A report on the potential of bamboo as an crop in the UK for The Farmers Club, Whitehall Court, London

Contents

(Front page: Pseudosasa guanxianensis)

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Summary

Southern China is one of the primary locations for agricultural production and processing of bamboo whereas bamboo cultivation in the central and northern areas of China was found to be small scale mainly supporting local commodity production. The climate of northern China, which has similarities to the UK, is a significant difference that affects the growth rates of bamboo for commercial production. Whilst the average annual precipitation in both northern China and the UK is fine for bamboo production, the distribution of summer and rainfall as many species of bamboo prefer an even distribution. Minimum and maximum temperatures are less significant as temperate *Phyllostachys* relatively cold hardy and bamboo seen in the northern and central China displayed similar growth rates to the equivalent plants growing in the UK. It was concluded that bamboo and *Phyllostachys* particularly would be easy to grow in the UK being especially on marginal land as is it more tolerant of poorer soils.

Yet, despite its widespread use as an ornamental in the UK, there is little evidence of any home grown commercial production of bamboo. As it is only plant suitable for producing canes which are used widely in the UK horticultural and forestry industries, the vast majority canes are imported from China with commensurate economic and ecological costs.

However, comparatively high labour costs and cultural barriers in the UK may significantly hamper investment in cane production.

Alternatively, bamboo should be considered as a bio-energy crop alongside wood and grass as it has some significant advantages over those other crops. It has burning characteristics approaching those of timber but with renewable cycles more similar to grass and it burns relatively cleanly reducing processing costs.

Control of the plant in the field is manageable and many technical constraints to farm-scale propagation appear to have been overcome although this needs to be started commercially before plant material becomes available.

Matching species to location is important and trails would help elucidate the best combinations.

The characteristics of *Phyllostachys* and the absence of established markets means it might be more suited to a mixed or diversified approach to production in the first instance.

Bamboo should be grown productively as well as ornamentally and whilst the opportunities for producing canes might be limited, there are possibilities for growing bamboo as a sustainable and efficient biomass crop.

Starting with biomass as a vanguard application will bring other benefits in terms of carbon-sequestration and possibly winter forage production. It may also help overcome some of the cultural and economic barriers to cane production.

Malcolm Goodwin *November 2011*

Introduction

Bamboo is one of the world's most versatile and widely grown crops economically supporting the livelihood of around 2.5 billion people worldwide around 40% of the world population (Scurlock, Dayton, and Hames, 2000) with worldwide trade is estimated to be between $2.5 billion and $7 billion annually (Hunter, 2008). Yet bamboo as an agricultural crop is virtually absent from the UK and Europe being restricted to ornamental uses in domestic and public gardens.

Of the many species of plants that are collectively known as bamboo, *Phyllostachys* was selected as it is well known in the UK and prominent China where it is perhaps the single most economically important genus. The aim of this study was to confirm whether *Phyllostachys* represented species suitable for cultivation in the UK and identify possible applications and markets.

About Bamboo

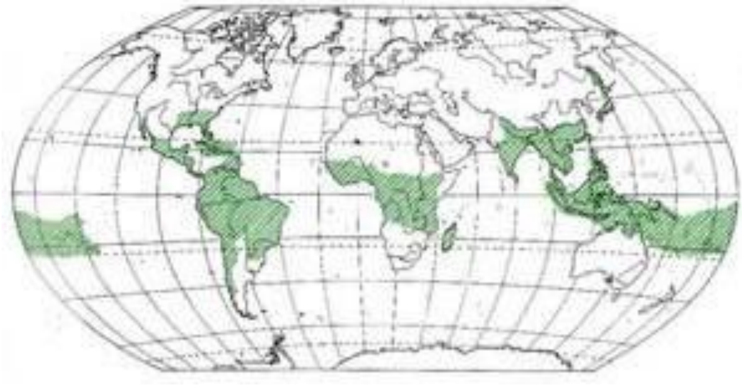
Taxonomy and Distribution

Plant taxonomy traditionally relies on floral characteristics for identification but the long flowering intervals of bamboo between 20 and 120 years (McClure, 1993). This means it is one of the least studied (and recognised) subfamilies of higher order plants (UNEP, 2003).

Bamboos are members of the Grass Family (Poaceae) and Ohrnberger (1999) recognises 1575 species of bamboo in the subfamily: Bambusoideae. Primarily (as shown in Figure 1) they naturally grow between latitudes 47°N and 46°S across North and South America, central Africa and South East Asia but they are not native to Europe.

They vary in height from 10cm to 40 metres (*Dendrocalamus giganteus*) and can be herbaceous or woody (arborescent) although some tropical climbing plants are also known (Scurlock, Dayton, and Hames, 2000 and Ohrnberger, 1999).

Figure 1 - Global Distribution of Bamboo Species



The majority of bamboo including around 626 species (40%) and 22 genera naturally occur in China which has the highest native diversity of species with up to 142 species per km^2 recorded in 900 km^2 of southern China (UNEP, 2003).

Clark (2006) recognises three tribes of bamboo including tropical woody bamboos (Bambuseae); herbaceous bamboos (Olyreae) and temperate woody bamboos (Arundinarieae) which includes the primary study genus *Phyllostachys*.

