming occurs throughout Japan, producing delicious brand rice such as koshihikari and sasanishiki. This is thanks to abundant clean water and the mild climate with four distinct seasons. A suitable natural environment for quality rice is equally good for bamboo. That is why Japan has some of the best quality bamboo in the world.
Bamboo grows rapidly, reaching a full size of around 20 meters in about three months. After three years, we can use it for materials. In famous folklore, "The Tale of The Bamboo Cutter", the heroine was born from bamboo and became fully grown in three months, just

like bamboo. The author of the story is unknown; the story evolved from the lives and culture of everyday people, illustrating the deep, enduring connection between bamboo and the lives of Japanese people.

Due to its rapid growth, bamboo is considered to be the only renewable plant resource that is both practical and easily sustainable. Since 1985, our company has repeatedly claimed that “the 21st century is the age of bamboo” because we believe in the unlimited possibility of bamboo. Its potential lies not only in its renewability but also in its potential for antibacterial action, deodorisation and healing. Sadly, however, effective utilisation of these properties has yet to be fully explored.

Plastic products started appearing in the middle of 1950s, and have come into wide use since then, taking the place of bamboo. As a result, bamboo products are rapidly disappearing from the Japanese lifestyle.
Our company has held a summer internship every year since 2000. One time, I was surprised to learn that a participant did not know of “Aodake-fumi”. This simple semi cylindrical health product, made from a length of bamboo cut in half, helps relieve fatigue or swollen legs simply by treading on it. It has been a regular household item in Japan for generations, so I was shocked to hear that the student had never seen one. Deeply-rooted bamboo culture, part of our lives for so many years, has been disappearing over the past few decades.
Our company now offers a bamboo grove visit to address this lack of familiarity with bamboo. To my surprise, young people who live in the countryside have hardly ever stepped into a bamboo grove. Even among people in their 50s or 60s, there are those who have never set foot in a bamboo grove. This is the present situation in Japan.

Anyone who visits our tiger bamboo grove feels relaxed. There are smiles accompanied by a sense of calm. Every time I see such smiles, I feel the connection between the Japanese people and bamboo. I think Japanese people have a deep-seated nostalgic fondness for bamboo, but they just do not realize it. It is like something they have forgotten.
On our mountain, many paths lead us to the tiger bamboo grove like capillary vessels. These are the same paths that my father walked, my grandfather walked, and my great-grandfather walked. I am proud of the fact that these narrow paths have been used for over 100 years and are still used for transporting the bamboo. Even though they look like ordinary mountain paths, they are our lifelines supplying tiger bamboo every year. They are the treasure that we must protect.

The carefully-tended bamboo grove of ours is not a farm for bamboo shoots. Our bamboo is used for materials to be processed as bamboo goods. Nowhere else in Japan can such a

beautiful bamboo grove be seen. Our challenge is how to deal with tiger bamboo and maintain its culture as a valuable local resource in the next 100 years.

3. The only bamboo electric vehicle, Take-Tracker

With our challenging task in mind, we needed a breakthrough to transform the situation. We wanted the younger generation to know about bamboo. We wanted people to realise the potential of bamboo. That is the reason why we made the first electric car with a bamboo body, the Take-Tracker.

There are a few significant aspects in making a bamboo car. Firstly, it is mobile. Usual bamboo goods are of course immobile and to see tiger bamboo, people need to come all the way to the only habitat, in Kochi, Japan. But a bamboo car enables us to visit customers. It may attract the attention of people who had no interest in bamboo before. Secondly, with a bamboo car, we can demonstrate the advantages of bamboo effectively. Bamboo is often used to make rulers, since it is quite hard and remains straight. However, the same material becomes flexible when it is split and peeled into thin slices; as a result, it can be bent into gentle curves. Bamboo is a fantastic material which can be hard or soft depending on requirements. The Take-Tracker is an ideal demonstration of this unique versatility and our traditional skills. Bamboo as a practical material enables the car to run at the 50 km/h, with two adults inside.

We wanted a lot of people to take part, so we opened a crowdfunding campaign for our Take-Tracker project. Then, as we promised to our contributors, we carried out a trial named "Challenge Run Yokohama". We attempted to run the Take-Tracker 1,000 km from our home Awa, in Kochi, to Yokohama in 11 days. Take-Tracker's battery only allows the car to keep running for two hours, then it takes six hours to recharge it. So, we repeated a two-hour run and six-hour recharge pattern, again and again, day after day. Thanks to the support from convenience stores along the route, we coordinated with three stores each day to charge the battery and relayed from one convenience store to another for 1,000 km from Kochi to Yokohama. It was a tough run, but I believed in my craftsmen's skill and the tiger bamboo. We made it. After 1,000 km, the woven bamboo was not loosened or deformed.
Take-Tracker completed the challenge run as scheduled and proved its strength and potential.

This trial had another important message to convey, which is a warning against global warming.

There is an old saying in my hometown; "When the frost comes, tiger bamboo patterns become clearer". I did not pay much attention to this saying when the bamboo harvest was abundant decades ago, but recently the tiger patterns have been fading. Even though Kochi

is well known as a warm place in Japan, when I was a child it snowed enough to have snowball fights.
Since the global warming issue became apparent, it has been noticeable that the temperature does not drop as much as before. Perhaps this change and the fading tiger patterns have some connection.

To be honest, climate change used to feel like an abstract concept to me. However, having seen the changes in the nearby mountains around our bamboo grove, I feel the threat more closely. If the warming of the earth progresses, we will face the danger of losing our long-inherited bamboo culture in this area.
When I came up with the idea of a bamboo car, I only considered an electrically-powered one, as a non-emission fuel cell is most suitable for bamboo as an eco-friendly material. We wanted more people to think about global warming by looking at the Take-Tracker and considering the threat posed to the tiger bamboo.

4. For the future
Now we are facing various problems, such as environmental issues, which individuals cannot possibly solve alone. When considering such problems, I think that we have something to learn from bamboo.
Bamboo grows straight up into the sky, focusing upon its purpose without any hesitation. Bamboo is so supple that it is never broken by strong winds; it endures and persists through adversity.
And bamboos are firmly connected to each other by their subterranean stems (roots), as if to demonstrate the importance of supporting one another.
The time has come for people around the world, regardless of race or nationality, to learn some valuable lessons from bamboo.

5. Closing
Finally, I have a favour to ask of you. Please give us an opportunity to run our Take-Tracker in your town or city. We will bring the car wherever we can in order to help raise people's awareness of environmental issues. This will lead us to a better future for our home of tiger bamboo. The potential of bamboo is indeed unlimited.

Pablo van der Lugt

Booming Bamboo

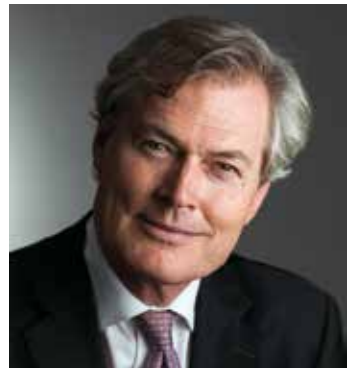
The (re)discovery of a sustainable material with endless possibilities

Keynote Els Zijlstra, Materia Exhibitions

This "leaflet" as a paper is a glimpse of the book Booming Bamboo by Pablo van der Lugt.

At the World Bamboo Congress 2018 in Mexico, Els Zijlstra, creative director of Materia and co-producer of this book will present the most important conclusions in her keynote lecture.

Foreword



The world of bamboo is fascinating, inspiring, pragmatic and yet far away. When Linda Garland, the late Queen of Bamboo, demonstrated this world of natural beauty to me, it was obvious that new life emerged in me. I could dream with my eyes wide open and wondered: “How can we ever reconcile the fact that about one billion people consider bamboo their symbol of poverty, and only a million revere bamboo as a symbol of natural art and sustainability, and perhaps only 10,000 consider bamboo their preferred choice of construction material?”

I set out on a mission to construct the largest modern-day bamboo structure and show this extravagance of nature’s engineering to a large audience: the visitors to the World Expo 2000 in Hannover, Germany. How would we convince the conservative construction engineers to grant a permit to a structure with a material and a building technique that they have never seen before?

There was only one way: science.

Thanks to Carolina Salazar and her team from Colombia we succeeded in this mission. Our ZERI bamboo pavilion, designed by Simon Velez and built in 4 months by 41 Colombian artisans, welcomed 6.4 million people, who reveled at the sight of this 14 m high pavilion that dances with the rhythm of the earth.

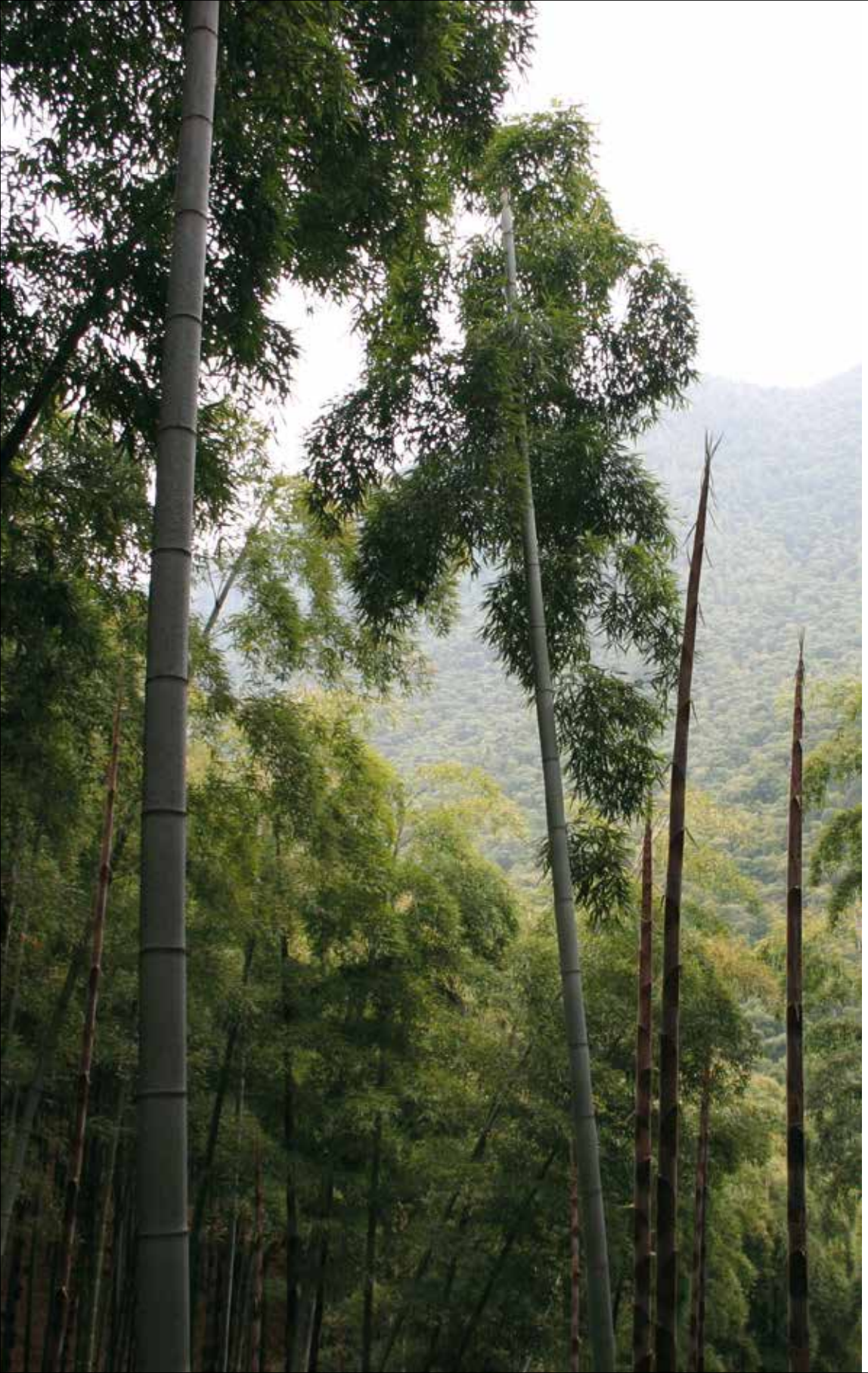
Bamboo is art combined with science and no one is left untouched by the sight of a dense bamboo forest or the marvels of a bamboo building.

It is from within this unique space of hard facts and spirit that bamboo must be understood in our present-day world of spreadsheet-based calculations with the objective to produce at an always lower cost and with an ever larger profit margin for a small number of people. If we only let the facts speak, we have insufficient logic to gather the attention for bamboo it so much deserves.

Facts are solid, since a social housing project with bamboo can provide shelter, while the land required to grow and harvest the bamboo will be cleansed and supply drinking water to the same community, offering a never-ending cycle of carbon sequestration.

But facts alone will not tip the balance: we must also open our hearts. This is why we need more bamboo ambassadors who speak from their deeper inside, who communicate through the Universe, and who ensure that tangible products are made available and can be enjoyed, both in function and with sight. Pablo van der Lugt is one of the unique players in this field. With his doctorate and engineering degrees, he incorporates the scientific perspective, but he also recognizes the wealth of bamboo beyond its mere functionality. Pablo starts from the hard facts of our predatory consumption patterns and the pervasive resource scarcity we are facing. Then he guides us through the technical details and finally opens up a world that is not only pleasing and soothing, it clearly embodies solutions our societies urgently need.

Prof. Gunter Pauli
Author ‘The Blue Economy’
Founder Zero Emissions Research & Initiatives (ZERI)



Contents

1

Material Scarcity

Because of the growing world population, overconsumption and a take-make-waste economy we are heading towards an imminent resource problem. Only through a transition to a circular economy, with an important role for renewable, bio-based materials, will we be able to safeguard resources for future generations.
This chapter explains the problem but also (part of) the solution.

