An investigation into the suitability of Paulownia as an agroforestry species for UK & NW European farming systems

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An investigation into the suitability of Paulownia as an agroforestry species for UK & NW European farming systems

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Declaration

I declare that the work reported in this thesis was devised and carried out by myself, and has not been accepted in any previous application for a degree. All information drawn from other sources, and any assistance received has been acknowledged in the appropriate place.

Summary

The combined impacts of climate change, soil erosion, deforestation, pollution, population growth and resource depletion require urgent attention in instituting regenerative agricultural practices worldwide. This is particularly the case in NW Europe where the current farming paradigm is becoming obsolete due to pressures from many fronts. A new way forward has become necessary using agroecology wherein agroforestry is a key component.

Paulownia species are indigenous to China and have been used as an agroforestry tree for over 2600 years due to their many positive attributes and multifaceted uses. Over the last four decades, the use of Paulownia intercropping systems have been established on up to three million hectares on the North China Plain and the species has been introduced as a plantation crop on all inhabited continents being one of fastest growing hardwood species in the world with up to six meters growth per year possible under optimal conditions.

Paulownia, in particular *P. tomentosa* has been planted as an ornamental tree in NW Europe since the early 1800s but has not been considered as a possible commercial species in the region until the last few years. This study set out to explore whether Paulownia species could be suitable as an agroforestry species in intercropping systems on a field scale in NW Europe using methods consisting of literature review, secondary data analysis, and interviews with experts and growers. Furthermore, two case studies were carried out from existing commercial operations growing Paulownia in the focus area.

Specific areas covered to assess suitability included a review of species and cultivars, ecological requirements, planting and growing techniques, invasiveness risk and market research into the timber product based on data from EU and abroad.

In addition to the species assessment, a review was carried out identifying the main barriers to the adoption of agroforestry in NW Europe as part of a broader overview and analysing how Paulownia species could possibly have added advantages in overcoming some of these barriers.

The results indicated that Paulownia species and hybrids could grow successfully as a commercial agroforestry crop in NW Europe based on data gathered from existing sites in the focus area established since 2009 where high survival rates and growth rates greater than 1 m per year were reported. No particular species or hybrid was identified as most suitable for agroforestry in the focus area but differences were confirmed depending on country of origin and propagation method. It was confirmed that species/hybrid selection, propagation method, site establishment, management practices in maintenance and pruning are critical factors to take into account in order to achieve timber of high quality.

Research showed that there is presently no established market in NW Europe for the timber but that interest in the unique properties of the wood is increasing in EU and the potential exists for profitable niche market in the future in particular for slow grown wood to be sold either in Europe or overseas.

The study concludes that Paulownia species' actual performance under local field conditions, adaptability and its diverse products and services fulfil most of the attributes of an ideal agroforestry tree and has the potential to be used more widely in NW European farming

systems with the recommendation that further field trials be carried out into finding the most suitable species/hybrids in addition to increased dissemination of knowledge to farmers about the species.

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1 Introduction

1.1 Background

The purpose of this study has been to investigate the suitability of the Paulownia species for broad scale introduction as an agroforestry crop for NW Europe. A consideration of novel species as part of agroecological farming systems is a component of a new 'systems thinking' approach required to address the converging global challenges of climate change, soil erosion, deforestation, pollution, population growth and resource depletion which demand an urgent transformation of how the world's croplands are managed.

A paradigm shift leading to sustainable agricultural systems is required and this is especially the case in NW Europe which has some of the most intensively managed and specialised agricultural systems in Europe (Eurostat, 2016) having very high inputs and external costs to the environment at large (Pretty *et al.*, 2000) while also coupled with a high reliance on public subsidies to stay profitable (Eurostat, 2015a). Conventional farmers in particular have also been facing increasing opposition to maintaining the status quo from the general public for what is considered unsustainable, unethical and unhealthy practices (EUFIC, 2013) with up to 84% desiring a transition towards organic production methods in return for subsidy payments (EU, 2010).

Furthermore, the bulk production of only a relatively few short-lived products has exposed the long-term viability of farms to risk due to volatile markets and price fluctuations (Tangermann, 2011; Scottish Government, 2010) with NW Europe in particular having the highest level of farm income volatility (Scottish Government, 2010).

These problems are not without solutions however and there is an increasing global consensus emerging that a major shift towards agroecological farming systems using organic methods is necessary (UNCTAD, 2013; De Schutter, 2010; IAASTD, 2007). The widespread implementation of agroecological practices such as agroforestry across NW Europe and elsewhere could form part of the greater undertaking required to address these urgent issues and work towards creating resilient agricultural systems for the future.

Agroforestry is a concept of integrated land use that combines elements of agriculture and forestry in a sustainable production system (Smith, 2010a). By deliberately combining woody vegetation (trees and/or shrubs) with crop and/or livestock, agroforestry systems enable farmers to diversify farm income while simultaneously benefiting from the resulting ecological interactions and in turn leading to improvements in soil and water quality, reduction of erosion, pollution, damage because of extreme weather conditions, and thus enhancing resource efficiency, biodiversity, and the overall resiliency of the production system (Vityi and Marosvölgyi, 2014).

Furthermore, agroforestry systems could deliver ecosystem services such as carbon sequestration, animal welfare by providing shelter and forage (Smith *et al.*, 2011; Shibu, 2009), increasing biodiversity (Briggs, 2012; Smith, 2010b; Burgess, 1999) and reducing pests while providing habitats for beneficial pest predators (Burgess, 1999; Shibu, 2009).

There is also evidence that well-managed agroforestry systems could be more profitable for farmers (Briggs, 2012; Yin, 2004; Wenhua, 2001; Zhao-Hua *et al.*, 1986) since in addition to

the synergy gained from the ecological interactions between trees and crops, the annual crops between the trees maintain the farmer's annual income while the managed low density tree plantings provide significant capital for the future (Briggs, 2012).

1.2 Rationale

Agroforestry despite being a term coined only recently in 1977 (Smith, 2010a) is not a new but an ancient practice and has a long and rich history in NW Europe with a diverse range of systems such as woodland pastures, 'pannage' with pigs foraging in beech and oak woodland, sheep grazing in orchards and hedgerows providing livestock fencing and forage on the field boundaries (Smith, 2010b). However, this versatile production system tested and proven over millennia has been in steep decline over the last 70 years due to trends towards simplification, specialisation, mechanised agriculture and the industrial/chemical paradigm prevalent from the middle of the 20th century (Conford, 2011) and further compounded by the European Common Agriculture Policy (CAP) payment structure encouraging specialisation (Briggs, 2012).

Taking into account due diligence and investigations into suitability, novel systems using exotic species should not be excluded per se and could play a major role in the NW European agroforestry systems of the future. By recognising that most of the annual crops, fruits and vegetables produced in NW Europe today originated from other continents (Gepts, 2014; Kislev, 2002), it follows that there might also be previously unutilised valuable exotic tree species which could benefit local agroforestry systems.

Paulownia appears to be a particularly promising candidate as a tree crop species due to its versatility and widespread success in agroforestry systems in North China under temperate conditions with the same main crop species currently grown in NW Europe. Hardy species of Paulownia, primarily *P. tomentosa* have been grown for ornamental purposes throughout NW Europe since the early 1800s (Barton *et al.*, 2007) although it is as of yet untried for broad scale commercial production in a cool temperate maritime European climate.

Plate 1 – Paulownia specimens near Canterbury, UK

Several species of this genus are currently extensively grown in alley cropping on up to three million hectares of agroforestry systems on the North Central China plain (Wang and Shogren, 1992) and have become more widely grown in plantations in US, Australia, South/Central Europe, Middle East, North Africa and elsewhere in recent decades (Bio Tree, 2012; TGG, 2011a; Hall, 2008; El-Showk and El-Showk, 2003).

Some of the hardiest Paulownia species rank among the fastest growing hardwoods in the world (Woods, 2008) yielding high quality timber and could possibly complement existing prevailing arable and livestock farming systems in the focus area and provide numerous benefits in yields and ecosystem services. If suitable Paulownia species/hybrids could be proven to grow well under local field conditions, this would address several of the primary barriers identified by Valdivia *et al.* (2012) preventing farmers from adopting agroforestry systems which are long term return on investment and profitability concerns.

Furthermore, Paulownia offers a significant advantage over most other tree species since it has a light sparse canopy with a late leaf emergence and leaf fall and therefore would not block sunlight from the field at the times most needed by many commonly grown arable cereal crops and hence mitigate concerns raised by farmers that trees would interfere with arable cropping and livestock operations due to shading as stated by Valdivia *et al.* (2012).

In fact, studies from China have shown greater productivity for wheat grown with Paulownia compared to wheat grown alone due to better microclimate and wind speed reduction (Wenhua, 2001). Paulownia trees also have 76% of their root systems below 40 cm from the soil surface and hence do not compete with the many crops such as wheat for water and nutrients (Wenhua, 2001).

Despite all these notable characteristics and over 2600 years of proven performance in agroforestry systems in temperate areas of China, there has been little published research to date into whether this versatile tree could be successfully integrated into the farming systems of NW maritime Europe. Increasing temperatures as a result of climate change might also increase the likelihood of Paulownia and other species becoming better adapted to NW Europe in the coming years.

1.3 Organic Context

Agroforestry is at the present time outside the mainstream of NW European farming practices for both organic and conventional systems. This has been attributed to a multitude of reasons including increased specialisation and mechanisation (Conford, 2011), lack of knowledge among farmers growing trees and uncertain end market for tree crops (Valdivia *et al.*, 2012), short-term tenancy contracts and an ambiguous CAP payments system which would discourage many farmers (Briggs, 2012).

While recognising that such barriers currently exist and need to be addressed, agroforestry systems have nevertheless been increasing in popularity all over Europe and there is extensive interest and research currently in progress to further their adoption in the EU (EU, 2016) with the CAP payment system also gradually changing to encourage this trend (EU, 2013a).

It is expected however that agroforestry as a practice is more likely to be initially adopted proportionally more by organic farmers since having converted their holdings from a conventional model, they could be considered as innovators and 'early adopters' (Padel, 2013). Another reason is that organic farmers already manage relatively more complex systems with crop rotations and livestock (Lampkin, 1990) and hence adding productive trees into the landscape could be considered the next step in terms of progression.

Additionally, agroforestry also fits in well with the organic principle that 'agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them' (IFOAM, 2016) since most of NW maritime European ecosystems would major in trees without human intervention (Douma *et al.*, 2012). There are already a growing number of organic farms adopting agroforestry (ORC, 2016; Aspin, 2015) and there is currently ongoing research into how agroforestry can be incorporated well into cool temperate agroforestry systems using organic methods (EU, 2016; Smith *et al.*, 2014; Wolfe, 2011).

Nevertheless, it must be emphasised that agroforestry systems could be appropriate for all farming systems (conventional/organic and livestock/arable/mixed) in order to establish more resilient and diverse enterprises and its benefits to farmers and the environment would be limited if restricted only to a 'niche' production sector. At the present time the percentage of utilised agricultural land (UAA) that is certified organic is still relatively low in the focus area as indicated by the Table 1.1 below although this has been and is still significantly increasing by up to 500,000 hectares a year over the last decade on an overall EU level (EU, 2013b).

Table 1.1 – Percentage of certified organic utilised agricultural land to total UAA for focus area countries - 2014

Country	**% Fully converted or under conversion to organic land**
Belgium	5.1
Denmark	6.33
Ireland	1.05
Netherlands	2.66
United Kingdom	3.05
EU-28 Average	**5.9**

(Eurostat, 2015b)

The above figures indicate the importance for agroforestry to be adopted especially for conventional farming systems since they presently cover the majority of the agricultural lands but it is expected that organic farmers would lead the way by demonstrating cases of efficient and profitable production systems that could be emulated by conventional farmers as part of the transition process.