There are 500 species of temperate woody bamboos which Li *et* al (2001) describes as extensive in south, central, and southwest China as far north as Beijing (see Figure 2). This sub-tribe is characterised by its monocarpic flowering (death after flowering) and the presence of culm leaves and complex vegetative branching (Bystriakova *et* al, 2003).

Figure 2 - Distribution of Temperate Woody Bamboo

(Reproduced by kind permission of Dr. Lynn Clark, Iowa State University)

The genus *Phyllostachys* comprises 51 species, 49 endemic to China and it is the single most economically important genus of bamboo (Wang and Stapleton, 2011).

In 2000, Scurlock *et al.* estimated worldwide commercial bamboo utilization is estimated to be 20 million tonnes per annum but this probably excludes millions of tonnes harvested but unrecorded in the local market-based systems of China.

Hunter (2008) notes that much of this commercial production relies on relatively few species (possibly 50) implying potential under-utilisation of the 1500 or so other known species worldwide.

Professor De-Zhu (2011) confirms that the most widespread and most important economic bamboo species in China are *Phyllostachys edulis* (Moso) and *Phyllostachys violascens*. Plantations of these species cover 3 million hectares in the Zhejiang and Jiangsu Provinces although De-Zhu (2011) also notes that, while most *Phyllostachys* species are distributed south of the Yangzi River there are populations in northern China.

Climate and Habitat

The seasonal extremes in China are greater than the UK and Tao *et al* (2004) suggest that some parts of Chinese agricultural productivity is vulnerable climatic variations including the East Asian summer monsoon and El Niño Southern Oscillation. However in general, Chinese climate varies from tropical in the south to sub-arctic in the north with temperate zones across the northern provinces (CIA, 2011).

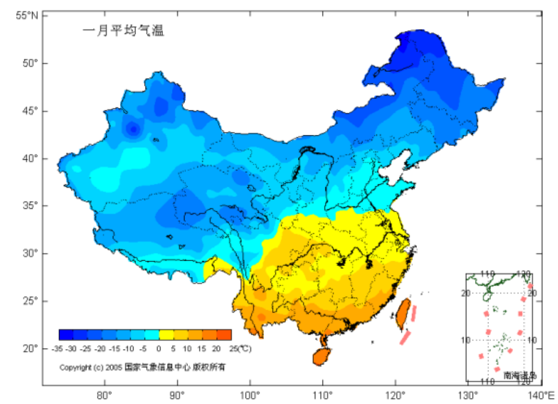
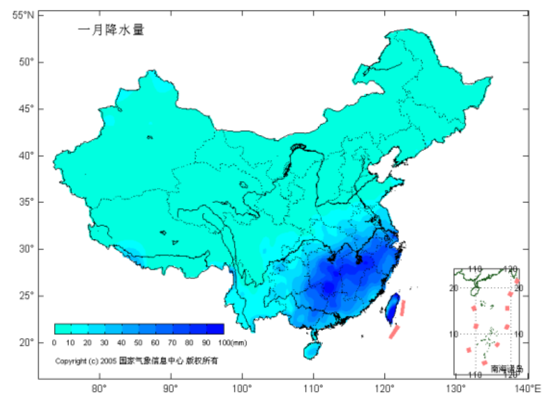
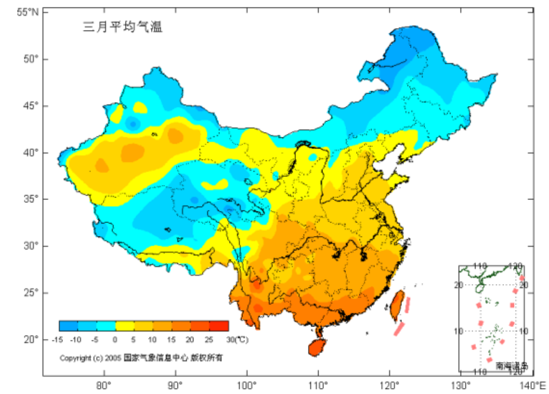
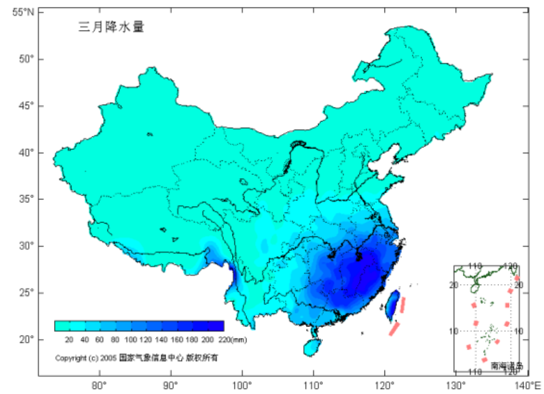
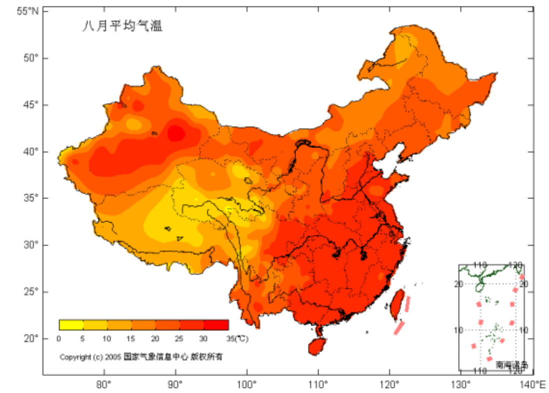
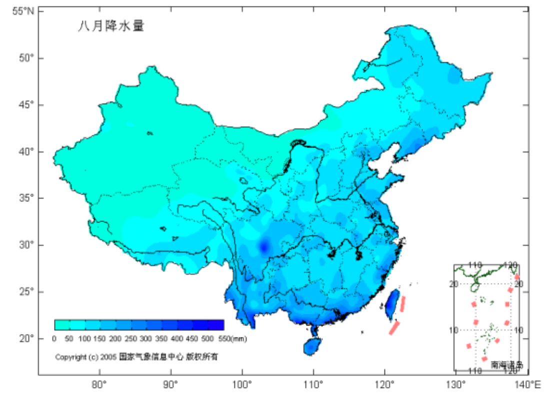
Ye *et al* (2004) show mean annual precipitation for China varies appreciably between 14mm to 2800 mm yet the mean for northwest China (including the Beijing area) and the Shaanxi province (including Xi'an and the Qinling mountain range) is comparable with a range of total rainfall 500mm to 600mm annually.