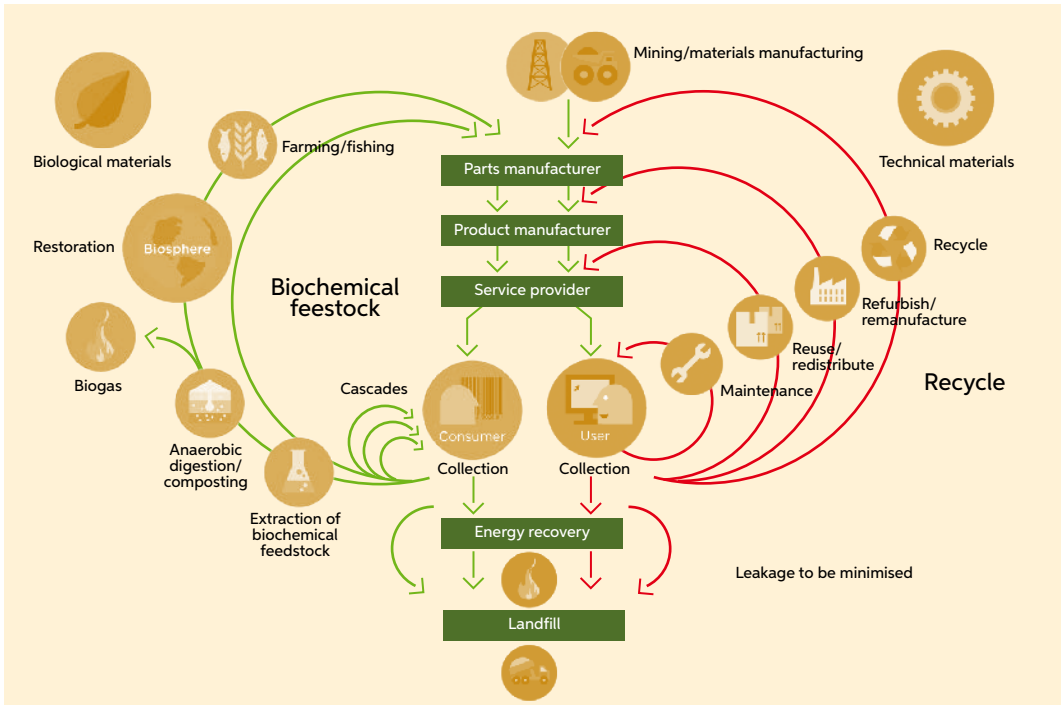
1.2
Required Transition to a Circular Economy

A New Economic Model: Designed for Circularity

As a response to increasing material scarcity, a transition from the traditional linear 'make-take-waste' production scenario to a more circular and renewable model is essential to be able to meet the needs of future generations. This explains the popularity of the Circular Economy model. [1.8] In a perfect Circular Economy, products are made using 100% renewable energy and are designed in such a way that their components either fit as nutrients in the biological cycle, i.e. biodegradable after use and recycled and regrown by nature itself, or in the technical cycle, i.e. non-renewable industrial materials whose finite stocks need to be secured by high-level recycling.

Although the Circular Economy model has gained a lot of momentum and is even implemented in EU Action Plans [1.9] and national policies of several EU

Figure 1.5 - The Circular Economy model [1.8]



1.3
Back to a Bio-based Economy

From the previous sections it is clear that because of consumption and population increases worldwide, in combination with our addiction to fossil-based resources, mankind is facing an imminent resource problem. Although implementing the Circular Economy principles will help extending the availability of techno-cycle materials in particular, at some point their reserves will run out, so there is only one way to go: a bio-based economy. Although the vision of a bio-based economy sounds appealing, there are some serious constraints that need to be addressed.

City hall of Venlo *(left)*
Designed by Kraaijvanger architects following Circular Economy principles, the city hall of Venlo features a lot of bio-based materials in the interior and exterior.

Limitations of Bio-based Materials

Although there are many benefits in using bio-based materials, there are also clear limitations. If exploitation related to demand is higher than can be reproduced naturally, this also leads to depletion. This applies in particular to hardwood, mainly from tropical regions. Hardwood forests will remain susceptible to deforestation because of their slow growth and long rotation cycles in combination with high demand because of the good technical performance of hardwood. For softwood from temperate regions this is not the case. The net area of forests in the Northern hemisphere is actually increasing, albeit slowly, see figure 1.8 and 1.9. Nevertheless, the hardwood example shows that also regrowable resources have their limitations because of potential overexploitation and competition with other land uses (agriculture, cattle land, infrastructure, etc.), especially in tropical regions.

Substituting Techno-Cycle Materials: Making the Right Decisions

The above makes clear that fully switching to wood or other bio-based materials is not yet an option. First, production capacity needs to be increased by investing in new, sustainably managed production forests worldwide (reforestation). This will also help capture more carbon for climate change mitigation, see also box 1.2 ‘Bio-based Materials in the Global Carbon Cycle’. Assuming that political support in favour of a bio-based economy will grow as a result of increasing material scarcity and possibly carbon taxing, where should the focus of the application of wood and other bio-based materials lie? Because of the sheer volume, substituting concrete and bricks in bearing constructions would certainly be beneficial and in that light the increasing interest in timber-frame housing is promising. Furthermore, recent large, high-rise building projects with a main bearing structure of wood show great potential, also for reducing CO_2 emissions. However, the reality is that the main components for concrete production (sand, gravel, cement) are abundantly available in the world and concrete recycling is increasing (see box 1.1).

2

Bamboo Basics

As one of the fastest growing plants in the world, bamboo is one of the key solutions to enable the transition towards a bio-based economy. This chapter explains the growth and distribution patterns of bamboo, as well as its efficient structural design in its natural form, the stem.

2.1
Bamboo, a Giant Grass

It Runs in the Bamboo Family

From a botanical point of view, bamboo belongs to the grasses, the Graminea, and is therefore not a tree. Bamboo is a collective name for a group of botanical species. Although the complete taxonomy of bamboo is still evolving, current estimations are that over 1600 different species of bamboo exist. There are considerable differences between species in size, color, node distribution and configuration, mechanical properties and climatic preferences. Some giant species reach up to 30 m with cross sections of up to 30 cm per stem, whereas some species do not reach above 1 m in height and 1 cm in diameter. Depending on the climatic circumstances, there can also be a lot of variation in size and quality of bamboo stems from the same species. Stems are larger in fertile, moist climates and smaller in dry, sandy climates.

Fundamentally Different from Trees

In general, bamboo stems are hollow (although some solid species exist), with separate sections at irregular distances formed by transverse diaphragms in the cavity of the stem. These diaphragms are visible on the wall of the stem as ring-shaped protrusions and this is also where the branches with the leaves sprout from, usually from the higher nodes. Bamboo plants have a root system consisting of underground parts called rhizomes, from which the stems grow above the ground. The rhizomes anchor the plant to the soil and supply it with food and water to produce new rhizomes. One single bamboo plant therefore has multiple stems. The extensive rhizome network also helps to hold soil and restore water tables, making bamboo very suitable for reforestation on poor grounds (more about this in chapter 4.3). Unlike a tree trunk, the bamboo stem does not grow in thickness. The thickness of the sprouting shoot determines the thickness of the mature stem, as cell growth only occurs in longitudinal direction. The various sections of a mature bamboo stem are already present right from the start and during growth extend from each other like the tubes of a sliding telescope.

Grow Bamboo, Grow!

One of the most interesting features of giant bamboo is its unsurpassed growing speed. During the growing season, the bamboo shoots will sprout from the ground and reach their final length of up to 30 m height within a couple of months, with a maximum recorded growing speed of up to 1 meter a day. Lignification (hardening of the stem) occurs within 2-3 years while maturity is attained after about 5 years, which is the moment the stem is ready for harvesting and for use in durable products in the building industry. Because of its fast growth, the bamboo plant absorbs a large amount of CO_2

2.2
Bamboo Anatomy

Efficient Mechanical Design of the Stem

In the cross section of a bamboo stem we can identify cellulose fibers (40%), vascular bundles (10%) and the in-between parenchyma tissue (50%), which largely consists of lignin. The fibers and the parenchyma tissue together function as a composite material: the cellulose fibers make the bamboo strong, functioning as the reinforcement in the matrix of the thin-walled parenchyma cells, similar to steel in reinforced concrete.

After about 4-5 years, the walls of the fiber cells have become mature and solid. Only then is the bamboo stem ready to be felled for construction purposes. For applications in which the fiber function is less important (such as bamboo pulp for the production of paper), the stem can be felled at an earlier stage.

The fibers run in a longitudinal direction around the vascular bundles. The outer wall of the stem consists of a thin silica layer of 0.25 mm that protects the stem. The outer and inner walls of the stem are also covered with a waxy layer. The solid patches (see picture on page 38) are the cross-sections of the cellulose fibers. The distribution of fibers increases from the inside toward the outside, where they are most needed to absorb moments of force caused by mechanical loads (see picture on page 39), an excellent example of structural design from nature. Also in its basic form, a hollow tube, bamboo has an efficient natural structural design that offers some major advantages (see also box 2.1). However, although it may feel counter-intuitive, to enable wide-spread application of bamboo for structural applications in Western markets, the efficient tubular bamboo stem needs to be transformed to a standardized, often solid, engineered building material (see next chapter).

distribution of fibers
According to Janssen, [2.1] the cellulose distribution in the stem increases from the inside toward the outside, resulting in a higher stiffness (E-modulus) at the outside (up to 21000 N/mm^2).

Chemical Composition and Structure

Although the chemical compositions of bamboo and wood are practically identical, [2.2] the differences in anatomical composition are considerable. For instance, bamboo has no rays or knots. Furthermore, the bamboo stem is hollow compared to the solid stem of trees. Due to the large starch content of the bamboo stem it is often exposed to attacks from insects, termites and fungi, resulting in low durability. However, with good design measures (keeping the bamboo stem off the ground, not directly exposed to rain and sun) considerable lifespans can be reached even by building with the bamboo stem. The lifespan can be extended further if the bamboo is treated appropriately with preservatives or smoke/heat treatment (for more information, see Liese [2.3]).

3

Bamboo Uses

From Traditional Handicraft to Engineered Industrial Material

The traditional use of bamboo as building and crafts material dates back thousands years ago. This chapter explains the multitude of applications in which bamboo has been used historically, including the recent rise of the next generation of industrialized bamboo materials fuelling a new industry in various bamboo growing countries.

3.1
Historical Development

Scaffolding *(left)*
Bamboo is used for scaffolding in Asia even during construction of skyscrapers.

Well Embedded in Asian Culture and Tradition

The Far East can pride itself on a long tradition of using bamboo. Bamboo is valued deeply within Asian cultures, for example as 'Friend of the People' (China) and 'Brother' (Vietnam), and is adopted in the Arts and Teahouse tradition in Japan. The history of the Chinese using bamboo for food, housing, transportation, musical instruments and weapons can be traced back to over 7000 years ago. This is also the reason why bamboo is valued so deeply in Chinese culture and literature, and explains why so many paintings and writings have been dedicated to this plant. [3.1]

In construction, bamboo has been used in Asia for centuries. Because of its excellent mechanical properties, it has been widely adopted for the construction of houses and bridges. One of the oldest bridges in the world, the Anjan bridge in China, was fully constructed out of bamboo before being replaced with steel cables at the end of the 20th century. In Asia, stems of bamboo are still being used extensively in scaffolding because of its light weight combined with excellent tensile and bending strength.

Poor Man's Timber in Other Regions

In other places in the world native to bamboo it is valued less. In Africa and Latin America, because of its ready availability and low cost, bamboo is often associated with poverty and known as 'the poor man's timber'. Even though in many cases living in a bamboo house is safer (earthquakes!) than in a small concrete house, people often prefer the latter out of social status considerations.

Bamboo's Potential for Regional Socio-Economic Development

Because of the often poor image of bamboo, awareness raising is required. In many bamboo-growing countries bamboo is often only known for its low value-added applications and its potential for higher value-added applications is not yet understood. To unleash this unexplored potential, knowledge and technology transfer from countries that develop high value-added bamboo products is required. This is crucial, as bamboo is often abundantly available (or can be easily planted) in poor rural communities, helping to meet local demands for housing and energy (e.g. charcoal) and at the same time act as an important driver for regional economic development. Since its establishment in 1997 the International Bamboo and Rattan Organisation (INBAR) has played a pivotal role in this development by fostering South-South and North-South cooperation.

3.2
Bamboo Industrialization

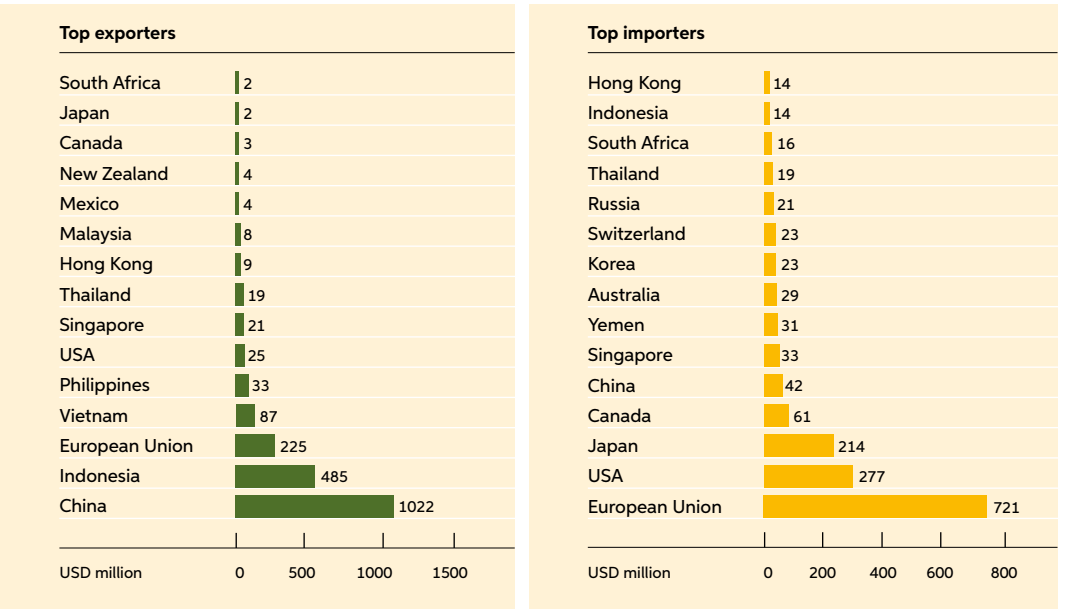
A Bamboo Industry Emerges

Whereas in China traditional bamboo products based on the stem and strips have been used for centuries, the industrialization of giant bamboo species such as *Phyllostachus Pubescens* (Moso bamboo) commenced only in the 1990s, growing from a niche, handicraft market towards a multi-billion dollar business fuelled by the development of engineered bamboo materials and other commodity goods such as paper, textile and energy.

