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ECOLOGICAL OPPORTUNITIES AND CHALLENGES FOR SUSTAINABLE BAMBOO CULTIVATION IN THE NETHERLANDS

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Abstract

Europe is the largest importer of bamboo raw materials on the market. However, due to the lack of transparency in bamboo cultivation in Asia, concerns arise about sustainability practices. This has led to a growing interest in bamboo production in the Netherlands. Although bamboo is grown in the Netherlands as an ornamental plant, it is not being grown at a commercial scale as of yet. This report looks at the feasibility of bamboo cultivation in the Netherlands and evaluates the ecological effects. The topics on which the report focusses are nutrient & water management, carbon credits and intercropping potential and ecological impacts and benefits.

By carefully examining the available literature, it can be concluded that it is possible to grow bamboo on a large scale in the Netherlands, but that further research on practices and ecological effects in Europe is needed. Possible negative environmental impacts and legal uncertainties cannot be excluded and must be considered before going forward to address existing knowledge gaps. Additional research is advised as to avoid unnecessary risks and uncertainties for farmers and nature.

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Introduction

Bamboo is a versatile plant that belongs to the grass family. It is considered as a sustainable alternative for wood and fibre due to its mechanical properties and fast growth. This plant originally comes from Asia, Africa and America and is a non-native for Europe. For this reason, Europe became the largest importer of raw bamboo materials in the global market (INBAR, 2019) with the Netherlands being the largest buyer for bamboo raw material in 2015-2019, account for € 72.020.545 worth of products (Eurostat, 2022 as cited in Lombardo, 2022). However, the lack of transparency in the bamboo growing system in Asia remains a major issue regarding the sustainability of bamboo in Europe (Lombardo, 2022). Shipping, from harbour to harbour, alone has been estimated to account for 25.4 % of the CO_2 emissions of "Plybamboo" boards (van der Lugt, 2008). This is likely to be much higher for bamboo raw materials which have a lower bulk density than processed products. These concerns about the sustainability of bamboo imports to the Netherlands have led to increased interest in domestic bamboo production. Although bamboo has been grown as an ornamental plant in the Netherlands for some time, there is a lack of knowledge and experience about commercial bamboo cultivation methods and their effects on the soil, nutrient and water balance. In addition, there are concerns and knowledge gaps regarding the environmental impact of commercial bamboo plantations and the potential for carbon sequestration and intercropping. These topics are particularly important in terms of economic opportunities and possibilities, and also play a major role in the designing of policies. Some of the potential species for cultivation in the Netherlands, e.g., *Phyllostachys* have been shown to be very competitive against other plants in their native countries and need careful management to control them (Xu et al., 2020). Therefore, it will be important to investigate the environmental opportunities and challenges of Dutch bamboo production.

Problem description and research questions

The project specific problem is the establishment of bamboo produced in the Netherlands as a sustainable alternative to imported bamboo. So far, farmers and growers lack knowledge and experience about specific problems related to soil, water management, carbon sequestration and ecological impacts in interaction with different bamboo species. There are also questions about the impact on biodiversity. Although bamboo is a very promising crop, some of these knowledge barriers are preventing farmers from considering it as an alternative crop. This report aims to identify and address the environmental opportunities and challenges of bamboo cultivation in the Netherlands. To answer this question, the team looked at the various aspects that make up this main question. The main parts that are addressed in the report are: The interaction between bamboo plantations and soil types, The carbon sequestration potential of bamboo, If bamboo plantations have potential to be combined with intercropping systems and what benefits and impacts bamboo has on the local ecosystem.

Bamboo Physiology

There are over a thousand different species of bamboo, but only the cold hardy ones can survive winter temperatures in the Netherlands. *Phyllostachys* and *Fargesia* are both part of the tribe of *Arundinarieae* that is part of the grass family *Poaceae,* And are species that can grow in the Netherlands. Even though they are from the same tribe there are quite some differences between these two genera. The most important components of *Phyllostachys* and *Fargesia* are the rhizomes, roots and culms. The type of rhizomes determine if the bamboo is a clumpy or non-clumpy type. Bamboo mainly reproduces vegetatively but can also produce flowers for sexual reproduction. Flowering only happens once in 60-130 years for example *Phyllostachys bambusoides* only flowers in inervals of 130 year (*Bamboo Biology - the Bamboo Flower*, n.d.).

Rhizome

The rhizome system in bamboo is an underground and wide spread structural foundation of the plant. Each individual axis of the rhizome can be seen as a segment of the bamboo. The rhizome is made of 2 parts: the neck and the proper. The neck is usually long in running bamboo and short in clumping bamboo. There is 2 types of rhizomes, sympodial (pachymorph) and monopodial (leptomorph), or determinate and indeterminate. In running species, the rhizomes are indeterminate or monopodial, while the clumping type has a determinate rhizome system (Liese & Köhl, 2015).

Running (indeterminate)

The indeterminate rhizomes, or leptomorph (Gr. *Leptos* = thin; *Morphē* = form) is a thin and long type of rhizome. Characteristics of these rhizomes include that it forms an approximate round shape with a width smaller than the original culm while being uniform in length and most of the time hollow with more internodes oriented lateral than diagonal (McClur, 1966). Multiple culms can be formed from one lateral bud. Various buds can make rhizomes to spread to nearby areas (Liese & Köhl, 2015). Because of the long rhizome necks, these species can travel large distances in just a couple of years which makes spreading easier(Figure 1). Therefore they are called running species.

Clumping (determinate)

The determinate rhizomes, or pachymorp (Gr. *Pachys* = thick; *Morphē* = form) have multiple lateral buds that grows into new bamboos on each side of the rhizome proper. The internodes are broader than they are long. They have a solid inside and the length is not uniform. The rhizomes consist of two main parts, the rhizome proper and rhizome neck. The rhizome neck sits under the rhizome proper and it serves as a connection from the mother rhizome to the new rhizome. This type of rhizomes are usually curved and rarely straight. From the base of the culm, a horizontally rhizome grows and forms a new shoot (Figure 1). Due to the short rhizome necks of these types of bamboo they grow closely to each other and from a clump, therefore this is also a clumping species(Liese & Köhl, 2015).

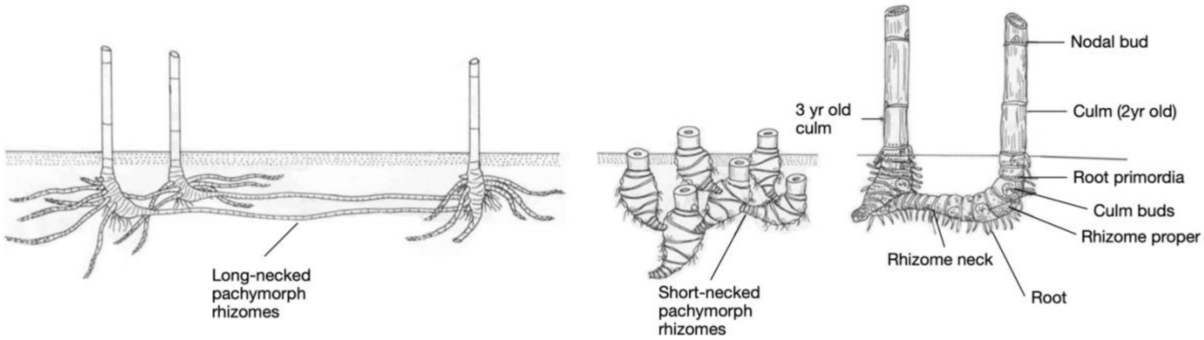

Figure 1: *Physiology of clumping and running Bamboo (adapted from Liese & Köhl, 2015)*

Roots

The roots of the bamboo plants are similar in shape and length and form at the base of the rhizomes nodes. On average the roots do not get deeper than 70 cm below the surface. But in some exceptional cases, it can grow up to 150 cm deep into the ground. A stunning 70 % to 80 % of the roots are present in the upper 33 cm of the soil, with a root diameter between 0.04 cm and 0.48 cm. The roots, together with the rhizomes, play an important role in water retention and absorption (Liese & Köhl, 2015).

Culms

As stated before, bamboo is categorised as either a clump forming type or a running type. It produces shoots from the rhizomes and elongate into the stem, commonly referred to as a culm (Latin: *culmus* = stalk, stem). In the clumping bamboo the culm forms from terminal buds, the tip of the rhizome. In running bamboo the culm emerge from the lateral buds, located on the sides of the rhizomes. Because of the kind of culm formation, the clumping bamboo has a higher culm density while the running bamboo spreads easier. The culms can vary in diameter, colour, length and thickness for different species. Some are more suited for material use than others (Liese & Köhl, 2015).

The culms rise from shoots that are produced by the rhizomes. Young shoots are edible if they emerge from the ground. When these shoots emerge they are soft and bendable, even when the shoots are over a half meter high (Figure 2). A shoots grows into a culm by the elongation of the basal internodal elongation.

Figure 2: *Two bamboo shoots of different heights, on the left a shoot of about half a meter and on the right a younger shoot that would still be edible*

Flowers

Bamboo does not produce flowers annually. Flowering intervals is species dependent. Tropical species flowers once every 15 to 60 years, while more temperate suitable bamboos only flower every 60-120 years. When this flowering starts for a species, All plants around the whole world of that species start flowering and die afterwards (Figure 3). There are cases, for example in *Phyllostachys pubescens*, where irregular flowering spread over multiple years in different areas was observed. This means that not all plants of that species start flowering at the same time worldwide (Watanabe et al. 1982).

Figure 3: *Bamboo flowers in the Netherlands*

1 Bamboo effects and requirements for soil, nutrients, fertilisation and water demand

This section deals with the topic of growing conditions which are optimal for bamboo and is compared to Dutch conditions. The factors that are considered are water demand and irrigation of bamboo, nutrient balance and demand as well as the interactions of this factors with the soil and the effect of bamboo on the soil. Furthermore, the temperature demands of bamboo are considered.

Key takeaways

Soils

- Bamboo invasion will reduce soil carbon and nitrogen content
- Bamboo can significantly change the dynamics of soil phosphorus, promote phosphorus mineralization and improve the efficiency of phosphorus use
- Bamboo litter can promote soil regeneration, and increasing the amount of bamboo litter can improve the carbon/nitrogen ratio of the soil
- It is necessary to avoid excessive use of fertilizers and excessively intensive management practices, because this will lead to a decrease in soil microbial biomass and total organic carbon content

Nutrient management and balance

Nutrient balance

- Quick replenishment of nutrients in the rhizomes from the soil
- root mat of bamboo allows to immediately and effectively absorb plant available nutrients from the topsoil layer
- Distribution of major plant nutrients within the different plant organs is an important factor to keep in mind when harvesting and fertilizing. Leaves contain the largest fraction of nitrogen in the plant

Fertilisation /management

- Fertilisation needed for sufficient growth in terms of commercial plantation
- Litter circulation provides adequate nutrition for normal growth
- Fertilisation is most impactful and necessary in seedling stage
- Comforting to Dutch regulation, the optimal way of fertilisation is with artificial fertiliser with a spreader or fertigation
- Fertilisation amount and regime should be customized to the particular field and environmental conditions

Water

- Water demand depends on culm age and is the highest in the first 3 years
- The available water depends on the soil type and is limited to the rooting depth of around 30cm to 40 cm

- Irrigation is necessary on soils which can only hold little water since the precipitation is not sufficient (including sand, sandy soils and heavy clay soils)
- Organic matter in the soils increases the water holding capacity and methods like smart irrigation schedules and drip irrigation make water supply more efficient

Temperature

- Bamboo can grow under Dutch temperatures but has a lower productivity compared to original habitats

1.1 Soil interactions

Limited information on the soil impacts in Europe was available. To work around this knowledge gap, scientific literature of other continents was used to identify general tendencies in the effects of bamboo on soil properties. It must be noted that real conditions in the Netherlands can differ from these findings. However, these findings are based on academic knowledge and evidence from outside of the European continent and should provide a comprehensive idea applicable to Dutch soils.

1.1.1 Impact of Bamboo on Soil Properties

Despite bamboo's high carbon sequestration ability, research results show that when bamboo acts as an invasive species, the pools of carbon (C) and nitrogen (N) in the soil decrease (Ben-zhi et al., 2005). This is largely due to a reduction in plant diversity, particularly trees and shrubs, as a result of bamboo's invasive nature. Additionally, the root growth and release of Moso bamboo, which is concentrated in the top 40 cm of soil, affect the growth and production of microorganisms, thereby altering the carbon and nitrogen content in the soil (Bai et al., 2016).

During the rapid growth period of the Moso bamboo the total nitrogen content in the soil, in the form or hydrolysable alkali, nitrogen and ammonium, declines. This indicates that the nitrogen in the soil would be absorbed by Moso bamboo in different forms, leading to a decrease in the total amount of soil nitrogen available in the soil (Wang et al., 2012).

The invasion of Moso bamboo into neighbouring Camellia (*Camellia japonica*) plantations in Japan, significantly altered soil phosphorus (P) composition and dynamics. Broad-leaved forests had significantly higher soil available phosphorus concentrations, soil acid phosphatase activity (APA), and soil microbial biomass phosphorus (MBP) concentrations, whereas Moso bamboo-invaded stands had significantly lower soil total P concentrations when compared to their adjacent pure stands of either Moso bamboo or camellia. The increase in soil available P suggested that the invasion of Moso bamboo promoted P mineralization while the increase in APA suggested that the invasion also resulted in higher P use efficiency (Wu et al., 2018).

The soil pH as well as the total phosphorus and available phosphorus levels decreases with the expansion of Moso bamboo. The higher the fraction of Moso bamboo in broad-leaved forests, the lower the soil pH, indicating that the growth of Moso bamboo accelerates soil acidification (Xia et al., 2022). Nevertheless, the pH-value is only slightly decreasing and does not need additional correcting during cultivation.

1.1.2 Contribution of Bamboo to Soil Regeneration

In a study conducted by Dong et al. (2022), the effect of bamboo litter on the soil microbial community was investigated when bamboo is introduced on a soil. In the centre of the research was the influence on the elemental balance of the Carbon (C) / Nitrogen (N) ratio. This ratio is an important indicator in soil science since it gives information about the "healthiness" of the soil and soil microbial community. The C/N ratio is desired to be around 24:1 (24 parts carbon per 1 part nitrogen) and higher.

Experimental results show that as the proportion of bamboo litter gradually increases from 0 %, 33 %, 50 %, 67 %, to 100 %, the C/N ratio in the litter decreases from 36.23 to 31.25. This means that the nitrogen in the litter increases and carbon decreases, this is usually an indicator for an increasing availability of nitrogen as a nutrient in the soil.

It was also found that a higher proportion of bamboo in mixed litters, causes faster decomposition and nutrient recuperation. Compared with broadleaf litter (forest litter), bamboo litter generally has a lower carbon to nitrogen ratio and lignin concentration. These findings suggest that the introduction of bamboo can benefit the soil microbial community in short term but also causes a release and fast consumption of nitrogen in the soil (Dong et al., 2022). This explains the fast decrease of nitrogen in a soil when bamboo is introduced.

1.1.3 Impact of Intensive Bamboo Agriculture on Soil Properties

Some research from China indicates that in intensive bamboo agriculture, the total organic carbon (C_T) in the soil of bamboo forests does not show significant changes after long-term cultivation, but the soil microbial biomass carbon (C_{MB}) shows a significant downward trend. The continuous use of fertilizers over the years causes a greater decline in C_{MB} and the ratio of C_{MB} to C_T in bamboo forests. This implies that with the unabated increase in the use of fertilizers, the soil quality of bamboo forests will severely decline, making it difficult to ensure the sustainable management of bamboo forests. (Peikun et al., 2002) Meanwhile, a study by Zhou et al (2022) indicates that in the early stages of intensive management of Moso bamboo forests, all types of organic carbon in the soil decrease. After 5 years of cultivation, the total organic carbon, water-soluble organic carbon, microbial biomass carbon, and mineralized carbon content are significantly lower than in extensively managed forests, with the total organic carbon content continuing to decline until it stabilizes about 20 years later. Although the above situation is unlikely to occur in the Netherlands, it is still necessary to avoid excessive use of fertilizers and overly intensive management.

1.2 Nutrient balance and management

This section will be covering nutrient balance and management. In order to maximize the output of the grown cultivation, knowledge about nutrient balance and management is important. Extensive knowledge of these factors can also contribute to developing a yield predicting model in the future. In order to know how to manage your nutrient input, a basis understanding in nutrient usage, storage and translocation is needed. Experimental trials gave insight in the optimal fertilisation regime for different purposes. This knowledge will be compared with Dutch conditions and legislation.

Nutrient balance is very much influenced by the type of rhizome structure, which is different for different species/conditions. The rhizome structure is located not deeper than 40 cm in the ground, this means that the nutrient flow is limited to the upper part of the soil. Hence this constriction, it has been shown that deeper penetration of the rhizomes decreases shoot quality. Older rhizomes however tend to be reaching further in the ground with accompanying increased biomass. This is probably caused by the overall age of the plant instead of the increased production due to deeper root penetration. The poor quality of shoots from deeper positioned rhizomes is hypothesized to be caused by the longer time required for the shoots to reach the soil surface. In response these shoots develop too late in the season to mature.

The shallower rhizomes seem to be the optimal method for growing quality bamboo. Deeper root penetration would only be beneficial in order to reach more water or to reach immobile nutrients like phosphate. A negative side effect is that overly wet environments can cause the dense root mat to be susceptible for diseases (Kleinhenz V, Midmore DJ 2001). The topmost soil layer is overall well aerated and natural mineralization of nutrients is quicker than in deeper soil layers. The thick shallow root mat of bamboo allows for immediate and effective absorption of plant available nutrients in the top soil. This explains the property of bamboo to accumulate and sequester a lot of nutrients. This quality causes bamboo to react quickly to fertilisation and reduces the leaching of nutrients. Consequently, a large amount of nutrients is stored in the rhizomes. The remobilisation of the nutrients from the rhizomes to new columns of bamboo seem to be insignificant, meaning that there is limited transport of N from rhizomes to shoots or that the N content in the rhizomes is quickly replenished from the soil (Li et al., 1998). From this fact, the deduction that the required N for shoot growth is directly absorbed from the soil, can be made.

Major plant nutrients (Nitrogen:Phosphate:Potassium N:P:K) accumulation and storage in *P. pubescence* has been determined experimentally in Japan. The total accumulation of N, P and K was 288, 44 and 324 kg/ha respectively (Isagi .Y, et al(1997). This leads to a N:P:K ratio of 7:1:7, the nutrient content of culms (151:32:265, N:P:K kg/ha) was higher than that of the rhizomes (115:10:73, N:P:K kg/ha). The reason for this was hypothesised to be because the aboveground biomass represents a larger fraction of the total biomass than the belowground biomass. Although foliage only accounts for 7-10 % of the total biomass, it functions as a major sink for plant nutrients. This can be attributed to photosynthesis, with the total leaf biomass representing 37 %, 23 % and 20 % of total N:P:K content respectively. The aboveground biomass, mainly the culms, on average represents a N:P:K ratio of 5:1:8, meaning that those parts contain more K. Whereas the rhizomes and in general below ground parts have a N:P:K ratio of 12:1:7, meaning that those parts contain a majority of N (Kleinhenz V, Midmore DJ 2001). This distribution within the different plant organs is an important factor to keep in mind when harvesting and fertilizing. Since the harvested above ground parts contain more K, fertilizing with a higher K ratio after harvest might be beneficial.

To touch upon micronutrients, research from Umemura and Takenaka suggests that *P. pubescens* has specific systems for accumulation and translocation of elements such as silicon, boron and zinc to support rapid growth (Umemura, M., & Takenaka, C. 2014). Due to complexity issues this report will not delve deeper into the micronutrient balance and requirements.

1.2.1 Fertilisation

Fertilisation of bamboo fields is generally regarded as a vital aspect of intensive material production. Bamboo is a plant with high nutrient demands, when no fertilizer is applied, rich soils can become depleted and degrade quickly. In most circumstances fertilisation is regarded as beneficial for maximizing bamboo growth and quality of biomass, especially when the on site conditions are suboptimal. Fertilisation is absolutely needed to obtain sufficient biomass growth for commercial plantations as lower nutrient levels automatically mean a reduced growth speed . Normal bamboo growth can be achieved with little to no fertilisation as long as the soil conditions and litter recycling are maintained at acceptable levels (R. van Til, personal communication, 23 June 2023). Due to the earlier discussed quick nutrient absorption characteristics of bamboo, is it hard to overfertilize since leaching of nutrients is minimal. However, abundance of N can cause a higher partitioning of nutrients to the canopy, leading to lower culm strength and reduced uprooting resistance increasing the risk of lodging (Aihara, Y., & Yoh, M. 2015b). Similar to most agricultural crops, nutrient application rates, scheduled nutrient application, nutrient placement and form of fertilizer are all factors that need to be carefully considered as they impact the biomass accumulation rate and quality. Bamboo is grown for multiple purposes and products, these different goals require specific fertilisation techniques. Also, because bamboo is a permanent crop that grows for extended periods of time on the field, long term soil health must be taken into account when considering management practices.