The Chinese Metereological Data Sharing Service (CMDSS) (2004) produces data that confirm these findings and their data shows that the Qinling mountains and Beijing share average air temperatures of 0℃ to -5°C in January, 10℃ to 15°C in

March rising to 25°C to 30°C Xi’an and 30°C to 35°C in Beijing in August. Generally the overall annual mean is around 15°C.

Equally, precipitation in Beijing and Xi’an exhibit similar monthly means of between 0 to 20 mm from January through to July rising to 150mm to 200mm for the month of August (CMDSS, 2004) with an average annual rainfall of about 650mm.

Table 1 – Mean Monthly Air Temperature and Rainfall for China 1951-2000 (CMDSS, 2004)

	Average Temperatures	Average Rainfall
January		
March		
August		

The International Network for Bamboo and Rattan (INBAR) consider that “bamboo will grow into the high fifties latitude where oceanic influences moderate winter temperatures (e.g. Western Canada, Western Europe)” (Hunter, 2008, p. 3).

Data for the UK shows annual temperatures of between 6.5°C and 12°C (mean 9.25°C) and rainfall between 20mm and 200mm annually (MetOffice, 2011) equating to an average rainfall of between 750mm and 1000mm annually.

Average annual rainfall is more significant to the success of bamboo cultivation that the mean temperature so there are significant similarities between the climate of northwest China, the Qinling region and the UK. This allows some comparison between the floras and underpins some of the expectations for establishment and growth of bamboo in this country.

Table 2 shows that for parts of Lincolnshire; Cambridgeshire; the South East; the North East; South Wales and the south coast, climate data for April in the UK is comparable to the March figures for Qinling and Beijing or even slightly favourable for some species of *Phyllostachys*.

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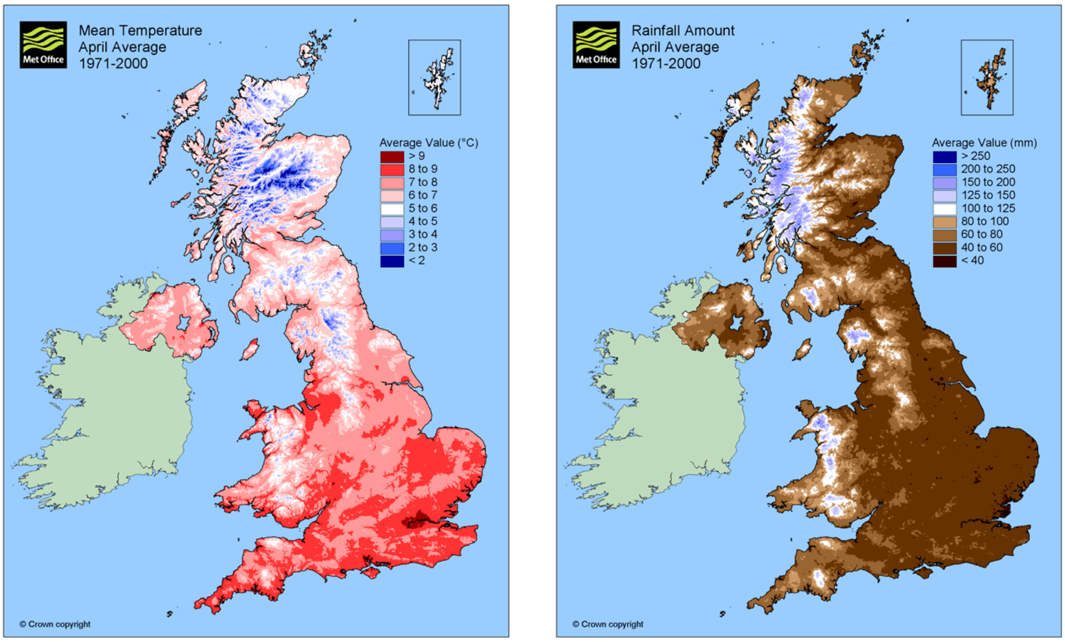
Table 2 – Map of Mean April Average Temperature and Rainfall in the UK (MetOffice, 2011)



Scurlock *et al.* (2000) suggest that *Phyllostachys pubescens,* a species widely cultivated in the south of China, needs annual rainfall of between 1200-1800 mm and mean annual temperatures of between 13-20°C but species like *Phyllostachys nigra* and *Phyllostachys bambusoides* require less rainfall.