Currently, the Chinese bamboo sector is the leading bamboo industry worldwide, employing 7.75 million people in 2016, worth 19.5 billion USD with an export value of just over 1 billion USD. China is responsible for 65% of worldwide export in bamboo products and even 97% for bamboo flooring. The global trade in bamboo and rattan products is worth 60 billion USD, but most of this is due to domestic sales in countries like China, India and Brazil.

export value
This sounds like a large amount but compared to the 226 billion USD export value of forest products [3.3] it is still marginal (< 1%). However, the bamboo industry certainly has the potential to become a far more important player on the global commodities market (see chapter 4.3).

Figure 3.1 - Top exporters and top importers of bamboo products (2016) [3.2]



4

Bamboo's Environmental Sustainability

The sustainability of a material can be measured based on its environmental impact (debit) or on its benefit (credit). This chapter explains in detail how industrial bamboo materials combine a low environmental impact with many beneficial features during growth and use, and thus provide an excellent alternative for carbon intensive, non-renewable materials.

Bamboo reforestation
Reforestation project by Ecoplanet Bamboo in Nicaragua, 4 years after establishment, showing the fast establishment time of a bamboo plantation, even on degraded land. The project was certified following the voluntary carbon credit system VCS (project ID #1085), with a total GHG benefit of 830716 tons CO_2 for 1235 certified hectares over a 20-year time frame. [4.7]

4.1
The Environmental Balance Sheet
The Debit and Credit Side of Sustainability

Due to its reforestation potential and fast growth, bamboo is commonly perceived as a sustainable building material. However, like any other resource, bamboo needs to be processed into a final material or product and transported to the final consumer, which has an environmental impact. To understand the full environmental profile of bamboo, in this chapter the sustainability of various bamboo building materials is assessed. There are various perspectives on sustainability. In this chapter we mainly focus on the environmental aspect of sustainability (planet), while the social (people) and economical (profit) aspects were – to a lesser extent – covered in previous chapters.

Different Schools of Thought: Eco-Efficiency vs. Eco-Effectiveness

Within the environmental sustainability realm there are various schools of thought. These can roughly be divided into damage-based measurement models (debit side of environmental balance) and benefit-related models (credit side). Damage-related models measure environmental impact through life cycle assessment or carbon footprint with the ultimate goal to increase eco-efficiency. Benefit-related models, such as the Circular Economy (see also chapter 1) and the related Cradle to Cradle (C2C) philosophy, focus on development of products and services that are actually beneficial to health and environment, with the ultimate goal of increasing eco-effectiveness. [4.1]

life cycle assessment
Life cycle assessment (LCA) is a methodology used to assess the environmental impact associated with all stages of a product's life cycle, from 'cradle to grave'. In contrast to a carbon footprint assessment, which only covers global warming potential, LCA is based on several environmental indicators, which apart from global warming potential (carbon footprint) also include acidification, eutrophication, smog, dust, toxicity, depletion, land use, waste, etc.

Both Views are Needed for a Holistic Approach of True Sustainability

Both the LCA and the C2C approach are needed to attain a holistic view regarding the true sustainability of a product. An LCA is very useful to pinpoint the environmental burden of a product over the lifecycle ('where we are now'). However, in order to be able to make improvements, circular design methodologies such as C2C are better suited to include contextual elements to create a positive development path ('where we want to go'). As touched upon in chapter 1, one of the weaker points of the Circular Economy model is that it assumes ample supply of renewable energy. It assumes no material scarcity, as a result of perfectly closed cycles to enable unlimited upcycling of technical materials and abundant renewable material production in the biosphere. Although the Circular Economy model provides a good development framework and a tempting future perspective, the reality is different, as was shown in chapter 1. Therefore, for a holistic review of the environmental sustainability of bamboo materials, in this chapter the debit side is covered through an environmental impact assessment (carbon footprint), while the credit side is covered through reforestation potential and annual yield.

4.2
Debit Side
Environmental Impact of Bamboo Materials

Measuring the Carbon Footprint of Bamboo Materials

Because of their rapid growth, good properties and wide applicability, giant bamboo species such as *Phyllostachus Pubescens* (Moso bamboo) are increasingly perceived as a high-performance bio-based alternative for incumbent building materials. However, the relatively long production process and transport distance could disturb the environmental profile. The environmental impact in terms of CO_2 emissions in this section is based on a recent INBAR LCA and carbon footprint study, [4.2] which was presented during the COP 21 climate conference in Paris, updated with the latest figures from the Idemat 2016 database. [4.5] Although the report also includes an LCA analysis (wider environmental scope), in this book we focus on CO_2 emissions, as it is the most commonly used environmental indicator directly linked to climate change. Furthermore, the carbon footprint is very often indicative of the environmental costs in terms of LCA (which is also the case for the industrial bamboo materials). In this chapter, we will not go into detail, but readers interested in all relevant technical background information, are referred to INBAR Technical Report 35 [4.2] and the Environmental Product Declarations of MOSO International. [4.3]

The carbon footprint of bamboo materials was measured for the four main manufacturing technologies to produce engineered bamboo materials (see chapter 3.2):

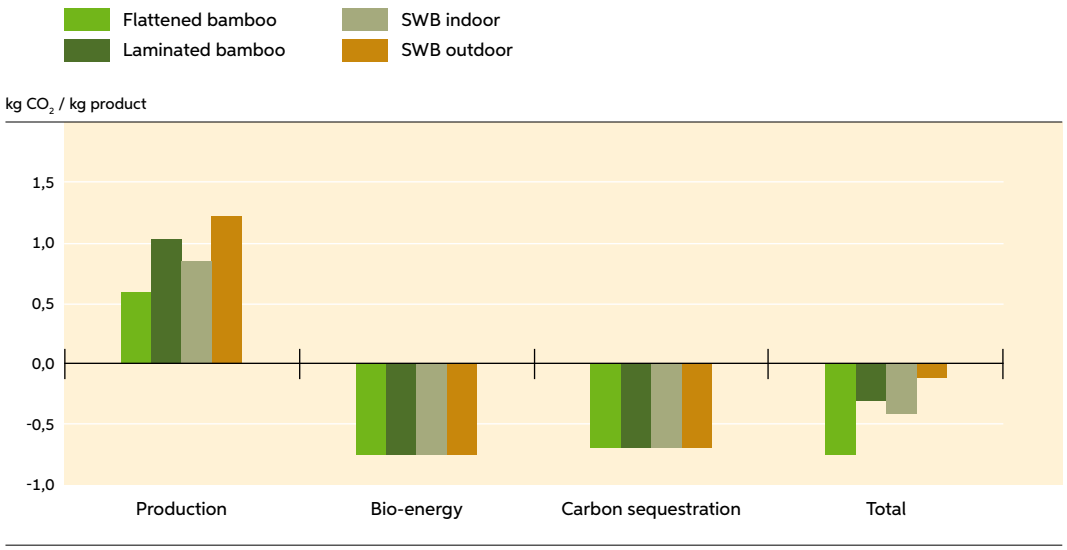
- flattened bamboo
- laminated bamboo
- strand woven bamboo (SWB) – indoor use
- thermally modified strand woven bamboo – outdoor use

These materials were assessed following a cradle-to-grave scenario, thus encompassing their full life cycle.

Emissions during Production

To determine greenhouse gas emissions during production, all the steps in the chain need to be taken into account, from sourcing the materials from plantations in China, to processing, treating and pressing in the manufacturing plant, to final packing and shipping. This so-called 'cradle-to-gate' analysis was executed based on best-practice production figures from the company MOSO International BV.

Figure 4.5 - Carbon footprint over life cycle (kg CO_2 eq/kg product), including carbon sequestration effect



Nevertheless, there are significant differences between the various production technologies:

- Flattened bamboo boards are clearly the best choice from an environmental point of view because of the relatively short production process involved, their high production efficiency and low resin content.
- Outdoor strand woven bamboo (SWB) performs less well than the indoor type as a result of relatively high energy consumption due to thermal modification and higher resin content.
- Indoor strand woven bamboo appears to perform better than laminated bamboo in terms of carbon footprint due to its shorter production process, resulting in lower energy consumption per kg material.

Energy Consumption – Not Glue or Transport – is Largest CO_2 Contributor

The main CO_2 emission components in the carbon footprint of engineered bamboo products can be identified as follows (range depending on the product assessed):

- energy consumption for processing: 52-63%
- international sea transport: 15-25%
- local transport (truck): 10%
- use of resin: 3% (flattened bamboo) to 16% (outdoor SWB)

Unlike commonly expected, not the use of glue nor the relatively long transport distance to Western markets, but the energy consumption in China (energy mix dominated by coal energy) contributes most to the carbon footprint of engineered bamboo products.

Increasing the amount of formaldehyde-free resins such as EPI could reduce the environmental impact still further and switching to a fully bio-based resin (EPI is a synthetic resin) would have the additional benefit of making the industrial bamboo product 100% bio-based, rendering it fully compliant within a bio-based economy. Obviously the same applies to other bamboo industries that use chemical additives during the production of the final product (e.g. finding non-toxic, bio-based alternatives for chemical solvents used during the production of bamboo textile and paper).

And What About the Bamboo Stem?

It is interesting to mention that the bamboo stem is potentially the most eco-friendly building material available, as it has the unique property that it can be used in construction in its natural form without further processing (see various examples in chapter 6). However, the ecoburden of sea transport is calculated using a volume-based eco-indicator at a low weight/volume ratio, [4.4] which is the case for the bamboo stem, resulting in a carbon footprint for production (cradle-to-gate) of 1.45 kg CO_2 eq/kg stem based on use in the Netherlands. This is about 1.5 times as high as the various industrial bamboo materials. However, when the bamboo stem is used in the country where it is harvested (in this case China), the sea transport is eradicated and the cradle-to-gate carbon footprint is only 0.19 kg CO_2 eq/kg stem, making it the most sustainable building material possible.

The Final Verdict – Which Material Wins the (Lowest) Carbon Footprint Trophy?

Figures 4.6 and 4.7 provide a complete overview of the carbon footprint of several commonly used building materials, including the engineered bamboo alternatives. Note that the carbon sequestration benefits from net afforestation of Chinese bamboo and Scandinavian softwood forests have been taken into account in these numbers, while for tropical hardwood such as meranti there is no carbon sequestration effect because of the net deforestation of tropical forests (see figure 1.9). The numbers are per m^3 (figure 4.6) or kg (figure 4.7) of material and not for a specific application, in which also maintenance and material use based on required mechanical and functional properties are included (functional unit). Still, these figures do give a good indication of how the various materials compare from an environmental impact point of view and can be used as a basis for more specific calculations for several applications. With respect to environmental impact, the graphs

Figure 4.6 - Carbon footprint over life cycle per volume unit (kg CO_2 eq/m^3 building material) [4.2 - 4.5]

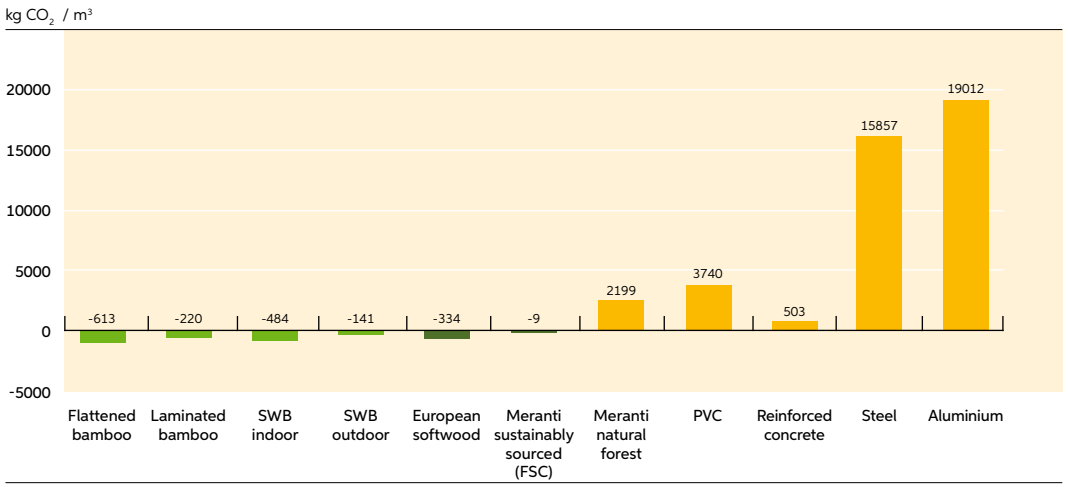
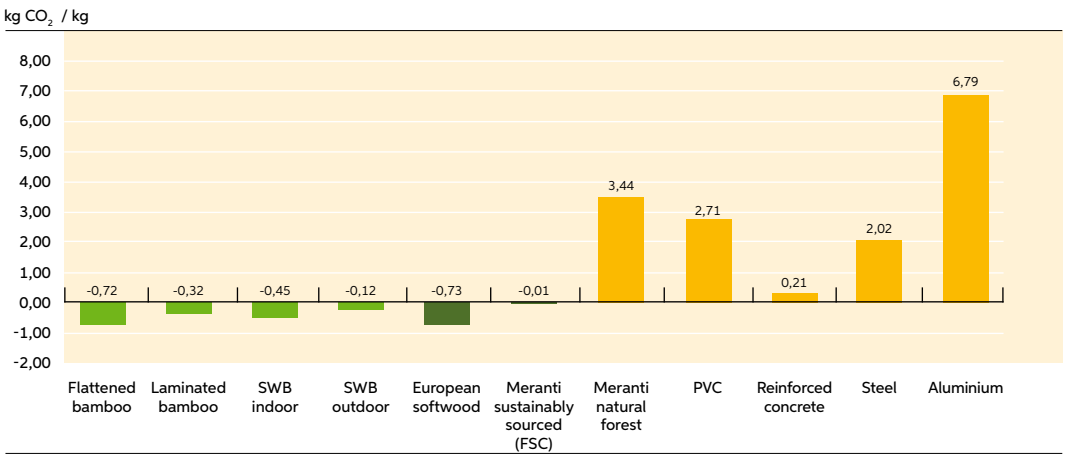


Figure 4.7 - Carbon footprint over life cycle per weight unit (kg CO_2 eq/kg building material) [4.2 - 4.5]



show that the various industrial bamboo materials have a similar and sometimes even lower footprint than sustainably-sourced European softwood (also a negative carbon footprint as a result of active reforestation in Europe and end-of-life credit for incineration of wood in bio-energy plants). Industrial bamboo materials score better than tropical hardwood from sustainably-managed plantations. Note that when hardwood is unsustainably sourced (deforestation), the carbon footprint is significantly higher. Unsurprisingly, from an environmental point of view all bio-based products (except unsustainably sourced hardwood) perform a lot better than carbon-intensive materials such as concrete and in particular PVC, steel and aluminium. In applications where bamboo could substitute these materials (e.g. window frames, cladding) this would result in a large CO_2 reduction through substitution. Therefore, from the environmental impact perspective of the sustainability balance, bamboo materials seem to be among the best-performing materials.