The distinct growth stages of the plant require different, situation tailored, fertilisation plans. In general, due to the small amount of biomass limiting the nutrient uptake, the seedlings and young plants can thrive with less nutrients. At the same time, is this growth stage is the most important stage where nutrient limitation can be detrimental to plant health and quality. When a mature stage is reached, the nutrient demand depends on the produce harvested. In general, there is more fertilizer needed when growing for edible shoots instead of shoot and timber. In case of timber production alone, the average amount of nutrients required is estimated at 225, 135 and 89 kg/ha of N, P and K respectively (Kleinhenz V, Midmore DJ, 2001). Asian literature recommends extreme amounts of fertilizer products of 1500 up to 4000 kg fertilizer/ha, this is impossible in Europe because of fertilizer regulations. The optimal fertilisation regime (amount and N:P:K ratio), should be customized per field with the use of nutrient content tests of the soil (Wang, H. et al 2020). Since bamboo is a perennial crop, the fertilisation amount cannot be calculated upon balancing nutrient balance through harvest, like is done with annual crops. This is because the Rhizomes remain in the ground, store nutrients and continue to grow overtime. This consideration is further added upon by the knowledge that only matured culms are harvested instead of the entire field.

1.2.2 Specifics

A significant proportion of the accumulated nutrients is returned to the soil through litter fall. Total annually litter fall can fluctuate greatly in *P. pubescens*, ranging from 0.2 t/ha to 2.9 t/ha per year, depending on the overall age of the leaves (Fu, M. et al, 1989). This litter, consisting of leaves, branches and sheets, has a lower nutrient content than the living biomass due to relocation of nutrients in senescing tissue. Nevertheless, is the litter a big contributor to the nutrient replenishment of the soil and influential for soil biodiversity. Therefor litter management is a valuable consideration.

In an experiment by the university of Turin, the production of leaves was researched under two different fertilisation regimes. Regime A. consisted of 1.6 kg fertilizer/m^{-3}, and regime B. of 0.8 kg fertilizer/m^{-3} with a N:P:K ratio of 16:11:10. This experiment found that regime A. increased the total number of bamboo leaves with 3 % (Larcher, F. et al, 2017). This increase in leaves will result in more biomass by higher photosynthesis but will not be proportional because of internal shading. A cost-benefit calculation must be made in this case.

When bamboo is cultivated in the Netherlands the Dutch fertilisation rules should be applied. In the Netherlands, the amount of fertilisation used is determined by the crop you grow. For bamboo there are no guidelines for fertilisation rates as of yet. The maximum fertilisation amount differs per province, which must be taken into account. The limit for animal manure based fertilisation is also crop-dependent, while the standard amount is 170 kg/ha. The capped maximum is 230 kg/ha in the provinces of Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg. In the other provinces this maximum is 250 kg/ha (RVO Netherlands 2023). However, animal manure cannot be applied directly on the soil surface anymore. The alternative is injecting the manure into the ground with a slurry injector, but within bamboo fields this is not a viable option in mature bamboo plantations since the injector cannot go through the bamboo. The only use for this is when the bamboo is not growing yet, or only fertilising the alleyways in between the bamboo, which is far from optimal. The better alternative is artificial fertilizer, which is approved for direct application onto the soil surface. This can be done with a fertilizer slinger or with a fertigation system. The maximum amount of artificial fertilisation has to be calculated through type of crop and province rules.

1.3 Water demand and irrigation

In order to assess the need for irrigation of the bamboo certain aspects must be considered. These aspects include plant characteristics and environmental conditions. Plants can use different strategies to household their water demands. In the following parts we elucidate which role plant traits like the transpiration, rooting depth, plant age and different water strategies can play and how these interact with environmental conditions like the availability of water in the soil, precipitation and radiation. For the project, the role of water household models and what role they can play in solutions for appropriate irrigation were looked at.

The transpiration of a bamboo crop depends largely on the culm-density of the crop (Xiu-Hua et al., 2016). In research on Moso bamboo, values of 324 mm/y (= 324 $L/m^2/y^1$) up to 567 mm (= 567 $L/m^2/y$) have been observed in plots that had densities of 3600 culms/ha and 4000 culms/ha respectively (Xiu-Hua et al., 2016; Komatsu et al., 2010). The culm-density can vary depending on age, species and plant densities but generally it lies in the range of 3000 culms/ ha up to 5000 culms/ha (Kleinhenz & Midmore, 2001).

Since the above-mentioned values are only averages of a stand, the water characteristics of a culm were described which can then be multiplied for more convenience with the culm density of a specific crop. The individual transpiration of culms depends highly on the age of a culm, the younger the more transpiration occurs (Xiu-Hua et al., 2016; Tong et al., 2021). This decrease in transpiration is the consequence of physiological changes which make the water transport system of the plant less efficient and causes a loss of vitality in the bamboo (Kleinhenz & Midmore, 2001). Xiu-Hua et al. (2016) divided the culms into three categories juvenile (1 year), mature (2-3 years) and senescent (3 years). The transpiration rates per day (L/day) differed significantly in the culms of over 3 years (>4 L/day) compared to the other two categories (>5 L/day) (Gu et al., 2019; Xiu-Hua et al., 2016). This suggests that the water demand of a bamboo crop is higher in the first three years of cultivation where additional irrigation might be necessary. These transpiration rates decrease during winter times to under 3 L/day but show that younger bamboo culms transpire more than older ones.

Another way to determine the transpiration is using the LINTUL 2 model which is a part of a bigger growing model. It describes growth under water limited conditions and assumes weed and pest free cultivation conditions. In this model, the transpiration of mature crops is calculated based on climate data like the daily radiation on a location, temperature and relative humidity as well as plant characteristics like the leaf area index (m^2 leaf area per m^2 soil). Furthermore, the model takes into account the Evaporation of the soil which is another source of water loss. We set up a model based on the LINTUL2 equations to calculate the water output of the soil by Evapotranspiration (Transpiration and Evaporation).

This calculation was made with standard parameters of the Netherlands and a leaf area of 28 m^2 per culm (*Climate - Groups - KNMI Data Platform,2023)*.

Table 1: *Optimum of growth temperature for Phyllostachys pubescens and average relative humidity, wind speed and total daily radiation for the Netherlands. (Climate - Groups - KNMI Data Platform, 2023)*

Temperature (Growth optimum *P. pubescens*)	20 °C
Relative humidity	0.75 %
Wind speed	5 m/s
Daily total radiation	15 MJ/d/m2

The water availability depends on the soil and the rooting depth. Different types of soils can hold different amounts of water which is available for plants. This parameter depends mainly on the pore size in the soil but also on factors like the organic matter in the soil. Common soils in the Netherlands are sand soils on the North Sea coast, behind which (marine) clay soils are located (Rijkswaterstraat, 2014). In the middle of the country, river clays and sandy soils (sand-loam) are predominant (Rijkswaterstraat, 2014).

The amount of water in m^3 water per m^3 soil which is accessible for a plant is determined by the wilting point (wp). The wilting point is the water held by the soil with a tension of 1500 kPa (Saxton & Rawls, 2006). At this tension and higher the water cannot be taken up by the plant and is referred to as hygroscopic water. The upper value is the field capacity (fc), this is the amount of water which is held by the soil with a tension of 33 kPa against gravity (Saxton & Rawls, 2006). If the tension is below 33 kPa the water runs off into the ground. Since the proportions of fine and coarse pores depends on the soil, the amounts of water (m^3 per m^3) are different in every soil. Based on the values of wilting point and the field capacity. With the following equation the available water content (WC) of a soil can be determined:

$$WC\text{plant available} = (WC_{fc}\left(\frac{m^3_{water}}{m^3_{soil}}\right) - WC_{wp}\left(\frac{m^3_{water}}{m^3_{soil}}\right))$$

Equation 1: *Plant available water content (WC) per m3 of soil.*

Although in 1 m^3 of soil a certain amount of water (m^3) is plant available, the amount of water available depends on the rooting depth (RD) of the induvial plant. This depth determines how much of the m^3 soil is penetrated by roots and resources can be used. Based on literature the average rooting depth of bamboo (*P. pubescens*) is 0,3 m (=30 cm) (Kleinhenz & Midmore, 2001). This means that from the m^3 of soil and its resources, only 30 % is used. This can vary depending on the consulted literature and is species and soil dependent. If the rooting depth (in m) is multiplied with the water content per soil ($WC_{\text{plant available}}$) the available water per m^2 can be calculated.

$$Available\ water\ \left(\frac{L}{m_{soil}^{2}}\right) = \left(WC_{fc}\left(\frac{m_{water}^{3}}{m_{soil}^{3}}\right) - WC_{wp}\left(\frac{m_{water}^{3}}{m_{soil}^{3}}\right)\right) * RD(m) * \left(\frac{L}{m_{water}^{3}}\right)$$

Equation 2: *Available water for a crop depending on its rooting depth converted into liters per m2 soil.*

Previously, the principles of water inputs and outputs of bamboo crops were clarified. This knowledge can help to set up an irrigation system and plan for bamboo crops. Since a new bamboo crops needs more irrigation in the first three years, implementing a tailored solution for nutrient admission and irrigation can improve efficiency and save resources (Gu et al., 2019; Xiu-Hua et al., 2016). Therefore, the water balance has to be monitored over the year. This can be done by sensors (Pardossi et al., 2009) or in a cheaper way by using weather data and water models.

As mentioned above, the amount of water depends on the capacity of a soil to hold plant available water. To get an idea of the different water content capacities with data from Pardossi et al. (2009) and the above-mentioned Equation 2 some water content capacities were calculated for 6 common soil categories (Table 2)

Table 2: *Soil types with the corresponding Field Capacity, Wilting Point and the plant available water capacity of the soil. Ordered from coarse to fine soil structure. (Pardossi et al., 2009)*

Soil	Field Capacity ($\frac{m^3}{m^3}$)	Wilting point ($\frac{m^3}{m^3}$)	Available water capacity ($\frac{L}{m^2}$)
Sand	0,10	0,04	18
Sand-loam	0,18	0,05	39
Loam	0,24	0,07	51
Silt-loam	0,28	0,10	54
Clay-loam	0,30	0,18	36
Clay	0,32	0,24	24

If the irrigation demand is supposed to be calculated the water outputs like the transpiration of the crop and the evaporation of the soil have to be subtracted by the amount of plant available water in the soil.

For calculations under standard Dutch conditions (Table 1) the transpiration of a bamboo crop that has a density of 3000 culms/ha has a transpiration of 5,28 kg_{water} /m^2. For the evaporation, a value of 0,0941 kg_{water} /m^2 was calculated. Both factors together (evapotranspiration) totals 5,376 L_{water} /m^2. Depending on the amount of plant available water in the soil, which differs between the different soil types, the water management strategy and climate predictions, the irrigation can be adapted according to the demands of the grower. The same crop can be evaluated with a density of 3000 culms/ha on a clay soil with the maximum amount of the plant available water which can be reached by the roots (24 L/m^2). Then the calculated time until the plant available water capacity is depleted in 4,46 days (= (24 L/m^2) / (5,376 L/m^2/day). At this point plant growth starts to be inhibited, showing reduced growing speed, and if not replenished by irrigation or rain the crop starts to wilt. Nevertheless, this does not mean that the bamboo plants immediately die off but the lack of water starts to be a stressing factor for the plants. Consequences can include a decrease in yield and quality, further inhibition of growth even if the water is replenished or in the worst case the death of the plant. The time needed to reach this point, depends highly on the distribution of rainfall over the growing period.

One way of increasing water holding capacity in soils is to increase the organic matter content of the soils (Basso et al., 2012). This is especially beneficial in sand and sandy soils which are common soil types in the Netherlands. Additionally, a bamboo cultivator in the Netherlands noted that when bamboo was cultivated on sandy soils, a higher organic matter content decreased the amount of irrigation needed (R. van Til, personal communication, 23 June 2023). Another way to make irrigation more efficient is switching to drip irrigation. In an experiment by Leghari et al. (2021) with maize it was proven that the evaporation and runoff can be reduced compared to conventional irrigation.

Nevertheless, the expenses of irrigation and fertilisation should always be weighed against the benefits. Although, the loam and silt-loam are the best soils for growing bamboo they are also nutritious soils for other plants and crops (see Table 2). In this case it should be considered to grow less resilient species or food crops on these soils since the bamboo can deal with more extreme soil conditions. This is not only a debate for bamboo but in general for agriculture if space should be used to grow food or material. The above-mentioned methods and water models are very site-specific and can help to make up the disadvantages of a poor soil using advanced water management. This includes watering when needed and only the amounts which the soil can hold by assessing and keeping track of the water balance of the crop. In general, the models give only a rough estimation but can nevertheless be a versatile tool for assessing sites for new plantations, determining irrigation demands for current plants and refining irrigation schedules. With more information about crop parameters, climate data and soils properties available, more complex models can be set up and better quality outputs can be generated.

Besides the precipitation which averages around 851 mm per year (851 L/m^2; averaged value from 1991 to 2020) in the Netherlands water from other sources can also be used and might be sometimes necessary for irrigation. The precipitation in the original habitats like China is higher than in the Netherlands mostly around 2000 mm per year (Tong et al., 2021; Xiu-Hua et al., 2016). This means that using growing date can not be used for models without adaptation to Dutch conditions. It is also the reason that irrigation can play an important role in the establishment phase of a bamboo plantation. Each of the available water sources has different advantages and disadvantages for the grower in terms of costs, water quality and availability.

An alternative source of water might be the wastewater of greenhouses. In most of the greenhouses, fertilizer is added directly to the water, so called fertigation. After a certain time, the minerals of the fertilizers start to accumulate in the irrigation water. Therefore, the EC-value and the nutrient concentrations increase and get too high for proper plant growth and are flushed out of the greenhouse water system (Stanghellini et al., 2019). This water can be used, after processing and dilution, for watering and fertilizing bamboo plantations. This way, water can be upvalued and recycled and remaining nutrients are used a second time. This can be done by adding an amount of clean water with a lower EC-value and lower nutrient concentration to the discharged wastewater of the greenhouse. The amount of wastewater which can be added can be calculated with Equation 3 which was derived from an equation of Stanghellini et al. (2019). The volume of wastewater depends on the nutrient concentration of the greenhouse wastewater (C_{max}), the concentration which is adequate for irrigating the bamboo (Ct), the concentration of the added clean water (C_{in}) and the total volume of the needed irrigation water (V_{total}). This might be an opportunity to simultaneously irrigate the bamboo crop with water of lower quality and purify the water in a natural way (see Subquestion 3 “Impact and benefits of agricultural bamboo”).

$$Volume\ of\ waste\ water\ [l] = \frac{(C_t\ \left[\frac{kg}{l}\right] - C_{in}\ \left[\frac{kg}{l}\right])}{C_{max}\ \left[\frac{kg}{l}\right]} * Volume_{total}\ [l]$$

Equation 3: *Wastewater amount (of a greenhouse) which can be added to the total volume of the irrigation water. Also available for the EC-value. Ct = Nutrient concentration for irrigation water.*

1.4 Temperature

The rate of plant development and biomass accumulation is dependent on the temperature. The temperature in the Netherlands mostly differs from the temperature conditions of native habitat of bamboo species. The yearly average temperature in the Netherlands was 10.5 °C (KMNI; averaged value 1991 to 2020) whereas the yearly average temperature in south China, the original habitat of most Moso bamboo species, is around 17 °C up to 20°C (Tong et al., 2021; Xiu-Hua et al., 2016). Since the growth and development of a plant can be hindered if the temperature falls below a certain temperature it is important for bamboo growers to know in which months the bamboo crop would grow when cultivated in the Netherlands. Gratani et al. (2008) derived an equation based on data of different bamboo species that calculates the photosynthetic rate for different leaf temperatures. For the bamboo species *P. pubescens* the maximal photosynthetic rate, represented as 100 %, was observed at 20.8 °C leaf temperature (Gratani et al., 2008). The photosynthesis stops when the leaf temperature is below 5 °C and above 37 °C (Figure 4). The leaf temperature is not always the same as the surrounding air temperature since it can be slightly higher or lower depending on other environmental factors (wind speed, humidity, etc.). But it gives a good estimation for the temperature rate at which bamboo can grow. In the Netherlands, the average daily temperature is only below 5 °C in 3 months, where no growth occurs (WMO, 2023). Based on the data equation of Gratani et al. (2008) at the average temperature in the Netherlands of 10.5 °C, the photosynthetic rate only reaches 57 % of the maximum. This must be taken into consideration when calculating estimated yields.

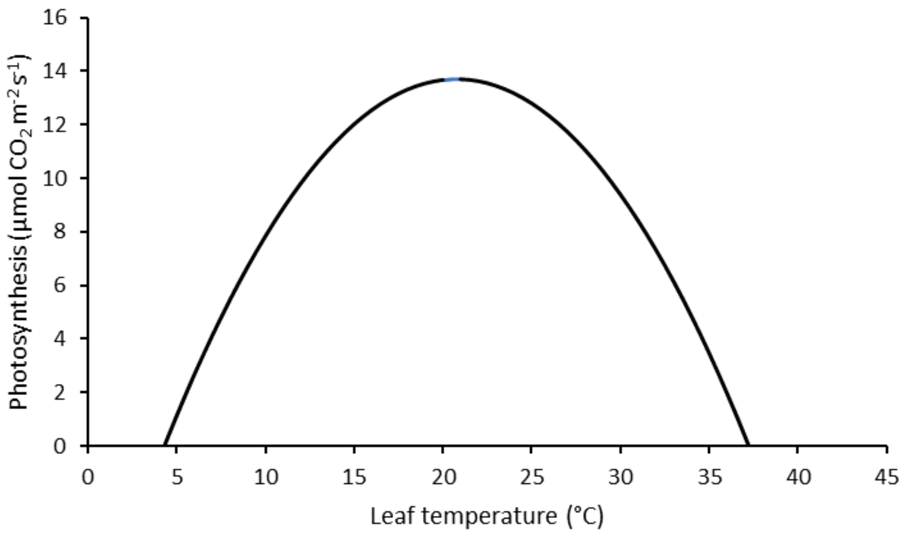

Figure 4: *Photosynthetic rate at different Leaf temperatures from an allometric function (r = 0,80). (Gratani et al., 2008)*

Summary

We aimed to investigate optimal growing conditions for a bamboo crop in the Netherlands in terms of soil conditions, water supply, temperature and climate as well as the nutrient demands. In order to grow bamboo for commercial purposes, management of nutrients and irrigation must be carefully managed. Additional fertilization aside from litter recirculation will enhance growth and products significantly. Bamboo also grows with only litter circulation and on poor soils but will show reduced performance and vigour. Animal manure application is not viable in the Netherlands because of regulatory and managerial constraints, so artificial application is preferred by slinger method or fertigation. This can even be seen as an opportunity to reuse nutrients and water discharged by greenhouses and reduce run off to the environment. The water demand of the crop is comparatively high in the first 3 years of cultivation and cannot be fulfilled by precipitation alone. This means that irrigation from other water sources is necessary for optimal growth. The amount and frequency of irrigation depends on the soil type and location where the crop is grown. The temperature in the Netherlands is sufficient to cultivate bamboo but is nevertheless lower than in original habitats like South China. Therefore, it will show reduced performance as compared to their native habitat.

In the Netherlands, it is preferable to plant bamboo in soil with sandy characteristics rather than clay characteristics. Soils with high chalk or clay content are less advisable. reference robert Moreover, there is a knowledge gap in the Netherlands concerning the relationship between agriculture bamboo and soil. Currently, there is a lack of relevant research in the Netherlands, but based on past studies from other continents, it can be confirmed that although bamboo has a widely recognized high carbon sequestration capability, it consumes a large amount of carbon (C) and nitrogen (N) from the soil during its rapid growth period. Simultaneously, bamboo is able to increase the availability of phosphorus in the soil, impacting the soil nutrient balance. Excessive use of fertilizers and intensive agriculture should be avoided to ensure the health of the soil where bamboo is planted. Furthermore, it is questionable if more suitable soils should be cultivated with bamboo for material applications instead of food crops which are heavily reliant on good soil conditions for quality produce.

2 The potential of bamboo cultivation for carbon sequestration, carbon credits and intercropping

This section looks at the potential of carbon sequestration, the carbon market and carbon policy, in which bamboo plantations are becoming increasingly important. It can make a significant contribution to meeting climate change mitigation goals. The emerging carbon market, a system for trading carbon credits, provides financial incentives to farmers, project developers and industry.

With these targets come farming practices that are critical for a successful project development. In this context, intercropping, the cultivation of mixed crops, can offer advantages in terms of the economic framework in the early stages of the project, as well as yields and biodiversity.