1.4 Literature Review

An extensive reference literature was found about the ecological and management requirements of the major Paulownia species grown in China (Wenhua, 2001; Zhao-Hua *et al.*, 1986), USA (Hall, 2008), Australia (TGG, 2011a) and Bulgaria (Bio Tree, 2012). The references for USA, Australia and Southern Europe focused on growing in plantation conditions, whereas the Chinese references described Paulownia growing in agroforestry systems. Its use in agroforestry has also been introduced in India since 1993 and has shown promising results in a wide range of cropping systems and described as the 'ideal agroforestry tree' (Singh *et al.*, 2001).

However, very little published documentation was found specifically for agroforestry in the focus area of NW maritime Europe. This current gap in knowledge about Paulownia has already been highlighted by Briggs (2012) who after visiting sites in North China recommended studies for using this species for agroforestry under UK conditions.

The literature review provides a brief overview of Paulownia, its uses and relevance for agroforestry based on references from China and worldwide, ecological requirements, planting and growing techniques, the current profile of the main species in NW Europe, invasiveness risk and market potential for its timber as the main end product.

1.4.1 Paulownia Overview

Paulownia species are indigenous to China and have been used as an agroforestry and plantation tree for over 2600 years (Zhao-Hua *et al.*, 1986) and extensive historical records exist recommending its benefits as a tree for human use. Published literature such as the 'Monograph on Paulownia' from 1049 B.C. describing the cultivation and utilisation of Paulownia timber could make it the world's oldest plantation tree (Hall, 2008). Another reference from the Warring States period (475-211 B.C.) mentioned that "one was not a good farmer who did not plant Paulownia" (Zhao-Hua *et al.*, 1986). It is stated by Barton *et al.* (2007) that "in the history of trees used by man, probably more is known about Paulownia than about any other genus."

These references clearly indicate that the value of Paulownia has been recognised for millennia in China and there are also many recent scientific references describing the best practices for its cultivation in detail under a diverse range of conditions in contemporary broad scale cropping systems (Wenhua, 2001; Zhao-Hua *et al.*, 1986).

The native distribution of Paulownia is in East Asia where it is planted in particular on the North China Plain in alley cropping systems with wheat and other cereals, but also with vegetables, pasture, herbs and fruit trees (Wenhua, 2001). Despite its limited native range, Paulownia is a highly adaptable pioneer species and today can be found on all the populated continents where it has been introduced for ornamental and commercial purposes (Hall, 2008) and can be found in a wide range of climatic conditions most frequently between 40°N and 40°S (El-Show and El-Showk, 2003)

The Paulownia tree, also referred to as the 'Kiri tree', 'Empress tree' 'Foxglove tree' or 'Princess tree' is highly respected in Chinese culture and has been planted for many centuries around dwellings in order to bring good luck and to attract the phoenix (Zhao-Hua *et al.*, 1986).

China has 22% of the world's population and 7% of the arable land, and hence the necessity of optimal multipurpose land use without compromising food production has led the Chinese government to facilitate the implementation of a diverse range of agroforestry systems across millions of hectares in China and this has greatly accelerated following land reforms in China since 1978 (Yin, 2004). Paulownia is one of the preferred species in suitable areas especially on the North Plain due to its multi-faceted characteristics and since its inclusion in agroforestry systems also tends to increase crop yields significantly (Wenhua, 2001; Wang and Shogren, 1992; Zhao-Hua *et al.*, 1986).

Paulownia has also been grown successfully commercially outside its native range and has been described as an 'agroforestry gem' (Hall, 2008), the 'tree of the future' (van der Mye, 2006), 'wonder tree' (Yoon and Toomey, 1986) and a 'miracle tree' (Reddy, 2000) due to its fast growth and many other positive features.

1.4.2 Species and Cultivars

Zhao-Hua *et al.* (1986) states that there are nine major species in the Paulownia genus which are all native to East Asia. The scope of this study has been limited to the review of the hardiest and fastest-growing species used for agroforestry and plantations in China and worldwide which are *P. tomentosa*, *P. elongata* and *P. fortunei* and their associated hybrids.

The primary choice of species for agroforestry intercropping systems in North China is *P. elongata* due its favourable form and canopy structure as stated by Wenhua (2001) who also noted that *P. tomentosa* is not used there since it has a short stem, denser branches and less light penetration.

However, Wenhua (2001) further noted that some excellent varieties/hybrids have been bred in recent years, for example *P. fortunei* x *P. tomentosa* that provide up to 30% higher timber volume than *P. elongata* while still being suitable for intercropping.

The choice of a suitable species/hybrid for a specific site has been confirmed to be a critical success factor based on Chinese experiences (Wenhua, 2001) and significant growth variations between various species/hybrids have been determined by Ayan *et al.* (2003) from experiments on a site in Turkey. There are many commercial hybrids available for sale from plant nurseries depending on the climate and end use and these are commonly available to be sold in Europe (iPaulownia, 2016; Bio Tree, 2012).

1.4.3 Paulownia Products and Services

Paulownia species could be considered as one of the most versatile trees for human use when considering the extensive range of beneficial products and services provided which are briefly covered in this section.

Timber

Paulownia has been reported to be one of the fastest growing hardwood trees in the world (Woods, 2008; Paulownia Reforestation Project, 2001) with growth up to 6 m a year where optimal conditions exist for light and water.

The tree yields high quality timber with beautiful grain that is in high demand in East Asia where it is used for a variety of products such as furniture, musical instruments and many other uses as described by Hall (2008) in Appendix A.

Paulownia can be harvested for timber from 8 years of age under optimal conditions in China (Wenhua, 2001). This short time span has been reported as unlikely to be achievable in NW Europe however; based on projections from a plantation in Germany (Robinia, Invest, 2015) it was estimated that the harvest would range from 12-20 years of age.

The timber has been referred to as the 'aluminium' of the timber world with one of highest strength to weight ratio of any type of wood; it is 30% lighter than comparable hardwoods such as oaks and 50% lighter than pine (Woods, 2008). Also, compared to other hardwoods, Paulownia wood dries quickly with air drying taking less than 30 days (Woods, 2008). Hall (2008) has stated that the wood does not warp or crack and generally free from deformation, is easy to work with, suitable for carving and has excellent insulation properties.

Fertiliser and Animal Feed

The leaves and flowers of Paulownia are rich in nitrogen and other nutrients which could serve as good fertiliser as compost and thus minimise off-farm inputs required for arable crops (Wang and Shogren, 1992). Zhao-Hua *et al.* (1986) estimated the dry matter of the leaves to contain 3.09% nitrogen content.

A study in Pakistan conducted by Mughal and Jalbani (1997) indicated from an experiment using pots that the leaf litter from Paulownia had a significant increase in plant growth and wheat grain yields compared to the control sample.

Furthermore, the leaves of Paulownia have a high nutritive content suitable for ruminants (Bodnár *et al.*, 2014) and can be ensiled as a fodder crop. Table 1.2 summarises the contents of a Paulownia leaf.

Table 1.2 – Contents of a Paulownia leaf

Item	**Quantity**
Ash @ 550ºC	7.8%
Protein (N x 6.25)	22.6%
Organic matter	91.4%
Phosphorus	0.6%
Calcium	2.1%
Iron	0.6%
Zinc	0.9%
Metabolisable energy	15-18MJ/kg

(El-Showk and El-Showk, 2003)

This is of significance when referring to a recent study by Luske and van Eekeren (2014) comparing the feeding value of perennial ryegrass with common agroforestry fodder tree species for NW Europe with the following protein contents reported as per Table 1.3.

Table 1.3 – Average Crude Protein levels in Tree Leaves

Species	Common Name	Average Protein (%)	Min Protein (%)	Max Protein (%)	n
Alnus glutinosa	Alder	19.2	14.4	26.2	6
Betulus pendula	Birch	17.5	14.0	22.9	5
Corylus avellana	Hazel	16.1	14.1	20.4	7
Fagus sylvatica	Beech	18.0	14.3	23.3	18
Fraxinus excelsior	Ash	15.7	5.9	26.8	8
Robinia pseudoacacia	Robinia	20.7	11.6	27.0	16
Salix spp.	Willow	15.9	9.8	23.1	10
Tilia platyphyllos	Large-leaved lime	21.4	15.3	28	13
Lolium perenne	Perennial ryegrass	16.5			

(Luske and van Eekeren (2014)

In comparison, Paulownia at 22.6% has been recorded the highest value compared to the average protein values all the mentioned species.

It has been recorded that an 8-10 year old Paulownia tree can produce 100 kg of fresh leaves per year (Wang and Shogren, 1992). Briggs (2012) has noted that with a planting density of 100 trees/hectare, an agroforestry system could potentially produce up to 10 tons/hectare/year of fresh forage from leaves. Based on dry weight of 28% (Zhao-Hua *et al.*, 1986) this would achieve a yield of 2.8 tonnes/hectare/year.

The leaves have been reported to be slightly bitter but palatable and livestock such as sheep and cows have been reported to preferentially feed on Paulownia leaves once they have become accustomed to them (El-Showk and El-Showk, 2003). The leaves are also fed to pigs (Wang and Shogren, 1992; Zhao-Hua *et al.*, 1986) and rabbits (Zhao-Hua *et al*, 1986) in China. Barton *et al.* (2007) also noted that pellets with up to 20% Paulownia leaves are produced for fish and chicken feed in China.

In a European context, an ongoing trial was identified in Hungary since 2012 growing Paulownia in an alley cropping system with lucerne as a shade-tolerant understory crop as part of a silvoarable system to determine whether the combined fodder from the crop and leaves will provide higher yields of quality fodder compared to a control plot (Vityi *et al.*, 2015).

Honey

Honey production and pollination services could be another valuable yield of Paulownia, which is of particular importance considering the decline in honey bee populations due to limited forage in monocultures growing in the countryside and the use of pesticides. This decline in honey bees and pollinators has resulted in a current shortage in populations to meet the needed pollination services for crops (Breeze *et al.*, 2014; Aizen and Harder, 2009).

The terminal branches of the Paulownia produce fragrant flowers before leaf emergence and are used by honeybees to produce royal jelly in China as per one company (Ecologistics, 2016).

Paulownia honey has been reported to be similar to acacia in quality and taste by some companies (Bikfalvi, 2014; Paulownia Europa, 2012). Honey production per hectare has been estimated to be 700 kg by Bikfalvi (2014) and 1200-1500 kg by Paulownia Europa (2012). However, little published information was found about Paulownia honey yields although it was widely considered to be a good source of nectar in China as reported by Barton *et al.* (2007) and Xiong (1990) reported that a hive can yield up to 10-15 kg honey during the Paulownia flowering season.

Firewood

Paulownia could also yield a sustainable source of firewood and charcoal for household use as a by-product from the timber harvest. It has been reported that a 10 year old tree when harvested can yield up to 350-400 kg of stick fuel for firewood (Woods, 2008).

Bioremediation

Paulownia has been reported to grow well even in nutrient poor soils due to its ability to selectively absorb Ca++ and Mg++ and to this effect has been used with great success in mine reclamation projects (Hall, 2008; Woods, 2008; El-Showk and El-Showk, 2003). Furthermore, its root system has been reported to absorb nitrates, heavy metals and other contaminants (Woods, 2008) which could be a beneficial side effect of planting Paulownia on arable and livestock farms by preventing leaching and pollution from field operations. As per a US study by Bergmann *et al.* (1997), it was identified that the application of pig waste effluent on different hybrids of *P. elongata* had a growth effect on the leaves similar to a complete chemical fertiliser.