Box 4.1

LEED & BREEAM

Bamboo in Green Building Projects

Green building certification is increasingly important for stakeholders in the building industry (principals, property developers, institutional investors, contractors, architects, etc.) to showcase the level of overall sustainability of a newly developed or refurbished building. Consisting of many different categories, ranging from water efficiency, energy use, reduced-impact building process to health and wellbeing, sustainable materialization is an important aspect in most schemes.

Given the low environmental footprint (proven by LCA/EPD), availability with FSC certification, low indoor emissions (VOCs), high durability & hardness, and rapid renewability, application of engineered bamboo materials can contribute to many credits in the materials section of the most important green building schemes, such as LEED, BREEAM, HQE and DGNB. For several BREEAM and LEED certified bamboo projects see chapter 6.

Fugro office
In the LEED Platinum certified head office of Fugro in Nootdorp, the Netherlands, a large amount of bamboo flooring, decking, wall & ceiling panels and staircases were applied.

4.3
Credit Side
Bamboo Resource Benefits, Reforestation and Annual Yield

After assessing the environmental impact of the production of bamboo materials (debit side), now the credit side of the environmental balance for bamboo will be assessed. It is clear that a major environmental benefit of bamboo, not included in the carbon footprint assessment in the previous section, lies at the resource side, most notably because of its reforestation potential combined with fast growth and associated high yields.

Bamboo as Ideal Reforestation Crop

Since bamboo is a giant grass species, it is less susceptible to clear-cutting/deforestation and is very suitable for reforestation. Due to its extensive root system, several bamboo species can be planted in areas where farming is not feasible, e.g. for rehabilitating degraded land – including eroded slopes – and re-establishing functioning and productive ecosystems by improving soil quality and restoring the water table.[4.6] Although bamboo provides many opportunities for landscape restoration, appropriate management and propagation techniques are needed, as with any crop. Monoculture plantations should be avoided to reduce susceptibility to pests and to prevent soil degradation and biodiversity loss.[4.8] Furthermore, restoration benefits particularly apply to degraded lands and should never come at the expense of natural forests.

Bamboo's Potential Role in the Bonn Challenge – the Global Reforestation Project of Degraded Land

Global deforestation has left large areas in the (sub)tropics degraded, with fertile topsoils often depleted and desertification as one of the logical consequences. Yet, also here there is hope. In the Bonn Challenge many countries worldwide have committed to restore 150 million ha of degraded and deforested land by 2020 and a total of 350 million ha by 2030. Actually, this just the beginning. The World Resource Institute[4.9] has identified 2 billion of hectares suitable for so-called mosaic restoration, integrating forests, including bamboo forests, with other land uses such as agroforestry and agriculture. As the restoration map largely overlaps with the natural growth area of giant bamboo, (see figure 4.8), it shows bamboo's huge potential in restoring degraded land in a short time, with high yields as an additional benefit. As a first step in involving bamboo in the Bonn Challenge, INBAR's 40 member countries have agreed[4.8] to restore 5 million ha with bamboo by 2020, recognizing that this could grow to 10 million as national plans and initiatives progress over the coming decade.

Figure 4.8 - Overlap in natural growing area of bamboo with potential landscape restoration area [4.8]

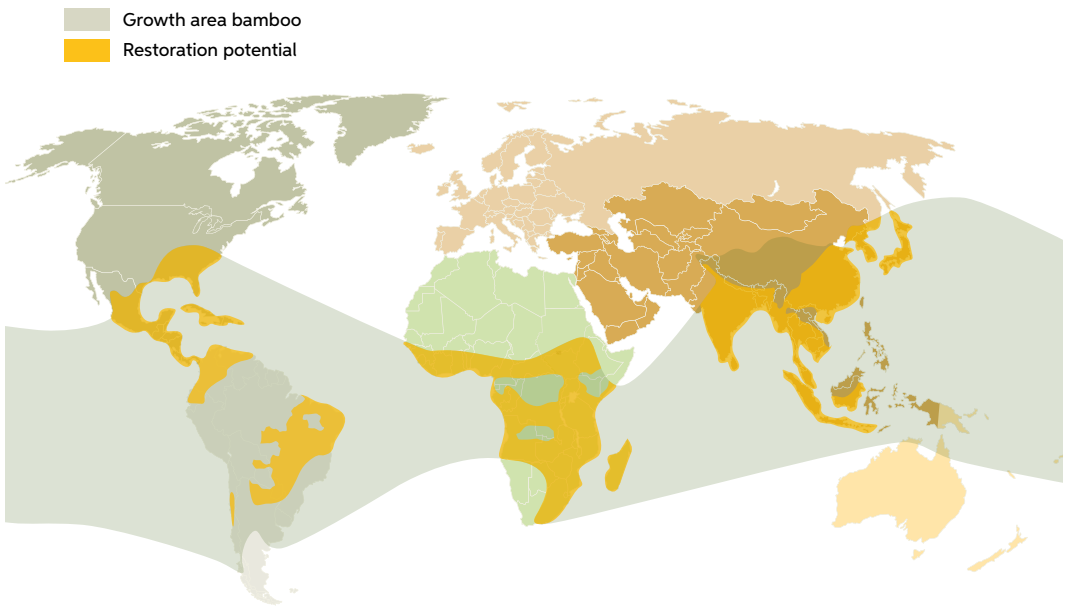
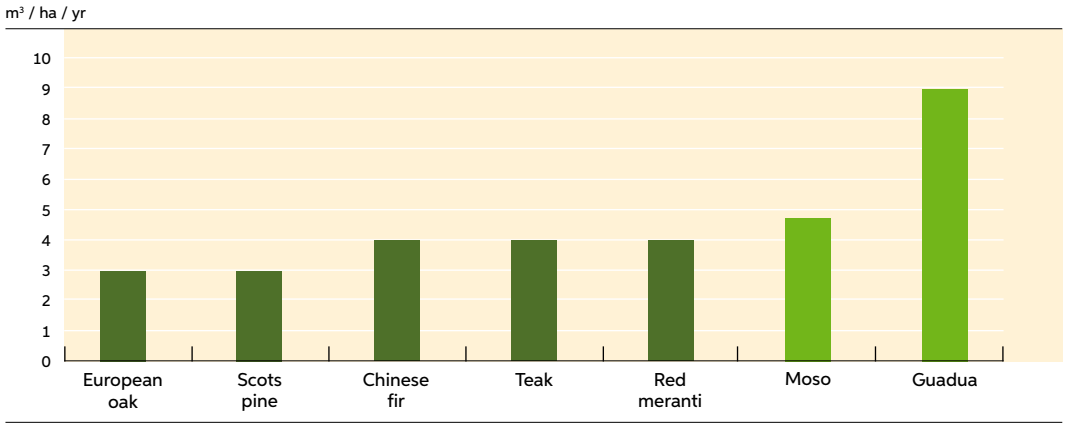


Figure 4.9 - Annual yield in cubic meters semi-finished material produced per hectare per year [4.2 - 4.11 - 4.12 - 4.13]



Annual Yield: An Important Overlooked Indicator in an Over-Populated World

Clearly the foremost advantage of bamboo is that its fast growth results in a high annual yield (here defined as m^3 of semi-finished material produced per ha per year). This advantage is particularly important due to the fact that land might become scarce in the future.

Figure 4.9 provides an overview comparing the annual yield of various bamboo species (*Phyllostachus Pubescens*-Moso bamboo as typical running bamboo and *Guadua Angustifolia* as typical giant clumping bamboo) and several commonly used, plantation-grown commercial wood species, based on an average conversion factor from roundwood to sawnwood of 50%. [4.10] Figure 4.9 shows that industrial bamboo materials have a larger annual yield than plantation-grown softwoods and hardwoods (with which they compete in terms of material properties), even more so in the case of giant bamboo species such as Guadua (with an annual yield almost twice as high as Moso). It should be noted that in the case of wood from natural forests, the annual yield is significantly lower, ranging between 0 to 2 m^3/ha/yr. [4.14] Also note that the annual yield figures are for production of engineered bamboo materials assuming average processing efficiency.

Figure 4.8
The natural growing area of bamboo neatly overlaps with large areas where reforestation on degraded land is necessary.

Figure 4.9
On average the density of industrial bamboo materials is far higher (average 900 kg/m^3) than that of wood, explaining the higher carbon stock in the durable products pool (figure 4.4).

Helping to Meet Increasing Material Demands in the (Building) Industry

Bamboo's high yield has several practical benefits to meet increasing demands in the built environment. One has to realize that with 1 m^3 of semi-finished material many applications can be met, for example 1 m^3 of bamboo material is enough to produce 15 typical window frames for use in a residential house. Taking into account that a giant bamboo species such as Guadua can produce up to 9 m^3 a year per hectare of land (in ideal circumstances annual yields of > 20 m^3 have been reported), this means material demand can be covered in a sustainable manner, based on a steady annual harvest (see also figure 4.10).

If we translate this to a positive global scenario in which the Bonn Challenge is met, it shows bamboo's potential to contribute to climate change mitigation while meeting global demands for resources. Based on the ambition of the Bonn Challenge to globally reforest 350 million ha of land, taking into account that 1 ha of bamboo plantation stores approx. 1000 ton of CO_2, this relates to a total CO_2 storage of 350 million kilotons of CO_2, which compensates the CO_2 emissions of the whole world (35,700,000 kilotons CO_2 per year) for almost 10 years!

From the point of view of material production, meeting the Bonn Challenge 100% with giant bamboo species such as Guadua would lead to an annual production of 350 million ha x 9 m^3 = 3150 million tons of bamboo (assuming that most material will be processed into strand woven bamboo with a density of > 1000 kg/m^3). From a more realistic perspective, we can assume that following the reforestation plans of INBAR's member countries, the total bamboo area worldwide will have grown to 40 million ha by 2020. If we assume that in 2020 about half of the bamboo forests consists of giant bamboo species and that half of that amount will be utilized for production of engineered bamboo (for other applications, such as pulp and pellets, yields might be even higher), the total annual production capacity would be:
10 million ha x 9 m^3/ha = 90 million tons of bamboo material (average scenario), which is still significant, close to the full annual production of non-coniferous wood worldwide (130 million tons). Adding these numbers to the world material production figures from figure 1.4 shows that if its true potential is captured (Bonn scenario), bamboo can actually become a significant player on the global building materials market and a true enabler towards a bio-based economy, see figure 4.11.

Figure 4.10 - Annual yield - applications comparison for bamboo vs. wood

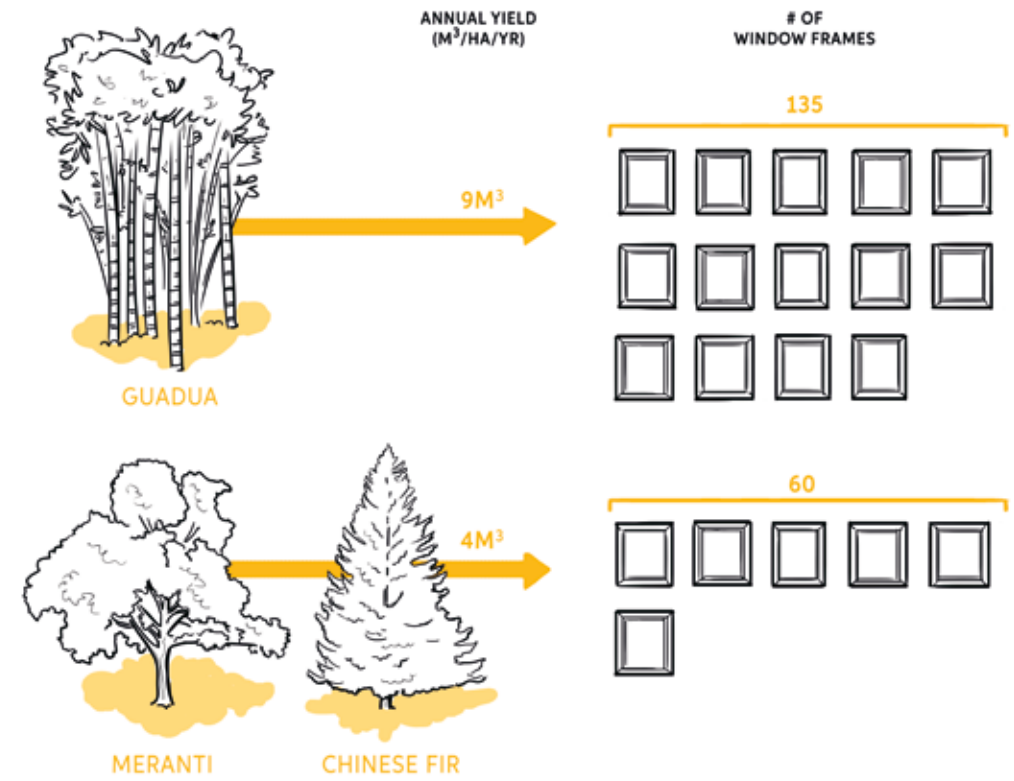


Figure 4.10
Because of its high annual yield more applications such as window frames can be made from a hectare of giant bamboo compared to a hectare of (wood-producing) forest.