In North America, in the US Department of Agriculture Agricultural Research Service (USDA-ARS) at the University of Georgia, the following growth characteristics for Chinese species have been recorded (see Table 3):

Table 3 – Growth of Chinese Species in North America (USDA-ARS)

Species	Culm Height	Culm Diameter	Cold Hardiness
Phyllostachys nigra 'Henon'	20m	11cm	-20°C
Phyllostachys bambusoides	11m	5cm	-18°C
Phyllostachys bissetii	7m	2.5cm	-23°C

Cultivation

Establishment of bamboo can take from 3 to 7 years but thereafter the plant will support annual cutting.

Alternatively, some tradition methods of cultivation follow the *talun-kebun* systems in which bamboo is grown, cut and cash-cropped then the left fallow for more than one year (Christanty, Kimmins and Mailly, 1997).

Chinese growing and harvesting of bamboo is generally un-mechanized with the individual culms (up to 8 years old) selected and removed by hand.

Clear-cutting stands has been shown as feasible using modified forage and sugar-cane harvesters with culms mechanically sorted post-harvest and without long-term damage to the crop (Scurlock *et al.,* 2000).

Leaf area index (i.e. canopy density) is high for most species (*P. pubescens* is 8.02) equating to absorption of 95% of incident solar radiation but leaf renewal and ultimately culm and stand quality appears to vary biennially (Scurlock *et al.,* 2000). This may suggest that rotational cutting of stands would be preferable to maintaining consistency of quality and supply.

Control

Czarnota and Derr (2007) looked at the control of *Phyllostachys spp*. with herbicides including *Glyophosate* and *Imazapyr* and concluded that these products provided 78% and 96% control of re-growth respectively although repeated applications would be needed for full eradication should a field need to be cleared.

Control via spraying is effective and available to most farms as skills and equipment are widely available. The use and management of wide margins or a *cordon sanitaire* would prevent spread (particularly in an agroforestry environment) and ploughing would be an alternative way of controlling spread or recovering a field.

Growth and Development

Semelparity

The biological trait known as semelparity refers to a plant's life strategy of producing as many offspring as possible in a single reproductive event requiring maximum energy and resources often resulting in death of the parent plant (Amasino, 2010).

Some bamboos exhibit this characteristic which botanically is called monocarpism meaning; they flower once then die shortly afterwards (Metcalf, *et al.*, 2003) which could obviously hinder commercial production.

In addition, Wei, Franklin, and Cirtain (2007) say: "little is known about factors that affect seed germination and seedling growth of bamboos" so natural re-growth from seed is often uncertain although it has been demonstrated that the addition of nitrogen aided the recovery of *Fargesia qinlingensis* seedlings when monocarpism is observed.

Although this characteristic of bamboo might have a significantly negative impact on production if a cultivated species dies before economic return is achieved, William (2010) suggests that semelparity might be reduced in introduced i.e. non-native territories so should be less of an issue in the UK.

Mass Flowering

Furthermore bamboos, particularly in the sub-tribe Arundinarieae, are also subject to gregarious (or mass) flowering events. Scurlock *et al.* (2000) notes that clear-cutting stands does not appear to arrest mortality. This implies that death is genetically pre-programmed and flowering is consequential rather that causational.

Franklin (2004) notes that this synchronised flowering of large percentages of a population of bamboo species and timed against an internal biological clock is intrinsically stochastic and endures because of allochronic speciation resulting from species differentiated by relatively slight phenotypic shifts rather than more significant sympatric events. The inference being that the genetic similarity of species confers the trait of synchronous flowering within and between species.

Whilst the effects of dieback after mass flowering in forest environments is poorly understood (Budke *et al*., 2010), the consequences of mass-flowering followed by mass-death are obvious for dependent species from the Giant Panda (*Ailuropoda melanoleuca*) and the bamboo farmer.

Flowering Period

There are potentially, some difficulties for cultivation associated with the synchronised flowering and monocarpism of bamboos but the extraordinarily long inter-flowering period of most species (up to 120 years) will offset these problems.

However, this also means that study and more importantly, research into breeding and genetic modification is severely limited reducing the number of commercial viable variants and development on advantageous plant characteristics.

Pests

Bamboo itself is relatively free from pests and few diseases particularly in this country. Arguably, there is more risk from bamboo as a vector for disease associated with the international trade of culms necessitating costly importation checks than there is from growing bamboo in this country and it becoming a host for pathogens.

Importation of dried bamboo canes (*Bambusa vulgaris)* into the US is subject to a Phytosanitary Pest Alert following the discovery of Asian Long Horned Beetles (Coleoptera: Cerambycidae) *Chlorophorus annularis, Stromatium barbatus* and *Purpuricenus spp.* (NAPPO, 2010) which is a significant pest of forest trees.

Establishment

Propagation of sufficient quantities of bamboo plants to establish a crop has been a barrier for production outside China. However, recent work by a Belgian company (Oprins) has gone some way to addressing this issue. Oprins (2010) were asked to resolve “large scale production of bamboo using tissue culture technology and integration of micro-propagated plants in optimised production scheme to produce quality plants at cost-effective prices”.