Carbon Sequestration

Paulownia as a C4 tree species has been reported to be an excellent tree for carbon sequestration by Hall (2008) due to its fast growth. TGG (2011b) states that the species' highly efficient photosynthesis results in effective carbon fixation especially under high light and temperature conditions and that the build-up of organic matter via the leaf fall and the extensive root systems could also play an important role in carbon sequestration. Paulownia has the advantage for this purpose that it can be cropped from the same root system at least 4 - 5 times (TGG, 2011b). There are many claims from online commercial sources that Paulownia can sequester more carbon than any other tree species (World Tree, 2016; Willow Rivers Wealth, 2016). Woods (2008) has stated however that there is no definitive source with the exact specifications but that estimates up to 1,235 tonne CO_2/year have been reported.

Medicinal Uses

Paulownia leaves and flowers have long been used in traditional Chinese medicine but there appears to have been little modern analysis of the potential of the genus in this area (Barton *et al.*, 2007.) An extensive reference on Paulownia by Zhao-Hua *et al.* (1986) stated that medicines made from Paulownia leaves, fruits and wood are reported to have a curative effect on bronchitis, cough relief, asthma, reducing blood pressure, promoting healthy hair growth and turning grey hair black.

Landscape Aesthetics

Paulownia trees produce masses of fragrant white/purple flowers reminiscent of foxgloves and it was for this reason that it was initially introduced to Europe as an ornamental tree in the 1800s. The flowers are colourful and beautiful in late spring and the trees are green and shady in summer up until leaf fall at the onset of frost. Old specimens of six Paulownia species can be found in parks around UK/NW Europe (Monumental Trees, 2016a), however *P. tomentosa* is the most commonly found species being the most ornamental and also the hardiest with the ability to tolerate temperatures down to around -20°C.

1.4.4 Ecological Requirements

In order to determine the suitability of growing Paulownia in NW Europe an understanding of the ecological requirements for the Paulownia species was necessary based on available data from this species published from China and worldwide.

Although there exists some variances between species with temperature in particular but also soil type and other factors, Paulownia trees have the following general indicative growing requirements as noted in Table 1.4.

Table 1.4 – Growing Requirements of Paulownia

No	Parameter	Limits
1	Mechanical composition, cont. of physical clay	Up to 30 %
2	pH	5,00 – 8,50
3	Content of water-soluble salts	under 1 %
4	Total porosity	under 50 %
5	Soil density	about 1,3 g/cm³
6	Height of groundwater	under 2,00 m
7	Altitude	up to 800m
8	Average year temperature	13 – 25°C
9	Max temperature	+40 °C
10	Min T °C	-24°C
11	Rain	above 150 mm/month
12	Wind speed	up to 28 km/h

(Bio Tree, 2012)

Zhao-Hua *et al.* (1986) summarised that "Paulownia is very adaptable except for places with too clayey, dry or poor soil, too strong wind, highly saline or alkaline soil, bad drainage, excessively high water table (less than 1.5 m deep) and extremely low minimum temperature (below -20°C). It can be planted on plains and mountains up to around 2,000 m elevation. However, it is best to plant them in places with fertile, deep, loose sandy loam or loam soil with good drainage and a water table deeper than 1.5 m."

Temperatures

Paulownia has been reported to require a long warm growing season to obtain the best growth (Biotree, 2012). Zhao-Hua *et al*. (1986) reported that different species vary in their cold

resistance with *P. tomentosa* being the hardiest species having the ability to withstand temperatures down to -20°C. The other two main agroforestry species *P. elongata* is reported to withstand temperatures from -15°C to -18°C and *P. fortunei* from -5°C to -10°C. Zhao-Hua *et al*. (1986) furthermore stated that the growth of Paulownia begins around a temperature level of +8°C and that good growth of Paulownia is closely related to temperature. Zhao-Hua *et al*. (1986) also reported that studies in various places around China indicated that the optimum temperatures for diameter and height growth is similar between species and usually around 24-29°C of mean daily temperature and the longer the optimum temperature lasts, the better the growth. El-Showk and El-Showk (2003) confirmed that *P. tomentosa* can withstand the most extreme temperatures ranging between -20°C and +40°C.

Frost damage has been reported to occur during cold winters and wrapping young trees in grass or soaking the trunks in lime during late autumn up to early spring are two techniques recommended by Zhao-Hua *et al.* (1986) to protect the tender bark of young trees. Furthermore, the apical bud of Paulownia is described to be susceptible to spring frosts that can damage new growth (Barton *et al.*, 2007) but this could be mitigated by selecting a site with a favourable sheltered microclimate with south-facing slope.

Based on trials in New Zealand, Barton *et al.* (2007) reported that seedling height growth in the nursery commenced when the Mean Monthly Temperature rose to 16°C and ceased at 14°C. During the peak growth season, it was recorded that growth rates declined whenever the mean weekly temperature fell below 16°C.

Light

Paulownia is a pioneer species and hence demands a lot of light. Barton *et al.* (2007) noted that the light saturation point for *P. elongata* has been shown to be 60,000 lux (60% full sun) which is a very high value compared to that for most other tree species (20,000 – 30,000 lux, 20-30% full sun). *P. fortunei* is noted to be the agroforestry species that shows the greatest tolerance for shade conditions (Woods, 2008).

Water

Paulownia has a very large leaf area with a high transpiration rate and also a well-developed root system and thus sufficient rainfall during the warm season of the year is considered to be very important for Paulownia growth (Zhao-Hua *et al.*, 1986).

However, rainfall can vary widely in its natural range and water requirements for Paulownia can range from between 500 mm and 3000 mm of rainfall annually as stated by Zhao-Hua *et al.* (1986). The same report also noted that *P. tomentosa* and *P. elongata* have been cultivated well without irrigation in regions of China where the rainfall is less than 500 mm provided that most of the rainfall occurs during the growing season in summer. It is considered especially important that Paulownia trees receive a reliable summer rainfall; otherwise watering irrigation would be critical for fast growth as confirmed by an Australian grower TGG (2011a). Bio Tree (2012) also noted irrigation would be required if the rainfall is less than 150 mm per month during the first growing period. Watering is needed in the subsequent years if the monthly rainfall is less than 50 mm. However, lack of watering after the first year slows the growth but does not kill the trees (Bio Tree, 2012).

Briggs (2012) stated that research into the drought resistance of the species conducted in China indicates that the best to worst are: *P. tomentosa*, *P. elongata*, *P. kawakami*, *P. fortunei*, and *P. catalpifolia*.

Wind

The wind factor is also an important consideration when determining the planting sites for Paulownia since the young trees are very tall but do not develop an extensive root system to provide sufficient anchorage. Wind protection is therefore especially important in the first year but also in the next early years. El-Showk and El-Showk (2003) stated that strong winds can cause breakage or inclined stems and it is therefore advisable to avoid highly exposed areas with strong wind. Breakage of stems and branches is mainly a problem in the first two years but does not cause much damage to older trees as per a study in China by Zhao-Hua *et al.* (1986).

Bio Tree (2012) confirmed that sites with strong winds reaching over 28km/h could damage trees and recommended planting a stabilizing post for each tree during the first year of development until they have formed a strong wooden stem.

Barton *et al.* (2007) reported that in windy areas of China, poplars are often planted as the first line of wind break since they are more wind resistant with the Paulownia forming the intermediate windbreak between the crops and the same approach has also been suggested by Woods (2008).

Soil

The preferred soil types for Paulownia are heavy peat or sandy soils with the clay and rocky soils being the least suitable. However, Barton *et al.* (2007) stated that the trees will grow in nutritionally infertile soils provided that the soil has a loose texture and is well-drained. Woods (2008) reported that a pH between 6.5 and 7.5 would be ideal, but that the trees would grow at a pH as low as 5 although this would not be advisable for optimum growth. Bio Tree (2012) reported that Paulownia grows much better in fertile soils and that fertilisers can increase growth rates.

Zhao-Hua *et al.* (1986) stated that in China Paulownia species are mostly found on light clay-sandy soils, and specifically that *P. fortunei* grows on soils with 16.25-23.49% clay while the other species are found on soils with less than 10% clay. *P. elongata* is noted to be the species the least tolerant of clay soils (Barton *et al.*, 2007) however a clay content above 25% is not suitable for any Paulownia species (Hu, 1959).

Paulownia species have a deep rooting system with well-developed lateral roots and consequently requires deep, loose, moist and well-aerated soil to thrive. Furthermore, Paulownia requires total soil porosity above 50% and soil ventilation above 30% as reported by Zhao-Hua *et al.* (1986).

Although Paulownia species are generally tolerant of a wide range of soil conditions, they are very sensitive to water logging. Barton *et al.* (2007) noted that the trees may struggle to survive if the soil becomes saturated with water during the winter for more than a few days.

Briggs (2012) noted that many farmers in China have in recent years preferred to plant poplars instead of Paulownia since increased winter rainfall led to a greater incidence of soil water logging where Paulownia could not thrive but poplar had a greater tolerance to very wet conditions.

Free-draining sites would therefore be a core success factor for growing Paulownia and it has been generally recommended to grow them on ridges or mounds (TGG, 2011a; Zhao-Hua *et al.*, 1986; Bio Tree, 2012). Barton *et al.* (2007) recommended mounds at a height of 30 cm and TGG (2011a) stated that it is difficult to over mound Paulownia trees.

Altitude

Zhao-Hua *et al.* (1986) reported that Paulownia can be found in China up to and around 2,400 m in altitude both on hills and in valleys and that *P. fortunei* adapts particularly well both at low and high altitudes. Bio Tree (2012) however advised that for commercial plantings it is generally recommended that the altitude is less than750 m – 800 m.

1.4.5 Paulownia in Agroforestry

Paulownia is extensively grown in China for agroforestry at the present time and is especially widely planted in a silvoarable system with winter wheat on the North China Plain between 30-40 °N, 109-122 °E where it has been estimated that up to 3 million hectares were grown in the early 1990s after its broad scale introduction (Wang and Shogren, 1992). Its widespread use has provided many social and economic benefits to the local farmers and the region overall due to increasing crop yields, higher crop quality, additional marketable products and farm diversification to offset risk (Yin, 2004; Wenhua, 2001; Wang and Shogren, 1992).

In recent decades, the wide scale intercropping of agricultural crops with Paulownia as the primary species has transformed the arable croplands on the broad plains in North Central China into model areas of agroforestry (Wenhua, 2001) transforming the region from an impoverished area to one of the most productive agricultural regions in the world while simultaneously increasing the forest cover of the plains from 5% in 1973 to 13% at the turn of the last century (Yin, 2004).

While winter-wheat/Paulownia alley cropping system is reported to be the most common combination due to the crops' complementary growth periods and root zones (Wang and Shogren, 1992), Paulownia is also grown in the following combinations as an alley crop as described by Wenhua (2001):

- Paulownia-vegetables
- Paulownia-medicinal herbs
- Paulownia-fruit tree-green manure crops
- Paulownia-tree shrub
- Paulownia-mushrooms

Barton *et al.* (2007) reported that another combination is Paulownia/grapes/crops.

Paulownia has been reported to be a nitrogen fixing tree that would impart fertility to the crops grown in the alley (Briggs, 2012). Intercropping with Paulownia has been confirmed to improve the microclimate for many crop species and has resulted in considerable yield

increases up to 23% for wheat and 20% for millet (Wenhua, 2001; Zhao-Hua *et al.*, 1986). The improvements in microclimate and yields have largely been attributed to the mitigation of the effects of more extreme climatic conditions than exist in NW Europe but nevertheless Paulownia species have several attributes which make it particularly suitable for an agroforestry tree beyond its native zone.