Figure 4.11 - Annual world production of materials vs. global reserves - including bamboo

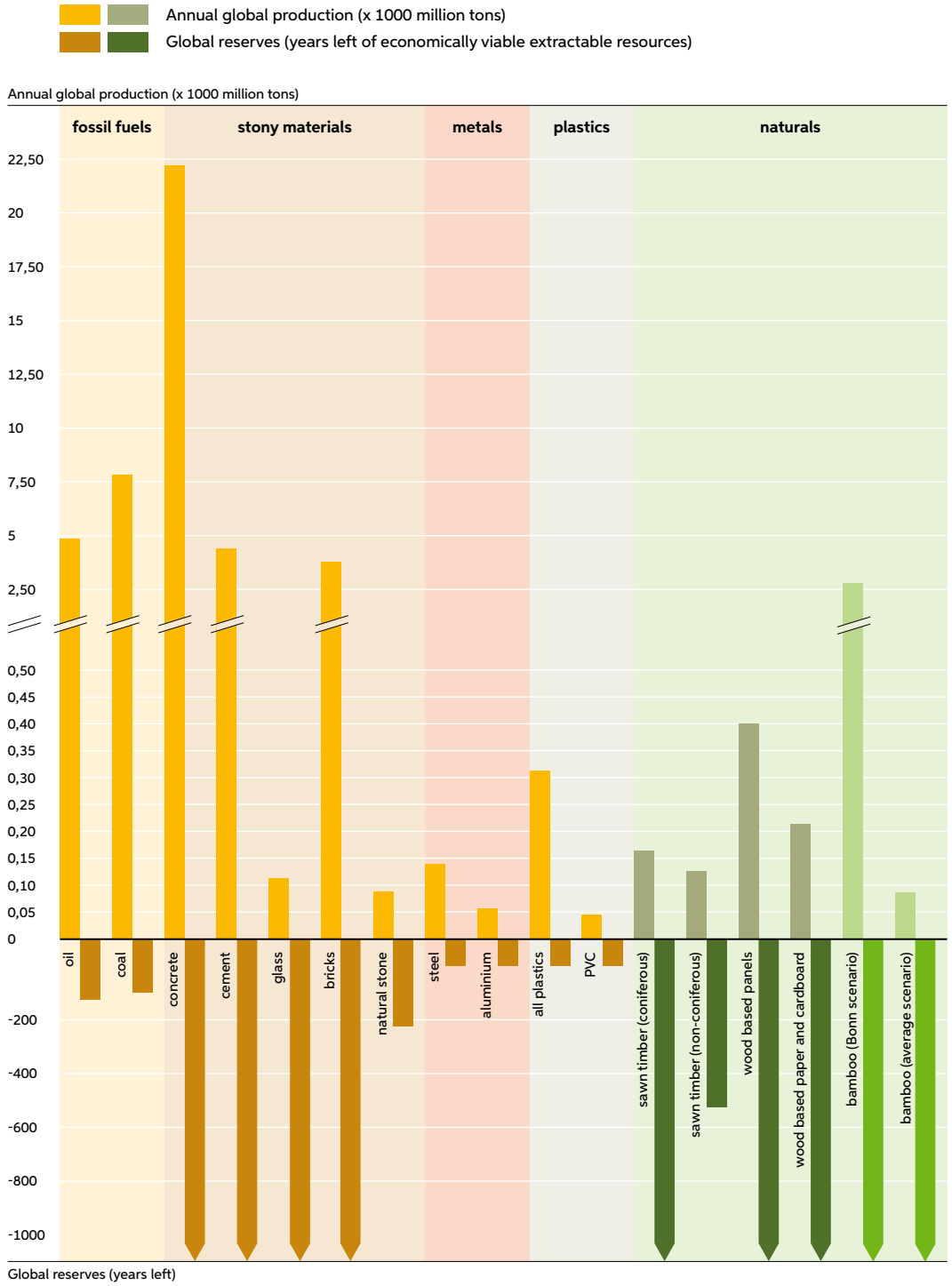
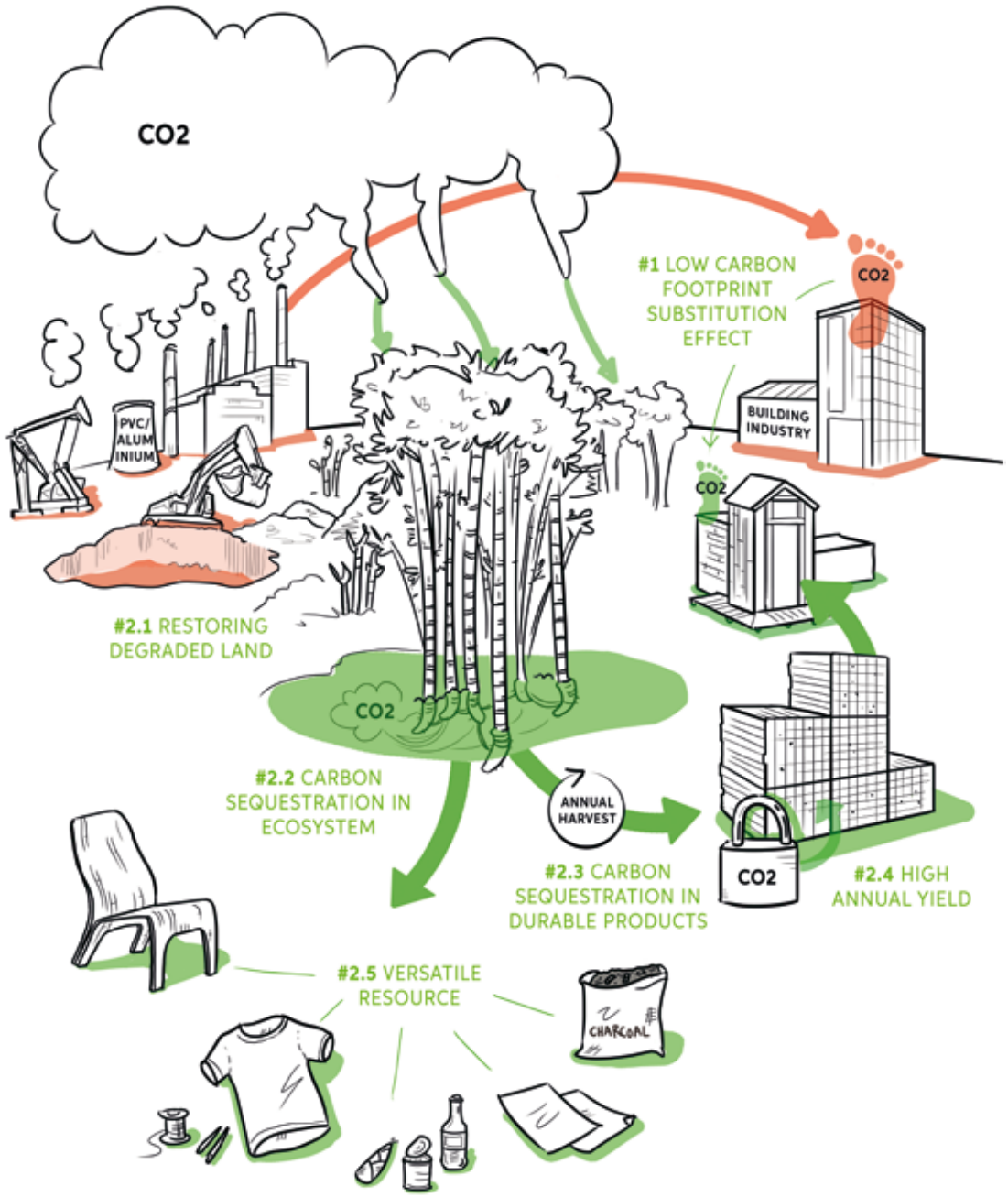


Figure 4.12 - Overview of bamboo's sustainability benefits



4.4
Conclusion
Weighing the Environmental Balance

After reviewing the environmental sustainability of bamboo from both perspectives of the balance it is time to draw conclusions.

Debit Side: Low-Carbon Footprint Alternative for Common Carbon Intensive Materials

From the debit (environmental damage) side it can be concluded that bamboo has a very low and through its carbon sequestration ability even possibly negative carbon footprint. Therefore, in applications where it is possible to replace high CO_2 emitting materials (metals, plastics, unsustainably sourced hardwood) with bamboo, this could lead to a high CO_2 reduction. If this substitution effect (**benefit #1**) would be included in climate agreements in the future, this could become a major incentive for further implementation of durable bamboo – and other bio-based products – in the building industry.

Credit Side: An Important Ally in the Required Transition to a Bio-Based Economy

From the credit side it is clear that bamboo can help meet the world's demand for resources by improving the productivity of the biosphere by:

- increasing the worldwide productive area by bringing degraded land back into production **benefit #2.1**
- capturing anthropogenic CO_2 in the eco-system **benefit #2.2** as well as in durable products made from annually sustainably harvested material **benefit #2.3**
- increasing the yield because of its fast growth and therefore the productivity of any suitable land **benefit #2.4**, providing a fiber that is highly versatile: suitable for use in various industries indispensable for mankind, such as the building, textile, paper and energy sectors **benefit #2.5**
- although not the focus of this chapter, this also brings great benefits for socio-economic development in the countries where bamboo grows (often these are countries where poverty levels are high)

The infographic in figure 4.12 summarizes all these benefits.

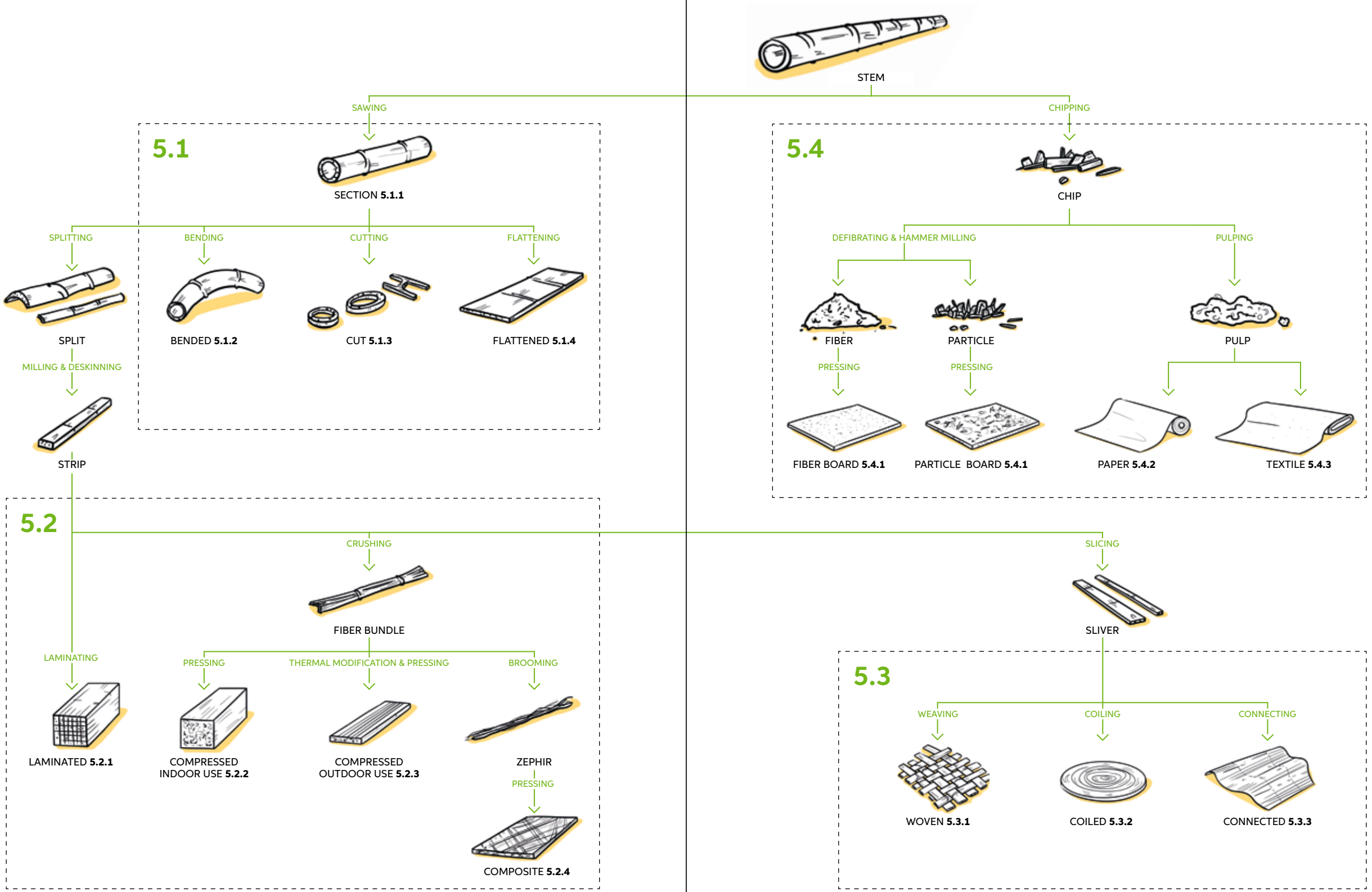
5

Bamboo Technology

Bamboo raw materials can be processed in various manual and industrial manners to create different kinds of semi-finished materials to be used in a large variety of applications (chapter 6). This chapter introduces the most important bamboo processing technologies, including their key advantages and disadvantages.

ChopValue
This startup in Vancouver upcycles discarded bamboo chopsticks to high-quality laminated boards (for more information see chapter 6.6.5).

Figure 5.0 - Transformation paths of bamboo stem to many engineered bamboo materials [5.1]



5.1
Bamboo Stem

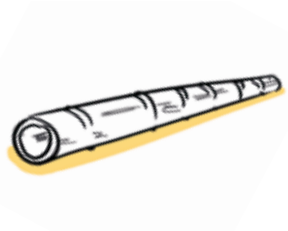
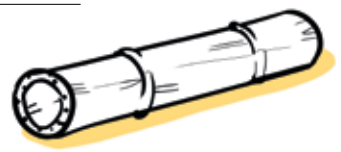


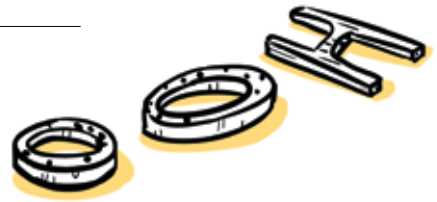
Figure 5.1 - Bamboo stem variations

5.1.1 BAMBOO SECTION

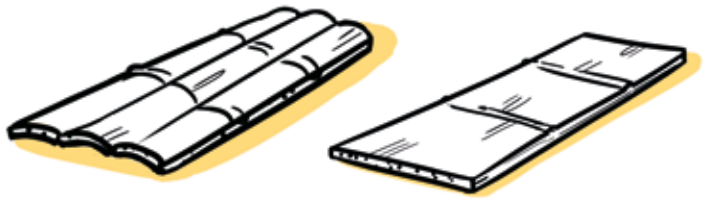


5.1.2 BENDED BAMBOO

5.1.3 CUT BAMBOO



5.1.4 FLATTENED BAMBOO

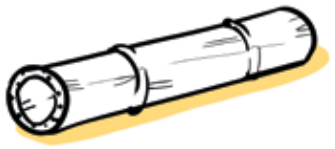


The bamboo stem is the most well-known appearance of any bamboo material. It is the starting point of many different materials that can be made out of bamboo. Also by itself the bamboo stem can actually act as a sound building material. Nevertheless, due to its form, building with the stem can be challenging and making statements about the mechanical properties of the bamboo stem is complicated, as there are many differences between species and even between stems from the same species due to differences in specific climatic and soil conditions. However, some general statements can be made (see table below). Besides using the bamboo stem as a building/ design element by itself, it can also be mechanically processed (sawn, sliced, bent, flattened, etc.) in several other forms, as shown in the remainder of this section.