Key takeaways

Carbon Credits

- Bamboo can play a local role in the rapidly growing market for carbon credits
- The market can be broadly divided into two categories: regulated and voluntary
- Regulated is not accessible for bamboo plantation projects.
- Voluntary is unregulated and not very transparent due to many different standards
- One player (Verra) has 70 % of world market share
- Risk assessment based on high biodiversity and well adapted plants
- EU plans to introduce regulations/guidelines
- Focus on biodiversity and ecosystem protection
- More than half of carbon credits are priced below $10/tonne
- Studies in tropical regions show high carbon sequestration potential of bamboo (25.67 - 33 tonne CO^2 ha/yr)
- Little to no data for the Netherlands
- Efficiency of carbon sequestration mainly depends on biomass production of bamboo

Intercropping

- European bamboo cultivation systems show potential for intercropping, but little data exists on the economic feasibility or best management practices
- The setup of the plantation depends on existing machinery, cultivated crops and desired management practices
- Clear felling: cultivate alleys with an adapted crop rotation based on the shading of the bamboo
- Selective felling: Cultivate shade-tolerant permanent companion crops such as forage mixes or berries
- Clover mixes will increase the nitrogen availability for the bamboo

- Forage can be a low maintenance intercrop that also benefits the bamboo via fertilisation effects when grazed by animals
- It is likely necessary to mechanically control bamboo’s competitiveness towards the companion crop
- It is uncertain whether bamboo plantations will be classified as agriculture or forestry, therefore being at risk of losing CAP payments

2.1 Carbon credits

Considering the EU's climate change targets of net zero emissions and a 55 % reduction in net emissions by 2030, natural carbon sequestration measures have become increasingly important and the focus of businesses, the public sector and individuals (Happe et al., 2019). Carbon sequestration, i.e. the verifiable reduction or removal of a given amount of CO_2, is no longer a topic of purely scientific interest. Rather, a market has developed around carbon trading. Trading in carbon credits provides incentives for farmers, companies and organizations to develop carbon-negative projects and be rewarded with carbon credits.

In this context, bamboo has increasingly come into focus. This is mainly due to its unique characteristics such as rapid growth, high annual post-harvest regrowth rates, high biomass production and high economic or material value, supporting permanent carbon sequestration. (Wu et al., 2015). Bamboo is also increasingly at the center of public discussions on carbon offsetting, such as at COP16 (Conference of the Parties, Cancún; Nerenberg, 2010).

As such, bamboo cultivation can play an important role, as several studies have shown. (Nerenberg, 2010; Wu et al., 2015). However, these mostly refer to cultivation in the subtropics (annual mean 12-24 °C) as well as in the tropics (annual mean above 24 °C) (Siegmund, 2008). In order to objectively assess the potential of bamboo cultivation in the Netherlands, it must be placed in a climatic context. Studies have shown that bamboo forests are broadly comparable to other forest types in terms of carbon cycling, which is why cultivation in mid-latitudes, including the Netherlands, is being considered.

In the following, the carbon market or carbon market policy is outlined in relation to the cultivation of bamboo in monoculture systems in the Netherlands.

2.1.1 Carbon pricing in the context of the carbon market and carbon market policy

The market for the offset or carbon credits can be divided into two distinct parts. A regulated market based on the criteria of the United Nations Framework Convention on Climate Change (UNFCCC), the mechanisms of the Kyoto Protocol or other regional, national or sub-national programs (Esche et al., 2022). Carbon credits are issued by governments or relevant regulatory authorities, although the exact structure and design of the emissions trading system may varying by country. Alongside this regulated system, a voluntary, unregulated market has developed.

This voluntary market, where, for example, carbon credits from bamboo cultivation are traded, is outside the international agreements. It is therefore not subject to government control or recognition. Credits from the voluntary market are not obligated in Europe to meet the standards of the regulated market. (Esche et al., 2022) It is characterized by a large number of providers of VERs (verified emission reductions) or carbon credits. One carbon credit represents one tonne of CO_2 equivalent emissions. To obtain these carbon credits from bamboo cultivation, the project must go through verification and validation procedures. These carbon credits can then be sold through various channels, exchanges or directly to end users.

The Dutch market for voluntary carbon offsets consists of a variety of players, such as ONCRA (Open Natural Carbon Removal Accounting), Climate Naturale Group, Fair Climate Fund and Trees for all. Organizations such as ONCRA, Fair Climate Fund and Trees for all are non-profit organizations. These actors have different approaches, business ideas and target different customers and end users.

On the demand side, businesses play the largest role, followed by public institutions that want to offset their own greenhouse gas emissions on a voluntary basis (Esche et al., 2022). According to a World Bank 2020 report, the global market price for carbon credits ranges from < US$ 1/tonne of CO_2 to US$ 119/tonne of CO_2. Half of all carbon credits are priced below US$ 10 per tonne of CO_2. (*State and Trends of Carbon Pricing 2020*, 2020)

Price differences are due to differences in quality, size and type of projects. These include projects that sequester CO_2 in a natural way, such as reforestation, but also technical projects, which have proliferated recently. In addition, it is usually cheaper to carry out CO_2 reduction projects in less developed countries. Other factors may include the age of the certificates and the demand for certain projects/project types and locations. The volume of allowances purchased also plays a role. (Wolters et al., 2018)

2.1.2 Classification and certification of carbon credits

In terms of transparency, risk and accusations of greenwashing, the type of carbon credits offered on the voluntary market plays an important role. (Schwager, 2022). In most cases, the certificates traded are "ex-post" certificates issued for emissions reductions or avoidance that have already been achieved.

However, there are also efforts to establish so-called "ex-ante" certificates where the mitigation or avoidance service has not yet been provided, so-called "forward crediting". In this case, the seller pays the purchase price for a certain number of carbon credits for which the emission reduction service has not yet been provided at the time the contract is established. This involves risks and uncertainties as to whether the agreed level of emission reductions can be achieved. (Esche et al., 2022; Wolters et al., 2018)

If the agreed upon contract does not provide for an "ex-post adjustment" of the purchase price to the lack of emission reductions, the customer bears the risk of a partial or complete loss of the purchase price. Transparency is also likely to suffer in such transactions, as the seller and buyer need to be informed of a possible shortfall in the calculated emission reductions. (Kollmuss et al., 2008) Consequently, such "ex-ante" certificates are only marginally suitable for offsetting, as past emissions are offset against reductions in the future. This aspect is particularly important in the case of bamboo cultivation, where emission reductions are expected to take place over the course of several years. On the other hand, such an approach can serve as start-up financing to bridge the time until the first revenues from the projects are generated.

Currently, emission reductions are not certified according to uniform quality standards, but the market is dominated by multiple individual standard setters. The voluntary market is therefore highly fragmented. By far the largest player is Verra (up 80 % market share), followed by the Gold Standard, the Climate Action Reserve and the American Carbon Registry (Klein, J, 2022).

Verra conducts risk analyses in the areas of agriculture, forestry and other land use (AFOLU Non-Permanence Risk Tool). These are used to determine the buffer credits to be paid out in the event of a shortfall in ex-ante issued allowances. The risk assessment is based on a number of factors that need to be taken into account when growing bamboo in the Netherlands. For example, it must be demonstrated that the species planted are adapted to the same or similar agro-ecological zones as the project, that the species planted have a high biodiversity and/or resistance to pests and diseases, and that they are tolerant to salinity fluctuations in the estuarine wetlands. However, the framework document does not go into detail. If the overall risk assessment for the project is too high or considered unacceptable, a project may be classified as "failed" and not eligible for credit. (AFOLU Non-Permanence Risk Tool, 2019)

Due to the high fragmentation of standards and the lack of transparency, the EU has proposed a voluntary EU-wide framework for the certification of carbon offsets produced in Europe. This includes criteria for defining high quality carbon sequestration, as well as procedures for monitoring, reporting and verifying the authenticity of such sequestration. It also explicitly addresses biodiversity requirements, which read as follows: "carbon farming activities, including the production of biomass for carbon sequestration activities, should only be eligible for certification if they can be shown to have co-benefits with biodiversity and ecosystem protection and restoration." (Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL Establishing a Union Certification Framework for Carbon Removals, 2022) Biodiversity and ecosystem impacts are addressed later on in the report.

2.1.3 Basis of the biological carbon Fixation of bamboo

Recent publications have raised high expectations for CO_2 sequestration and storage by bamboo. Most studies quantifying carbon sequestration and storage have taken place in tropical regions such as India, China, Africa and Central America (annual mean above 24 °C; Sarjubala Devi & Suresh, 2021; Abebe et al., 2021; Xu et al., 2018; Rathour et al., 2022). However, projects are also increasingly found in subtropical regions such as parts of Italy (annual mean 12-24 °C; Marchi et al., 2023). As studies on bamboo monocultures in temperate zones such as the Netherlands are rare or non-existent, this section attempts to put the available data into a climatic context and draw conclusions about the potential of bamboo monocultures in the Netherlands.

The carbon storage of bamboo can be divided into two parts that have different carbon storage capacities. The below-ground part includes the rhizomes and root systems, but also the humus soil and the overlying litter layer, while the above-ground compartments include the culms, branches and leaves (Düking et al., 2011).

The carbon enters the plant system through photosynthesis and is used through autotrophic and heterotrophic respiration. for example, *P. bambusoides* uses about 63 % of the carbon originally taken up for the plant metabolism (Isagi, 1994). This is mainly due to soil respiration as well as aerial respiration. The remaining carbon is used to increase the plant biomass.

The carbon concentration of *Phyllostachys* species is lowest in the fine roots and highest in the branches and culms, ranging from 40 % to 47 %. At the same time, culms account for the largest proportion of biomass (84 %), followed by branches (12%) and leaves (5%) (Isagi et al., 1997).

In comparison, a European mixed forest with beech (*Fagus sylvatica*) and oak (*Quercus petraea*) has a biomass carbon concentration of 40.4 % to 44.4 % (Holtmann et al., 2021). The carbon storage capacity is therefore similar to that of European mixed forests. In addition, the stems of forest ecosystems generally store more carbon over time. In contrast, bamboo stems are hollow and have no secondary growth. Therefore, an unused bamboo forest in a stable state after about 20 years, i.e. when it has reached its maximum carbon storage capacity, has a lower carbon stock in the plant body than a comparable European forest ecosystem. Taking into account the carbon input and output of an unused bamboo stand, the balance is zero according to Isagi et al. (Isagi et al., 1997; Düking et al., 2011). However, a managed plantation that is regularly harvested can store more carbon through its specific growth pattern and photosynthetic activities, and the biomass is subsequently transformed into long-lasting products. (Marchi et al., 2023) Due to the rapid growth and harvesting before biological equilibrium or the end of the growth phase of the bamboo plant, more carbon can be sequestered in a short time. The effect of bamboo on carbon storage thus depends on productivity, i.e. the sum of aboveground living biomass and belowground carbon stocks. In order to achieve the most efficient carbon sequestration using the regenerative capacity of the culms or biomass, management, cultivation practices and harvesting need to be considered.

The typical life cycle of a bamboo monoculture can be divided into three phases. The first phase relates to field preparation in the first year of cultivation. In this phase, field preparation, planting of seedlings and other treatments take place. The second phase refers to plant growth and covers the period from the first to the eighth year. During this period the plants grow for four years before thinning and other maintenance is carried out. By the sixth year, the bamboo plant is fully grown and can be harvested in the eighth year. The third phase covers the maturing period of the plant from the eighth to the hundredth year. Each year 1/3 of the culms is harvested. Within 3-4 months, the shoots return to their original height or diameter of the cut stalks. This is possible because the remaining stands are supported by the communication of the rootstocks. This is not applicable for clear cutting harvesting strategies (Marchi et al., 2023). Intensive management can prevent negative correlations of declining growth rates due to competing culms and increase CO_2 storage capacity (Düking et al., 2011). According to a study by Marchi et al, CO_2 emissions during the planting and growth phase are significantly higher than the average annual CO_2 emissions from management (Marchi et al., 2023). However, there is considerable variation in biomass yield or carbon sequestration depending on the intensity and type of management and climatic conditions.

This high variability makes comparisons between studies difficult. For example, Chen et al. report an average total aboveground biomass of 960 t/ha for Moso bamboo in China. Vadalà et al. reported an aboveground biomass yield of 156.17 t/ha in Italy. (Vadalà et al., 2022; Chen et al., 2016). This difference might be partially caused by different climatic conditions and management practices.

A realistic estimate of the CO_2 sequestration of Moso bamboo in Japan (*P. pubescens*) is given by Nath et al. as 7-9 tonne C/ ha/year, corresponding to about 25.67-33 t CO_2 ha/year (Nath et al., 2015). Further sequestration rates are listed in the appendix (Figure 12). It is questionable whether such levels can be achieved in temperate zones.

Many factors such as environment, management practices, biological characteristics, analytical methods for quantification and location contribute significantly to the variability (Vadalà et al., 20-22). For example, it should be taken into account that at the latitude of the Netherlands there is a slower growth rate and a high variability in annual shoot production, so that bamboo may have years without shoot production at irregular intervals (R. van Til, personal communication, 23 June 2023). Nevertheless, available studies suggest that bamboo is capable of removing significant amounts of carbon from the atmosphere and generating tradable carbon credits. The carbon storage or sequestration is expected comparable to that of temperate forest ecosystems.

Given the changing climatic conditions and bamboo's ability to adapt to these conditions and mitigate climate change, bamboo can make a remarkable social and economic contribution. It can contribute to income diversification in rural areas and provide other environmental services such as carbon sequestration and carbon trading. However, its potential as a CO_2 sink in the Dutch climate zone should not be overestimated, and tropical or subtropical studies should not be simply transferred to the Netherlands. The rapid growth of bamboo culms should not be used as a productivity criteria, as this growth does not consist of its own continuous photosynthesis, but of the allocation of organic matter stored in the rhizome system of the bamboo plant (Düking et al., 2011).

2.2 Current bamboo cultivation systems and opportunities for intercropping

Bamboo trials in Europe have been mainly conducted as a monocrop (van Goethem, 2014; Gielis, 2005). However, there is an interest in growing bamboo as an intercrop to facilitate the establishment of bamboo by providing an income during starting phase. In traditional bamboo growing regions, bamboo is often grown in existing or natural forests as a form of mixed forestry but there are also dedicated bamboo plantations in China. Bamboo that is cultivated for commercial reasons is mostly grown as a monocrop (Cai et al., 2018 as cited in Gai et al., 2021). When grown in a mixed forest, it is often accompanied by understory growth and there have been various reports of bamboo intercropping, e.g., in India (Troya Mera & Xu, 2014; Garima et al., 2021), Ghana (Akoto et al., 2020), and China (Shi et al., 2022). Therefore, it should be possible to grow bamboo in an intercropping system in the Netherlands, but the potential for this depends on the setup of the plantation. In turn, the setup is highly dependent on the desired level of mechanisation of the plantation and the farm. Therefore, the discussion will focus on the intercropping potential of different (potential) plantation setups and the differences of intercropping in time or space.

2.2.1 Random planting/very dense rows

Some early bamboo plantation trials in Europe were conducted using very high planting densities (e.g., in Belgium, as shown in Gielis, 2005). Figure 6 shows one of these trials at harvest time. There is no understory growth due to the competition and accumulating leaf litter. In this system, intercropping will likely not be possible and selective harvesting would be difficult. However, if the biomass is chipped and used for energy, this system would allow for relatively easy mechanisation of the harvest because there are headers available for use with a conventional forage harvester.

Figure 5: A dense bamboo plantation trial in Belgium (Gielis, 2005)

2.2.2 Narrow rows

Another planting procedure was trialled by van Goethem et al. (2014) in Ireland (see figure 6). Here, the bamboo was planted in rows 1.8 metres apart and with a plant distance of 2 metres. Due to the short distance between rows (alleys), the bamboo plants intercept most of the light after establishment of a full canopy cover, limiting the possibility of intercropping for selective harvesting systems. Additionally, the narrow rows prohibit the mechanised cultivation for intercropping during establishment or after harvest.

However, the provided shade and room may allow mushroom cultivation in the understory using mushroom logs. Shiitake mushrooms, for example, are a premium product which grows in the Netherlands and has an already established market (Haveman Groen B.V., n.d.). However, the cultivation of mushroom logs is very labour intensive and might interfere with the harvesting operations. Additionally, it is likely that the mushrooms would be more suited to a selective felling system because of the need for shading.

Depending on the light penetration of the canopy, it might also be possible to grow shade tolerant and low input grass/clover forage mixes beneath the canopy and use this for extensive grazing after the initial establishment or harvest. Sheep or chicken would be best suited for this because they are less likely to damage the bamboo as compared to cows or goats, but careful management during critical development phases such as shoot emergence would still be needed (R. van Til, personal communication, 23 June 2023)

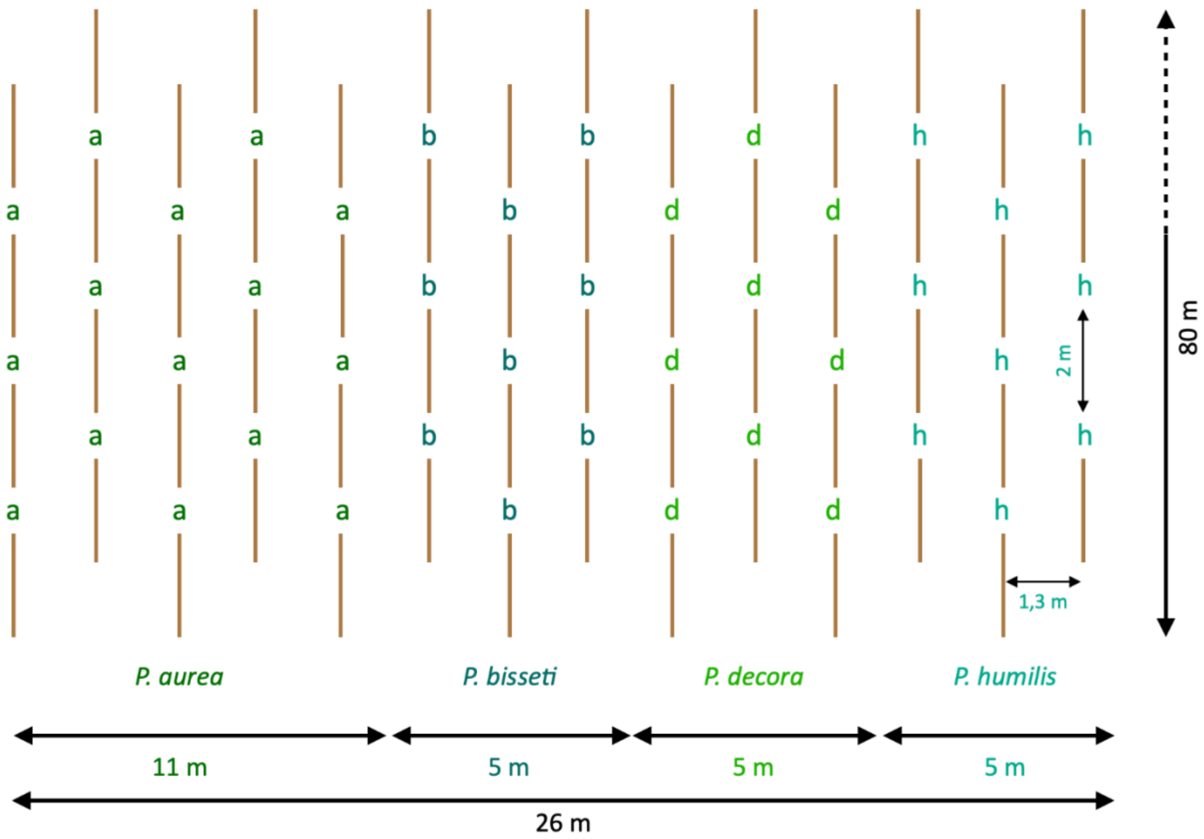

Figure 6: The planting density of a bamboo plantation in Ireland (adapted from van Goethem et al., 2014)

2.2.3 Wider rows

Once the alleys between rows become wide enough to allow tractor operations the intercropping potential increases. Newer plantations seem to tend towards this, e.g., 2.9 m x 2.9 m in Italy (Lombardo, 2022) or around 4 m x 2 m in the Netherlands (Climate Cleanup, 2023) and Portugal (Rede Rural Nacional, 2020). Because of the relatively large amount of shading, these systems are likely to be best suited for forage or green manure mixes based on clovers (e.g., white clover *(Trifolium repens*) or red clover *(Trifolium pratense)*). The forage yield and quality will be higher due to the increased light availability, compared to narrow alleys. Additionally, the forage could be harvested mechanically and transported to livestock. While this would be more labour-intensive than grazing, there is a lower chance of damage to the bamboo and the forage could be sold to another (livestock) farmer more easily than when grazed. Forage crops will likely be the best intercropping possibility for this system under selective felling because of the continuous shading.