However, there are also some widely grown summer crop species that have been reported not to thrive with Paulownia. For instance, seven year old Paulownia in a 5 m x 15 m alley cropping system reduced yields of 63% and 68% for maize and beans respectively compared to the control plots (Newman *et al.*, 1997). Another study by Wenhua (2001) from random samples indicated that maize increased in yields between 7.5-17%, although no mention was given of tree density. Other crops reported to perform poorly with Paulownia are sesame and sweet potato (Wenhua, 2001) but these are of little relevance to NW European farming systems.

Briggs (2012) noted that Paulownia is not used in association with silvopastoral systems in China since it does not grow in areas which are used for extensive animal grazing.

A few published references to agroforestry in continental Europe have been published for conditions in Sardinia (Puxedo *et al.*, 2012) and Hungary (Vityi *et al.*, 2015; Vityi and Marosvölgyi, 2014). These reported generally encouraging results but the climatic conditions in these sites are different than the focus area in particular with warmer and longer summers.

The literature review identified several key factors that would favour Paulownia over other trees in an alley cropping agroforestry system which would also be relevant in an NW European context.

Canopy Structure

Light penetration through the canopy structure is an important characteristic for an agroforestry tree species to minimise the effect on the annual crops in the system and increased sunlight is preferable in a temperate agroforestry system. Zhao-Hua *et al.* (1986) noted that in a comparison to other popular tree species for agroforestry in China, the light penetration through *P. elongata* crowns is 20% more than that of poplar (*Populus tomentosa*) and 38% more than that of black locust (*Robinia pseudoacacia*).

Leaf emergence

Compared to many species native to NW Europe, Paulownia has a late leaf emergence usually from May with the result that there is less interference with the sunlight requirements of the annual crops at the most critical time of their growth. Furthermore, the leaf fall is also late in the season occurring from October the first onset of frost and hence the litter does not obstruct the harvest operations but instead could provide a mulch and nutrient source over the winter months.

It is for this reason that winter wheat/Paulownia has been a particularly successful combination on the North China Plain since the wheat crop is sown in the autumn after Paulownia leaf fall around November and the wheat will normally begin to senesce just before Paulownia leaf development in the spring around May (Newman *et al.*, 1997).

Briggs (2012) stated that tree species which leaf later in the spring and retain their leaves until later in the autumn are better choices in agroforestry systems than trees which leaf early and thus shade crops earlier in the season for climate conditions in the UK.

Root system

Paulownia has a root system which grows deep in the earth and therefore makes the species more compatible with agroforestry since competition between trees and crops for water and nutrients is very low (Wenhua, 2001). Roots have been reported to reach 0.8 - 2 m in depth in sandy and other soils, however 76% of the absorbing roots reach a depth of 40-100 cm with only around 12% of the roots within 0-40 cm of the soil surface. This is important since when compared to two popular arable crops, almost 80% of wheat roots and 95% of maize roots are usually distributed 40 cm into the soil (Wenhua, 2001). Consequently, regular tillage and other agricultural operations would have minimal impact on the tree root system and the trees would not compete with the annual crop for nutrients in the soil profile.

Microclimate

Researchers in China have conducted extensive studies indicating that Paulownia trees significantly enhance the microclimate for growing crops. For example, it was reported that Paulownia trees grown in the western Henan Province of China reduced the speed of wind by 45-50%, increased the relative humidity by 5-17%, reduced water evaporation by 15-30% and increased water content in a tillage layer by 5-15% (Woods, 2008).

Research by Zhao-Hua *et al.* (1986) also confirmed that intercropping with Paulownia could reduce wind speeds by 21-52% and reduce evaporation by 9.7% during the day and 4.3% at night. The soil moisture content at 0-50 cm was found to be 19.4% higher than at control sites (Zhao-Hua *et al.*, 1986). Furthermore, Paulownia trees had a moderating effect on the climate in the alleys; the reduction in wind speed during the winter increased temperature by 1°C while the shade provided in the summer reduced the temperature by the same amount when compared with the control plot (El-Showk and El-Showk, 2003; Zhao-Hua *et al.*, 1986).

Many crop species have been found to benefit particularly well from the protection of the Paulownia trees when they are planted at a specified density of 45-120 trees/hectare, in particular wheat/millet leading to increases in yield between 10-38% (Wang and Shogren, 1992). This is supported by a comprehensive study on Paulownia by Zhao-Hua *et al.* (1986) who established from trials that after the trees planted at 60 trees/hectare reach close to maturity at seven years old, only 20% of the wheat crop in the alleys decreased in yield whereas the remaining 80% still had a higher yield than the control plots.

Coppicing

Paulownia is known as the 'Phoenix tree' in China due to its very strong coppicing ability. It is a general management practice to coppice the tree in the spring after the first growing season to obtain a straight stem. When the tree is harvested for timber after 8-10 years, a new tree will then regrow at a faster rate which is an advantage to farmers that work is minimised since no replanting is necessary (Wenhua, 2001; Zhao-Hua *et al.*, 1986).

As a result of having an intact root system, the regenerated sprouts grow fast in the early spring and normally reach 5-6 m in the first year of the next rotation and sometimes can exceed 10 m (Zhao-Hua *et al.*, 1986). The best stem is then selected to grow onwards with the remainder removed.

Based on plantation reports in Germany, trees are typically thinned at Year 12 with the final harvest either in Year 12 or 15 and the same rotation can be done up to three times with the latter two rotations having a higher yield in timber (Robinia Invest, 2015). At the end of the rotation, the root system can be harvested as cuttings and replanted again on another site.

One possible disadvantage as reported in China, however, was that the tree growth from regenerated stumps could be more susceptible to diseases (Zhao-Hua *et al.*, 1986).

1.4.6 Planting and Growing Techniques

In addition to covering an outline of the ecological requirements for growing Paulownia, the literature review also identified some 'best practices' in cultivation techniques practiced in China and worldwide over recent decades which might also be applicable for NW Europe. It should be stated however that while climate analogues comparison can be useful, each region is unique and what works or does not work in one bioregion cannot by default be an indicator for success or failure in the focus area of NW maritime Europe. The literature review has nevertheless identified some main areas for consideration.

The focus was given first on Chinese practices which have been proven over millennia but also from experiences under more similar temperate conditions in New Zealand where some experiences in growing this species for commercial use have been well documented by Barton *et al.* (2007). Documentation was also found from a grower in Bulgaria (Bio Tree, 2012) and the available published data in the focus area. The information provided is not comprehensive in its detail but aims to provide a summary of the main critical success factors identified for successful establishment of the species in agroforestry systems in NW Europe.

Species Selection

Different Paulownia species have varying light penetration ratios with *P. elongata* being considered the most suitable for agroforestry due to its sparse branching structure, thin branches and leaf arrangement (Wenhua, 2001; Wang and Shogren, 1992) whereas *P. tomentosa* has a shorter stem, denser branches and leaves which makes it less suitable for intercropping (Wenhua, 2001).

Nevertheless, there has been extensive research resulting in a wide range of cultivars and clones having been developed in China and worldwide for different purposes and climatic conditions including some developed in Southern and Central Europe (Paulownia Development, 2016; Bio Tree, 2012; Paulownia Europa, 2012) but also varieties bred specifically for colder climates such as 'Arctic' in USA that are exported worldwide (World Paulownia, 2016).

The hardiest Paulownia species considered to be the most likely candidates for NW Europe (*P. tomentosa*, *P. elongata*, *P. fortunei*) are highly adaptable to a wide range of climatic conditions given its current worldwide distribution, but each have their unique limitations

such as minimum temperature tolerance that needs to be considered when selecting a species or hybrid for a specific site.

Propagation

Paulownia trees have been reported to be easy to propagate via seeds, stem cuttings or root cuttings with root cuttings being the most common approach in China to ensure easy management, high survival rate and uniform and desirable characteristics from superior specimens (Zhao-Hua *et al.*, 1986). The same report specified that root cuttings can be taken from either 1-2 year old or mature trees and are generally 15-18 cm long and 1-4 cm in diameter. These cuttings are then planted into ridged beds in early spring when the mean temperature is between 4-8°C.

Zhao-Hua *et al.* (1986) states that production from seeds taken from superior phenotypes is also an important method of propagating Paulownia with the advantages that the roots are better developed in seedlings compared to seedlings propagated by root or stem cuttings with faster growth and stronger trees with less susceptibility to heartwood-rot. Paulownia seeds are small and winged, and collected from capsules at the right time when the seeds are mature. The germination rate can be 75-90% even after one year as reported by Zhao-Hua *et al.* (1986). The germination process can be accelerated by soaking in warm water for 10 minutes and then planting under intensive light conditions and warm temperatures (Zhao-Hua *et al.*, 1986) or by stratification as reported by Barton *et al.* (2007) by mimicking the temperature and moisture conditions of the natural winter dormancy period. The same report noted that storage for 4-6 weeks in moist peat or sand at approximately 5°C had been found to work well.

Barton *et al.* (2007) reported that the seed should be sown in early spring when the mean monthly temperatures reaches 11°C with a maximum 16°C and minimum 6°C. The seeds are very small and young seedlings are prone to attacks by slugs and snails and therefore protection would be necessary.

Woods (2008) noted that most Paulownia trees grown in UK were propagated from seed but that it would be generally advisable to propagate from root cuttings to get the strongest specimens. This was also confirmed in a US trial (Bergmann, 2003) where survival was lowest from trees propagated from seed and the trees propagated via vegetative means were taller and had a higher diameter at breast height (dbh).

Site Establishment

In addition to determining the most suitable species/hybrid, it is of vital importance to understand the local site conditions of the correct species in order to obtain fast growth and high yields (Zhao-Hua *et al.*, 1986). The ideal site would be on flat terrain with a light south facing slope to maximise sunlight and improve drainage (Zhao-Hua *et al.*, 1986). Some wind protection has also been recommended since Paulownia has large leaves and stems that can be easily damaged by strong winds (Zhao-Hua *et al.*, 1986; Bio Tree, 2012).

Site Preparation

TGG (2011a) stated that cultivation for Paulownia is more similar to cultivation for vegetables or fruit trees rather than for most other forestry trees since the surface site should be broken up using discs, rotary cultivator or chisel plough.

Layout and Spacing

The typical spacing of Paulownia in agroforestry is 5 m within the row (Wenhua, 2001; Zhao-Hua *et al.*, 1986) however Briggs (2012) reported that Chinese scientists now consider 6 m spacing to be better for fast growth.

The between-row spacing can vary from 6 m to 50 m depending on relative importance of the wood harvest and arable crops (Yin, 2004). Depending on the priorities of the farmer, the most common layouts in China vary from 5 x 6 m (333 trees/hectare), 5 x 10 m (200 trees/hectare), 5 x 20 m (100 trees/hectare), 5 x 30 m (67 trees/hectare), 5x40 m (50 trees/hectare), and 5 x 50 m (40 trees/hectare).

However, more than 70% of the area surveyed by Yin (2004) was in the range from 5 x 20 m to 5 x 50 m. It is expected that a range from 5 x 40 m to 5 x 50 m would be most suitable for NW Europe in order to give the crops maximum sunlight exposure and also to remain within the limits of eligibility for CAP payments where a maximum number of trees is set to 100 per hectare (EU, 2014).

The rows in China are nearly always planted in a North-South orientation (Newman *et al.*, 1997). This is the same recommended orientation for NW Europe as stated by Briggs (2012) for limiting shading of the alley crop and ensuring that both sides of the tree row receive sunlight during the day.

Pruning

Some pruning would be required if the end product is high value timber since without management most Paulownia will have short stems and large crowns as stated by Wenhua (2001).