Strengths	Weaknesses
• Very efficient structural design from nature (strong, hollow tube with most fibers on the outside, see also box 2.1) • Relatively high bending strength and tensile strength • Light-weight, flexible material i.e. high linear elasticity (the stem will bend further without breaking) ideal for construction in earthquake prone areas • Tough, hard outer skin providing protection • If used locally (no transportation burden), most environmentally friendly material around	• Relatively low compression strength • Risk of shear in structural joints (can be solved by filling last bamboo compartments with concrete or wood props for larger contact area with metal connection parts) • Irregular material (hollow, round, tapering, protruding rings) making standardization and connections difficult and thus labor-intensive and costly • Lack of building codes and classification systems • Low biological durability; in (semi) outdoor applications needs to be kept away from sunlight and moisture (rain/ground contact) • Image problem, either as ‘poor man’s timber’ (Africa, Latin America) or as rustic/traditional (Western countries)

5.1.1
Bamboo Section

Figure 5.1.1 - Bamboo section



bamboo preservation
For more information about bamboo preservation, see the Bamboo Preservation Compendium. [2,3]

How It's Made

The production process of the bamboo stem is very simple: grown by nature! There is hardly any other building material in the world that can just be cut with a machete and then act directly as structural beam or column in a construction or piece of furniture. After harvesting, it is recommended to preserve the bamboo culm through chemical (e.g. borax solution), heat or smoke treatment.

Application Area

The distinct form does give the bamboo stem a very rustic appearance, which so far has prevented large-scale application in the West, and in some bamboo growing countries bamboo stems also have a questionable image as 'poor man's timber'. Nevertheless, the use of the bamboo stem with its efficient natural structural design offers some interesting opportunities, in particular for building and civil engineering projects, but also for product design and furniture.

However, due to lack of building codes, classification systems for quality and strength, and the irregularity of the material, the use of the bamboo stem in Western countries will most likely be limited to specific purposes such as temporary constructions, sculptures and tents. Note that in bamboo-growing countries the situation is often completely different, where it has a far higher potential for mass application in the building industry.

Design Challenge

A promising development area in Western countries is in standardizing the ends of the bamboo stem to solve the normally labor-intensive connections, thus yielding a light-weight space structure system that is easy to mount, ideal for temporary constructions.

5.1.2
Bended Bamboo

Figure 5.1.2 - Bended bamboo

How It's Made

Through local heat treatment, e.g. using torches, the lignin holding the cellulose fibers can be made thermo-elastic, enabling the bamboo stem to bend and keep its bended shape after cooling down. Another manner of bending bamboo is by removing material or casting V-shaped incisions, preferably just below the nodes. Finally, by careful selection of bamboo stems that are already curved by nature and additionally forcing and fixating the already curved stem even further, impressive curvatures can be reached without any mechanical intrusion, even with large bamboo stems.

Application Area

This treatment is especially used on thinner bamboo stems for the development of curved furniture parts, but it can also be used for other smaller items such as toys and household objects. Further, curved bamboo stems can be useful also in construction, either in a decorative manner (e.g. bannisters) or for structural purposes.

Design Challenge

Bamboo can also be deformed during growth. By positioning a mold over the sprouting shoot, the stem can actually be forced in a certain shape (e.g. rectangular) or form (e.g. curved). By standardizing the molds and optimizing growth conditions this could be a promising way to standardize (curved) bamboo stem elements to create surprising architectural structures.

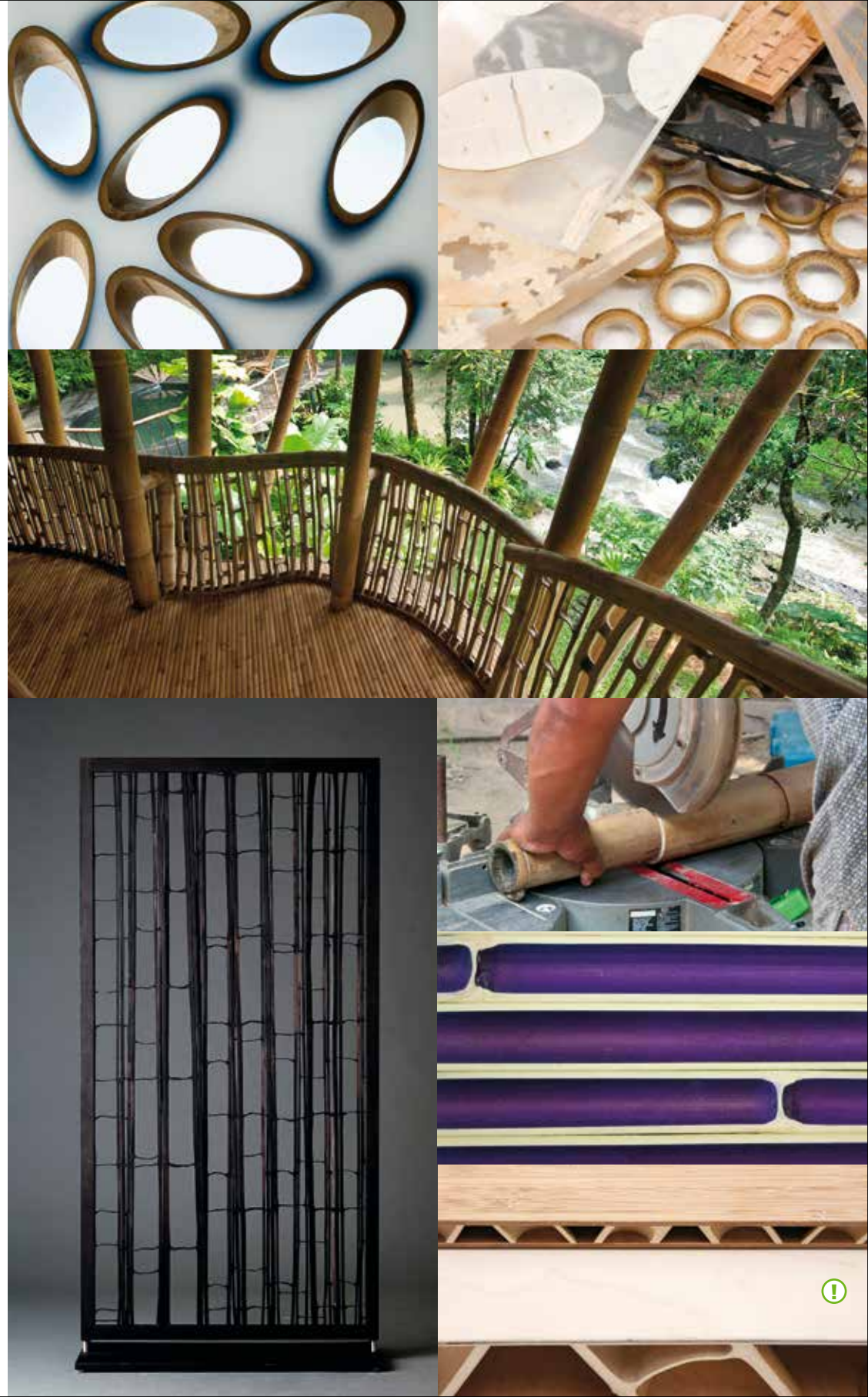
5.1.3
Cut Bamboo

Figure 5.1.3 - Cut bamboo

How It's Made
A very simple and effective manner to get rid of the distinct appearance of the bamboo stem is to crosscut or saw it in a perpendicular, diagonal or longitudinal manner. In particular in combination with other materials and other colors this can yield surprising results.

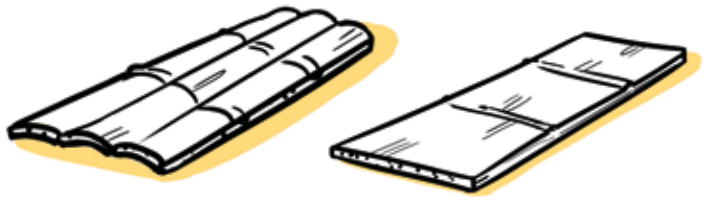
Application Area
Cutting or slicing the bamboo stem provides many application opportunities, in particular for interior design and furniture.

Design Challenge
Using bamboo slices as core material in a honeycomb sandwich panel with thin wood/bamboo panels or veneer at the top and bottom can provide a light-weight, potentially low-cost panel with lots of potential for structural applications.



5.1.4
Flattened Bamboo

Figure 5.1.4 - Flattened bamboo



How It's Made

Flattened bamboo is made by longitudinally slicing the bamboo stem, after which the diaphragms are removed and the bamboo is flattened. This can be done in a very rough, mechanical way, resulting in a course, cracked board (referred to as 'esterilla' in Latin America) or through a more gentle vapor treatment in combination with a mesh of incisions at the back side to make sure the bamboo does not bend back, to produce sophisticated flooring boards. A benefit of this technique is that there is hardly any waste (environmental and cost benefit) and the hard and strong outer part of the bamboo, including the skin, is kept intact.

Application Area

Mechanically flattened bamboo in its rough form (esterilla) is often used as sheet in low-cost housing for walls and flooring. The more aesthetical vapor-treated flattened bamboo boards are often used as flooring because of their robust, hard (density approx. 850 kg/m^3) and wear-resistant top-layer. Incidentally they are used as decoration material on walls and bars.

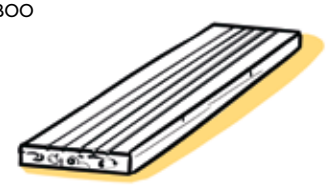
5.2
Bamboo Strip

Figure 5.2 - Bamboo strip variations

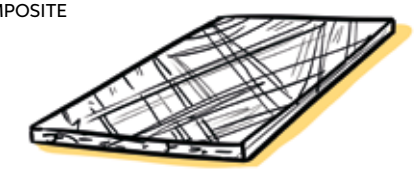
5.2.1 LAMINATED BAMBOO

5.2.2 STRAND WOVEN BAMBOO INDOOR USE

5.2.3 STRAND WOVEN BAMBOO OUTDOOR USE



5.2.4 BAMBOO COMPOSITE



The bamboo strip is the most important component in the bamboo industry. It forms the building block of many different engineered bamboo materials, the most important ones (in volume) being laminated bamboo and strand woven bamboo. After harvesting, the stems are sawn to 2.5 m long pieces, split lengthwise to produce strips, after which the outer and inner skin is removed in a planing machine. The strips have a light yellow color (natural), but they can be steamed to acquire a light brown color (caramel). Alternatively, they can be thermally treated to acquire a dark brown color (chocolate).

Strengths

- Easy to engineer a custom-made semi-finished material with strips serving as small, rectangular building blocks
- Good aesthetical appearance
- Dimensionally stable (especially if thermally treated)
- Fire safe (can reach Euroclass B – EN 13501-1 when in compressed form)
- Durable (can reach durability class 1, EN 350 when thermally treated and compressed)
- Environmentally friendly, negative CO_2 footprint (see chapter 4)
- High hardness (especially in compressed form)
- Mechanical properties similar to high-quality glue-laminated spruce, in general somewhat higher bending and tensile strength (see also box 3.3)
- If used as zephyr (isolated cellulose fibers) even higher tensile strength and stiffness, ideal for bending-load cases

Weaknesses

- Engineered bamboo is not an easy product to manufacture; many production parameters (moisture content, balancing, material age, pressing time, etc.) need to be perfectly aligned for a good final product
- Good-quality product is relatively expensive
- Low outdoor durability (susceptible for fungi and insect attacks) if not thermally treated
- Use of synthetic glue (2-10% dry weight, depending on the product)

5.2.1
Laminated Bamboo

Figure 5.2.1 - Laminated bamboo

How It's Made

After planing the strips, they are sorted according to color and size, after which they are dried. Glue is applied on the dry strips, which are then hot-pressed to produce a one-layer panel. Subsequently, glue is applied on the separate one-ply panels to press them into a multilayer panel or beam. The panel/beam is then sawn and sanded to become the final product.
A new development in China is finger-jointing (hook joint) on strip level instead of on beam level, resulting in a beam with a more homogeneous strength distribution, seemingly very interesting for structural applications. These beams, also available as panels/boards, can be impregnated by EU approved biocides to increase the outdoor durability, enabling outdoor application. See box 3.3 for more information. An alternative production path for laminated bamboo is to slice thin sheets of veneer from a giant laminated bamboo block. Rotary veneer in bamboo is also possible, although its quality and output is considerably lower than that of block veneer, explaining its lower popularity.

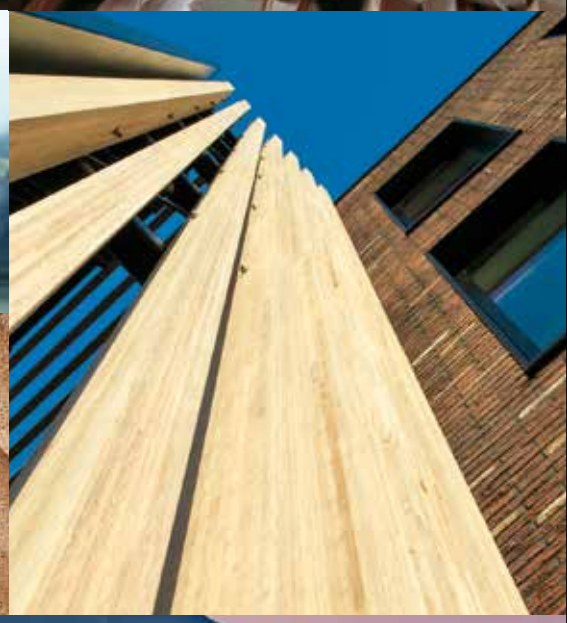
finger-jointing on strip level
Note that although the E-modulus is in general somewhat lower compared to that of wood (mean value: 9721 N/mm²) because of the higher flexibility, the bending strength is relatively higher (characteristic value: 56,7 N/mm²).
Test results courtesy of MOSO International BV.