Clover mixtures have increased soil nitrate levels by up to 222 % in short rotation coppice willow intercropping systems (Schults et al., 2020) and could therefore increase bamboo yield in low-input systems. Lucerne (*Medicago sativa*, also known as Alfalfa) is another example of a nitrogen fixing forage which may be suitable for intercropping with bamboo as it has been shown to tolerate up to 50 % shading (Laub et al., 2022). In the same review, Laub et al. found that the most shade tolerant crops are berries, followed by other fruits and fruity vegetables. They even benefitted from up to 40 % shade, which Laub et al. hypothesised is due to the reduced water demand in the shade. Considering that many berries, e.g., blueberries (*Vaccinium spp.)*, naturally grow in forests, they should be an ideal intercrop companion for tree-like crops like bamboo. This could either be accomplished by alternate rows of bamboo and blueberries, with alleys of groundcover in-between for access, or by planting blueberries within the rows of bamboo. The spread of bamboo rhizomes could prove detrimental to the intercrop as it would cause nutrient competition. As such, careful management is required.

With clear cutting, the bigger spacing would also allow for a different approach to intercropping, i.e., a crop rotation in the alleys. A new bamboo plantation requires around 8 years for establishment and, afterwards, one third of the plantation can be harvested every year (Marchi et al., 2023). Therefore, a 5- to 8-year rotation during establishment and then a 3-year rotation can be considered. For example: the rotation during establishment could start with a cash crop like potato *(Solanum tuberosum),* wheat *(Triticum aestivum)* or maize *(Zea mays),* with a similar crop in the second year. In the third year, a moderately shade tolerant crop like field peas (*Pisum sativum*) or beans (*Vicia faba*) should be cultivated. Then, starting from the fourth year, a 2- to 3-year forage or green manure mix should be established and cut until the harvest of the bamboo. After the harvest, the 3-year rotation could start with another cash crop and sowing a spring crop would facilitate the bamboo harvest by allowing a tractor and trailer combination to drive along the bamboo rows. This could then be followed by beans and a 1-year forage mix. Like in conventional farming systems, the choice of (companion) crops depends on the environmental factors but also on the bamboo species and spacing of the plantation.

A regular cultivation of common arable crops (e.g., winter wheat, maize, potatoes) will likely only be feasible on very wide rows. There have been various studies on intercropping willows as a short rotation coppice for biomass with various companion crops. This system should have similar shading and water competition effects as a bamboo strip intercropping system due to a similar growth habit. Here, it was found that winter wheat yields showed reduced performance up to 24 metres from the willow rows (Swieter et al., 2014; see figure 8).

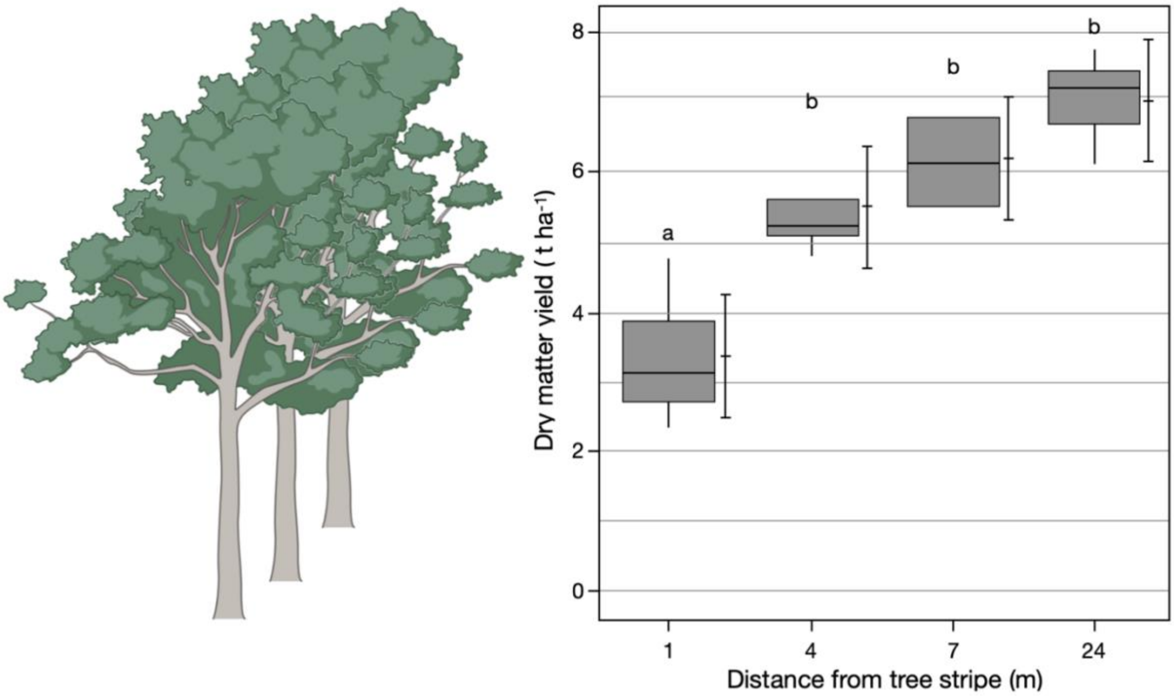

Figure 7: *dry matter yield of winter wheat in a short rotation coppice willow plantation (adapted from Swieter et al., 2014)*

Furthermore, (bamboo) row orientation matters much more in a plantation with smaller alleys than bigger alleys. For the optimal growth of the companion crop, the rows should be orientated from north to south to minimise internal shading (Howard, 2016). Additionally, using a mechanic sub-soil cultivator in the alleys prunes the roots of the bamboo and therefore limits the water and nutrient competition towards the companion crop (Howard, 2016).

There is not yet any data on the interactions between bamboo and other crops in intercropping systems in the Netherlands. As a general rule, the yield of each crop will be roughly proportional to the crop's share of the area but the more competitive crop, in this case the bamboo, will yield slightly more and the less competitive crop slightly less than in a monocrop system. With some crop combinations, yield changes are not precisely proportional, and this is where intercropping provides benefits. I.e., If the yield increase of once crop is higher than the yield decrease of the other crop and as such compensates.

Finally, it is uncertain how bamboo plantations, and bamboo intercrops, will be classified by the Dutch authorities when it comes to permits or payments under the common agricultural policy (CAP). Due to the woody nature and growth habit, it might be classified as forestry. While the EU is passing legislation to account for agroforestry as part of agricultural practices it remains to be seen how this will be interpreted by member states (Lawson, 2022). In the Dutch national strategic plan of the EU CAP, (Gemeenschapelijk Landbouwbeleid, Nationaal Strategisch Plan), land will only be classified as agricultural land if the tree density is below 100 trees per hectare otherwise it is classified as forest land with agricultural land in-between (Lawson, 2023). Therefore, there is a real risk of farmers losing their subsidy payments from the CAP when growing bamboo.

Summary

In principle, there is agreement that CO_2 emissions should be avoided and reduced as much as possible before offsetting takes place. Voluntary offsetting is therefore not intended to replace or displace the strategy of avoiding and reducing emissions. Nevertheless, the voluntary carbon market offers companies and private individuals the opportunity to actively participate in climate protection, to show climate responsibility and to demonstrate commitment to sustainable action. When offsetting through carbon credits, attention must be paid to the transparency and integrity of the project as well as the certification process. In particular, when implementing projects in the Netherlands to sequester CO_2 through bamboo monocultures on agricultural land, it is important to ensure that the yields of existing crops are maintained when their area is reduced through the introduction of bamboo plantations. Furthermore, there are too few fundamental studies on the cultivation and sequestration potential of bamboo in temperate climates. Tropical and subtropical studies cannot be readily used because they are limited to specific climatic zones. Various assessments conclude that sequestration rates of bamboo are comparable to those of native forest ecosystems, but that carbon sequestration can be significantly improved through cultivation practices and management methods. Pilot projects and baseline studies in the Netherlands are needed to provide reliable estimates of sequestration. However, such projects should not focus on the monetary attractiveness of carbon credits or intensive management and should not limit native biodiversity, especially as efforts increase at EU level to protect biodiversity in carbon credit generation projects. In this context, intercropping can make a positive contribution, but there is little data on the economic feasibility and best management practices for intercropping bamboo. While research on intercropping short rotation pasture can give an indication of possible companion crops and their interactions with bamboo, there is an urgent need for research to identify best bamboo cultivation practices in Europe. Based on the limited information available from Europe, extrapolation of data from outside Europe and general agronomic knowledge concludes that the optimal design of bamboo intercropping plantations depends strongly on the desired management practices and the available machinery. In addition, companion plants must be selected for their shade tolerance. In a clear-cut system, it is possible to manage the alleys with an adapted crop rotation based on the shading of the bamboo in its (re)growth phase. However, growing shade-tolerant permanent crops such as forage mixtures or berries is probably a better choice for selective cutting systems. Both systems have the potential to integrate livestock and legumes, which would improve bamboo growth by providing nutrients. In addition, both systems are likely to require mechanical control of bamboo's ability to compete with companion plants. Finally, it is unclear how bamboo plantations will be classified by the Dutch authorities, which poses a significant risk to farmers' income.

3 Impacts and benefits of agricultural bamboo

This section discusses the impact of a commercial bamboo plantation in the Netherlands on the surrounding area. A comprehensive overview of the challenges and benefits of a bamboo plantation in the Netherlands is given. The starting point for this section is the question What is the environmental impact of agricultural bamboo cultivation on a local area?

Key takeaways

Environmental Impacts

- Bamboo plantation ecosystem services are largely limited to material provisioning and water table management, with a small effect on habitat for organisms
- Distinct lack of sources pertaining to ecosystem impacts of bamboo on the ecosystem in the Netherlands

Pests & disease

- Bamboo pests mainly come from Asia and arrived in Europe through bamboo importation
- Several pests successfully established populations in Europe (Aphids, Scale Insects, and Spider Mites)
- No record about bamboo disease in Europe
- Ecological technique to manage pest infestations can support ecosystem function

Biodiversity effects

- Bamboo plantation can have both negative and positive impact on the local biodiversity
- Bamboo plantations in polyculture system can provide habitat and food for some animals such as insects and birds
- Bamboo plant also serves rich-nutrient litters from dropped leaves and sheaths to the ground for soil microbiome
- Monoculture system of bamboo tend to have negative impact to local environment by habitat simplification
- Other uses of bamboo cultivation could be explored more to find opportunities

Ecosystem services

- Bamboo can provide valuable raw biomaterial for the Dutch processing and construction industries because of the excellent material properties
- Bamboo has a high carbon sequestration potential in the form of underground and harvestable aboveground biomass

- A bamboo field can provide significant benefits to water management through water purification and storage and runoff prevention
- A significant trade-off between regulating and provisioning ecosystem services depending on the management choices was found. A focus on bamboo shoots would inevitably lead to a lower material yield and vice versa
- During the literature review for ecosystem services of bamboo in the Netherlands, a distinct lack of research on the effects of bamboo in Europe was found. This knowledge gap proves to be a challenge to the establishment of relevant regulation and future businesses
- Multiple sources found that the data used to research bamboo ES was of poor and inconsistent quality, leading to difficulty for statistic calculations of the ES impact. A lack of common approaches and tools was identified to be the cause of this. The fact that bamboo is rarely found as a monoculture species but is often spread in other landscapes proves an extra challenge. Because of these factors, proper data models are not available, further hindering good bamboo management decision making

3.1 Invasiveness

Bamboo is not native to the European continent. Species that are not native to a certain region are classified as an invasive exotic (NVWA, 2023). Being regarded as an exotic, non-native species, is not the same as being classified as an invasive species. Invasive species are regarded as a threat to the native ecosystems and shunned. Currently there are no species of bamboo on the list of invasive plants of the NVWA, the Netherlands Food and Consumer Product Safety Authority (NVWA, 2022). While the Netherlands does not classify any type of bamboo as invasive, the U.S. department of agriculture has classified "Golden Bamboo" (*Phyllostachys aurea*) as an invasive species (U.S. DEPARTMENT OF AGRICULTURE, n.d.). This bamboo species can quickly take over an area, outcompeting and replacing native plants and is therefore considered invasive. Similar concerns are also present in Europe, urging for close monitoring of the current bamboo present and the reaction of these plants to predicted climatic changes.

Fears that bamboo will invade local ecosystems largely stems from people's concerns that the rhizomes of ornamental bamboo spreads to neighbouring properties. In agricultural context these worries are manageable as there is more space available to stop the rhizomes. An example of management practices to prevent spreading is a ditch of about 60 cm deep around the field can be used to keep the rhizomes from expanding into neighbouring areas. The ditch should be kept free of leaves, water and other material to prevent the bamboo from spreading, which can be achieved by cleaning the ditch multiple times per year (R. van Til, personal communication, 23 June 2023). An extra unknown risk factor is the spreading of bamboo via seed dispersal. Currently there is no knowledge about the risk of spreading of bamboo through seeds in the Netherlands. This risk may be mitigated by clear cutting the bamboo field before the flowers are fully developed.

3.2 Bamboo Pest

This section discusses bamboo pest species that have survived and established in the climate of Europe and their potential to do the same in Netherlands. Alternative control management of the problematic species is also addressed.

Bamboo plants are usually low maintenance and resilient, often thriving for many years without much care. This is due to their natural resistance to pests and disease. As a result, the presence of pests and disease receives less attention. Besides, in many cases, natural enemies of the pest play a significant part in managing these pest populations withing the bamboo habitat, particularly in Asian countries (Wang et al., 1998). However, the ecological balance and dynamic of insect populations can be disrupted by both human intervention and climate change, thereby favouring the survival and growth of insect pests (Skendžić et al., 2021). A large-scale bamboo monoculture system can foster the reproduction of herbivorous insects by providing them with an enormous quantity of food, thus impacting local food cycles (Ouyang et al., 2016). Excessive usage of insecticide, as a response to pest infestation, is a form of human intervention. Pesticides do not only targets pests but also unintentionally harms natural enemies. Pest population can grow explosively due to the absence of natural enemies and the continued availability of a suitable food source (Wang et al., 1998). Consequently, pest-related problems can have a big impact on the quantity and quality of bamboo production.

A comprehensive study of native insects that feed on bamboo plant species in the Netherlands is still lacking. The idea that insects are not adapted to the natural defence systems of bamboo is one reason for this knowledge gap. The physical and chemical defences might make the plant unsuitable as a food source and habitat for native insects, as they have not co-evolved with the plant (Rashid War et al., 2018). However, cases of native insects colonizing non-native plants suggests that insects in the Netherlands can adapt to eat exotic crops. There is a viable risk that native insects to the Netherlands may attack bamboo if this plant is grown for an extended period (Meijer et al., 2012). Therefore, additional research is required to investigate potential adaptation and the consequent implications for bamboo cultivation in the Netherlands.

3.2.1 Potential Non-native pest establishment

Multiple insect herbivore and spider mite species feed bamboo in their country of origin and cause damages in this way. According to Wang et al. (1998), there are more than 800 insect species that are classified as pests for bamboo in the world and most originate from Asia. Some of these pests have been discovered in European countries, including the Netherlands **(**Malumphy & Salisbury, 2016; Piron 2009). Most bamboo pests in Europe were accidentally introduced with the import of exotic bamboo plants. These pests have shown the ability to adapt in the altered environment, which has helped them to establish and spread. In addition, the growing number of bamboo plants in Europe provides suitable habitat and food sources for these non-indigenous pests, which makes it easier for these insect pests to settle and grow in number (Wieczorek., 2023). Therefore, the combination of pest adaptability and bamboo plant availability could facilitate to the establishment of non-native insect pests in the Netherlands.

3.2.2 Aphids

The invasive leaf aphid species from the genus *Takecallis,* originating from China, has been found on bamboo plant species Fargesia in Poland (Wieczorek, 2023) and in the Netherlands (Piron, 2009). This aphid species has spread widely and can live in large numbers on many bamboo species in the family *Bambusoideae*, such as *Dendrocalamus* spp., *Bambusa* spp., *Arundinaria* spp., and *Phyllostachys* spp. (Lee & Lee, 2018). The Handbook of Alien species in Europe lists this leaf aphid as an invasive pest that threatens bamboo plants (Roques et al., 2009 as cited in Wieczorek, 2023). Aphids sustains themselves by extracting nutrients from the sap of bamboo plants, leading to symptoms such as leaf yellowing, stunted growth and morphological abnormalities (Wieczorek, 2023). Initially, aphid infestations may not have a big effect on bamboo plants. However, as their populations grows, the negative affects become more noticeable (Revathi & Remadevi, 2011). They can also act as a vector that can quickly spread plant diseases between multiple plants. Aphids have proven to be one of the most challenging pests to control in the Netherlands due to their high reproductive rate and resistance to pesticides (Messelink et al., 2014; Leather & Dixon, 1984). Therefore, due to the lack of its natural enemies and high population growth, management of this pest need to be considered when undertaking large-scale bamboo plantations in the Netherlands.

3.2.3 Scale Insects

Scale insects, specifically those belonging to the *Diaspididae* family within the order Hemiptera, are often inconspicuous and go undetected during plant quarantine inspections. These insects became a significant group of invasive pests worldwide as highlighted in various studies (Ülgentürk et al., 2014; Malumphy & Badmin, 2012). Like Aphids, the scale insects threaten bamboo plants by consuming phloem fluid. This feeding behaviour also leads to sap depletion, which results in reduced plant vigour and the development of chlorotic, meaning colour loss, areas at the feeding sites. Furthermore, scale insect infestations can cause premature leaf detachment and distortion of the stems (Wang et al., 1998).

In Europe, the successful establishment of several scale insect species from Asia has been observed, particularly in relation to the import and cultivation of bamboo (Ülgentürk et al., 2014). Jansen (2009) reported that *Trionymus bambusae,* an exotic species from Bangladesh and India, has been observed in the Netherlands and Belgium both in greenhouse and outdoor environments. Another species, *Balanococcus kwoni,* believed to be native to South Korea, was initially identified in Italy on bamboo from the genera *Pseudosasa* and *Phyllostachis* (Pelizzari & Danzig, 2007) and in a commercial nursery in the UK in Kent **(**Malumphy & Badmin, 2012). In addition, the white scale insect species *Kuwanapsis howardi* became widely naturalized in the UK on various bamboo genera including *Bambusa, Fargasia*, and *Phyllostachys* (Malumphy & Salisbury, 2016). As a result, potential attack and establishment of these pests in the Netherlands is increasingly likely due to its adaptability to local environments.

3.2.4 Spider Mites

Bamboo spider mites, which belong to the family of *Tetranychidae,* pose a serious threat to Moso bamboo plantations in China (Zhang et al., 2003). The infestation of this mite caused damage both to newly planted as well as established bamboo plantations. Spider mites extract the sap of bamboo plants by feeding on the underside of leaves (Pellizzari & Duso, 2016). The feeding activity of *S.najingensis* on bamboo leaves caused a reduction of sugar and chlorophyll content. It also reduced the overall dimension of the leaves and stunts culm growth (Zhang et al., 2000). Moreover, reduced chlorophyll concentrations induced yellowing of the leaves and consequent dropping (Pellizzari & Duso, 2016). Economic losses due to the outbreak of spider mites have been reported on monoculture bamboo plantation in Fujian province, China (Zhang et al., 2004). These findings showed the harmful impact of spider mites on bamboo plants, both physiologically and economically. The two prevalent pest species in this category are *Schizotetranychus bambusae* and *Stigmaeopsis najingensis*, which originate from East Asia and have successfully established populations in several European countries (Kiss et al 2017; Kontschán et al., 2015; CABI, 2020)**.** The first evidence of these mites was found on bamboo plantation in a botanical park in Hungary (Kontschán et al., 2015). Moreover, Pellizzari & Duso (2016) reported that *S. najingensis* has been observed to be prevalent in large numbers in the Veneto Region, Northeast Italy. In addition, the first establishment of another bamboo mite species, *Aponychus corpuzae* in Europe was reported in Slovenia, occurring on the bamboo species *P. bambusoides* (Seljak, 2015). Since these mites can live in a variety of areas in Europe, it is possible that they could spread and establish to other places with similar climatic condition, like the Netherlands. Therefore, the establishment of these pests needs to be closely monitored and considered when considering bamboo management practices.

3.2.5 Bamboo Disease

Most bamboo diseases in Asia are associated with fungal pathogen. Some Moso bamboo diseases such as culm rhomboid rot (*Arthrinium arundinis*), web blight disease (*Rhizoctonia solani)* and dieback blight (*Ceratosphaeria phyllostachydis*) have caused significant crop losses in China and India (Zheng et al., 2022; Bhamra & Borah, 2021). Bamboo mosaic virus (BaMV) is another pathogen that causes significant trouble in China and Australia and is transmitted by multiple fly species (Chang et al., 2017; Thomas & Dodman, 1999). Aphids and scale insects, as bamboo pest, can also act as a vector for some fungal diseases through their honeydew. This nutrient-rich substance, secreted by the aphids, is a good growth medium for sooty mould (Nelson, 2008). Even though there is no detailed study pertaining to bamboo diseases occurring in Europe, there is still a chance that these diseases could spread in the Netherlands.