The standard practice as described in Chinese references to obtain a straight trunk (Zhao-Hua *et al.*, 1986) and applied elsewhere in Australia (TGG, 2011a) and Bulgaria (Bio Tree, 2012) is to let the tree grow unpruned during the first growing season with the intention to help the tree establish a strong rooting system. In Year 2, when the tree has sometimes reached a height of 6 m it is then coppiced in the early spring time before leaf emergence by a slanting cut near the base of the stem. This will result in several stems emerging and all except the strongest one are removed to form the new trunk.

Further pruning is carried out from Year 3 by removing large side branches in the winter and this is done up to Year 4 or until the trunk reaches a height of 5-6 m as per documentation from a grower in Germany ((Robinia Invest, 2015) and Australia (TGG, 2011a). The pollarding and pruning techniques referred to as ‘trunk extension’ are described in detail in the Chinese literature (Zhao-Hua *et al.*, 1986).

Briggs (2012) however noted that whether to do a trunk extension will vary depending on the species and that is not commonly carried out on *P. fortunei* because it develops good form naturally. It is mainly carried out on *P. elongata*, which is the most popular Chinese agroforestry species and occasionally *P. tomentosa*.

Pests

Zhao-Hua *et al.* (1986) reported that there are various endemic pests for Paulownia in China where attacks by leaf-eating insects can be a serious problem and woodpecker damage is also common.

Pest problems are mitigated in China by having a low planting density and mixed plantings to provide habitats for insect predators (Zhao-Hua *et al.*, 1986). It was noted by Barton *et al.* (2007) that there were no major pest problems reported based on experiences growing Paulownia in New Zealand, but that a few endemic species such as ghost moth, wood termites and possums caused light damage to the trees.

No published references exist regarding pest damage in NW Europe except from Aspin (2015) who also reported woodpecker damage to Paulownia planted in a silvopastoral system in Shropshire, UK. Olave *et al.* (2015) reported that there was no significant pest damage from several Paulownia plantation sites in Northern Ireland since trials started in 2009. Paulownia plantations in Germany are fenced in to prevent damage from deer and wild boar (Robinia Invest, 2015)

Experiments in Hungary by Vityi *et al.* (2015) also reported that smaller animals are able to get through wire net fencing and can damage the whole of one year-old Paulownia trees, whereas in case of older plants the damage is restricted to only the trunks.

Diseases

Paulownia as a pioneer species is generally resilient to diseases (El-Showk and El-Showk, 2003); however "witches' broom" disease presents a major problem for Paulownia trees in China (Zhao-Hua *et al.*, 1986). This is an infectious disease caused by a microscopic organism where the pathogen sets in a series of physiological changes in the infected trees causing metabolic disorders, imbalance in the supply and demand of energy, undernourishment and gradual death. Barton *et al.* (2007) stated that this disease can only be transferred in vegetative material and hence recommended that it is of critical importance that seed should be the only Paulownia material imported into New Zealand.

Remedial measures taken in China to prevent this disease is to propagate from seed instead of cuttings and developing disease-resistant hybrids via breeding programs. Soaking root cuttings in warm water and antibiotic solutions have also been noted to reduce this disease and these measures are described in detail by Zhao-Hua *et al.* (1986).

Briggs (2012) also noted that in addition to selective breeding, more recent Chinese agronomic advice has been to increase the diversity of varieties of Paulownia used in intercropping and to also plant mixed stands of Poplar, Paulownia and other timber, nut and fruit trees in order to introduce more diversity to mitigate diseases.

Weed Management

Paulownia is a light-demanding genus and slight shade can cause deformation in saplings and 70% shade may be fatal for younger trees (El-Showk and El-Showk, 2003). Therefore it is consequently necessary to carry out effective weeding for the first year so that weeds do not out-compete the young trees.

Robinia Invest (2015) reported from experiences with Paulownia plantations in Germany that weeding is an essential procedure in the first few years of establishment in order to avoid competition between the trees and the weeds for water, sun and nutrients. This can be carried out either manually or mechanically and should continue until the trees reach a height of 3-4 m. Bio Tree (2012) and Barton *et al.* (2007) also confirmed the importance of weed control and recommended that a circle with a diameter of 1.5 m around every single tree should be left clear of weeds at least for the following two years after planting.

An Australian grower (TGG, 2011a) advised that ideally the ground should be cleared of weeds before planting. Alternatively, a protective biodegradable mat or leguminous mulch such as peas and beans has also been shown to be effective with no adverse effects for water and nutrients. TGG (2011a) also stated that another method to prevent weed problems is to regularly lightly cultivate or harrow between the tree rows since this has the added advantage of aerating the soil.

Harvest and yield

Zhao-Hua *et al.* (1986) reported that Paulownia grows better under the intensive management conditions of the agroforestry intercropping systems than in plantations.

Paulownia trees in China are mostly harvested for timber after 10 years (Barton *et al.*, 2007) and this is typically done in late autumn/winter (Bio Tree, 2012). It is estimated by Yin (2004) that an 11-year-old Paulownia tree in an intercropping system will have an average diameter of 38 cm at breast height (dbh) and a height of 12 m.

Timber volume will vary depending on species/hybrid and growing conditions but the range given by Yin (2004) and Zhao-Hua *et al.* (1986) for intercropping conditions is between 0.4 – 0.5 m^3/tree with the better ones reaching up to 1.5 m^3 per tree for 10 year old trees having reached a diameter between 35-40 cm. Barton *et al* (2007) reported that sawmills in China indicate an average log size of 0.6 - 0.7 m^3 for trees aged 7 - 10 years.

Woods (2008) estimates however that with the lower temperatures in UK the expected harvest age for timber would be between 20-30 years. Figures from a Paulownia plantation in Brandenburg in North-eastern Germany (Robinia Invest, 2015) reported expected yields of 0.6 m^3/tree at 12 years, 0.8 m^3 at 15 years and 1 m^3 at 20 years.

After harvest, several more rotations are possible via regeneration from sprouts as stated by a grower in Germany (Robinia Invest, 2015). This is also the most common practice by farmers in China although the subsequent coppiced trees can be more susceptible to disease as per Zhao-Hua *et al.* (1986).

If the trees are left unharvested, they can grow to up to 26 m tall and have a life expectancy of at least 85 years as per living specimens measured and recorded in NW Europe

(Monumental Trees, 2016a; TROBI, 2016). It has been noted however by World Paulownia (2016) that Paulownia is among the oldest trees recorded in China and specimens have been found in the US over 200 years old.

1.4.7 Paulownia in NW Europe

The literature review identified that Paulownia has been planted in NW Europe as an ornamental for almost 200 years since it was introduced by the Dutch East India Company. It is possible that earlier historical records have been lost but the likely dates of introduction in the focus areas are:

United Kingdom	1830 (Hu, 1959)
Holland and Belgium	1838 (Hu, 1959)
Denmark	1872 (Copenhagen University, 2016)
Ireland	1913 (TROBI, 2016).

The study located hundreds of specimens from six Paulownia species but mainly *P. tomentosa* currently growing in the UK from Cornwall to Scotland, and other NW European countries although only for ornamental purposes (TROBI, 2016; Monumental Trees, 2016a; GBIF, 2013).

For example, there are also five different Paulownia species including *P. tomentosa* but also other species not usually associated with agroforestry currently growing at Kew Gardens in Southern UK. These were grown from seed for research purposes and it has been reported by Woods (2008) that the trees grew about 20 m their first ten years with no irrigation or fertiliser other than organic mulch although there has been some adverse effect by wind (Kew Gardens, 2016).

The primary reference found from UK/NW Europe closely related to the purpose of this study was from Woods (2008) who published a detailed and comprehensive overview of Paulownia based on sites worldwide in order to assess its possible suitability for introduction in Northern Ireland for biomass production as an alternative to willow which is currently the primary crop for this purpose. It was also suggested in the report that Paulownia could be grown in alley cropping with winter wheat and oilseed rape in the UK with the estimated rotation of 20-30 years due to the lower temperatures in UK compared to China.

1.5 Aims and Objectives

The primary objective of this study has been to investigate the suitability of Paulownia as an agroforestry species in the cool temperate maritime farming systems of NW Europe. As per well documented successes in China (Yin, 2004; Wang and Shogren, 1992), there is increasing evidence now available from the last two decades that agroforestry systems could also be more productive than monoculture systems in temperate climatic conditions since they provide diverse yields and the trees occupy additional dimensions higher above ground and deeper into the soil profile and can thus capture nutrients that arable crops cannot utilise (Smith *et al.*, 2011; Briggs, 2012; Shibu, 2009).

Paulownia is one of the primary agroforestry species used in China since it provides many unique advantages, nevertheless the climate and conditions in its native range and other temperate regions around the world where it is grown are not directly comparable to NW

Europe and thus there is a gap in knowledge whether the species is suitable for broad scale commercial use in the focus area.

Suitability in the context of this study is intended to indicate not only if the Paulownia species 'could' be grown in the focus area as a farm crop but whether they 'should' as well, meaning that besides aesthetic and ecosystem services delivered, they would need to present a potentially profitable proposition for farmers as part of the necessary transition into a more diverse and resilient agricultural landscape.

The secondary aim of this report is to expand on the existing limited knowledge about Paulownia as a crop which could become more widespread in the focus area of NW Europe covered in this study (UK, Ireland, Belgium, Netherlands and Denmark) if the species is found to be potentially suitable for broad scale introduction.

This focus area of NW Europe had been chosen since it has some of the most productive agricultural land in the world with a mild climate favourable for both agriculture and many native and non-endemic tree species but has undergone severe deforestation over the last centuries resulting in comparative low tree cover today as per Table 1.5 when compared to the overall EU average of 42%.

Table 1.5 – Percentage of Woodland and Shrubland to total area in NW Europe

Country	**% Wood and Shrubs**
Belgium	24.9
Denmark	19.6
Ireland	15.2
Netherlands	14.4
United Kingdom	25.4
EU28 Average	**42**

(Eurostat, 2015c)

Furthermore, the spread of Dutch elm disease and ash dieback in the focus area in recent decades have created a gap in local hardwood timber species for forestry and supply restrictions due to tropical deforestation also indicate increased importance for finding suitable species for local timber production in the future. Paulownia, like ash, has a light canopy and is hence also a promising candidate for agroforestry.

Since over 60% of the land is devoted to agriculture (arable crops and grasslands) in the focus area (Eurostat, 2012) it would be more realistic to incorporate productive trees into the existing agricultural landscape for rapid tree cover and vital ecosystem services than growing forests separately in competition with productive land (Briggs, 2012).

The study focused specifically on agroforestry systems in the cool temperate maritime climates in NW Europe and not plantation forestry which is more common in the focus area.

Given the expected lack of reference sites, the scope of the research considered all types of agroforestry systems (silvoarable, silvopastoral and others).

Another reason for selecting this focus area was that in terms of agroforestry systems covering the utilised agricultural area (UAA), NW Europe is far below the EU27 average of 14% as well as from its nearest continental neighbours as indicated in Table 1.6. The topography of the focus area inclines easily towards agroforestry but more efforts need to be undertaken towards its wider adoption using suitable species based on systems that have been proven to work elsewhere in the world in comparable conditions.

Table 1.6– Percentage of UAA covered by agroforestry systems in NW Europe

Country	**% Estimated proportion of agroforestry**
Belgium	5.9
Denmark	3.4
Ireland	10.1
Netherlands	4.8
United Kingdom	6.4
EU27 Average	**14**

Den Herder *et al.* (2015).

Finally, NW Europe has experienced a major decline in biodiversity as a result of specialised farming practices using monocultures. For example, as per recent comprehensive study it has been estimated that 60% of UK wildlife species have declined over the last 50 years and 31% have declined strongly (RSPB, 2013). This timeframe correlates well with the rise of conventional farming methods in the focus area (Conford, 2011).