For reasons already expressed relating to flowering, bamboo is primarily propagated clonally and while some propagation from rhizomes is possible for *Phyllostachys* generally numbers are increased by division but this method is difficult to upscale to volumes suitable for agroforestry. Further, Oprins (2010) found that because of the established market for ornamental bamboos in the horticulture industry, prices are maintained a levels that would make the establishment of commercial plantations unviable.

Generally, micro-propagation from tissue culture facilitates the production of plants in volumes suitable for mass production of consistent quality and in a short time frame resulting in reasonable costs.

Oprins (2010) investigated micro-propagation through organogenesis; somatic embryogenesis and forced axillary branching on 60 species of bamboo including temperate *Phyllostachys* as given in

Table 4.

Organogenesis proved to be difficult to reproduce reliably, somatic embryogenesis was easily reproduced but the resulting clonal quality was variable but forced axillary branching did produce stable somaclonal plants in a limited time frame with little risk of loss of the original genotype. This has been recommended as the preferred method for commercial propagation although production needs to be scaled up from laboratory conditions.

Table 4 – Micro-propagated species in the *Phyllostachys* Group

Genus	**Species**	**Cultivar**
Phyllostachys	*bissetii*	
Phyllostachys	*decora*	
Phyllostachys	*humilis*	
Phyllostachys	*meyeri*	
Phyllostachys	*viridi-glaucescens*	
Phyllostachys	*atrovaginata*	
Phyllostachys	*aurea*	'Albovariegata'
Phyllostachys	*aurea*	'Koi'
Phyllostachys	*aureosulcata*	'Alata'
Phyllostachys	*aureosulcata*	'Spectabilis'
Phyllostachys	*aureosulcata*	'Harbin-inversa'
Phyllostachys	*aureosulcata*	'Harbin'
Phyllostachys	*aureosulcata*	'Aureocaulis'
Phyllostachys	*nigra*	'Punctata'
Phyllostachys	*nigra*	'Boryana'
Phyllostachys	*nigra*	'Henonis'
Phyllostachys	*vivax*	'Huanwenzhu'
Phyllostachys	*vivax*	'Aureocaulis'
Shibataea	*kumasaca*	
Semiarundinaria	*fastuosa*	Viridis

Cropping and Processing

In China, most production is undertaken by primarily manual methods in many parts of the country with limited mechanisation of much of the rural agriculture and this is often not as advanced as European production systems (Barnes, 2011).

Because of the similarities with other species, it is likely that forage harvesters would be suitable for harvesting and agroforestry machinery suitable for transporting, stacking and storage but post-harvest processing would vary depending on the application.

Cane Production

In China, much of the bamboo farming is administered through localised responsibilities known as the House Responsibility Systems (HRS) centred on quota-based systems of production as part of a basic market economy (Zhang et al, 2006).

Bamboo is most often classified as a non-timber forest product (NTFP) and often excluded for forest inventories while ongoing taxonomical and terminological ambiguities associated with bamboo and its products. This means that good statistical data on the supply and utilisation is difficult to obtain in China (UNEP, 2003).

Correspondingly, UK trade information does not specifically classify bamboo canes separately from other general bamboo and rattan products so importation figures are impossible to extract (HMRC, 2011).

Also, UK importers were reluctant to divulge detailed figures about the values and volumes of cane imports. Therefore, the actual size of the potential market for cane production has been hard to quantify nevertheless all UK imports of canes emanate from China.

Chinese cane production is primarily in an area in the north east of the Guangdong Province with culms of *Phyllostachys spp.* and *Arundinaria amabilis* harvested rather than farmed, cyclically, every 3 years (Reycroft, 2001).

Well-managed production on bamboo plantations increases yields to around 36 tonnes ha^{-1} representing a five-fold increase over indiscriminate harvest from heterogeneous forest stands (Oprins, 2011).

In Arunachal Pradesh, India, 90% of all bamboo demand is met by *Phyllostachys bambusoides (*Sundriyal, 2002) but in the UK a wider range of species are likely to be suitable given climatic and geographic variability. Some of these species are given in Table 5

Table 5 – Bamboo Suitable for Cane Production

Species	Growth Pattern	Reference(s)
Arundinaria hindsii	Leptomorphic	Forest Floor (2002)
Phyllostachys aurea	Leptomorphic	Forest Floor (2002); Home Sufficiency (2009)
Phyllostachys bambusoides	Leptomorphic	(Sundriyal, 2002)
Phyllostachys nigra.	Leptomorphic	Forest Floor (2002)
Bambusa multiplex	Pachymorphic	Forest Floor (2002)
Bambusa "Wong Tsai"	Pachymorphic	Forest Floor (2002)
Bambusa gracilis	Pachymorphic	Forest Floor (2002)

Some of these species suitable for cane production are running varieties and some are clumping species so the methods of planting and cropping will vary considerably as the leptomorphs should be harvested on *en-masse* but this means a high level of wastage after grading unless sub-standard culms are processed into biomass.

The pachymorphs should be selectively harvested but this is likely to be time-consuming and un-economic for anything other than very small scale production or very high quality product for the floristry, cut-flower or interior design industries.