3.2.6 Pest & Disease Management

Various techniques are available to control pests on bamboo plants, including physical, chemical and biological methods. Physical treatment involves cutting down or removing infested bamboo. In case of moderate pest damage, treatment with pesticides is an option to control insect pest populations (Wang et al., 1998). While chemical control is commonly practiced in Asian countries, it is not preferred option in the Netherlands due to the limited use of synthetic pesticides. On the other hand, biological techniques are considered highly relevant for pest management in bamboo plants. One such approach is the release of natural enemies. A successful example of this is the use of a predatory mite *Amblyseius longispinosus*, to reduce populations of bamboo mites in Moso bamboo plantation in Fujian district, China (Zhang et al., 2000). Using exotic insects as natural enemies does however raise regulatory and biodiversity concern, as they may have negative impacts on local ecosystems. An alternative is to employ native natural enemies that are prevalent in the Netherlands. Szenasi et al (2017) reported that a predatory mite *Phytoseiulus persimilis*, a species that is commercially available in Europe and Netherlands, significantly reduced population of two highly destructive bamboo mites, *Stigmaeopsis nanjingensis* and *Schizotetranychus bambusae* in laboratory experiments in Hungary. However, further research is necessary to evaluate the efficacy of realizing this usage of natural enemies in actual bamboo plantations. Moreover, additional studies are needed to explore the potential of other native natural enemies for controlling pests in bamboo plants. Growing healthy and disease-free plants is also an important factor to ensure that bamboo plants are not attacked by diseases. A screening of bamboo seeds and saplings is one way of ensuring the quality of planting material.

3.2 Effects above ground biodiversity

Bamboo plays a significant role in providing habitat and food for variety of animals withing its indigenous ecosystems. The plant provides benefits to both herbivorous and non-herbivorous insects because it gives them places for foraging and nesting. For example, ants that eat honeydew could be attracted to aphids-infested bamboo because the aphids produce honeydew as a byproduct of digestion (Watanabe et al., 2018). Several ant species in Brazil rely on bamboo to provide safe nesting site, affording them protection against potential predators (Arruda et al., 2015). Furthermore, bamboo can also serve as a Phytotelmata, a plant capable of retaining stagnant water and functioning as an insect breeding site, even inside the stalks (Campos, 2013). Louton (1996) reported that bamboo supports the biodiversity of several aquatic macrofauna such as dragonflies, damselflies, and mosquitoes in the lowland tropical forest in Peru by providing breeding place for those insects.

Additionally, insectivorous and granivorous bird species use bamboo as feeding place in Chilean temperate rainforests (Díaz et al., 2005). According to Rother et al. (2013), the invasion of *Guada tagora* bamboo improved the forest's structural heterogeneity, which increased bird biodiversity in the Atlantic Forest in south-eastern Brazil. As a result, the provision of shelter, nesting and feeding site by bamboo in polyculture systems could encourage a complex and linked environment in the Netherlands, which is beneficial to a variety of animal species. Besides birds, another native species that could potentially use bamboo as a habitat would be the European hedgehog. This animal is attracted to shrublike habitats to find prey such as ants, earwigs or other small insects (Pettett et al., 2017).

In monoculture systems, bamboo can have negative impacts on above-ground biodiversity by simplifying the habitat structure (Ouyang et al., 2016). An example of this is Touyama et al. (1998) which found that the ant fauna in Moso bamboo forests was less diverse than in bamboo mixed-forest and broad-leaves forests in Japan. Yang et al. (2008) as cited in Xu et al., (2020) reported a reduction in avian biodiversity in the Tianmushan Nature Reserve, Zhejiang Province, China due to the expansion of Moso bamboo (*P.pubescens*). Regarding plant biodiversity, Moso bamboo is recognized as a highly invasive species that tends to outcompete indigenous plant species through light and nutrient competition (Liu et al., 2011), resulting in a decline in plant diversity (Bai et al., 2013). The risk assessment conducted by Matthews et al. (2015) suggested that the expansion of giant timber bamboo (*P.reticulata)* in the Netherlands could result in the establishment of the Southeast-Asian carpenter bee (*X. tranquebarorum),* which has a symbiotic association with a non-native mite (*Sennertia alfkeni*). This exotic mite may interfere with the interaction between the native violet carpenter bee (*X.violacea*) and its symbiotic mite (*Sennertia cerambycina*) due to a mite host switch. The authors added that this host switch is a threat to the violet carpenter bee population, especially since *X.violacea* is already listed as a vulnerable species in the Netherland. Negative effects such as the ones described above area real risks that are applicable to the Netherlands.

3.3 Effects below ground biodiversity

Most research on how bamboo's expansion affects the below-ground biodiversity has been done on soil microbes. The results of these investigations have been inconsistent and often times contradictory. Several studies have indicated that the bamboo invasion into an area can have positive effects on soil microflora biodiversity (Xu et al., 2014; Lin et al., 2017). The study conducted by Xu et al. (2014) revealed that the invasion of Moso bamboo into broadleaf forests in the Tianmushan National Nature Reserve in China resulted in a significant increase in microbial biomass and soil community structures. In Taiwan, researched moso bamboo plantations showed a higher soil bacteria diversity as compared to broadleaf forest and cedar plantation (Lin et al., 2017). On the other hand, monoculture system of Moso bamboo (*P.edulis)* showed lower diversity of arbuscular mycorrhizal fungi (AMF) when compared to a mixed bamboo-cedar forest in Japan (Zou et al., 2023). These fungi are able to fixate nitrogen into the soil and are thus beneficial organisms. The negative impact of bamboo encroaching into new areas aligns with Wei et al (2021), which found that Moso bamboo (*P.edulis*) invasion into secondary broadleaved forest in south China decreased the richness and diversity of soil mesofauna such as root herbivores and microbivores. Another study by Xiao et al. (2023) revealed a significant decline in the soil nematode biodiversity caused by Moso bamboo expansion in comparable forest locations. The decline of soil mesofauna correlates with the changes in soil properties, including the reduction of native plant diversity, total organic carbon, soil fungal richness and increased soil acidification (Wang et al., 2019; Liu et al., 2019; Xiao et al., 2023). Since bamboo is non-native to Netherlands, this plant could also have negative impacts on the below ground biodiversity, especially when it comes to monoculture systems that simplify the soil food chain and can potentially alter soil properties.

In the Netherlands, positive and negative effects of bamboo invasion could occur in both above and below-ground environments. Exotic plants in the Netherlands could prove to have negative impacts to local biodiversity (van der Burg et al., 2012). However, Meisner et al., (2012) found that biennial wormwood *(Artemisia biennis*), native to north America had positive effect to local soil by providing rich-nutrient litter to the soil which enhances soil microbe diversity. In a bamboo nursery in the Netherlands named Bandus, at least 3 species of native birds (Eurasian Blackcap, Common Chaffinch, and Common Chiffchaf, identified by the Cornell Lab Merlin v2.1.8) that used bamboo as their feeding place were spotted, proving a valuable addition to local biodiversity. The method of cutting culms in this bamboo nursery creates bamboo stumps that can provide stagnant water, a potential mosquito breeding place. A prospering mosquito population was also observed in the bamboo nursery and acted as a feeding source for local animals. A downside to the prevalence of mosquitos is that these insects play a significant role in transmitting various diseases to humans. Therefore, the increase of mosquitos in bamboo plantations needs to be considered a health risk as some mosquito species from Asia can adapt to Dutch climatic condition and transfer diseases (Scholte et al., 2010). Extensive studies on the ecological impact of bamboo plantation to the local biodiversity in Netherlands is still lacking. Therefore, the effect of bamboo invasion to biodiversity in the Netherlands needs to be further researched.

3.4 Ecosystem services

Ecosystem services is an encompassing term used to describe the goods, services and positive impacts that an ecosystem can provide for humans. The millennium ecosystem assessment provides a framework to give a detailed and quantifiable overview of the possible ecosystem services (united nations environment programme, 2017). These benefits are classified in 4 categories, namely: provisioning, regulating, habitat, cultural. This subsection will focus on the benefits that can be derived from a bamboo plantation (Figure 8). The description of this framework and the accompanying calculations and statistics fall outside of the scope of this report, which will focus on making an overview based on available literature pertaining to bamboo cultivation.

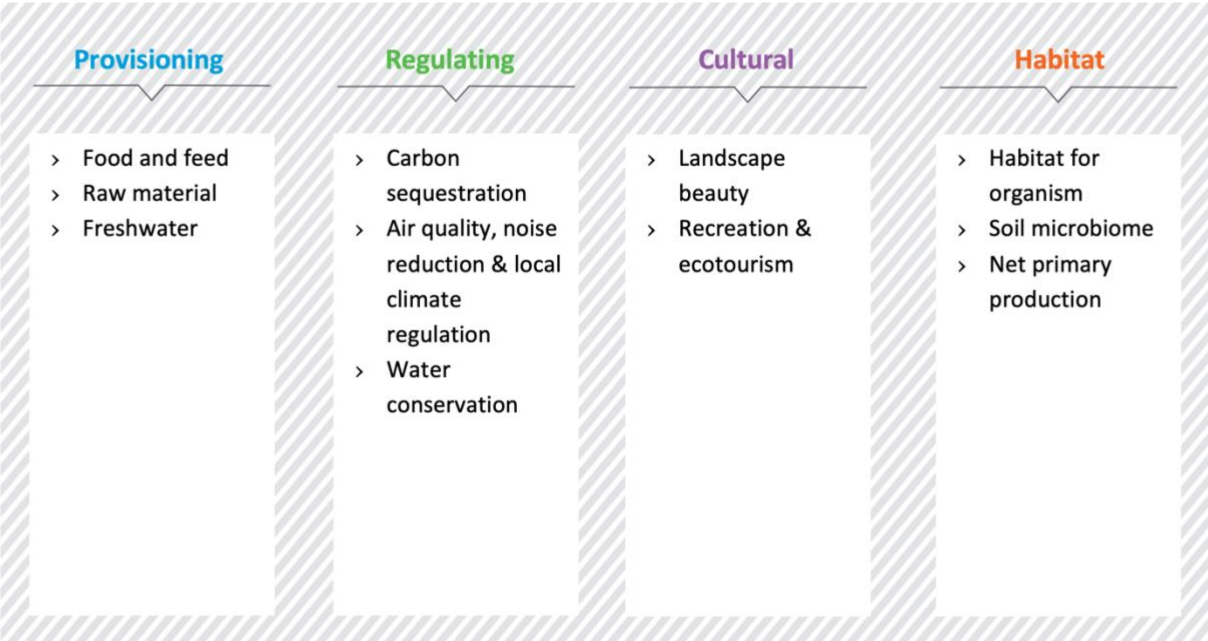

Figure 8: *ecosystem benefits of a bamboo plantation in the Netherlands*

Important to note is that the literature review found a distinct lack of scientific papers related to commercial bamboo cultivation in the temperate and cold regions of Europe, including the Netherlands. It is therefore highly advised to conduct more studies on the benefits and risk of bamboo cultivation in the Netherlands pertaining to ecosystem impacts and benefits. Using literature pertaining to other parts of the world comes with a risk as it is unknown how the plant will behave under different climatic and soil conditions. This means that literature about ecosystem services from bamboo plantations cannot be applied without alterations and reflection.

Reports from the International Bamboo and Rattan Organization (INBAR) and other literature concluded that the ecosystem services provided by bamboo forests, not bamboo plantations, in rural areas in the native habitat of the bamboo, are equal or higher than degraded or planted forest, grassland or agricultural land. The ecosystem services of bamboo forest is lower than that of natural forests (Paudyal et al., 2022; Buziquia et al., 2019). The estimated ecosystem services for a commercial bamboo plantation in the Netherlands are severely diminished, or not applicable as compared to bamboo forests in their native areas. The ecosystem services listed below are speculations based on literature gathered from other parts of the world and the in-house expertise of the team. Real life conditions may very well diverge from the situations listed here.

The description of ecosystem services given below is adapted from available literature, which is not specified to the European continent. As such, a selection was made to exclude benefits that are not applicable to the situation in the Netherlands. As the goal of the commissioner of this project is to establish a commercial bamboo plantation, benefits derived from natural, extensive and long term bamboo forests were also excluded or severely diminished. Ecosystem services that were only applicable in rural and underdeveloped regions where bamboo is native, such as the cultural value, were also excluded. Lastly, ecosystem services pertaining to soil erosion and anchoring were excluded because they were not applicable to the geographic features found in the Netherlands. A difference in management goals for a plantation can have a significant impact on which benefits are applicable and on what scale. For example, extensive cultivation in the form of a long term, planted, bamboo forest will have more ecosystem benefits and of a different scale as compared to a commercially exploited plantations where the bamboo culms are harvested every few years. Evaluating the ecosystem services of a plantation is thus highly dependent on the location and management choices.

For the sake of selecting suitable ecosystem services some assumptions about the bamboo were made. The species on which most assumptions were made is *P. pubescens*, also known as Moso bamboo. This was done because a significant portion of literature was available for this species as compared to other options. For speculation based on management practices, the following assumptions were made: The bamboo is harvested on rotation every 3-4 years while maintaining optimal management practices for the area, located in the Netherlands. An establishment period of 8-10 years was considered. The focus of the plantation is on material production not food production. It was also assumed that the spread of bamboo is contained though management practices.

3.4.1 Provisioning services

Provisioning services describe the tangible materials and products that humans can obtain from the bamboo plantation.

- *Food provisioning*

  The bamboo shoots, young emerging culms, are an edible produce with over 200 million tons consumed worldwide annually. In Europe, the consumption of bamboo shoots is growing in popularity through the emergence of a more globalised food culture (Wang et al., 2020). Depending on the management decisions made in a plantation, a portion of the fresh bamboo shoots can be sold to local retailers and restaurants during specific periods. Focussing on the bamboo shoot production comes with a drawback. Harvesting the shoots obviously presents a trade-off with material production as it lowers the amount of new culms that grow. As the project goal is focussed on carbon sequestration and material production, this service is expected to be minimal.

- *Feed provisioning*

  Bamboo is an evergreen plant, known to grow and replace leaves continuously. The old leaves fall down and form a layer of litter on the soil. These leaves form a potential biomass source that is rich in proteins and could be mixed into livestock feed. This is already common practice in countries such as India and Nepal for animals such as goats, sheep and cows. The suitability of the biomass for Dutch livestock needs further evaluation Fresh green leaves, separated from the harvested culms, could also be used for tea or as green fodder. The use of this biomass source is a management decision as it is also possible to leave the litter as is to prevent weeds from growing and to replenish the soil organic matter content (Partey et al., 2017).

- *Raw material (biochar, construction materials or as an input to processing industry)*

  Raw material refers to the unrefined, non-food, outputs of a bamboo plantation. This consists of the culms and the leaves. The culms can be used for a multitude of applications thanks to the material properties while the leaves are usually used either as fodder, mulch or for biobased applications such as biogas production. Culms serve as raw input in processing industry to make composite boards, floors and a wide variety of bamboo based products. The woody material serves as an excellent replacement of traditional wood obtained from forestry or it is used for entirely new ones. Specifying the multitude of possible uses for the bamboo culm exceeds the scope of this report.

- *Freshwater provisioning*

  Bamboo is adept at storing water within an extensive rhizome network and in the culms. It is estimated that one hectare of bamboo forest can store up to 30 000 Litres of water depending on the species and soil conditions. The canopy cover and the litter also reduce evaporation of water from the soil. This can lead to long term, on-site and regional benefits such as a elevated groundwater level and soil moisture content. The water absorption and retention of bamboo is described to be higher than that of forest and agricultural land. This benefit could be impacted by management decisions such as harvest time and method. The potential changes resulting from different management decisions could not be quantified and thus forms an unknown factor in decision making (Schröder, 2021; Paudyal et al., 2019).

3.4.2 Regulating services

Regulating services refers to the effects of the bamboo plantation on local ecosystems that provide a benefit for lifeforms in proximity to the production site.

- *Carbon sequestration*

  Bamboo is known to be very efficient at carbon fixation resulting in a significantly faster growth speed than other carbon fixating plants such as trees. The carbon is fixated in aboveground biomass such as leaves and culms, and underground biomass in the form of an extensive rhizome network and roots. This means that bamboo has a significant carbon sequestration potential. Depending on the bamboo species and the growing conditions estimates for carbon sequestration potential varies. A plantation with P. Pubescens, that is well managed in suitable growing conditions, could reach as much as 305.77 tonne C/ha in a timespan of 60 years. This is possible because only the aboveground biomass is regularly harvested, which regenerates within a few growing seasons. The feasibility of reaching these estimates in the growing conditions prevalent in the Netherlands remains highly doubtful. The climatic conditions in this part of Europe are not optimal for bamboo cultivation resulting in a slower growth speed and thus also less carbon sequestration (Kuehl et al., 2013).

- *Air quality, noise reduction and local climate regulation*

  Bamboo forests have been proven to improve air quality on site by removing odours and dust particles. The surface of the leaves is able to capture dust particles while the natural gas exchange removes smell. On top of this, a belt of bamboo is able to significantly reduce noise pollution. A 40 m wide belt could result in a drop of 10 to 15 decibels. Through transpiration the bamboo also regulates the on-site temperature (Paudyal et al., 2019; Song et al., 2011).

- *Water source conservation, purification and groundwater recharge*

  Bamboo is able to regulate the on-site water cycle because it intercepts and holds rainfall. It improves the moisture retention and penetration into the soil thanks to the canopy, an extensive root and rhizome network and the litter on the ground. On top of this, it also reduces the water runoff from the area. Literature states that bamboo forest have better water retention capacity as compared to natural or degraded forests (Song et al., 2011). Estimates are that one hectare of Moso bamboo forest, not a plantation, is able to store up to 4000 tons of water at the saturation point. This varies according to the plant density and soil type. This is only true for extensive bamboo fields and the effect will be reduced when bamboo is exploited commercially in the form of a plantation. Even in regularly harvested bamboo plantation, the roots and rhizomes in the soil provide structural support and reduce water runoff (Song et al., 2011). The bamboo also has the added benefit that it has antibacterial and antifungal properties and that it is able to remove some toxic substances from water, thus providing a water purification service (Das S. & Saha M., 2013).

3.4.3 Habitat services

Habitat services refers to how a bamboo plantation can provide living space for local species and how it can support genetic biodiversity.

- *Habitat provisioning*
  The litter produced in the bamboo plantation could provide a habitat for soil based micro-organisms and small insects. This is only applicable if the management of the plantation decides to not use the litter for other applications and leave it as it is. Besides this, a bamboo plantation in the Netherlands could provide a habitat to a limited number of native bird species and some small, insect eating, mammals. A bamboo plantation would serve as a feeding ground for the bird species. The habitat provisioning is severely limited because of the exotic nature of bamboo. The animal species native to the Netherlands are naturally not adapted to this new type of habitat. Intensive management and the method of harvesting also play a role in how much the plantation can contribute as a habitat.

- *Soil effects*
  Reports on the effect that bamboo has on the soil nutrient compositions, pH and water retention vary. As such it is difficult to form a comprehensive overview. What is sure is that the extensive root and rhizome networks work as an anchor for the soil, preventing erosion and increasing the water permeability. Bamboo forests can help regenerate lands by changing the local microbiome and nutrient cycles to increase soil fertility. This is only relevant in extensive cultivation and not in a commercial bamboo plantation. For commercial exploitation, intensive management is needed which has been proven to lead to soil degradation. As such the soil effects of a plantation focussed on intensive biomass production, can not be classified as an ecosystem benefit (Dong et al., 2022; Paudyal et al., 2022; Wu et al., 2018).

- *Net primary production*
  Net primary production is a term used to describe how productive an area is. It is an indicator for biomass accumulation and carbon sink potential. Multiple studies concluded that the land use efficiency of bamboo forestry is higher than monoculture cultivation. It can also have an effect on the soil fertility. The high net primary production supports other ecosystem services. Though these benefits are limited within a commercial exploitation of bamboo fields, especially if it is a bamboo monoculture (Song et al., 2017; Chen et al., 2018).

3.4.4 Cultural services

Cultural services refers to the nonmaterial benefits that can be obtained from a bamboo plantation. This includes social, cultural and educational values attributed to the bamboo.

- *Landscape beauty, recreation and ecotourism*
  Bamboo forests or bamboo dominated landscapes are known to have high aesthetic and recreational value. As such bamboo forests can be a viable part of ecotourism and promoting sustainable values. Bamboo plays an important socio-cultural role in Southeast Asia and other parts of the world where it is native. Within Europe it is mainly known as an ornamental plant in gardens and not as an important part of the local culture and recreation opportunities. The bamboo would only provide socio-cultural benefits in an in extensive cultivation system and not be applicable to intensively exploited bamboo fields. It is important to note that there might be

societal resistance to large scale bamboo cultivation because of a phenomenon called landscape pollution(Paudyal et al., 2019; Wu et al., 2019; Food and Agriculture Organisation of the United Nations, 2007). As such, pushback by local governments can be expected, their worries aggravated by the concerns over invasiveness.