Application Area

Because it is made of thin strips serving as building blocks, laminated bamboo can be used to create aesthetical, high-quality, semi-finished materials in many different dimensions, from thin veneer sheets to medium-size flooring planks to large panels and beams. It can therefore serve as base material for many architectural and interior design applications, such as flooring, walls, ceilings, window frames, table tops, but also for several user goods ranging from cutting boards to computer housings.

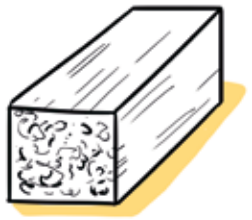
Design Challenge

A promising niche market is to combine laminated bamboo with several kinds of color finishes as well as other materials, such as fabrics.



5.2.2
Strand Woven Bamboo
Indoor Use

Figure 5.2.2 - Strand woven bamboo – indoor use



How It's Made

In the beginning of the 2000s, a new production technology was developed in which rough bamboo fiber bundles (actively crushed to increase the potential glue bonding area) are submerged in a resin, after which they are cold-pressed in molds under high compression (increasing the density from 700 kg/m^3 to 1050 kg/m^3). After this, the glue is activated in an oven to yield high-density beams and panels. The result is an extremely hard material (see also figure 3.2) with a look that can hardly be distinguished from tropical hardwood.

Besides its good mechanical properties, another benefit of this production technology is that strips which are not suitable to produce laminated products due to their dimensions, can be used as input material. Also, this product is available in different colors, i.e. natural (boiled input strips), caramel (carbonized input strips) or chocolate (thermally modified input strips, often used for outdoor application – see the next section). This type of bamboo product is also referred to as high-density bamboo or bamboo scrimber.

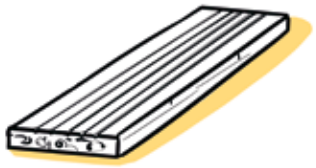
Note that not all strand woven bamboo is the same. Depending on the production parameters, its quality (stability, durability, hardness) can be very different. For example, by more controlled crushing and hot-pressing, panels can be created suitable for extremely heavy traffic and semi-outdoor use, such as in train station halls and horse stables.

Application Area

Strand woven bamboo is available in beams or is sawn to form planks. Because of the high hardness and hardwood look, strand woven bamboo is ideally used in indoor applications where the high hardness is utilized, such as (top-layers of) flooring and panels for table tops. Because of the high relative weight, its use for structural beams is limited, although the good bending strength may be utilized in some other indoor applications, such as self-supporting staircases, balconies and boardwalks.

5.2.3
Strand Woven Bamboo
Outdoor Use

Figure 5.2.3 - Strand woven bamboo – outdoor use



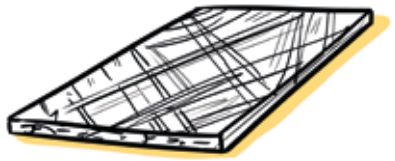
How It's Made
A relatively recent innovation is an outdoor variation of strand woven bamboo for which the input strips are first thermally modified to increase the durability to the highest class possible (durability class 1 according to EN 350, see also figure 3.3) which also strongly increases the dimensional stability (shrink/swell). Another difference compared to the indoor version is that the pressing and glue activation occur at the same time (hot-pressing).

Due to the higher resin content and compression, this product has an even higher density than regular strand woven bamboo boards (1200 kg/m^3 instead of 1050 kg/m^3), also resulting in a very high fire resistance (Euroclass B – EN 13501-1) without impregnation with fire retardants. However, because of the thermal modification, the input strips are more brittle, lowering the E-modulus (10373 N/mm^2, mean value) and bending strength (50,3 N/mm^2, characteristic value – *all test results courtesy of MOSO International BV*) compared to the indoor version of strand woven bamboo (E-modulus 12505 N/mm^2, mean value, bending strength 65,4 N/mm^2, characteristic value). Also, because of the energy-intensive thermal modification and the increased resin content, the environmental impact of this product is greater than that of regular strand woven bamboo (see also chapter 4.2).

Application Area
Thermally modified strand woven bamboo comes in the form of panels, small beams and boards. Because of the increased durability, it is ideally used in applications where normally tropical hardwood is used, such as decking, cladding and outdoor furniture. Also applications in the civil sector, such as canal lining, sheet piling and bridges, are possible with this strong and durable material.

5.2.4
Bamboo Composite

Figure 5.2.4 - Bamboo composite



How It's Made

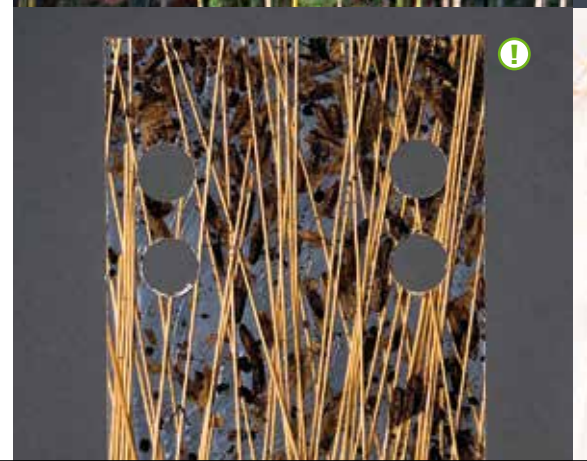
The base material of high-quality bamboo composites is zephyr, which are fine, long-fiber bundles that are isolated from the parenchyma cells and vessels through a process called brooming. Brooming can be done in several manners and involves the mechanical or chemical separation of thick-fiber bundles into the more fine and pure zephyrs. Another production path is through steam explosion followed by mechanical separation using block needles.
The zephyrs form a strong anisotropic linear building block, which, if combined in a mat or mesh, can be used as preform or pre-preg in composite materials. As zephyrs are large enough to be positioned in a certain direction (high stiffness and tensile strength, competitive with glass fiber), in combination with a thermosetting binder (high compression strength), they can act as a mesh in a uni (or iso) directional composite material, which can have both mechanical (maximum strength in a certain direction) and aesthetical advantages (molded in different forms).

Application Area

Because of the excellent mechanical performance, zephyr mats are typically used to produce high-performance composite materials for applications where light weight, form freedom and strength are key attributes, such as the automotive, aerospace, boat and sports equipment industries but also for high strength components in the building and infrastructure/waterworks industry (e.g. canal lining, reinforcement rods, etc.).

Design Challenge

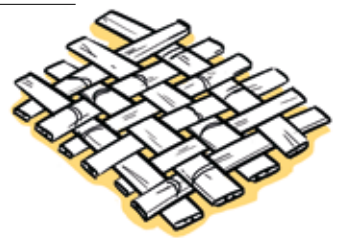
As bamboo composites are a quite new material, there is still a lot of room for improvement in terms of technical and environmental performance, which requires further research (i.e. which bamboo species have the strongest zephyrs, what is the best manner to extract the zephyrs, what is the best resin to use – including the use of resins such as PLA or bio-based PP to minimize environmental impact, etc.).



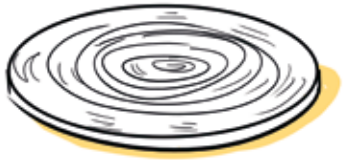
5.3
Bamboo Sliver

Figure 5.3 - Bamboo sliver variations

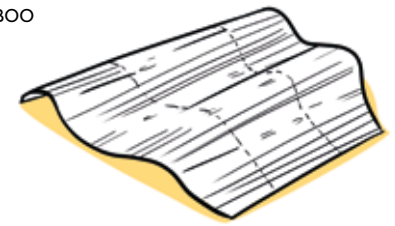
5.3.1 WOVEN BAMBOO



5.3.2 COILED BAMBOO



5.3.3 CONNECTED BAMBOO



Slivers and threads are made from bamboo strips, often deriving from the upper middle part of the stem, where the wall thickness is lower and the strips are not directly suitable for use in the panel industry (see laminated bamboo and strand woven bamboo). Sliver making is easiest when the culm is still green. Slivers are usually produced mechanically by splitting bamboo strips, sometimes several times, depending on the size of the input strip. This splitting can be done with special slivering machines but also simply by means of a machete. The slivers often have a rectangular cross section but can also have a circular cross section, for example for use as input material to produce curtains (sheets made from stitched slivers). The slivers may also be connected in various other manners to yield several new bamboo materials, as presented in this section.

Strengths	Weaknesses
• Good tensile strength • Easy to deform/bend because of high flexibility and low thickness • Often low-cost technology • If done well, high value addition possible to lower-quality bamboo (thin pieces, top pieces, etc.)	• Handicraft image • Usually labor-intensive processing (coiling, weaving, lacing)

5.3.1
Woven Bamboo

Figure 5.3.1 - Woven bamboo

How It's Made

One of the best-known and most historic processing technologies for bamboo is weaving of thin bamboo strips and slivers to produce bamboo mats. In general, weaving is done manually. It is also possible to industrialize the process through weaving machines, but this is more common for connected bamboo (see chapter 5.3.3). To produce suitable slivers and threads for weaving, relatively young bamboo (1-3 years old) can be used, with some species more suitable than others.

Application Area

In South-East Asia there is a long tradition of bamboo weaving, dating back about 6000 years. Manual weaving is usually done with a focus on products for everyday use such as bowls, baskets, animal cages and carpets. Yet in some countries, such as Japan, bamboo weaving is deeply embedded in the culture and perceived as an art.

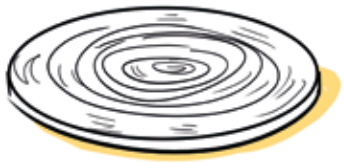
With the industrialization of the bamboo industry in China, also some new processing technologies have been introduced to expand the application area of woven bamboo to the building industry. Bamboo mat board for example is made by dipping sheets of woven bamboo in resin, after which they are hot-pressed and cured to form rough hard boards suitable for various applications (pallets, concrete casting, construction, container flooring, etc.). Alternatively, they can be pressed in various forms, including corrugated boards, providing a low-cost, relatively environmentally friendly alternative for zinc sheets often still used for roofing in developing countries.

Design Challenge

Because of the long tradition of bamboo weaving it has a strong colonial, handicraft image. Nevertheless, because of the many different weaving possibilities combined with an unconventional use of colors it can provide many exciting results. Also, exploration of new, unconventional applications can open up new possibilities for woven bamboo (e.g. lamps).

5.3.2
Coiled Bamboo

Figure 5.3.2 - Coiled bamboo



How It's Made

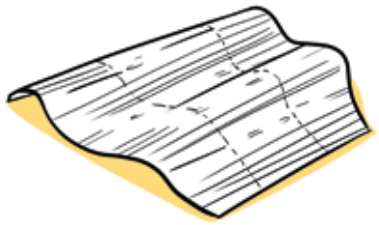
Coiled bamboo is a technique that derives from Vietnam, in which 1-mm thick bamboo slivers are first curved in a roller. Next, they are assembled tightly in a mold (usually a bamboo ring), after which they can be put over another 3-dimensional mold to create the eventual form in the final product. Finally, an adhesive is applied to both sides and the coiled structure can be finished (sanding and coloring). Although this process is quite labor-intensive, the aesthetical quality of coiled bamboo, especially if combined with colors, is generally appreciated in Western markets.

Application Area

Coiled bamboo is commonly used in various decorative household products such as bowls, vases and trays. Because of the fine aesthetical qualities it is worthwhile to further explore application of coiled bamboo in larger interior design objects such as furniture and lamps.

5.3.3
Connected Bamboo

Figure 5.3.3 - Connected bamboo

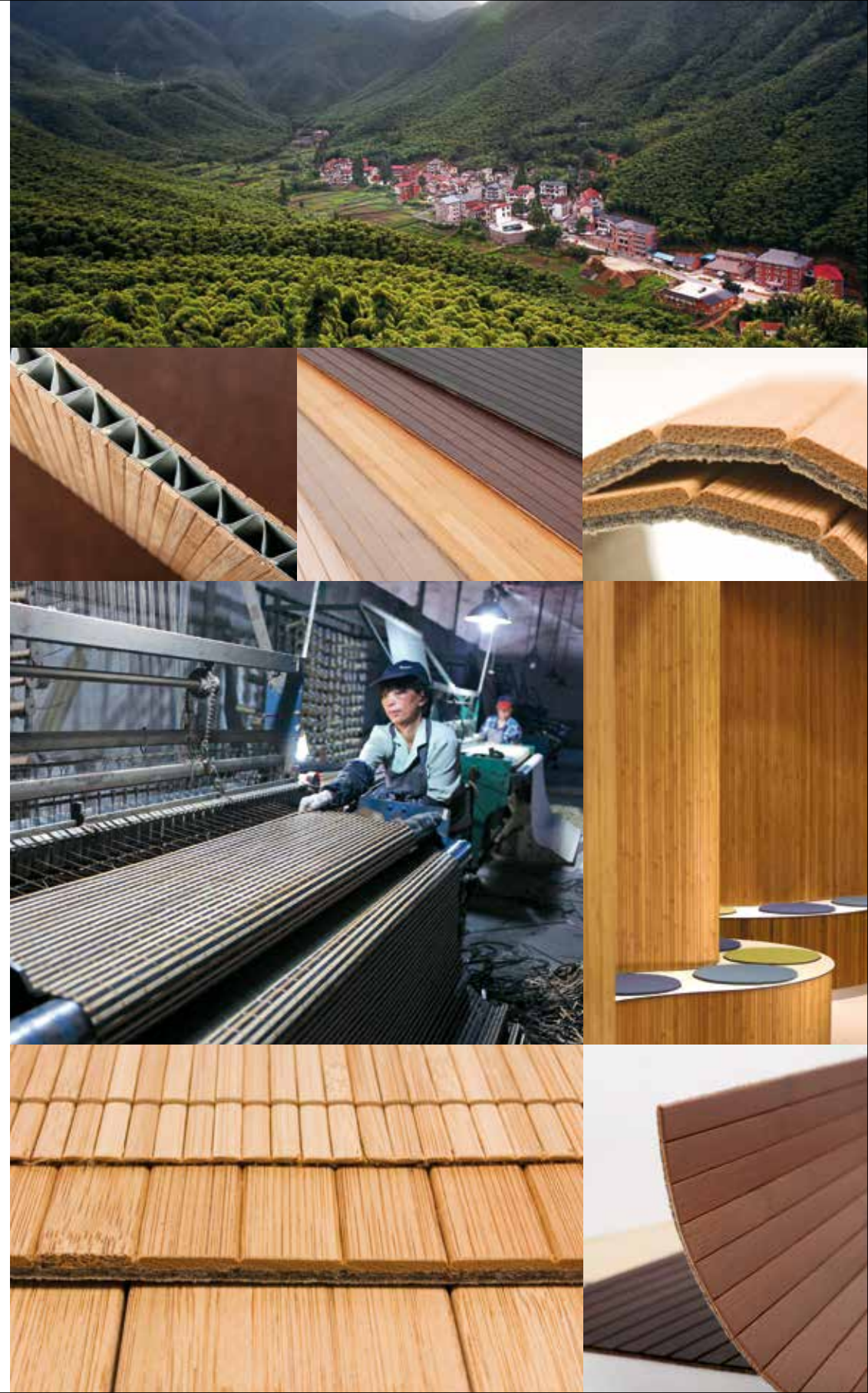


How It's Made

Instead of weaving the slivers, they can also be aligned side by side and stitched together by means of a thread to produce a large preform or mat, which is often called a bamboo curtain. In China, this process is highly industrialized, using specially developed machines that produce vast amounts of bamboo curtain mats every year. Instead of a thread also a flexible fabric or latex backing can be used to connect the separate bamboo elements.