Bioenergy

Collecting, transporting, and storing biomass can be expensive and can have a low-heat content and is own associated problem with pollutions and waste (ESMAP, 2005) nevertheless, biomass currently meets 11% of global energy demands (Kaygusuz, 2010). It is the key to energy supply for several billion people in developing countries with direct combustion biomass crops accounting for 95% of production (Farrell and Gopal, 2008).

Harberl *et al* (2011) examined the complex interactions between demand, agricultural production and climate change and extrapolated global bioenergy potentials for 2050 to suggest that gross (primary) bioenergy potential ranges from 64 to 161 EJ y^{-1}.

In China, annual energy demands are projected to increase by 4–5% per year up to 2015 and its Five Year Plan for Renewable Energy Development suggests greater biomass production leading Zhuang *et al.* (2010) to predict massive potential for bioenergy production in China particularly in the colder central north and northwest with plans to increase capacity to 30GW per year by 2020. China's bioenergy currently depends on plants including poplar; willow; Yang grass (*Leymus chinensis*) and bamboo with further research looking at new species (Zhuang *et al.,* 2010).

In the UK, the Department of Energy and Climate Change (2011) predicts that Bioenergy could account for half of all UK renewables and the UK has committed to supply 15% of energy by 2020 from renewable sources backed up by subsidies for renewable electricity (in the form of Renewable Obligation Certificates or ROCs) of up to £17.5 million per year for a 20 MW power station.

There are currently around 16 operational biomass power stations in the UK with a further 15 or so approved for development and around 20 proposed, or in planning (Bio Fuel Watch, 2011). The DRAX power station in North Yorkshire typically burns 1,068,803 tonnes of *Miscanthus* and wood each year producing 222 MW pa^{-1} while

ELEAN near Peterborough uses 220,000 tonnes of straw annually to generate 38 MW pa^{-1}.

Conventional biomass production in the UK is based either on Elephant Grass (*Miscanthus giganteus*) or broadleaved coppice forestry with no bamboo biomass evident from research in this country.

Elephant Grass (*Miscanthus giganteus*) is planted as rhizome divisions at a density of 20,000 per ha often using conventional agricultural machinery such as a potato planters and then takes 2 years to initial harvest and plantations can last for 15-20 years before re-planting is required (BEC, 2011c).

Alternatively, traditional forestry utilises coppiced common trees including Hazel, Ash, Sweet chestnut and Sycamore whereas Short Rotation Coppice (SRC) depends on faster growing like Willows and Poplars planted at 2500 stems ha^{-1}.

Some recent concerns about co-emission of the greenhouse gas Nitrous Oxide (N_2O) associated with increased production of bioenergy crops have recently been discounted (Popp *et al*, 2011).

Other problems associated with bioenergy production include high levels of particulates (ash content) and high sulphur content that cause pollution, erosion and corrosion (Farrell and Gopal, 2008) but bamboo has been shown to be relatively low in both these respects.

Bamboo Biomass

Studying three species for the US Department of Agriculture, Scurlock *et al.* (2000) produced some comparative data between *Phyllostachys* and other biomass feed stocks which are summarised in Table 6.

These demonstrate a relatively low ash and sulphur content, a low moisture content yet a high heating value of bamboo compared to other grasses. Bamboo therefore should be a favourable source of energy compared to other grasses especially as it also has a longer life expectancy.

Table 6 – Bioenergy comparison between Bamboo and traditional grass crops (Scurlock *et al,* 2000)

Property	Bamboo (*Phyllostachys*)	Elephant Grass (*Miscanthus*)	Switch Grass (*Panicum*)
Gross Heating Value (GJ t^{-1})	19.1-19.6	17.1-19.4	18.3
Moisture content (%)	8.4-22.6	15	15
Ash content (%)	<1.0	1.5-4.5	4.5-5.8
Sulfur content (%)	0.03-0.05	0.1	0.12

In South Africa, bamboo is used for biomass energy production but undergoes a torrefaction process (partial pyrolysis or charcoaling) before combustion to reduce water and tar content and the subsequent torrefied bamboo is consider as:

- a 100% renewable alternative to fossil fuels
- CO_2 neutral/negative
- a low cost alternative to fossil coal
- a low pollution replacement with reduced greenhouse gases (GHGs)
- immediately usable in power plants without retro-fitting (BioMass Corp., 2008).

Phyllostachys is generally found to exhibit the following advantageous characteristics for fuel production:

- Heating values appreciably higher than most grasses and straws
- Heating values slightly lower but comparable to traditional woody biomass feed stocks
- Very low Nitrogen (N) content that reduces the production of harmful NO_x gases that subsequently form smog, acid rain and tropospheric ozone
- Very low Sulphur (S) content that reduces pollution and acid-rain
- Low ash content reducing fouling and slagging and post-combustion processing
- Low moisture content reducing pre-processing drying times

Despite this, Scurlock *et al.* (2000) does not see bamboo as a potential biomass energy crop for the US citing: climate limitations (but recognises little has been done to identify appropriate species/genotypes); restrictions scaling to commercial volumes due to propagation methods (although solutions to this have been discussed earlier') and noting that non-fuel applications as potentially more profitable than energy-recovery, which is not relevant to the UK that does not have a developed bamboo industry.

Harvest and Yield

Elephant Grass is cropped using a forage harvester when moistures is around 20%, dried in the swath and baled like hay achieving yields of around 12-14 tonnes per hectare (BEC, 2011c).