Agroforestry systems could play a part in reversing this decline, in particular if the tree crops chosen for intercropping have benefits for local wildlife. Paulownia could play a role here due to its value for pollinators in particular honey bees due its fragrant flowers noted as a primary source of honey production in China.

1.6 Experimental Strategy

The experimental strategy commenced with a literature review of all published academic references for Paulownia in NW Europe regardless of cropping system, followed by a general review of all Paulownia references related to agroforestry. This second search focused on areas with either a close geographical proximity to NW maritime Europe such as France, Germany and Poland or a similar climate, such as New Zealand. Following a review of academic references, further searches were made for online non-academic references relevant to the study.

The intended outcome of the literature review was to identify if any existing information had already been published regarding whether Paulownia could be grown on a commercial scale in the focus area, and also to identify qualified participants who authored these reports and request their participation in interviews to discuss the topic in further detail.

While the interviews were conducted, a review was performed in parallel on the secondary data sources online namely GBIF (2013), Tree Register (TROBI, 2016), Monumental Trees (2016a) and any other references on Paulownia in the focus area from internet searches.

The intention was to identify some commercial Paulownia sites in NW Europe preferably using agroforestry that could be visited for the purpose of conducting case studies.

Market research was also considered an indicator of suitability for this study since farmers would be less likely to grow a crop that had no viable market. The first data source was asking questions via interviews to plant nurseries and plantation managers growing Paulownia trees about the end markets and expected prices for timber. The second data source was from available data online about Paulownia prices from existing publications and growers in Europe and overseas. The third data source was from case studies growing Paulownia for timber commercially as part of an agroforestry system.

The objective was that the data gathered from the interviews, internet searches and case studies would subsequently provide some indicative information about the current market for Paulownia timber if growing conditions were found to be suitable.

Upon completion of the data gathering using these methods it was anticipated that from the analysis an assessment could be made regarding whether Paulownia could have a possible future as an agroforestry crop in NW Europe.

2 Materials and Methods

The methodology used to determine the suitability of Paulownia in NW Europe involved a combination of several research methods to ensure that a more comprehensive overview could be established. The introduction of an exotic species on a broad scale requires exploration from many different angles and hence a 'triangulation' approach was deployed as often recommended in qualitative research in order to validate and cross-check findings (Rennie and Smyth, 2015; Hennink *et al.,* 2011; Patton, 1990).

The following research questions were formulated and linked to the different methods where found most fitting as per Table 2.1.

Table 2.1 – Research Questions and Methodology

Question	Methodology
What are the suitable Paulownia species/hybrids that can be grown in agroforestry systems in NW Europe?	Literature Review
	Secondary Data Review
	Interview/Written Responses
	Case Study
What are the reasons why Paulownia has not gained widespread use in NW Europe on a commercial scale yet?	Literature Review
	Interview/Written Responses
	Case Study
What are the possible risks in planting Paulownia on a wide scale in NW Europe?	Literature Review
	Interview/Written Responses
	Case Study
Where are the locations growing Paulownia in NW Europe and what can be learned from these sites?	Literature Review
	Interview/Written Responses
	Case Study
Does a market for the yield (timber) currently exist in NW Europe?	Literature Review
	Interview/Written Responses
	Case Study
What are the main factors preventing farmers from adopting agroforestry systems in NW Europe that Paulownia could mitigate?	Literature Review
	Interview/Written Responses
	Case Study

2.1 Literature Review

The starting point of the study involved a literature review of all existing knowledge published about Paulownia with a primary focus on a cool temperate climate similar to NW Europe wherever possible. Academic references given priority but other online sources were also consulted when no academic reference could be found. Since very few published references specific to the focus area were found, the literature review also covered references from other parts of the world where found relevant to the research.

Given that Paulownia has not yet been widely grown on a commercial scale in the focus area, the research also compiled published data about the ecological requirements and growing requirements based on these experiences from abroad with the intention to disseminate knowledge and thus improve the chances of growing the species successfully on sites in NW Europe.

2.2 Secondary Data Review

Following the literature review, further data was gathered from various secondary data sources restricted to NW Europe in order to learn from these sites which Paulownia species have been planted with their age, height and growth rates. It was recognised that although Paulownia trees have been grown in parks and ornamentally since the early 1800s, this in itself would not necessarily mean success on a field scale in the countryside due to different climatic factors compared to a sheltered locations in an urban environment where temperatures tend to be milder.

Three main databases were identified as the major references for secondary data in addition to any additional secondary data sources that could be found online.

2.2.1 Global Biodiversity Information Facility

Recorded occurrences of the Paulownia within NW Europe were gathered from the Global Biodiversity Information Facility (GBIF) which is an international open data infrastructure containing hundreds of millions of records for species, shared freely by hundreds of institutions worldwide making it the biggest biodiversity database on the Internet (GBIF, 2013).

This database was considered to be a reliable secondary data reference because of its reported high standards for data collected over 300 years and its use in ecological research with over 1,400 peer-reviewed research publications having cited GBIF as a source of data (GBIF, 2013).

2.2.2 Monumental Trees Database

Monumental Trees is an interactive community site where registered users can add details about noteworthy old trees worldwide such as location, height, measurements and photos; although this is based on user-uploaded content and not an academic reference site, there are over 3,500 users with over 22,000 individual trees recorded (Monumental Trees, 2016b).

2.2.3 Tree Register of Britain and Ireland

The Tree Register is a registered charity collating and maintaining a database of over 150,000 notable trees throughout Britain and Ireland with historical recordings going back over 200 years (TROBI, 2016). The data about size and growth of old trees recorded in this database is not available from any other sources and is referenced by dendrologists, botanists, scientists, arborists, foresters, and professional organisations (TROBI, 2016).

2.2.4 Additional Sources

General internet searching on Paulownia in the countries of NW Europe was also carried out to find relevant information to the study.

2.3 Interviews and Written Responses

One of the primary sources of data to assess suitability was determined to be via interviews in order to learn from actual experiences of agroforestry experts and growers having worked with or researched Paulownia in the focus area of NW Europe.

It was expected that due to various reasons such as busy schedules and proficiency in English as a second language that some participants would be more comfortable completing the interview questions in writing instead and therefore this option was offered to all participants for the aim of obtaining a larger and more representative sample. These written responses received have been referred to as a ‘written responses’ in this study to distinguish the means of obtaining this data but the questions asked were identical to the interview questionnaire.

2.3.1 Participant Selection

Five categories of experts relevant to the study were identified and defined as per Table 2.2

Table 2.2 Participant Categories

Participant Group	Definition	Participant Code
Agroforestry Expert	Expert with experience and qualifications in agroforestry systems in NW Europe or a similar climate (e.g. New Zealand) or geographical proximity (e.g. Central Europe).	AE
Agroforestry Farmer	Farmer with practical experience growing Paulownia on a field scale in NW Europe in an agroforestry system (i.e. not in a plantation system with tree monocultures).	AF
Plantation Manager	Grower with experience growing Paulownia as a plantation crop in NW Europe or a similar climate or geographical proximity (e.g. Central Europe).	PT
Plant Nursery Manager	Plant Nursery Manager with experience growing Paulownia for the purpose of selling to an end market in NW Europe, ideally specialising in Paulownia for bulk sales to plantation owners and farmers.	PN
Park Manager	Park Manager with experience or knowledge of growing Paulownia as an ornamental tree in NW Europe.	PM

2.3.2 Interview Questionnaire Design

The preferred method of data gathering was by means of an informal semi-structured interview to discuss various indicators of suitability via open-ended questions commonly used to discuss a particular subject in depth (Hennink *et al.*, 2011). The method of open-ended interviews was considered to be the optimal method for seeking out detailed responses and enabling probing for further detail (Hennink *et al.*, 2011).

Interview questionnaires were designed to contain questions that were "open, short and simple" (Hennink *et al.*, 2011) about specific species/hybrids, site conditions, ecological requirements, markets and general agroforestry issues required for the research questions to be answered. The content of the written responses offered as an alternative option contained the same questions where relevant for each respective participant group (agroforestry expert, agroforestry farmer, plantation manager, plant nursery manager and park manager) in order to align responses and collate meaningful data based on the same parameters. Taking into account the diverse areas of expertise of participants around a shared topic, some questions were reworded as per relevance/knowledge area of the specific target group in order to remain pertinent to the participant and to gather meaningful comparisons and collation of data. The full list of questions and their variations has been provided in Appendix B. The topics covered included Paulownia ecological requirements, agroforestry questions, planting

and growing techniques, market information, opportunities and barriers to adopting Paulownia in particular and agroforestry in general in NW Europe and local projections for the species in the future.

Four main question types were used as formulated by Patton (1990) with associated examples as noted in Table 2.3.

Table 2.3 –Main Question Types and Examples

Question Category	Purpose	Example
Background/Demographic	Identify key characteristics of participants	Please describe briefly your background and involvement with agroforestry.
Experience/Behaviour	Explore what participants are doing/have done	Are diseases encountered with growing Paulownia? a. If yes, please specify. b. What preventive measures are undertaken?
Knowledge Questions	Obtain factual information from participants	Are you aware of any pests encountered with growing Paulownia on the site?
Opinion/Value	Identify what participants think of an issue.	Do you see Paulownia increasing in popularity as a tree crop in your area over the coming years?

(Adjusted from Patton, 1990)

Some questions were added or removed as appropriate for each respective participant group depending on their unique area of expertise. For example, plantation managers were not asked questions related to agroforestry but received the same questions about climatic factors and biodiversity as all other participant groups. All questions were given an appropriate code used to collate responses received from the various participant groups in order to provide meaningful analysis for common trends as noted in Appendix B.

The order of the questions were sequenced using a 'funnel approach' starting from general opening questions, moving to specific questions and ending with closing general questions in order to gain the most information out of the participants.

2.3.3 Interview Process

A list of questions was prepared in advance as an interview guide that was used to focus interviews and act as a memory aide to the interviewer to ensure all topics were covered (Hennink *et al.*, 2011; Patton, 1990). A conversational approach was deployed during the interview process with flexibility to allow for responses to be expanded upon via probing, questions to be clarified, and interviewees to direct conversation toward relevant topics in order to gain a more holistic understanding of the interviewee's point of view about the research topic.

It was expected that due to the various locations of the interviewees that most interviews would be conducted via telephone or Skype but some face-to-face interviews would also be offered as a possibility in case the participants preferred this approach. Participants were

informed in advance that the interview duration was not expected to exceed 60 minutes. Notes were taken by the interviewer throughout the interview with the entire conversation also recorded using a call recorder via Skype after permission was received. Interviews were transcribed post interview from the voice recording.

All interviews were conducted in English. Although English is commonly spoken in the focus area it was recognised there could be a possible exclusion of expert advice due to this approach.

2.3.4 Participant Recruitment

Due to the context of qualitative research via the interview and written responses process, the intended aim was to gain depth rather than breadth from selected participants who were 'information-rich' and learn from their distinct experiences of the research topic based on their area of expertise (Hennink *et al.*, 2011).

An initial list of agroforestry experts and farmers with experience working on sites in NW Europe were identified from academic referrals and research via the internet from published references.

The participant groups recruited for the study were requested to fulfil either one of these two criteria and ideally both:

1) Expert in agroforestry or forestry with professional background in NW Europe or from a similar climate
2) Past or current experience growing Paulownia in NW Europe or from a similar climate

Additionally, a recruiting request was sent out via Farm Woodland Forum (http://www.agroforestry.ac.uk/) requesting members with expertise in Paulownia to participate in the project. In order to obtain maximum participation, recruits were also asked if they knew other qualified contacts that could assist in the study via the 'snowball approach' (Hennink *et al.*, 2011).