Application Area

Typical applications of bamboo curtain are as a table, bath or floor mat, but it is also used as window curtain or car seat cover. If combined with a latex backing it is very suitable for use as (sound-insulating) floor carpet or floor tiles. Because of its flexibility, application on curved elements (e.g. lamps, cabinets, furniture) and walls is also an interesting design possibility.



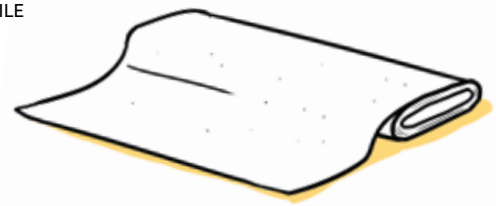
5.4
Bamboo Chip

Figure 5.4 - Bamboo chip variations

5.4.1 BAMBOO FIBER BOARD & PARTICLE BOARD

5.4.2 BAMBOO PAPER

5.4.3 BAMBOO TEXTILE



The smallest elements to manufacture industrial bamboo products are bamboo fibers and particles. These are produced from the complete bamboo stem serving as feedstock, which is fed through large rotating blades at defined angles to create small chips with as large as possible cross-sectional surface to ensure uniform compaction (particle/fiber board) or intrusion by pulp-digesting chemicals (paper/textile). Depending on the industry and even the final application (e.g. packaging vs. toilet paper) the best bamboo species to use differs.

To produce cellulose pulp through traditional pulping technology, the bamboo chips are fully saturated under the influence of steam, heat and pressure in an acid solution to remove the lignin and later also the silica. This pulp is then used as feedstock for the paper or textile industry, where it undergoes further treatment. During traditional pulping, several chemicals are used and a considerable amount of liquid waste is created. Nevertheless, bamboo textile or paper is often still marketed as being environmentally friendly. Although the feedstock is fast-growing bamboo, traditional pulping processes are not environmentally friendly. Thankfully, several new technologies incorporating more environmentally friendly bio-refinery processes and closed-loop systems are emerging that lower the environmental impact of bamboo textile and paper production.

Strengths

- Good mechanical properties of the bamboo microfiber combined with high yields make it an interesting fiber source
- Textile: similar properties as cellulose-based viscose with good hydroscopic, thermal regulating and tactile (softness) properties
- MDF/particle board: added value to lower-quality, under-utilized mill waste material (sawdust, chips, shavings), yet similar mechanical properties as wood-based panels

Weaknesses

- Because of lower volumes compared to wood (MDF/paper) and cotton (textile) industry, still relatively expensive
- Textile/paper: extraction methods and treatments using chemicals negatively impact environmental footprint and yield of bamboo cellulose fiber (but increase quality)
- MDF/particle board: because the bamboo material is fragmented to small elements, competitive advantages in tensile and bending strength of bamboo are reduced (compared to long-fiber composites, see 5.2.4)

5.4.1
Bamboo Fiber Board & Particle Board

Figure 5.4.1 - Bamboo fiber board & particle board

How It's Made

The production process of bamboo particle board and MDF is very similar to that of its wood-based counterpart. However, instead of using full trunks as input material (as is often the case in the wood industry), more often waste streams of other bamboo industries (preprocessing or final-product manufacturing factories) are used as feedstock.

First of all the bamboo chips are washed, after which they are refined in a thermo-mechanical pulping process using steam to soften the chips. After this, they are grinded and mixed with resin. After drying, the fibers are formed and transported on a conveyor belt feeding a continuous hot press, which presses the bamboo chips into a uniform board of medium (approx. 700 kg/m^3) or high (> 800 kg/m^3) density. After formatting and conditioning, the MDF/HDF boards are ready for shipment.

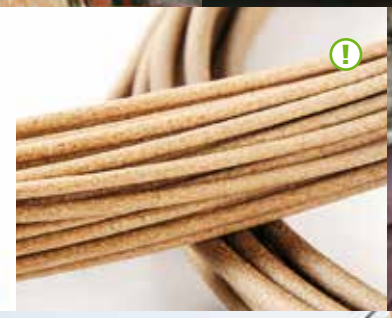
Production of bamboo particle board is similar, only the chips for particle board are larger, ranging from 1-5 mm in width/thickness and 1-20 mm in length, made through flake or hammer milling. It can be produced in a continuous press or in a multilayer press.

Application Area

Bamboo fiber and particle boards are used in similar areas as wood fiber boards, i.e. for internal sheeting in the building industry but most commonly in furniture construction (cabinets), flooring underlayment and as non-decorative semi-structural panels.

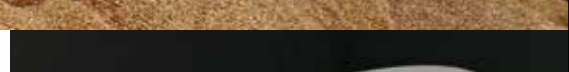
Design Challenge

A more innovative application of the bamboo fiber is as filler in granules suitable for 3D printing or compression molding, especially when combined with a bio-based resin such as PLA. This provides an eco-friendly, potentially fully bio-based alternative for plastics in multiple applications where bio-degradability is an issue (e.g. biodegradable vases, packaging, temporary drainage sheets, etc.).



5.4.2
Bamboo Paper

Figure 5.4.2 - Bamboo paper



How It's Made

Because of its high yields combined with relatively long fibers and good mechanical/physical resistance, bamboo is a potentially interesting material for the paper and cardboard industry. The giant bamboo species *Bambusa Vulgaris* is often used for bamboo paper production, although other species are suitable as well.

The most common process to produce paper from natural fibers including bamboo is known as the 'kraft' process, where chips are mixed and heated with water, sodium sulphide and sodium hydroxide (known as 'white liquor') to delignify the chips and retrieve cellulose pulp. During this process a considerable amount of harmful waste known as 'black liquor' is produced, which needs to be recovered and settled to prevent pollution of ecosystems. Often the cellulose pulp is then bleached, after which water and additives such as calcium carbonate are added to eventually produce a (white) paper. In this process, large amounts of clean water are required, which can be almost fully recycled on site if the process is designed well.

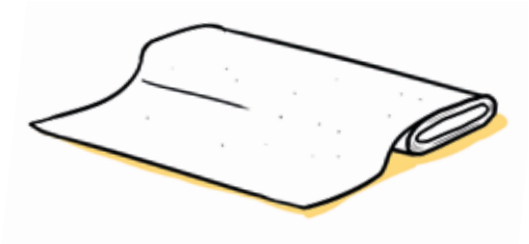
The above shows that a large number of chemicals and waste products are related to traditional paper production, also for bamboo paper. New, cleaner bio-refinery production methods are being developed and will play an important role to improve the sustainability of this sector.

Application Area

Bamboo pulp can be used for various kinds of paper and cardboard production, ranging from office paper to sturdy packaging material.

5.4.3
Bamboo Textile

Figure 5.4.3 - Bamboo textile



How It's Made

Instead of being used for producing paper, bamboo cellulose can also follow a fully different pulping route to produce viscose for the subsequent production of bamboo textiles. Bamboo viscose/rayon has become very popular in a short time because of many proposed beneficial properties (softness, low wrinkle, good thermal properties, etc.), although these are not very different from viscose produced from other cellulose sources (these beneficial properties are mainly based on the processing parameters during viscose production).

The downside is that the production process, although improving the pureness and quality of the fiber, negatively influences the yield and the environmental profile. The main reason is that the conventional pulp dissolving process involves several chemicals, such as sodium hydroxide (caustic soda) and carbon disulphide, to produce a liquid homogeneous viscose solution. After aging for several days, the bamboo viscose liquid is forced through a spinneret into a sulfuric acid bath, which reconverts it into cellulose bamboo fibers, which can then be spun into yarns of various sizes. After washing, bleaching and drying, the final yarn can be woven or spun to eventually produce several kinds of bamboo fabrics. In final garments, bamboo yarn is usually combined with other materials such as cotton to make the fabric sturdier.

Although, theoretically, the many chemical solvents used can be kept in a closed-loop system to reduce environmental impact, they can still be hazardous for the health of the workers. Therefore, announced improvements of the production process by some bamboo textile producers through nano-technology, more eco-friendly solvents and/or new cellulose filament production processes (e.g. Lyocell) are more than welcome.

Application Area

Bamboo viscose can be used in all kinds of garments, in particular where the good thermal, tactile and hydroscopic features can be beneficial, such as in socks, underwear and T-shirts.

6

Bamboo Applications

The various processing technologies introduced in chapter 5 lead to several exciting bamboo materials that can be applied in a multitude of novel applications in various industries. In our worldwide search for inspiring bamboo applications we came across far more examples then could fit in this book. Therefore we decided to select only the most breath-taking and inspiring projects and products. We hope that the examples in this book contribute to inspire you to adopt this magnificent material in your own projects and will lead to many more ground-breaking bamboo projects and products for a second edition!

Madrid international airport
The spectacular curved ceiling of Madrid airport features 200,000 m² of bamboo (for more information see section 6.3.4).

6.1 Structural

6.1.1

Project
Bamboo Hostels

Location
Baoxi, China

Architect
Anna Heringer

Anna Heringer was one of the 12 architects invited to build habitable structures from bamboo for the occasion of the Inaugural Bamboo Biennale in 2016 in the village of Baoxi, China. Baoxi has a rich cultural tradition and heritage, which influenced the characteristic shapes of the three buildings: one male and one female hostel and a guesthouse. Heringer was inspired by the shapes of local woven baskets and ceramic vases, which she translated into the vessel-like form of the structures.
The rammed-earth core is surrounded by an expressive weaved skin, to which the sleeping units are attached. The latter are designed like Chinese lampshades that glow at night.

Photos
Studio Anna Heringer

6.2 Architecture

6.2.1

Project
Beer Sheva Bridge

Location
Beer Sheva, Israel

Architect
Bar Orian Architects & Rokach Ashkenazi

Commissioned by the municipality of Beer Sheva, this pedestrian bridge spans the railroad and connects the local university with an industrial zone on the other side. The bridge achieves its 180-meter span over the city's train station with only three anchors. The full length of the bridge is covered, both on the ceilings and on the walkway, with thermally modified strand woven bamboo boards (Bamboo X-treme) for a beautiful, homogenous appearance.

Photos
Lior Teitler

6.3 Interior

6.3.1

Project
Rijkswaterstaat (Directorate General for Public Works)

Location
Middelburg, the Netherlands

Architect
Paul de Ruiter

This project designed by Paul de Ruiter architects, an architectural firm well known for its green buildings, is recognized for its energy efficiency, its use of sustainable materials as well as the flexibility of the building itself. Whereas the facade and building structure feature many technical materials such as glass, steel and concrete, the laminated bamboo beams on the walls and ceilings of the central staircase hall provide a nice warm contrast.

Photos
Rob 't Hart

6.4 Furniture

6.4.1

Product
Bamboo Chair

Designer
Tejo Remy &
René Veenhuizen

Dutch designers Tejo Remy and René Veenhuizen wanted to plait laminated bamboo slabs similarly to traditional plaiting or weaving techniques with bamboo strips and slivers, as often applied in Asia. The lightness of the material is expressed in the design and full use is made of its flexibility. Laminated bamboo slabs with a width of 14 cm and a thickness of 10 mm were bent into semi-circles to form the basis of the product. This Dutch Design chair resembles a tub chair, reminiscent of deck-chairs on a passenger ship, and combines sitting-comfort with an aesthetically unique character.

Photos
Stan Koolen

6.5
Sports and Mobility

6.5.1

Product
Phoenix Concept Car

Designer
Kenneth Cobonpue & Albrecht Birkner

This project attempts to unveil the future of green vehicles using woven skins from organic fibers combined with composite materials and powered by green technology. The designers wanted to create a lightweight yet economically viable concept car largely made of bamboo and rattan. The concept car was constructed entirely by hand by a team of skilled weavers and craftsmen in only 10 days.
Phoenix is inspired by forms and structures found in nature. Utilizing a single spine as found in vertebrae and plants, the concept car uses an exterior structure similar to that of a leaf. The interior is formed by a single woven surface that starts at the front and incorporates the dashboard, floor and seats. The flowing exterior weaving meets the interior lines in a single bundle at the back.

Photos
Kenneth Cobonpue & Albrecht Birkner

6.6 Product

6.6.1

Product
Mine Kafon Wind-powered Minesweeper

Designer
Massoud Hassani

The Mine Kafon Minesweeper is designed to be blown around in the wind, detonating landmines in its path. Each device has a GPS tracking device linked to a website to show which areas have been cleared. Made of 70 bamboo legs, a metal sphere and biodegradable plastic 'feet', each mine-sweeper is relatively cheap to produce and can withstand the impact of up to 4 bombs before being too damaged for further use.
Massoud Hassani grew up in Afghanistan. As a child he would take small toys out into the hills to play with, but as the wind picked them up, they rolled faster than he could run. Eventually he would have to let the wind take his toys, because the land was covered in millions of land mines. Some children would attempt to get their toys back, often with fatal consequences.

Photos
Massoud Hassani