Summary

For a commercially exploited bamboo plantation in the Netherlands, multiple ecological effects relating to ecological impact and ecosystem benefits can be identified. These findings were based on literature from different climatic and geographic conditions and adapted through deliberation and reflection, combined with the in-house expertise. This was done because literature pertaining to bamboo cultivation in the temperate zones of Europe was found to be lacking or non-existent for some topics. As such, all findings can differ from reality and must not be taken at face value.

The introduction of bamboo to Europe for commercial purposes could lead to a noticeable impact on the local ecosystems and biodiversity. Multiple bamboo species are known to exhibit invasive behaviour and pose a risk to plots neighbouring cultivation plots. Research on the effect of bamboo on above and underground biodiversity was inconsistent. Positive effects on local biodiversity came in the form of feeding places, breeding grounds and increases in soil bacterial structures. However, other literature found decreases in soil based nematodes and fungal structures. As such a definitive conclusion for this topic was unachievable.

A commercial bamboo plantation in the Netherlands could also face challenges in the form of pests and diseases. Native insect populations can adapt to prey upon the introduced bamboo. Non-native bamboo pests are already introduced in various European countries and can easily establish populations on bamboo in the Netherlands. The insect pests can act as vectors for plant diseases, which can impact the bamboo growth performance. Some insects that act as disease vectors for humans, such as mosquitos, also use bamboo as a breeding ground. Furthermore, the proliferation of insect pests could lead to changes in the local food chain.

Luckily, in the Netherlands a wide variety of pest control measures can be taken to control the pest populations. These measures vary from synthetic pesticides to the use of native species to act as a predator for non-native pests. Careful pest management can negate at least a part of the risks associated with pests and diseases.

Of all the various ecosystem benefits that a natural bamboo forest provides, only a select few are applicable to the situation in the Netherlands. The main ecosystem benefits that can be derived from a commercial bamboo plantation are limited to material, and in second instance food, provisioning. A minimal benefit to the local water management and habitat provisioning can also be expected.

4 Alternative growing opportunities

In this section, alternative growing opportunities for bamboo are explored. The current goal is to grow bamboo on a large scale, aiming for culms and as a secondary priority, food. Within Europe, the only common occurrence and use of bamboo is as an ornamental plant. There are barely any commercial endeavours that aim to grow bamboo at a large scale. While interest is rising in the Netherlands, concerns over competition with food production and regulations are restrictive. However, there are some possibilities to grow bamboo in the Netherlands in unconventional places or with unconventional goals.

4.1 Lodging prevention

Lodging is the phenomenon of crops falling over because of water or wind. The main cause of wind lodging is high wind speeds going over and against the field while the crops become taller and unstable. This lodging decreases the overall yield and increases the difficulty of mechanical harvesting (Dahiya, 2018). Wind lodging can be reduced by setting up a barrier around the field to reduce windspeeds (Cleugh et al., 1998). For example, a barrier made of Douglas fir can be used as a windbreak and help prevent lodging (Sturrock, 1981). The planting of bamboo around the field can create a wind barrier for crops that have a high risk for lodging. This is because bamboo is a strong crop that reaches a considerable height fairly quick, while possessing strong culms that are less prone to lodging. Lodging in bamboo can be caused by a soil that is oversaturated with nitrogen, impacting the stability. Cases of this happening are rare (Aihara & Yoh, 2015). It is best to use bamboo species that have a high culm density to increase the effectiveness.

4.2 Noise barrier

Currently, massive artificial barriers are used to reduce noise from highways to improve the living conditions in the proximity of the roads. However, these barriers often display visually unappealing attributes and involve significant expenses for construction and maintenance. Bamboo can help reduce the noise of motorways or highways up to 12 dB with a screen of 5 meters high and 6 meters wide. This is a slightly better performance than an artificial sound barrier of 3 meters high (Van Leeuwen, 2016) Only a part behind the artificial barrier is better than a bamboo lane, but the further away the bamboo is better for the noise reduction (Figure 9). A wall of bamboo would not only help with noise reduction but also create a greener environment. Such bamboo strips could even be combined with a carbon credit system to make the placement cheaper. The only disadvantage of this is that the bamboo strips would need a couple years for establishment and that culm harvesting would be limited.

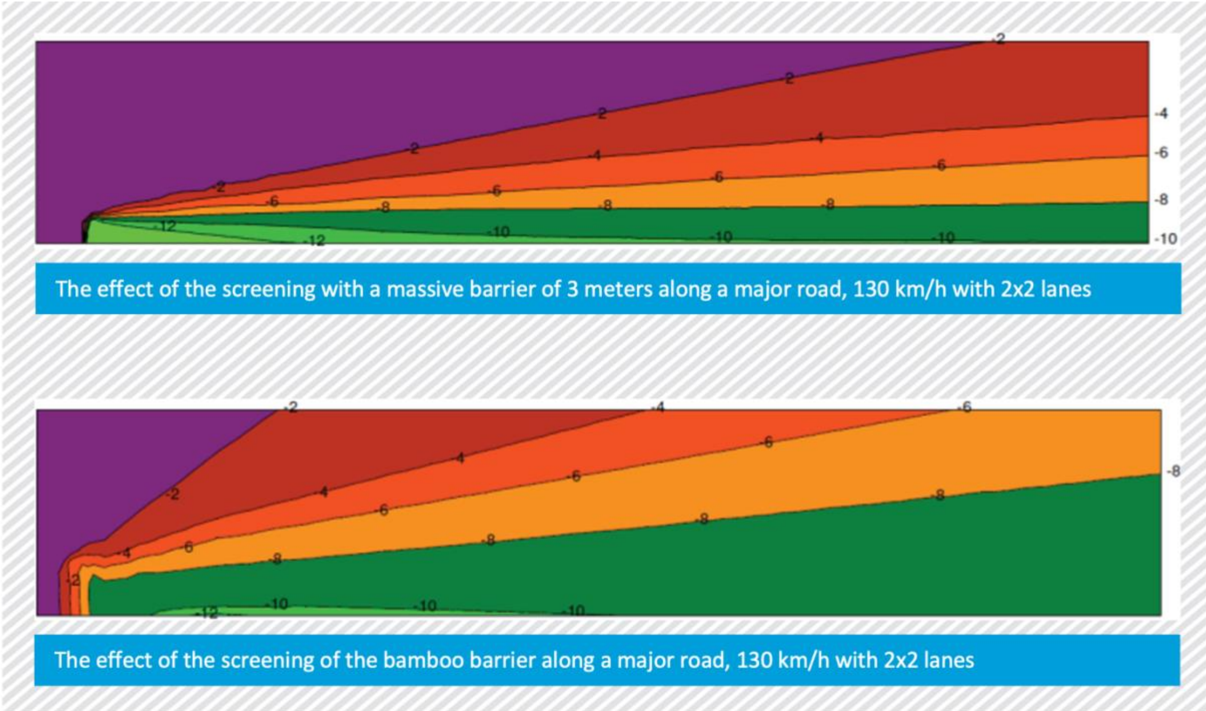

Figure 9: *Effect of artificial and bamboo barrier next to a highway inside of the Netherlands. (adapted from Van Leeuwen, 2016)*

4.3 Bamboo maze

Mazes present a good touristic attraction for tourist. In the Netherlands, mazes are usually made of maize or hedges. Maize mazes need to be replaced every year while the harvest becomes limited after a season of tourist, while hedge mazes take many years to grow and have no other use apart from the touristic value. A bamboo maze does not currently exist in the Netherlands. The best example of a bamboo maze is in Italy, which is the biggest bamboo maze in worlds. This maze was designed, built and fully grown within 10 years while with a classic boxwood style it would have taken over 20 years to grow (Novozhilova, 2015; Bian et al., 2020).

4.4 Phytoremediation

Recent literature states that bamboo, mainly Moso bamboo, can be used for phytoremediation. This is a method to extracting toxic heavy metal out of the ground using fast growing plants that can take up the toxic compounds and hold them. Moso bamboo can survive without any visual metal toxicity symptoms when exposed to high concentrations of heavy metals (Yan et al., 2015). These traits can be used to extract heavy metals from an area that is polluted or to create a green zone close to industry, where it acts as a buffer. In this way, unusable land can still be used while improving the ground quality. More research on what zones in the Netherlands are highly contaminated and if it is allowed to grow bamboo there is needed.

4.5 Natural purification systems

As already mentioned previously, the wastewater of greenhouses can be used for the irrigation and fertilization of the bamboo. This is not only saving costs on fertilizer and irrigation water for the grower but also serves other purposes. Greenhouse growers have emission restrictions for the wastewater, they discharge. This wastewater is not harmful for the surrounding areas but still contains high nutrient concentrations that are suboptimal for plant growth. By diluting the wastewater to optimal nutrient concentrations, the bamboo plants can reuse the water and the unused nutrients and salts from the greenhouse fertilizer. An additional benefit of this is that the nutrients do not accumulate in the lower soil layers or groundwater.

Conclusion

The first research question aims to investigate the optimal growing conditions for a bamboo crop in the Netherlands in terms of soil conditions, water supply, temperature & climate, and nutrient requirements. In order to grow bamboo for commercial purposes, nutrient supply and irrigation need to be carefully managed. Supplemental fertilisation, in addition to litter recirculation, will significantly improve growth and products. The preferred methods of artificial fertilisation are the slinger method or fertigation. This can even be seen as an opportunity to recycle nutrients and water from greenhouses and reduce run-off to the environment. The water requirements of the crop are relatively high in the first 3 years of cultivation and cannot be met by rainfall alone. This means that irrigation from other water sources is necessary for optimal growth. The amount and frequency of irrigation and fertilisation depends on the type of soil and the location where the crop is grown. The temperature in the Netherlands is sufficient to grow bamboo, but it is lower than in its original habitat, such as southern China. As a result, the crop performance will be lower than in its native habitat.

As for suitable cultivation soils in the Netherlands, it is preferable to plant bamboo on sandy soils rather than clay soils. Soils with a high chalk or clay content are not recommended as they show reduced productivity. Based on previous studies from other continents, it can be confirmed that although bamboo has a widely recognised carbon sequestration capacity, it consumes a large amount of carbon and nitrogen from the soil while growing. At the same time, bamboo can increase the availability of phosphorus in the soil, thus affecting the soil nutrient balance. It is also questionable whether bamboo should be grown on fertile, high productivity soils for material applications rather than food crops.

The second research question explored the potential of bamboo cultivation for carbon sequestration, carbon credits and intercropping. A voluntary carbon market is available in Europe and offers companies and individuals the opportunity to actively participate in climate protection, show climate responsibility and demonstrate their commitment to sustainable action. When offsetting through carbon credits, measures to ensure the transparency and integrity of the project and the certification process are advisable. There is also a lack of basic research on the cultivation and sequestration potential of bamboo in temperate climates, such as the Netherlands. Pilot projects and baseline studies in the Netherlands are needed to provide reliable estimates for the sequestration potential. Tropical and subtropical studies cannot be readily used because they are limited to specific climatic zones. Research in the Netherlands should not focus on the monetary attractiveness of carbon credits but on providing reliable date. Additionally, intensive management should not limit native biodiversity as this would negatively impact certification efforts. The application of intercropping in bamboo growing projects could prove beneficial to productivity and yield reliability. The limited availability of information on feasibility, and best management practices form a challenge for implementing this into bamboo cultivation. While literature on intercropping with crops comparable to bamboo can give an indication of possible companion plants and their interactions with bamboo, there is an urgent need for research on this topic. According to the limited information available from Europe, extrapolation of data from outside Europe and general agronomic knowledge, the optimal design of bamboo intercropping plantations is highly dependent on the desired management practices and available machinery. In addition, companion plants need to be selected for their shade tolerance to thrive in intercropping systems. In a clear-cut system, it is possible to manage the alleys with an adapted crop rotation based on the shade provided by the bamboo during the (re)growth phase. However, growing shade-tolerant perennial crops such as forage mixes or berries are a better choice for selective cutting systems. Both systems have the potential to integrate livestock and legumes, which would improve bamboo growth by providing nutrients through nitrogen fixation. In addition, both systems are likely to require mechanical control of bamboo's ability to compete with companion crops. Finally, it is unclear how bamboo plantations will be classified by the Dutch authorities, which poses a significant risk to the incomes of farmers.

The third research question evaluated the ecological impacts and benefits of agricultural bamboo. For a commercially exploited bamboo plantation in the Netherlands, several ecological effects can be identified in the form of ecological impacts and ecosystem benefits. These findings were based on literature from different climatic and geographical conditions and adapted through deliberation and reflection, combined with in-house expertise, to fit the situation in the Netherlands. It was concluded that bamboo can provide valuable ecosystem services in the form of raw material for the Dutch manufacturing and construction industries, a high carbon sequestration potential in biomass, significant water management benefits through water purification and storage, and run-off prevention. The drawbacks of bamboo, in the form of ecosystem impacts, include risk from pests & diseases, invasive behaviour and altered biodiversity structures. It is a real possibility that some pest species can survive and establish populations in European climates. Their ability to adapt to temperate climates forms a potential threat to bamboo cultivation the Netherlands. On the other hand, bamboo diseases have not yet occurred in the Netherlands. Some known bamboo pests have already established populations in other European countries which increases the chances of them also appearing in the Netherlands. Although bamboo is resistant to most pests and diseases, ecological management to control pest populations is highly recommended as they can acts as disease vectors for both plants, and in the case of mosquitos, humans. The impact of bamboo plantations on biodiversity is complex, with both positive and negative effects on the environment. However, the monoculture system of bamboo plantations in the Netherlands can lead to habitat simplification and a decline in local biodiversity.

In conclusion, bamboo cultivation in the Netherlands is possible with good management when looking at the soil requirements and temperature. It is advised to focus on further research and development before starting big projects as considerable knowledge gaps on the effects and good management practices for bamboo in the Netherlands still exist. Extra attention is also needed to further explore pest & disease management and intercropping potential.

Ethical rating

Despite the feasibility of growing bamboo in the Netherlands, there are a number of ethical concerns that need to be considered. These mainly concern how and for what purpose bamboo is cultivated.

A major concern, which is a general issue in agriculture, is the food versus material controversy. This controversy deals with the question whether agricultural land should be used to grow food crops or crops for raw materials, such as bamboo. This controversy becomes increasingly important for fertile soils with optimal growing conditions for high quality food production.

The introducing an exotic species into the Netherlands is also considered as a risk factor. Although initial bamboo plantations do not appear to have a negative impact on the native environment, the effects of large-scale plantations for long term cultivation are not known. In addition, some effects or problems cannot be predicted or are beyond our current knowledge. In particular, the invasiveness of some bamboo species and how this will be impacted by the predicted climatic changes is worrying. Problems that may arise include: plants escaping containment procedures through adaptation or improper plot management. Also seed dispersal by wind or birds might become a big risk. These concerns are particularly relevant for poorly managed or abandoned bamboo fields, where the risk of invasion into surrounding areas is much higher.

Greenwashing is an issue that was encountered multiple times during span of this project. This term is used to describe the creation and promotion of an image of sustainability and environmental friendliness for products or company objectives, without having substantial proof of this. In relation to bamboo, the following problems that can be considered as greenwashing were encountered: A promise of CO_2 capture and carbon sequestration opportunities using data from Asia, while this data can not accurately represent the real situation in different locations. In particular, when Asian data on bamboo is used as proof to provide overestimations of the carbon sequestration potential. In many cases, however, these data came from Asia and is not representative for the biomass production and photosynthesis in the Netherlands, which is lower than in natural habitats (see subsection 1.4 "Temperature"). This is also very important for companies that rely on carbon credits for income, as the amount of carbon sequestered may be lower than expected. Additionally, promises of increased biodiversity are frequently made without providing academically valid proof. Although, bamboo fields can be a habitat for some animals, plants and microorganisms, it cannot be stated with certainty that it increases the biodiversity or which effect it has on surrounding biodiversity.

Looking ahead

The possibilities for bamboo are apparent, but there is still a lot of unknowns. More research needs to be done on bamboo cultivation in the Netherlands and Europe. One such important topic that requires more research is legislation within the Netherlands. Bamboo cultivation on a commercial scale is new in the Netherlands and therefore there is a lack applicable legislation. For example, in terms of landscape pollution, local governments can oppose the cultivation of bamboo on agricultural land because it is not an annual crop and bamboo grows to more than 10 metres high within a few years. In addition to local governments, the federal government could also get involved because the entire Dutch landscape will be changed. Another risk for farmers is that the bamboo farm could be considered forestry land instead of agricultural land. If this happens, the farmer could lose any subsidies.

The lack of information about the possibility of intercropping, carbon sequestration and overall biomass production in the Netherlands makes it near impossible to estimate the economic feasibility. More research on bamboo intercropping and how it compares to monocrop systems is needed to make accurate predictions.

A risk assessment of the biodiversity changes in and around large bamboo fields in the Netherlands was not found. It is advised to contact an independent institution to do an extensive study on this topic. The establishment of pests and diseases could pose dangers to native ecosystems in the Netherlands if bamboo cultivation becomes more widespread. Several ecological effects were identified in terms of ecological impact and ecosystem benefits, but due to the lack of literature on this in Europe, these may differ from reality. It is therefore recommended that further research is carried out to ensure that these statements are correct. Conducting research on ecosystem impacts could prove beneficial in the future as it would allow for easier policy making and could help with deciding the best management practices.

The most important step to take now is to focus on scientific research to provide a basis for local and national legislation for bamboo farmers. Upon getting a better grasp on this, more certainty can be given to farmers who want to start growing bamboo.

References

Abebe, S., Minale, A. S., Teketay, D., Jayaraman, D., & Long, T. T. (2021). Biomass, carbon stock and sequestration potential of Oxytenanthera abyssinica forests in Lower Beles River Basin, Northwestern Ethiopia. *Carbon Balance and Management*, *16*(1). https://doi.org/10.1186/s13021-021-00192-5

AFOLU Non-Permanence Risk Tool. (2019). Verra Verified Carbon Standard. https://verra.org/wp-content/uploads/AFOLU_Non-Permanence_Risk-Tool_v4.0.pdf

Ahdab, Y. D., Schücking, G., Rehman, D., & Lienhard, J. H. (2021). Treatment of greenhouse wastewater for reuse or disposal using monovalent selective electrodialysis. *Desalination*, *507*, 115037. https://doi.org/10.1016/j.desal.2021.115037

Aihara, Y., & Yoh, M. (2015, May 1). *Bamboo lodging associated with nitrogen saturation: its morphological and mechanical reasons*. Confit.atlas.jp. https://confit.atlas.jp/guide/event/jpgu2015/subject/04123/detail

Akoto, D. S., Partey, S. T., Denich, M., Kwaku, M., Borgemeister, C., & Schmitt, C. B. (2020). Towards bamboo agroforestry development in Ghana: evaluation of crop performance, soil properties and economic benefit. *Agroforestry Systems*, *94*(5), 1759–1780. https://doi.org/10.1007/S10457020004937

Antonio, F., & Xu, C. (2014). PLANTATION MANAGEMENT AND BAMBOO RESOURCE ECONOMICS IN China. *Ciencia Y Tecnología*, *7*(1), 1–1. https://doi.org/10.18779/CYT.V7I1.181

Arruda, F., Pesquero, M. A., Dianes Gomes Marcelino, Grazianny Andrade Leite, Delabie, J., & Fagundes, R. (2015). Size and condition of bamboo as structural factors behind the vertical stratification of the bamboo-nesting ant community. *Insectes Sociaux*, *63*(1), 99–107. https://doi.org/10.1007/s00040-015-0440-4

Bai, S., Conant, R. T., Zhou, G., Wang, Y., Wang, N., Li, Y., & Zhang, K. (2016). Effects of moso bamboo encroachment into native, broad-leaved forests on soil carbon and nitrogen pools. *Scientific Reports*, *6*(1), 1-8.