Traditional forestry may not mature between 30 and 100 years for broadleaved coppice cropping cycles can be between 10 to 15 years after a 5 year establishment period with is reduced to 3 to 5 years for short-rotation coppice whose stools remain productive for 30 years and with a moisture content of around 60% it takes longer to dry (BEC, 2007b).

Hong *et al.* (2011) undertook a comparative study of bamboo and *Miscanthus* in China and found that the above-ground biomass of *Phyllostachys spp.* varied between 5.9 tonnes and 26.66 tonnes ha^{-1} yr^{-1} compared to *Miscanthus* which ranged between 3.2 tonnes and 25.5 tonnes ha^{-1} yr^{-1}.

The EC-funded “Bamboos for Europe” trials established bamboos including *Phyllostachys vivax; P. aureosulcata; P. propinqua; P. humilis; P. nigra; P. praecox; P. viridoglaucescens* and *Phyllostachys* var. ‘Zwijnenburg’ and recorded yields ranging between 7 tonnes dry-matter ha^{-1} year $^{-1}$ to 15 dry-matter ha^{-1} year $^{-1}$ (Hunter, 2008).

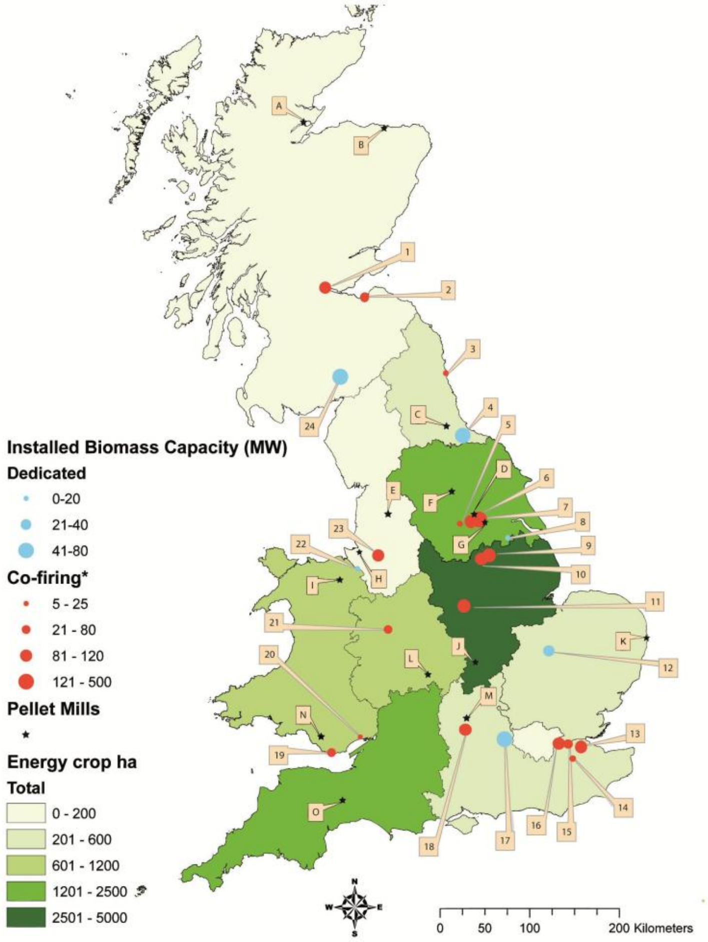
Other studies include another European project which funded a four-year programme of biomass energy production from bamboo charcoal in Africa for completion in 2013 including *Phyllostachys pubescens* (INBAR, 2011a).

INBAR consider bamboo to be “a serious contender for biomass production" (Hunter, 2008, p.3) because of:

- its high productivity
- it can yield continuously
- its evergreen all year (useful as a screen or wind-break)
- it high water-use efficiency and
- its desirable physical qualities for biomass energy conversion.

The 16 biomass power stations in production process around 1,685,000 tonnes per year and generate 305.1 MWe in total. Adding the 35 additional power stations (currently in planning) will add capacity for 35,501,000 tonnes per year and 4,230 MWe of power generation. The potential for increased market and production are large.

Figure 3 - Biomass Processing Facilities (NNFCC, 2010)



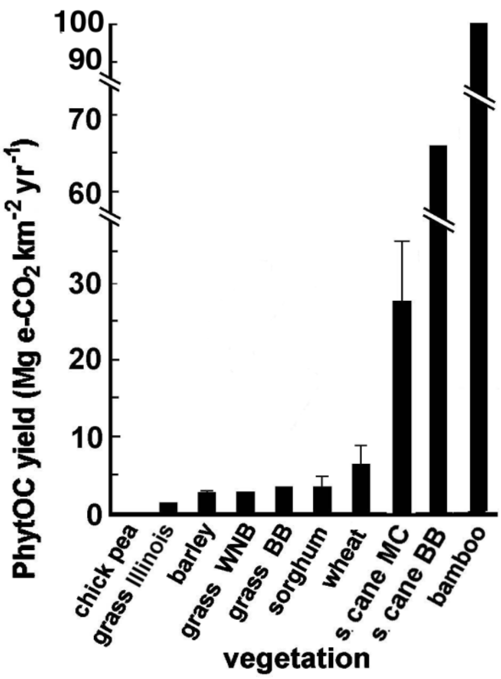
By-products

Biosequestration

Silica is taken up by plants as Silicic Acid $Si(OH)_4$ and aggregated into silicate tetrahedra (SiO_4) known as phytoliths that subsequently amass organic carbon as Phytolith Occluded Carbon (PhytOC) (Parr and Sullivan, 2004).