2.3.5 Sampling

The sample was projected to be small since the focus of this qualitative research was on obtaining 'quality' data from a purposefully selected group based on their subject knowledge as opposed to 'quantity' with a higher number of randomly samples with the latter being the standard approach for quantitative research (Patton, 1990).

Given the low profile of Paulownia as a commercial species in NW Europe, it was also expected that the majority of participants would not have practical growing experience with Paulownia but the aim was to obtain a representative sample with the target numbers as specified in Table 2.4.

Table 2.4 – Participant Group Target Sampling

Participant Group	Target Sample
Agroforestry Expert	10
Agroforestry Farmer	3
Plantation Manager	3
Plant Nursery Manager	3
Park Manager	3
Total	**22**

No generalisations could be made from such a small sample but the intention was to gain a better understanding from these groups about their various experiences growing Paulownia in the focus area as an indicator of suitability. The low sample number was a compromise since it would not be possible to carry out further interviews within the project timescales.

2.3.6 Data Collection and Analysis

The interview questions were allocated a three letter code followed by a number in order facilitate the collation of data from the various participants.

BCK – Background/introductory question
PLW – Paulownia specific question
AGR – Paulownia specific agroforestry question (experts and farmers)
EXP – General expert question (not specifically about Paulownia)
PLT – Plantation manager specific question

Due to the low sample size, no specific analytical tools were deemed to be required for this type of qualitative research and the data would be compiled using Excel to determine overall trends in responses received.

Post interview and questionnaire analysis involved identifying the dominant concepts, recurring themes, possible conflicting information and statements that were correlated across the different target groups.

2.3.7 Ethics

Interviewees were informed in advance via email requesting their participation and the purpose of the study. Participants were also informed in advance requesting their consent to be interviewed at a date and time convenient for them and that their names and responses would be kept confidential in the report although they would be known to the researcher.

Participants were furthermore asked for permission at the introduction to record the conversation for later transcription in case all information was not captured from taking notes and advised that the voice recordings would be deleted after the report had been published.

Finally, participants were informed that they would receive a copy of the report upon completion if interested as a ‘thank you’ for their efforts and to ensure transparency.

2.4 Case Studies

A case study approach was considered of great importance for this study to locate and learn from actual agroforestry systems using Paulownia in the focus area. Case studies can be beneficial for research by combining a number of different methods in order to focus on specific situations and contexts and observe and learn from actual 'on the ground' experiences (Rennie and Smyth, 2015).

This method was considered to be of major importance to determine suitability; a recent review by Cirrou and Hannachi (2014) indicated that existing reference showcase agroforestry sites are very important since many farmers would be more likely to adopt new practices if other farmers could 'see' systems that have been proven to work successfully and this would carry more weight than recommendations by researchers.

The primary data gathering tool for the case studies would be the same questions used in the interviews and questionnaires as well as actual observation but the results would be compiled under a separate research method to distinguish from the interviewees.

3 Results

The results from the various methodologies have been outlined in this section firstly as a general overview and summary of the data gathered. Subsequently, these results have been categorised and compiled per research method when addressing each separate research question stated in the project.

Literature Review Summary

The literature review identified 59 references that were considered relevant to the study specific to Paulownia or agroforestry for the focus area. The details of the publications reviewed and their focus country have been included in Table 3.1.

It should be noted that although most were published with a focus for a certain country the information found was considered relevant for NW Europe.

Table 3.1 – Published References per Country

Country focus	**Number of References reviewed**
Australia	8
Austria	1
Belgium	1
Bulgaria	1
China	9
Colombia	1
Denmark	1
Germany	1
Hungary	4
India	2
Ireland	3
Italy	1
Lebanon	1
Pakistan	1
Panama	1
Poland	1
New Zealand	1
Romania	3
Slovakia	1
Spain	1
Turkey	1
United Kingdom	1
United States	14
Total	**59**

Secondary Data Review Summary

The following results of Paulownia recordings in the focus area were compiled from three databases, GBIF (2013), Monumental Trees (2016a) and Tree Register (TROBI, 2016).

Global Biodiversity Information Facility

60 occurrences of the genus 'Paulownia' were retrieved for the United Kingdom, Ireland, Belgium, Netherlands and Denmark. The details of the location, and observation type are recorded in Table 3.2 below.

Table 3.2 – GBIF Recordings of Paulownia

Country	Number of Recordings	Basis of Record
Belgium	30	Human Observation
Denmark	0	
Netherlands	12	Specimen
Ireland	1	Human Observation
United Kingdom	17	Observation (15) Specimen (2)
Total	60	

(GBIF, 2013)

The following map shows the locations where coordinates were provided.

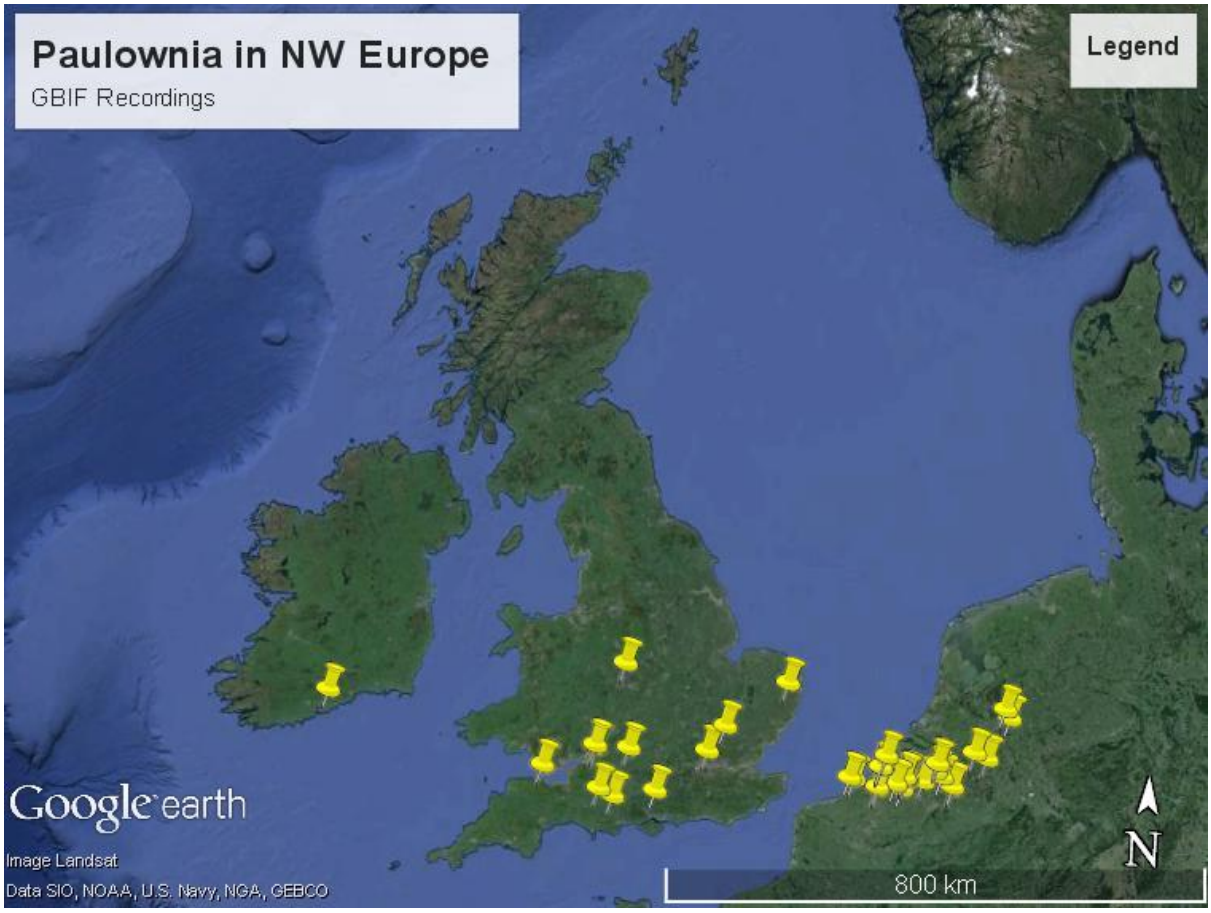

Plate 2 – Paulownia specimens recorded in GBIF

In summary, the only species recorded in the focus area were *P. tomentosa* although all the other Paulownia species were represented elsewhere in the GBIF database for other regions worldwide.

Monumental Trees

The only species in the Monumental Trees (2016a) database was *P. tomentosa* with 14 occurrences recorded in Belgium, Netherlands and the UK.
Pictures were uploaded for a majority of the recordings with many of them showing the trees with flowers. The locations were generally in towns or parks with shelter from other trees.

The details recorded for these specimens are summarised in Table 3.3.

Table 3.3 – Paulownia specimens recorded by Monumental Trees Database

Country	Location	Age in years	Girth	Girth growth/ year	Height	Year Measured
Belgium	Estate of Mariemont in Morlanwelz	N/A	3.12 m @ 1.5 m	3 cm	~16 m	2015
Belgium	Kapelleberg in Winksele	61 ± 10	2.99 m @ 1.5 m	N/A	N/A	2011
Belgium	Hotel de Ville, Grand Place in Bergen	N/A	2.26 m @ 1.3 m	N/A	N/A	2015
Netherlands	Waldeckpark in Maastricht	95	2.78 m @ 1.3 m	N/A	N/A	2012
Netherlands	Winston Churchillaan in Eindhoven	56 ± 10	2.67 m @ 1.4 m	3 cm	17.20 (in 2010)	2016
Netherlands	Zuiderpark in Den Haag	86 ± 10	1.82 m @ 1 m	N/A	N/A	2016
Netherlands	Moreelsepark in Utrecht	N/A	1.53 m @ 1.3 m	N/A	N/A	2015
Netherlands	Private Garden 9 in Woudt	N/A	1.5 m @ 1.3 m	N/A	N/A	2015
Netherlands	Hoek van de Alvenberg met de Duivelsberg in Heikant	32 ± 5	1.21 m @ 1.3 m	N/A	N/A	2015
Netherlands	Private Garden 11 in Woudt	N/A	1.17 m @ 1.3 m	N/A	N/A	2015
Netherlands	Tuinen van Appeltern in Appeltern	N/A	N/A	N/A	N/A	N/A
Netherlands	Main building 2 College Wandelbos in Tilburg	56 ± 10	N/A	N/A	N/A	N/A
Netherlands	Hortus Botanicus in Leiden	N/A	N/A	N/A	N/A	N/A
United Kingdom	Bute Park in Cardiff	66 ± 3	4.11 m @ 1.5 m	N/A	N/A	N/A

(Monumental Trees, 2016a)

Tree Register

There were 354 records of Paulownia recorded in the Tree Register Database (TROBI, 2016). This database covers UK and Ireland only.

Plate 3 – Picture of a mature Paulownia specimen taken in Canterbury, UK

The details in the database about Paulownia with relevance to the study are the following:

Planted Year
Species
Height (m)
Girth (cm)
Measurement Year
Comment
Town
County
Country

Not all these details were recorded per tree and therefore it was not possible to obtain a complete depiction by comparing the data items, however some core figures were extracted following a review of the data in a summary as per Table 3.4 below. The details of the locations for all Paulownia specimens recorded in Tree Register can be found in Appendix C.