Bai, S., Guomo, Z., Yixiang, W., Qianqian, L., Juan, C., Yanyan, C., & Rui, S. (2013). Plant species diversity and dynamics in forests invaded by Moso bamboo (*Phyllostachys edulis*) in Tianmu Mountain Nature Reserve. *Biodiversity Science*, *21*(3), 288–295. https://doi.org/10.3724/sp.j.1003.2013.08258

Bamboo. (2015). In W. Liese & M. Köhl (Eds.), *Tropical Forestry*. Springer International Publishing. https://doi.org/10.1007/978-3-319-14133-6

Bamboo Biology - The Bamboo Flower. (n.d.). Completebamboo.com. Retrieved June 20, 2023, from https://completebamboo.com/bamboo_flower.html

Basso, A. S., Miguez, F. E., Laird, D. A., Horton, R., & Westgate, M. (2012). Assessing potential of biochar for increasing water-holding capacity of sandy soils. *GCB Bioenergy*, *5*(2), 132–143. https://doi.org/10.1111/gcbb.12026

Ben-zhi, Z., Mao-yi, F., Jin-zhong, X., Xiao-sheng, Y., & Zheng-cai, L. (2005). Ecological functions of bamboo forest: Research and Application. *Journal of Forestry Research*, *16*(2), 143-147. https://doi.org/10.1007/BF02857909

Bhamra, G. K., & Borah, R. K. (2021). Incidence and Management of Bamboo Diseases in North East India. *International Journal of Current Microbiology and Applied Sciences*, *10*(11), 266–276. https://doi.org/10.20546/ijcmas.2021.1011.031

Bian, F., Zhong, Z., Zhang, X., Yang, C., & Gai, X. (2020). Bamboo – An untapped plant resource for the phytoremediation of heavy metal contaminated soils. *Chemosphere*, *246*, 125750. https://doi.org/10.1016/j.chemosphere.2019.125750

Buziquia, S. T., Lopes, P. V. F., Almeida, A. K., & de Almeida, I. K. (2019). Impacts of bamboo spreading: a review. *Biodiversity and Conservation*, *28*(14), 3695–3711. https://doi.org/10.1007/s10531-019-01875-9

Campos, R. E. (2013). The aquatic communities inhabiting internodes of two sympatric bamboos in Argentinean Subtropical Forest. *Journal of Insect Science*, *13*(93), 1–17. https://doi.org/10.1673/031.013.9301

Centre for Agriculture and Bioscience International (CABI). (2020). *Schizotetranychus bambusae*. *CABI Compendium*. https://doi.org/10.1079/cabicompendium.116957

Chang, K.-C., Chang, L.-T., Huang, Y.-W., Lai, Y.-C., Lee, C.-W., Liao, J.-T., Lin, N.-S., Hsu, Y.-H., & Hu, C.-C. (2017). Transmission of Bamboo mosaic virus in Bamboos Mediated by Insects in the Order Diptera. *Frontiers in Microbiology*, *8*, 870. https://doi.org/10.3389/fmicb.2017.00870

Chen, S., Jiang, H., Cai, Z., Zhou, X., & Peng, C. (2018). The response of the net primary production of Moso bamboo forest to the On and Off-year management: A case study in Anji County, Zhejiang, China. *Forest Ecology and Management*, *409*, 1–7. https://doi.org/10.1016/j.foreco.2017.11.008

Chen, T.-H., Wang, D., & Wang, S. (2016). The trend of growth characteristics of moso bamboo (*Phyllostachys pubescens*) forests under an unmanaged condition in central Taiwan. *Taiwan Journal of Forest Science*, *31*, 75–88.

Cleugh, H. A., Miller, J. M., & Böhm, M. (1998). Direct mechanical effects of wind on crops. *Agroforestry Systems*, *41*(1), 85–112. https://doi.org/10.1023/a:1006067721039

Climate - Groups - KNMI Data Platform. (n.d.). Dataplatform.knmi.nl. Retrieved June 20, 2023, from https://dataplatform.knmi.nl/group/climate

Climate Cleanup. (2023, May 20). *Nederlandse boeren ontdekken bamboe met carbon removal credits*. www.youtube.com. https://www.youtube.com/watch?v=YQDiyI2kOJY

Cruz Rios, H. (2016). *Biomass generation and Carbon fixation in Guadua Bamboo: Guadua angustifolia Kunth HORMILSON CRUZ RIOS BACKGROUND OF THE INVESTIGATION*. https://worldbamboo.net/wbcx/Powerpoints/Ecology%20and%20Environment%20Concerns/BiomassGenerationCarbonFixationGuaduaMexico_HormilsonCruzRios.pdf

Dahiya, S., Kumar, S., Chaudhary, C., & Chaudhary, C. (2018). Lodging: Significance and preventive measures for increasing crop production. *International journal of chemical studies, 6(*2), 700-705.

Das, S. & Saha, Mitali. (2013). Preparation of carbon nanosphere from bamboo and its use in water purification. *Current Trends in Technology & Science, 2.* 174-177.

Díaz, I. A., Armesto, J. J., Reid, S., Sieving, K. E., & Willson, M. F. (2005). Linking forest structure and composition: avian diversity in successional forests of Chiloé Island, Chile. *Biological Conservation*, *123*(1), 91–101. https://doi.org/10.1016/j.biocon.2004.10.011

Dong, H., Shao, S., Liang, C., Xu, Q., Chen, J., & Qin, H. (2022). Impacts of litter composition on the structure and functional pathways of soil microbial community during *Phyllostachys edulis* expansion. *Agronomy*, *12*(1), 220. https://www.mdpi.com/2073-4395/12/1/220

Düking, R., Gielis, J., & Liese, W. (2011). Carbon flux and carbon stock in a bamboo stand and their relevance for mitigating climate change. *The Journal of the American Bamboo Society, 24*(1). 1-6

Esche, C., Steinemann, M., & Füssler, J. (2022). Freiwillige Treibhausgaskompensationen Marktentwicklung und freiwillige Instrumente zur besseren Marktdurchdringung Fallstudie im Rahmen des Vorhabens „Marktanalyse und Interventionen zur Förderung von grünen Produkten“. *INFRAS*.

Food and Agriculture Organisation of the United Nations. (2007). *World bamboo resources A thematic study prepared in the framework of the Global Forest Resources Assessment 2005 World bamboo resources A thematic study prepared in the framework of the Global Forest Resources Assessment 2005*. https://www.fao.org/3/a1243e/a1243e.pdf

Fu Maoyi, Fang Mingyu, & Xie Jingzhong. (1989). *Nutrient cycling in bamboo stands I. Leaf litter and its decomposition in pure Phyllostachys pubescens stands*.

Gai, X., Li, S., Zhang, X.-P., Bian, F., Yang, C., & Zhong, Z. (2021). Changes in soil phosphorus availability and associated microbial properties after chicken farming in Lei bamboo (*Phyllostachys praecox*) forest ecosystems. *Land Degradation and Development*, *32*(10), 3008–3022. https://doi.org/10.1002/ldr.3963

Garima, R, B. D., L, T. C., Kaushal, R., Sharma, P., Kumar, D., & Kumari, Y. (2021). Bamboo-based agroforestry system effects on soil fertility: Ginger performance in the bamboo subcanopy in the Himalayas (India). *Agronomy Journal*, *113*(3), 2832–2845. https://doi.org/10.1002/AGJ2.20684

Gielis, J., Temmerman, M., Delcarte, Belle, V., & Brias, V. (2005). *Bamboo as a source of bioenergy*. https://doi.org/10.13140/RG.2.1.5049.5608

Goethem Davina, Van. (2014). *Growth and ecophysiological characterisation of the bamboo Phyllostachys humilis Muroi in a plantation in Ireland*. Universiteit Antwerpen (Belgium) ProQuest Dissertations Publishing.

Gratani, L., Crescente, M. F., Varone, L., Fabrini, G., & Digiulio, E. (2008). Growth pattern and photosynthetic activity of different bamboo species growing in the Botanical Garden of Rome. *Flora*, *203*(1), 77–84. https://doi.org/10.1016/j.flora.2007.11.002

Gu, D., He, W., Huang, K., Otieno, D. O., Zhou, C., He, C., & Huang, Y. (2019). Transpiration of moso bamboo in southern China is influenced by ramet age, phenology, and drought. *Forest Ecology and Management*, *450*, 117526. https://doi.org/10.1016/j.foreco.2019.117526

Happe, K., Anton, C., Mengel, J., Windhausen, S., & Deutsche Akademie der Naturforscher Leopoldina (Hrsg.). (2019). *Klimaziele 2030: Wege zu einer nachhaltigen Reduktion der CO2-Emissionen*. Deutsche Akademie der Naturforscher Leopoldina e.V. - Nationale Akademie der Wissenschaften.

Haveman Groen B.V. (n.d.). *Home - English*. Shiitakekwekerij Haveman. Retrieved June 29, 2023, from https://www.shiitakekwekerij.nl/en/home-english/

Hoeveel stikstof landbouwgrond. (2019, November 6). RVO.nl. https://www.rvo.nl/onderwerpen/mest/gebruiken-en-uitrijden/stikstof-landbouwgrond

Howard, A. (2016). *The potential for companion cropping and intercropping on UK arable farmsAgricology*. https://agricology.co.uk/resource/potentialcompanioncroppingandintercroppingukarablefarms/

INBAR. (2019). *Trade Overview 2017: Bamboo and Rattan Commodities in the International Market*. INBAR. https://www.inbar.int/resources/inbar_

Isagi, Y., Kawahara, T., Kamo, K., & Ito, H. (1997). Net production and carbon cycling in a bamboo *Phyllostachys pubescens* stand. *Plant Ecology*, *130*(1), 41–52. Scopus. https://doi.org/10.1023/A:1009711814070

Jansen, M. (2009). New and less observed scale insect species for the Dutch fauna (Hemiptera: Coccoidea). *Entomologische Berichten*, *69*(5), 162–168.

Kamran, M., Cui, W., Ahmad, I., Meng, X., Zhang, X., Su, W., Chen, J., Ahmad, S., Shah Fahad, Han, Q., & Liu, T. (2017). Effect of paclobutrazol, a potential growth regulator on stalk mechanical strength, lignin accumulation and its relation with lodging resistance of maize. *Plant Growth Regulation*, *84*(2), 317–332. https://doi.org/10.1007/s10725-017-0342-8

Kiss, E., Szénási, Á., Neményi, A., & Kontschán, J. (2017). Can we use the predatory mites against the invasive bamboo pest spider mites? *Acta Phytopathologica et Entomologica Hungarica*, *52*(1), 91–96. https://doi.org/10.1556/038.52.2017.014

Klein, J. (2022). *4 insights into voluntary carbon market trends*. Greenbiz.com. Retrivied Juni 2023, von https://www.greenbiz.com/article/4-insights-voluntary-carbon-market-trends

Kleinhenz, V., & Midmore, D. J. (2001). Aspects of bamboo agronomy. *Advances in Agronomy, 74*. 99–153. https://doi.org/10.1016/s0065-2113(01)74032-1

Kollmuss, A., Zink, H., & Polycarp, C. (2008). *Making Sense of the Voluntary Carbon Market: A Comparison of Carbon Offset Standards*. Stockholm Environment Institute and Tricorona. http://sei-us.org/Publications_PDF/SEIWWF-ComparisonCarbonOffset-08.pdf).

Komatsu, H., Onozawa, Y., Kume, T., Tsuruta, K., Kumagai, T., Shinohara, Y., & Otsuki, K. (2010). Stand-scale transpiration estimates in a Moso bamboo forest: II. Comparison with coniferous forests. *Forest Ecology and Management*, *260*(8), 1295–1302. https://doi.org/10.1016/j.foreco.2010.06.040

Kontschán, J., Ács, A., Wang, G., & Neményi, A. (2015). New data to the mite fauna of Hungarian bamboo plantations. *Acta Phytopathologica et Entomologica Hungarica*, *50*(1), 77–83.

Kuehl, Y., Li, Y., & Henley, G. (2013). Impacts of selective harvest on the carbon sequestration potential in Moso bamboo (*Phyllostachys pubescens*) plantations. *Forests, Trees and Livelihoods*, *22*(1), 1–18. https://doi.org/10.1080/14728028.2013.773652

LARCHER, F., BATTISTI, L., GAINO, W., & DEVECCHI, M. (2017). Evaluation of alternative substrates and fertilizer regimes for the nursery cultivation of *Phyllostachys pubescens* (carrière) J. Houz. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *45*(2), 442–445. https://doi.org/10.15835/nbha45210859

Laub, M., Pataczek, L., Feuerbacher, A., Zikeli, S., & Högy, P. (2022). Contrasting yield responses at varying levels of shade suggest different suitability of crops for dual landuse systems: a metaanalysis. *Agronomy for Sustainable Development*, *42*(3), 1–13. https://doi.org/10.1007/S13593022007837/FIGURES/5

Lawson, G. (2022, January 14). *EURAF Policy Briefing #14 - Agroforestry in the CAP post 1/1/2023*. Docs.google.com. https://docs.google.com/document/d/e/2PACX-1vSWDsuFtAV4Bp3cQfTiNtHaejFgut3tvj2cTphkriMrGjQr0iK7DhRS1LnuzQ_2jNTbrvOxetVRQwHr/pub

Lawson, G. (2023, February). *EURAF Policy Briefing #22 - Agroforestry Definitions in the new CAP*. Google Docs. https://docs.google.com/document/d/13dlN6x62uRk6lBgWkX1w-zDNsNhRJIpZH9IpKiXWjP4/edit#

Leather, S. R., & Dixon, A. F. G. (1984). Aphid growth and reproductive rates. *Entomologia Experimentalis et Applicata*, *35*(2), 137–140. https://doi.org/10.1111/j.1570-7458.1984.tb03373.x

Lee, Y., & Lee, S. (2018). A review of the genus *Takecallis mastumura* in Korea with the description of a new species (Hemiptera, Aphididae). *ZooKeys*, *748*, 131.

Leghari, S. J., Hu, K., Wei, Y., Wang, T., Bhutto, T. A., & Buriro, M. (2021). Modelling water consumption, N fates and maize yield under different water-saving management practices in China and Pakistan. *Agricultural Water Management*, *255*, 107033. https://doi.org/10.1016/j.agwat.2021.107033

Li, R., Werger, M. J. A., During, H. J., and Zhong, Z.-C. (1998c). Carbon and nutrient dynamics in relation to growth rhythm in the giant bamboo *Phyllostachys pubescens*. *Plant and Soil, 201*, 113-123.

Lin, Y.-T., Whitman, W. B., Coleman, D. C., Jien, S.-H., & Chiu, C.-Y. (2017). Cedar and bamboo plantations alter structure and diversity of the soil bacterial community from a hardwood forest in subtropical mountain. *Applied Soil Ecology*, *112*, 28–33. https://doi.org/10.1016/j.apsoil.2017.01.001

Liu, S., Zhou, G., & Bai, S. (2011). Light intensity changes on Cunninghamia lanceolata in mixed stands with different concentrations of *Phyllostachys pubescens. Journal of Zhejiang A&F University*, *28*(4), 550–554.

Liu, X., Siemann, E., Cui, C., Liu, Y., Guo, X., & Zhang, L. (2019). Moso bamboo (*Phyllostachys edulis*) invasion effects on litter, soil and microbial PLFA characteristics depend on sites and invaded forests. *Plant and Soil*, *438*(1-2), 85–99. https://doi.org/10.1007/s11104-019-04010-3

Lombardo, E. (2022). An overview of bamboo cultivation in Southern Italy. *Advances in Bamboo Science*, *1*, 100002–100002. https://doi.org/10.1016/J.BAMBOO.2022.100002

Louton, J., Gelhaus, J., & Bouchard, R. (1996). The Aquatic Macrofauna of Water-Filled Bamboo (Poaceae: Bambusoideae: Guadua) Internodes in a Peruvian Lowland Tropical Forest. *Biotropica*, *28*(2), 228. https://doi.org/10.2307/2389077

Malumphy, C. (2014). An annotated checklist of scale insects (Hemiptera: Coccoidea) of Saint Lucia, Lesser Antilles . *Zootaxa*, *3846*(1), 69. https://doi.org/10.11646/zootaxa.3846.1.3

Malumphy, C., & Salisbury, A. (2016). First incursion in Europe of bamboo white scale *Kuwanaspis howardi* (Hemiptera: Diaspididae), with a review of Kuwanaspis species detected ub/brutaub. *British Journal of Entomology and Natural History*, *29*(2), 97–103.

Marchi, M., Marchettini, N., Neri, E., Esposito, G., Niccolucci, V., Pulselli, F. M., Lajo, M., Rissone, E., & Pulselli, R. M. (2023). Carbon Footprint offset of a managed bamboo plantation in temperate regions. *Sustainable Production and Consumption*. https://doi.org/10.1016/j.spc.2023.05.025

Matthews, J., Beringen, R., Huijbregts, M., Van, Odé, B., Trindade, L., Valkenburg, V., Velde, G., & Leuven, R. (2015). *Horizon scanning and environmental risk analyses of nonnative biomass crops in the Netherlands*. Department of Environmental Science, Faculty of Science, Institute for Water and Wetland Research, Radboud University Nijmegen, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands.

McClure FA (1966) The bamboos: a fresh perspective. Harvard University Press, Cambridge, MA.

Meijer, K., Smit, C., Beukeboom, L. W., & Schilthuizen, M. (2012). Native insects on nonnative plants in The Netherlands: curiosities or common practice? *Entomologische Berichten*, *72*(6), 288–293.

Meisner, A., de Boer, W., Cornelissen, J. H. C., & van der Putten, W. H. (2012). Reciprocal Effects of Litter from Exotic and Congeneric Native Plant Species via Soil Nutrients. *PLoS ONE*, *7*(2), e31596. https://doi.org/10.1371/journal.pone.0031596

Messelink, G. J., Bennison, J., Alomar, O., Ingegno, B. L., Tavella, L., Shipp, L., Palevsky, E., & Wäckers, F. L. (2014). Approaches to conserving natural enemy populations in greenhouse crops: current methods and future prospects. *BioControl*, *59*(4), 377–393. https://doi.org/10.1007/s10526-014-9579-6

Miller, C. N., Harper, A. L., Trick, M., Wellner, N., Werner, P., Waldron, K. W., & Bancroft, I. (2018). Dissecting the complex regulation of lodging resistance in Brassica napus. *Molecular Breeding*, *38*(3). https://doi.org/10.1007/s11032-018-0781-6

Nath, A. J., Lal, R., & Das, A. K. (2015). Managing woody bamboos for carbon farming and carbon trading. *Global Ecology and Conservation*, *3*, 654–663. https://doi.org/10.1016/j.gecco.2015.03.002

Nelson, S. (2008). Sooty mold. *Plant Disease*, *52*, 1–6.

Nerenberg, J. (2010, Dezember 3). Using Bamboo to Fight Climate Change. *Fast Company*. https://www.fastcompany.com/1707116/using-bamboo-fight-climate-change

Novozhilova, M. (2015). The world's largest bamboo maze is the massive Labirinto della Masone in Italy. Inhabitat - Green Design, Innovation, Architecture, Green Building | Green Design & Innovation for a Better World. https://inhabitat.com/aging-artist-speeds-up-growth-of-massive-maze-with-fast-growing-bamboo/

NVWA. (2022, July 18). *Overzicht soorten invasieve landplanten - Invasieve exoten - NVWA*. Www.nvwa.nl. https://www.nvwa.nl/onderwerpen/invasieve-exoten/invasieve-planten/invasieve-landplanten/overzicht-soorten-invasieve-landplanten

NVWA. (2023, May 12). *Invasieve exoten - NVWA*. Www.nvwa.nl. https://www.nvwa.nl/onderwerpen/invasieve-exoten

Ouyang, M., Yang, Q., Chen, X., Yang, G., Shi, J., & Fang, X. (2016). Effects of the expansion of Phyllostachys edulis on species composition, structure and diversity of the secondary evergreen broad-leaved forests. *Biodiversity Science*, *24*(6), 649–657. https://doi.org/10.17520/biods.2015290

Pardossi, A., Incrocci, L., Incrocci, G., Malorgio, F., Battista, P., Bacci, L., Rapi, B., Marzialetti, P., Hemming, J., & Balendonck, J. (2009). Root Zone Sensors for Irrigation Management in Intensive Agriculture. *Sensors*, *9*(4), 2809–2835. https://doi.org/10.3390/s90402809

Partey, S. T., Sarfo, D. A., Frith, O., Kwaku, M., & Thevathasan, N. V. (2017). Potentials of Bamboo-Based Agroforestry for Sustainable Development in Sub-Saharan Africa: A Review. *Agricultural Research*, *6*(1), 22–32. https://doi.org/10.1007/s40003-017-0244-z

Paudyal, K., Adhikari, S., Sharma, S., Samsudin, Y. B., Paudyal, B. R., Bhandari, A., Birhane, E., Darcha, G., Trinh, T. L., & Baral, H. (2019, November 6). *Array - CIFOR Knowledge*. CIFOR. https://www.cifor.org/knowledge/publication/7433/

Paudyal, K., Yanxia, L., Long, T., Adhikari, S., Lama, S., & Prasad Bhatta, K. (2022). *INBAR Working Paper Technical Paper Ecosystem Services From Bamboo Forests: Key Findings, Lessons Learnt And Call For Actions From Global Synthesis*. https://www.inbar.int/wp-content/uploads/2022/01/Ecosystem-Services-from-Bamboo-Forests.pdf

Peikun, J., Guomo, Z., & Qiufang, X. (2002). Effect of intensive cultivation on the carbon pool of soil in *Phyllostachys praecox* stands. *Scientia Silvae Sinicae*, *38*(6), 6-11. https://doi.org/10.11707/j.1001-7488.20020602

Pellizari, G., & Danzig, E. (2007). The bamboo mealybugs *Balanococcus kwoni* n.sp. and *Palmicultor lumpurensis* (Takahashi) (Hemiptera, Pseudococcidae). *Zootaxa*, *1583*(1), 65–68. https://doi.org/10.11646/zootaxa.1583.1.8

Pellizzari, G., & Duso, C. (2009). Occurrence of *Stigmaeopsis nanjingensis* in Europe. *Bulletin of Insectology*, *62*(2), 149–151.