Bamboos are especially good accumulators of PhytOC (see Figure 4) absorbing up around 3 tonnes CO_2e ha^{-1} yr^{-1} (assuming 25 tonnes of biomass) and carbon so acquired, can remain in the plant or soil phytoliths for thousands of years helped to reduce damaging 'legacy' atmospheric CO_2 by around 1.5 billion tonnes of equivalent CO_2 yr^{-1} (Parr and Sullivan, 2004 and Parr *et al.*, 2010).

Figure 4 - Biosequestraion Rates of Selected Agricultural Crops (see Parr and Sullivan, 2004)



Fodder and Cover Crop

If bamboo is farmed in the UK then stands of bamboo would represent a semi-permanent part of the countryside. Also, to be used for cane production or biomass, the leave need to be removed in the finishing process but these leaves can also have value as a fodder supplement, particularly in the winter time.

Worldwide, native stands of bamboo are habitats and forage for a range of wild animals, a selection of which are given in Table 7.

Table 7 – Summary of bamboos as a food source

Animal/Location Studied	*Target Species*	Reference
Giant Panda *Ailuropoda melanoleuca,* Wolong Nature Reserve, China	*Fargesia nitida*	Tao *et al* (2007)
Giant Panda *Ailuropoda melanoleuca,* China	*Phyllostachys spp.* *Fargesia spp.* *Chusquea spp.*	Carter *et al* (1999)
Red Panda *Ailurus fulgens,* Fengtongzhai Nature Reserve, China	*Various*	Zang *et al* (2009)
Red Panda *Ailurus fulgens* , Yele Natural Reserve in Sichuan, China	*Bashania spanostachya*	Wei *et al* (1999)
Yunnan Snub-nosed Monkey, Montane Samage Forest	*Fargesia spp.*	Grueter *et al* (2009)
Sika Deer, Yakushima Island, southern Japan	*Pseudosasa owatarii*	Takatsuki (1990)
Golden Monkeys *Cercopithecus mitis kandti,* Mgahinga Gorilla National Park, Uganda	*Arundinaria alpina*	Twinomugisha and Chapman (2008)
Grauer's Gorillas, Montane Forest of Kahuzi, Democratic Republic of Congo	*Various*	Yamagiwa *et al* (2005)
Lemurs *Hapalemur g. griseus, H. aureus, and H. (Prolemur) simus*, Ranomafana National Park, Madagascar	*Various species*	Yamasita *et al* (2009)
Indian Elephants, Chandaja Wildllife Sanctuary, Orissa	*Various*	Roy *et al* (1992)
Human *Homo sapiens,* Worldwide	*Schizostachyum funghomii*	Van Hoang, Baas and Keβler (2008)
South America Birds Rhinocryptidae and Furnariidae, South American temperate rainforests	*Chusquea valdiviensis*	Reid *et al (2004)*

Whilst obviously none of these animals are endemic to the UK, game bird would likely take advantage of the cover as well as other native wildlife.

Holvorsona *et al* (2011) specifically examined the nutritional value of *Phyllostachys* for selected ruminants and found leaf fibre and protein were sufficient to meet the maintenance needs of adult goats while non-structural carbohydrates remained stable or actually increased during winter.

Low growing and spreading species (as shown in Table 8) are an ideal cover crop for game birds and could potentially supplement winter feed for livestock although more research would need to be undertaken to clarify specific suitability.

Table 8 – Bamboo species suitable for cover crop and winter forage

Species
Bashania qingchengshanensis
Borinda macclureana
***Fargesia murielae* 'Bimbo'**
Fargesia nitida
Fargesia rufa
Pleioblastus pygmaeus
Sasa kurilensis
Sasa tsuboiana
Sasa veitchii
Sasaella ramose
Shibataea kumasaca
Yushania anceps

Conclusion

Bamboo is an extraordinarily versatile raw material and is widely used on many parts of the world except Europe and the UK where is only used as a garden plant. The species distribution and climate tolerance means that many species of bamboo, particularly *Phyllostachys spp.* will thrive in the UK although growth rates of temperate species will be low compared tropical species they are comparable to other grasses and much faster than timber.

Sourcing sufficient volumes of plants to establish a crop will be difficult as no suppliers exist but the technicalities of propagation have mainly be accomplished and this is something that could be achieved and scaled up as demand increases. Equally, there is likely to be very limited experience in establishing, maintaining and harvesting bamboo on a large-scale in this country but many of the processes will be adapted from familiar work on similar crops.

Cane production is unlikely to be the driver for large scale production as the relatively high production costs and low margins on the final product will make it commercially unviable.

However, there is high potential for bamboo as a biomass crop. It have many characteristics in common with other biomass crops and several distinct advantages. Production and processing is likely to be adaptable from one crop to another with the major hurdle being the acquisition of significant volumes of plants and the establishment of stands of sufficient size to make is worthwhile.

If bamboo can be established a crop in this way, it is expected that a number of other applications and opportunities would develop. What is required in an initial interest and support to start production and allow more detailed research into species suitability, cultivation and processing.

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