Pettett, C. E., Moorhouse, T. P., Johnson, P. J., & Macdonald, D. W. (2017). Factors affecting hedgehog (*Erinaceus europaeus*) attraction to rural villages in arable landscapes. *European Journal of Wildlife Research*, *63*(3). https://doi.org/10.1007/s10344-017-1113-6

Piron, P. G. M. (2009). New aphid (Aphidoidea) records for the Netherlands (1984-2005). *Mitteilungen Des Internationalen Entomologischen Vereins*, *33*(3-4), 119–126. https://library.wur.nl/WebQuery/wurpubs/413005

Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a Union certification framework for carbon removals, 2022/0394 (2022). https://climate.ec.europa.eu/system/files/2022-11/Proposal_for_a_Regulation_establishing_a_Union_certification_framework_for_carbon_removals.pdf

Rashid War, A., Kumar Taggar, G., Hussain, B., Sachdeva Taggar, M., Nair, R. M., & Sharma, H. C. (2018). Plant Defense Against Herbivory and Insect Adaptations. *AoB PLANTS*, *10*(4). https://doi.org/10.1093/aobpla/ply037

Rathour, R., Kumar, H., Prasad, K., Anerao, P., Kumar, M., Kapley, A., Pandey, A., Kumar Awasthi, M., & Singh, L. (2022). Multifunctional applications of bamboo crop beyond environmental management: An Indian prospective. *Bioengineered*, *13*(4), 8893–8914. https://doi.org/10.1080/21655979.2022.2056689

Rede Rural Nacional. (2020, November 9). *Alenbambu - Exploração agrícola de bambu*. Www.youtube.com. https://www.youtube.com/watch?v=TzE1_2kI8Eo

Revathi, T., & Remadevi, O. (2011). Aphids as major pest of bamboos in nurseries of South India and association of potential biocontrol agents. *Journal of American Bamboo Society*, *24*(1), 1–6.

Rijkswaterstraat. (2014). *Into Dutch Soils - Rijkswaterstaat Environment*. Rijkswaterstraat.

Rother, D. C., Alves, K. J. F., & Pizo, M. A. (2013). Avian assemblages in bamboo and non-bamboo habitats in a tropical rainforest. *Emu - Austral Ornithology*, *113*(1), 52–61. https://doi.org/10.1071/mu12017

Sarjubala Devi, A., & Suresh, K. (2021). Carbon storage and sequestration potential in aboveground biomass of bamboos in North East India. *Scientific Reports*, *11*. https://doi.org/10.1038/s41598-020-80887-w

Saxton, K. E., & Rawls, W. J. (2006). Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. *Soil Science Society of America Journal*, *70*(5), 1569–1578. https://doi.org/10.2136/sssaj2005.0117

Scholte, E., Hartog, D., Dik, M., Schoelitsz, B., Brooks, M., Schaffner, F., Foussadier, R., Braks, M., & Beeuwkes, J. (2010). Introduction and control of three invasive mosquito species in the Netherlands, July-October 2010. *Eurosurveillance*, *15*(45), 19710.

Schröder, S. (2021). *Environmental Impact of Guadua Bamboo*. Guadua Bamboo. https://www.guaduabamboo.com/blog/environmental-impact-of-guadua-bamboo

Schwager, B. (2022). *CSR und Nachhaltigkeitsstandards: Normung und Standards im Nachhaltigkeitskontext*(1. Aufl.). Springer Gabler.

Seljak, G. (2015). The bamboo spider mite *Aponychus corpuzae Rimando* (Acari: Tetranychidae); first record in the West-Palaearctic. *EPPO Bulletin*, *45*(2), 199–204. https://doi.org/10.1111/epp.12201

Shi, M., Li, Q., Zhang, H., Sun, J., Zhang, J., & Song, X. (2022). Agroforestry alters the fluxes of greenhouse gases of moso bamboo plantation soil. *Environmental Research Letters*, *17*(11), 115003–115003. https://doi.org/10.1088/17489326/AC9ACB

Shults, P., Nzokou, P., & Koc, I. (2020). Nitrogen contributions of alley cropped Trifolium pratense may sustain short rotation woody crop yields on marginal lands. *Nutrient Cycling in Agroecosystems*, *117*(2), 261–272. https://doi.org/10.1007/S10705020100688/TABLES/5

Siegmund, A. (2008). Die Klimakarte nach Siegmund/Frankenberg im Baukastensystem. *Westermann*, 2.

Skendžić, S., Zovko, M., Živković, I. P., Lešić, V., & Lemić, D. (2021). The Impact of Climate Change on Agricultural Insect Pests. *Insects*, *12*(5), 440. https://doi.org/10.3390/insects12050440

Song, Q., Lu, H., Liu, J., Yang, J., Yang, G., & Yang, Q. (2017). Accessing the impacts of bamboo expansion on NPP and N cycling in evergreen broadleaved forest in subtropical China. *Scientific Reports*, *7*(1). https://doi.org/10.1038/srep40383

Song, X., Zhou, G., Jiang, H., Yu, S., Fu, J., Li, W., Wang, W., Ma, Z., & Peng, C. (2011). Carbon sequestration by Chinese bamboo forests and their ecological benefits: assessment of potential, problems, and future challenges. *Environmental Reviews*, *19*(NA), 418–428. https://doi.org/10.1139/a11-015

Stanghellini, C., Van 't Ooster, B., & Heuvelink, E. (2019). *Greenhouse Horticulture: Technology for Optimal Crop Production*. Wageningen Academic Publishers.

State and trends of carbon pricing 2020. (2020). World Bank.

Swieter A, Langhof, M., Lamerre J, & Jm, G. (2014). *Tree Crop Animal competition and facilitation 484 4 th European Agroforestry Conference Agroforestry as Sustainable Land Use COMPARING LONGTERM CROP YIELDS OF A SHORT ROTATION ALLEY CROPPING AGROFORESTRY SYSTEM AND OF A STANDARD AGRICULTURAL FIELD IN NORTHERN GERMANY*.

Swieter, A., Langhof, M., & Lamerre, J. (2022). Competition, stress and benefits: Trees and crops in the transition zone of a temperate short rotation alley cropping agroforestry system. *Journal of Agronomy and Crop Science*, *208*(2), 209–224. https://doi.org/10.1111/JAC.12553

Thomas, J. E., & Dodman, R. L. (1999). The first record of bamboo mosaic potexvirus from Australia. *Australasian Plant Pathology*, *28*(4), 337. https://doi.org/10.1071/ap99054

Tong, C., Zhang, X., Xie, J., Mei, T., Fang, D., & Li, Y. (2021). Water use strategies of different aged moso bamboo culms under summer drought. *Forest Ecology and Management*, *498*, 119567. https://doi.org/10.1016/j.foreco.2021.119567

Touyama, Y., Yamamoto, T., & Nakagoshi, N. (1998). Myrmecofaunal Change with Bamboo Invasion into Broadleaf Forests. *Journal of Forest Research*, *3*(3), 155–159. https://doi.org/10.1007/bf02762137

Troya Mera, F. A., & Xu, C. (2014). Plantation management and bamboo resource economics in China. *Ciencia y Tecnología*, *7*(1), 1. https://doi.org/10.18779/CYT.V7I1.181

U.S. DEPARTMENT OF AGRICULTURE. (n.d.). *Golden Bamboo | National Invasive Species Information Center*. Www.invasivespeciesinfo.gov. https://www.invasivespeciesinfo.gov/terrestrial/plants/golden-bamboo

Ülgentürk, S., Porcelli, F., & Pellizzari, G. (2014). The Scale Insects (Hemiptera: Coccoidea) on Bamboos in the Western Palearctic Region: New Records and Distributional Data. *Acta Zoologica Bulgarica*, *66*, 77–82.

Umemura, M., & Takenaka, C. (2014). Retranslocation and localization of nutrient elements in various organs of moso bamboo (*Phyllostachys pubescens*). *Science of the Total Environment*, *493*(493), 845–853. https://doi.org/10.1016/j.scitotenv.2014.06.078

united nations environment programme. (2017, September 16). *Ecosystem and Human Well-Being - A framework for assessment*. UNEP - UN Environment Programme. https://www.unep.org/resources/report/ecosystem-and-human-well-being-framework-assessment#:~:text=Ecosystems%20and%20Human%20Well%2Dbeing

Vadalà, R., Cicero, N., Dugo, G., & Costa, R. (2022). Suitability and eligibility of *Phyllostachys pubescens* (moso bamboo) afforestation for GHG (greenhouse gases) projects: case study in central Italy. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.817177

van der Burg, W. J., Freitas, D., Debrot, A., & Lotz, L. (2012). *Naturalised and invasive alien plant species in the Caribbean Netherlands: status, distribution, threats, priorities and recommendations: report of a joint Imares/Carmabi/PRI project financed by the Dutch Ministry of Economic Affairs, Agriculture & Innovation*. Plant Research International, Business Unit Agrosystems Research.

van der Lugt, P. (2008). Design interventions for stimulating bamboo commercialization - Dutch design meets bamboo as a replicable model.

van Leeuwen, H. J.: Bamboo plants as a noise barrier to reduce road traffic noise. In INTER-NOISE and NOISE-CON Congress and Conference Proceedings, 253(4), 4481-4487 (2016). (researchgate.net/publication/312198747_Bamboo_plants_as_a_noise_barrier_to_reduce_road_traffic_noise)

van Til, R. (2023, Juni 23). *Bandus Bamboekwekerij* [Interview]. https://www.bandus.nlWolters, S., Schaller, S., & Götz, M. (2018). *Freiwillige CO2—Kompensation durch Klimaschutzprojekte*. Umweltbundesamt. https://www.umweltbundesamt.de/publikationen

Wang, H., Jin, J., Yu, P., Fu, W., Morrison, L., Lin, H., Meng, M., Zhou, X., Lv, Y., & Wu, J. (2020). Converting evergreen broad-leaved forests into tea and Moso bamboo plantations affects labile carbon pools and the chemical composition of soil organic carbon. *Science of the Total Environment*, *711*, 135225. https://doi.org/10.1016/j.scitotenv.2019.135225

Wang, H., Varma, R. V., & Xu, T. (1998). *Insect pests of bamboos in Asia. An illustrated manual.* International Network for Bamboo and Rattan, Art Options, New Delhi, India.

Wang, M., Li, Y., Chesters, D., Perttu Anttonen, Helge Bruelheide, Chen, J. C., Durka, W., Guo, P., Härdtle, W., Ma, K., Michalski, S. G., Schmid, B., Goddert von Oheimb, Wu, C. Y., Zhang, N., Zhou, Q.-L., Schuldt, A., & Cheng Guang Zhu. (2019). Multiple components of plant diversity loss determine herbivore phylogenetic diversity in a subtropical forest experiment. *Journal of Ecology*, *107*(6), 2697–2712. https://doi.org/10.1111/1365-2745.13273

Wang, X., Zhang, Q., & Yao, H. (2012). Soil carbon, nitrogen and microbiological characteristics during bamboo highspeed growth [Article]. *Shengtai Xuebao/ Acta Ecologica Sinica*, *32*(5), 1412-1418. https://doi.org/10.5846/stxb201101110047

Wang, Y., Chen, J., Wang, D., Ye, F., He, Y., Hu, Z., & Zhao, G. (2020). A systematic review on the composition, storage, processing of bamboo shoots: Focusing the nutritional and functional benefits. *Journal of Functional Foods*, *71*, 104015. https://doi.org/10.1016/j.jff.2020.104015

Watanabe M, Ueda K, Manabe I, Akai T. (1982) Flowering, seeding, germination and periodicity of Phyllostachys pubescens. J Jpn For Soc 64(3):107–111

Watanabe, S., Yoshimura, J., & Hasegawa, E. (2018). Ants improve the reproduction of inferior morphs to maintain a polymorphism in symbiont aphids. *Scientific Reports*, *8*(1). https://doi.org/10.1038/s41598-018-20159-w

Wei, Q., Yin, R., Huang, J., Vogler, A. P., Li, Y., Miao, X., & Kardol, P. (2021). The diversity of soil mesofauna declines after bamboo invasion in subtropical China. *Science of the Total Environment*, *789*, 147982. https://doi.org/10.1016/j.scitotenv.2021.147982

Wieczorek, K. (2023). The first detection of an alien, invasive bamboo aphid species of the genus *Takecallis* (Hemiptera: Aphididae) in Poland. *Journal of Plant Protection Research*, *63*(2), 233–238. https://doi.org/10.24425/jppr.2023.145755

WMO. (n.d.). *World Weather Information Service*. World Weather Information Service. Retrieved June 21, 2023, from https://worldweather.wmo.int/en/city.html?cityId=143

Wu, C., Mo, Q., Wang, H., Zhang, Z., Huang, G., Ye, Q., Zou, Q., Kong, F., Liu, Y., & Geoff Wang, G. (2018). Moso bamboo (*Phyllostachys edulis* (Carriere) J. Houzeau) invasion affects soil phosphorus dynamics in adjacent coniferous forests in subtropical China. *Annals of Forest Science*, *75*(1), 24. https://doi.org/10.1007/s13595-018-0703-0

Wu, J., Zhong, Y., & Deng, J. (2019). Assessing and Mapping Forest Landscape Quality in China. *Forests*, *10*(8), 684. https://doi.org/10.3390/f10080684

Wu, W., Liu, Q., Zhu, Z., & Shen, Y. (2015). Managing Bamboo for Carbon Sequestration, Bamboo Stem and Bamboo Shoots. *Small-scale Forestry*, *14*(2), 233–243. https://doi.org/10.1007/s11842-014-9284-4

XIA, E., LIU, G., NONG, J., WEI, S., & LIU, X. (2022). Changes in soil nutrient characteristics in moso bamboo forest expanding into broadleaved forest. *Ecology and Environment*, *31*(6), 1110-1117. https://doi.org/10.16258/j.cnki.1674-5906.2022.06.005

Xiao, H., Liu, J., & Li, F. (2023). Both alpha and beta diversity of nematode declines in response to moso bamboo expansion in south China. *Applied Soil Ecology*, *183*, 104761–104761. https://doi.org/10.1016/j.apsoil.2022.104761

Xiu-Hua, Z., Ping, Z., Zhen-Zhen, Z., Li-Wei, Z., Jun-Feng, N., Guang-Yan, N., Yan-Ting, H., & Lei, O. (2016). Sap flow-based transpiration in *Phyllostachys pubescens:* applicability of the TDP methodology, age effect and rhizome role. *Trees*, *31*(2), 765–779. https://doi.org/10.1007/s00468-016-1407-4

Xu, M., Ji, H., & Zhuang, S. (2018). Carbon stock of moso bamboo (*Phyllostachys pubescens*) forests along a latitude gradient in the subtropical region of China. *PLOS ONE*, *13*(2), e0193024. https://doi.org/10.1371/journal.pone.0193024

Xu, Q.-F., Jiang, P.-K., Wu, J.-S., Zhou, G.-M., Shen, R.-F., & Fuhrmann, J. J. (2014). Bamboo invasion of native broadleaf forest modified soil microbial communities and diversity. *Biological Invasions*, *17*(1), 433–444. https://doi.org/10.1007/s10530-014-0741-y

Xu, Q.-F., Liang, C.-F., Chen, J.-H., Li, Y.-C., Qin, H., & Fuhrmann, J. J. (2020). Rapid bamboo invasion (expansion) and its effects on biodiversity and soil processes. *Global Ecology and Conservation*, *21*, e00787. https://doi.org/10.1016/j.gecco.2019.e00787

Yan, W., Mahmood, Q., Peng, D., Fu, W., Chen, T., Wang, Y., Li, S., Chen, J., & Liu, D. (2015). The spatial distribution pattern of heavy metals and risk assessment of moso bamboo forest soil around lead–zinc mine in Southeastern China. In *Soil & Tillage Research* (Vol. 153, pp. 120–130). Elsevier BV. https://doi.org/10.1016/j.still.2015.05.013

Zhang, Y., Saito, Y., Lin, J., Chittenden, A. R., Ji, J., & Sato, Y. (2003). Ambulatory migration in mites (Acari: Tetranychidae, Phytoseiidae) to new leaves of moso bamboo shoots. *Experimental & Applied Acarology*, *31*, 59–70.

Zhang, Y., Zhang, Z., Liu, Q., Lin, J., & Ji, J. (2000). An overview of occurrence, development and damage of bamboo mites and their integrated management in Fujian, China. *Systematic and Applied Acarology Special Publications*, *4*, 9–17.

Zhang, Y., Zhang, Z., Yutaka, S., Liu, Q., & Ji, J. (2004). On the causes of mite pest outbreaks in mono and polycultured moso bamboo forests. *Ying Yong Sheng Tai Xue Bao= the Journal of Applied Ecology*, *15*(7), 1161–1165.

Zheng, S., Zhang, Q.-H., Song, Z., Zhou, H., Liao, Y., & Zhang, F. (2022). *Arthrinium arundinis,* a Novel Causal Agent of Moso Bamboo (*Phyllostachys edulis)* Culm Rhomboid Rot and Its Sensitivity to Fungicides. *Forests*, *13*(10), 1–12. https://doi.org/10.3390/f13101616

Zhou, G., Xu, J. M., Wu, J., & Jiang, P. K. (2006). Changes in soil active organic carbon with history of intensive management of *Phyllostachy pubescens* forest. *Scientia Silvae Sinicae*, *42*, 124-128.

Zou, G., Wu, B., Chen, B., Yang, Y., Feng, Y., Huang, J., Liu, Y., Murray, P. J., & Liu, W. (2023). What are the effects of moso bamboo expansion into japanese cedar on arbuscular mycorrhizal fungi: altering the community composition rather than the diversity. *Journal of Fungi*, *9*(2), 273–273. https://doi.org/10.3390/jof9020273

Appendix

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Daily Minimum Temperature (°C)	0.5	0.2	2.4	4	7.8	10.4	12.5	12.3	10.2	7	3.9	1.9
Mean Daily Maximum Temperature (°C)	5.4	6	9.2	12.4	17.1	19.2	21.4	21.8	18.4	14.1	9.2	6.5
Average Daily	2.95	3.1	5.8	8.2	12.45	14.8	16.95	17.05	14.3	10.55	6.55	4.2

Figure 10: *Minimum, maximum and average daily temperature in the Netherlands for each month. Red indicates a stop of bamboo growth, green indicates growth of bamboo (WMO, 2023).*

	Bamboo species	**Ecosystem type**	**Growth pattern**	**Location**	**Biomass (Mgha −1)**	**Biomass C storage (Mg ha−1)**	**Biomass carbon sequestration rate (Mgha−1yr−1)**	**Culm density (ha−1)**
1	*Bambusa blumeana*	Forest	Sympodial	Philippines	143	72	–	7600
2	*Bambusa vulgaris*	Forest	Sympodial	Philippines	106	53	–	9000
3	*Gigantochloa levis*	Forest	Sympodial	Philippines	147	73	–	9300
4	*Phyllostachys bambusoides*	Plantation	Monopodial	Japan	136	68	13	12 000
5	*Gigantochloa ater* and *G.verticilleta*	Forest	Sympodial	Indonesia	77	37	–	6820
6	*Bambusa pallida*	Plantation	Sympodial	India	319	160	13	35 000
7	*Phyllostachys pubescens*	Plantation	Monopodial	Japan	138	69	9	7100
8	*Bambusa bamboos*	Plantation	Sympodial	India	287	144	24	4250
9	*Dendrocalamus strictus*	Plantation	Sympodial	India	60	30	13	27 000
10	*Bambusa bambos*	Plantation	Sympodial	India	242	121	6	8000
11	*Yushania alpina*	Forest	Sympodial	Ethiopia	110	55		8840
12	*Bambusa cacharensis, B. vulgaris* and *B. balcooa*	Plantation	Sympodial	India	121	61	–	8950

13	*Phyllostachys makinoi*	Forest	Monopodial	Taiwan	105	50	10	21 191
14	*Phyllostachys heterocycla*	Forest	Monopodial	Taiwan	89	41	8	7100
15	*Bambusa oldhamii*	Plantation	Sympodial	Mexico	104	51,5	16	10 101
16	*Guadua angustifolia*	Forest	Sympodial	Bolivia	200	100	–	4500
17	*Phyllostachys pubescens*	Forest	Monopodial	China	88	40	7	3968

Figure 11: *Biomass carbon stock and sequestration rate in bamboo plants (Nath et al., 2015)*