Table 3.4 – Paulownia specimens recorded by Tree Register

Description	UK and Ireland	Location	Comments
Total trees recorded	354	England (302) Wales (13) Scotland (4) Ireland (35)	Trees in England appear throughout the country, but with most in the South and Midlands. There are only 8 specimens recorded in the northerly counties (Cheshire, Cumbria, Lancashire and Yorkshire).
Earliest year of planting	1888	Whitbourne Hall, Herefordshire	Seedling taken from the Vatican
Species distribution	*P. tomentosa* (82%) *P. fortunei* (4%) *P. kawakamii* (4%) *P. coreana* (3%) *P. elongata* (2%) *P. fargesii* (2%) Other (1%) Unknown (2%)		All 35 specimens in Ireland are *P. tomentosa* except for 1 *P. fortunei*.
Maximum recorded height	26 m	Gloucestershire, England	Specimen died in 1990, planting year unknown. 2.5% of recorded specimens are over 20 m tall and all are *P. tomentosa* except one *P. fargesii* which was planted in 2001. The planting dates for the *P. tomentosa* are not listed.
Maximum girth	410 cm	Cardiff, Wales	Specimen is 21 m tall when measured in 2013, planting year not recorded. This is the same tree recorded in the Monumental Trees database where it was estimated to be 66 ± 3

(TROBI, 2016)

Interviews and Written Responses Summary

A total of 17 participants contributed to the project either via interview or written response as per Table 3.5.

Table 3.5 Participant Groups and Response Rates

Participant Group	Number Contacted	Number Responded	Response Rate
Agroforestry Expert	19	13	72%
Agroforestry Farmer	1	1	100%
Plant Nursery Manager	2	1	50%
Plantation Manager	5	2	40%
Park Manager	2	0	0%

The breakdown of the data gathering method for the participants has been compiled in Table 3.6.

Table 3.6 Participant Choice for Interview/Written Response

Participant Group	Interview	Written Response
Agroforestry Expert	54%	46%
Agroforestry Farmer	0%	100%
Plant Nursery Manager	100%	0%
Plantation Manager	50%	50%
Park Manager	0%	0%

The focus areas per participant has been summarised in Table 3.7. The focus area was not always the same as the nationality of the participant. In some cases, the agroforestry experts interviewed had diverse global experience and in these cases the focus area chosen was the one where one of the species worked with was Paulownia.

Table 3.7 Participants per Area of Expertise

Participant Group	Area of Agroforestry/Paulownia Expertise	Number
Agroforestry Expert	China	3
	Hungary	1
	Ireland	1
	New Zealand	1
	Poland	1
	United Kingdom	6
Agroforestry Farmer	United Kingdom	1
Plant Nursery Manager	Bulgaria	1
Plantation Manager	Germany	1
	UK and Northern Europe	1
Total		**17**

Case Studies Summary

Two site visits were conducted as part of this research and the information gathered has been presented in a case study format.

Case Study 1 – East Sussex, United Kingdom

Overview

Grower is specialising in Japanese vegetables and based in Rickstaddle Farm in East Sussex, United Kingdom. The farm was founded in 2005 and comprises of 24 hectares and produces a wide diversity of crops in addition to vegetables, including soft and top fruit, such as Japanese quince. The grower is a primary supplier of this rare produce via vegetable boxes and restaurant deliveries to the surrounding area including London (NamaYasai, 2016).

The grower had initiated contact via the recruitment request on Farm Woodland Forum requesting participation in the project and the site was visited on a sunny, cool and windy afternoon on April 29th 2016.

Species

Twenty-one *P. elongata* trees had been planted on the farm in January 2013. The seeds were purchased from Lithuania and were stratified and planted in pots until March 2014 when they were planted in the field. The motive for planting Paulownia was farm diversification and experimentation based on prior research indicating possible suitability.

Site

The site was chosen because it had sandy soil (0711j Kingston) and least suitable for vegetable growing. The site had a sunny aspect with no nearby areas causing shade. The water table was reported to be quite near the surface. Altitude was 33 m above sea level.

The site was managed by organic principles using no artificial fertilisers, herbicides or pesticides as part of 'natural agriculture' although the site was not certified organic.

The trees did not have leaves at the time of visit but some growth buds were starting to emerge.

Planting and Cultivation

Manure had been added into the planting hole at the time of establishment and black plastic mulch was put on the ground afterwards for weed control. The leaves of the trees grew very large and some browning of the leaves was identified in April/May following establishment but no damage was caused.

The spacing was 6-7 m between trees and 40 m between the two rows both aligned North-South. The land between the rows was used for growing vegetables in between and had bunching onions planted in 2015. No advantages or disadvantages were mentioned for the intercrops due to the young age of the trees.

The trees were reported to grow well in the first growing season and the survival rate from the winter of 2014 was around 90% with only two losses. There were some cases of die-back on the lead stem due to frosts in some cases but in the following growing season in 2015 the regrowth continued from the root system with some trees reaching up to 1 m in height. The same frost damage was noticed on the site visit although it had been a mild winter in 2015. The frost damage had not affected all the trees however and several had a strong stem about 1 m high. Overall survival rate after two growing seasons was reported to be around 90%.

Grass had penetrated through the black plastic mulch at the time of visit and the farmer acknowledged that little time had been given to management of the trees since the initial establishment.

Pests and Diseases

The field where the Paulownia was grown was surrounded by a deer fence. There had however been some vole damage in the first year and this was mitigated by putting tree guards around the young trees. No other pests or diseases were reported.

Invasiveness

The trees on the site were still too young to be in flower, but the farmer had no information about possible invasiveness. There were no restrictions as stated by the farmer to growing Paulownia as per the local legislation.

End Market

The farmer had no definite plans to sell the trees for timber since it was still early days and he had no information about possible markets for the timber.

Barriers

Some possible barriers to wider adoption of agroforestry in NW Europe were mentioned by the farmer as:

- Unclear rules whether trees qualify for CAP payments
- Lack of knowledge about trees among many farmers
- Concerns about mechanisation possibly complicated by trees

Future Outlook

The farmer considered it too early to indicate whether the species would be suitable for UK or NW Europe in general based on his own experiences. He believed the reasons for it not having been considered prior was that farmers often prefer to grow crops they are used to and that everyone knows about. Furthermore, there had been no recordings of growth/feasibility for Paulownia under local conditions and it could therefore be high risk. He considered that it was unlikely that it would be increase in popularity for his home area in the future since there were other tree timber crops that perform better under local conditions.

However, the farmer expressed contentment with the growth rate of the trees considering the little input invested to date and its possible associated future benefits to the farming system such as shelter and food source for bees and possible honey production. The farmer intended to grow more Paulownia trees on the farm but this time using root cuttings from one of the stronger specimens as per the recommended practice instead of via seed propagation as was done previously.

Other general positive factors the farmer had noted from his experiences were the fast growth rate and the ease of germination from seed.

Plate 4 - Picture taken during first growing season (September 2014)

Plate 5 - Alley Row with Paulownia trees at 6-7 m spacing (April 29th 2016)

Plate 6 - Two-year old Paulownia with new stems following frost damage. (April 29th 2016)

Plate 7 - Two-year old Paulownia with single stem (April 29th 2016)

Case Study 2 – Ballydehob, SW Ireland

Overview

Grower is the owner of a plot of 1.2 hectares in Ballydehob, SW Ireland purchased for the primary purpose of producing timber crops. The enterprise is spread over three different fields where a wide range of tree species have been planted, primarily disease-resistant elms and Paulownia, but also poplar, willow, walnut, red oak and cherry and with some diversification into growing soft fruit. The grower was located via a recommendation on Farm Woodland Forum and the site was visited on a cloudy, mild and light windy morning on May 8th 2016.

Species

800 Paulownia trees from six different species/hybrids had been planted on the site:

- *P. tomentosa*
- *P. elongata*
- *P.* 'Shandong' (hybrid)
- *P.* 'Arctic' (hybrid)
- *P. catalpifolia*
- Unspecified, sourced from Bulgaria

All trees were sourced as young plants from suppliers in the US and Bulgaria and were supplied as bare-rooted plants. These were planted in spring 2013 except for the 'Arctic' hybrid which was planted in 2014 and delivered as a root ball. 'Arctic' was chosen since it was a recommended US hybrid by World Paulownia (2016) for colder climates. It did not perform well in the first year of establishment but this was attributed to the delay in delivery by customs and the plants were therefore not received in an optimal state.

The motive for planting Paulownia was based on possible indicators for success based on experiences by growers in Germany.

Site

The soil type of the site was sandy clay loam and was located on a north facing slope with windbreak on the south side but not all the fields were fenced in. The site has occasional strong westerly winds. The water table was reported to be quite near the surface, although the soil was confirmed to be free-draining. Altitude was unknown but the site was near the coast. The site was managed by organic principles as part of a polyculture using no artificial fertilisers and herbicides.

The trees did not have leaves at the time of visit but some leaves were starting to emerge.

Planting and Cultivation

Holes were dug via a tree planter in early spring but no nutrients were added prior to planting with grass as the understory. Shropshire sheep were introduced in 2015 to keep the grass down and no damage was reported from the sheep debarking the Paulownia trees.

The spacing was 2 m between the Paulownia trees intercropped primarily with disease-resistant elm, but other species had been planted as well in small numbers. One of the fields had Paulownia growing with poplar and soft fruit bushes, such as raspberries, aronia and blackcurrants. No advantages or disadvantages were mentioned for the intercrops due to the young age of the trees.

The trees were reported to grow well in the first growing season and the survival rate from the winter of 2013 was very high, with only 5 trees lost out of 800. Frost is very rare in SW Ireland due to the mild maritime climate. The second two growing seasons in 2014 and 2015 were reported to be less positive and this was attributed to cooler springs and summers than normally expected. Although the site was windy, no damage was reported to the large leaves.

In summary, the grower indicated that he believed the limiting factor on the site was not generally low temperatures throughout the growing season, frost or wind but more so that a warm spring was necessary to get the plants to a good start early in the season starting at 15 °C.

There was no pruning done in the first year, but pruning was carried out the two following years. The grower mentioned that pruning in the first year would possibly have led to better performance in the subsequent years.

There was no indication from the current experience since 2013 whether any of the six species/hybrids had performed particularly better than the others. The highest tree was measured at 4.8 m in height. The trees on the highest field had grown significantly better than the trees on the lower fields and this was attributed to the coniferous windbreak providing a better microclimate.

The main challenges reported was keeping up with the rapid grass growth on the site which was at times out-competing the Paulownia.

Overall survival rate after three growing seasons was still close to 100%.

Pests and Diseases

Not all the fields on the site were fenced in. Deer had been spotted on the site but there had not been any damage to the trees. Slugs were reported to be the main pest problem affecting Paulownia on the site and this was managed using slug pellets.

No diseases had affected the trees since establishment.

Invasiveness

The trees on the site were sourced from abroad (US and Bulgaria) and had received clearance from Irish customs authorities. It was not expected that there would be an issue with invasiveness on the site but the trees were too young to be in flower.

End Market

The grower intended to sell the timber eventually when trees reached a marketable size of at least 6 m trunk and 40 cm dbh and it was hoped that this could be achieved in 25 years. The grower had no information about end market or expected selling price at the time of visit.

Barriers

Some possible barriers to wider adoption of agroforestry in NW Europe were mentioned by the grower as:

- Conformity amongst many farmers only growing what they know about
- Preference for farmers to grow trees on marginal land only
- Concerns about subsidies and bureaucracy

Future Outlook

The grower indicated disappointment that the last two growing seasons were not up to expectations compared with the first year when the trees had undergone very rapid growth. This was attributed to unusually cool spring and summers in 2014 and 2015 and it was hoped that the 2016 growing season would allow a better assessment of the potential of the species for the site. The grower was as yet unsure whether to grow more Paulownia trees until assessing the status at the end of the season.

Nevertheless, the grower indicated the many positive characteristics of Paulownia as a tree crop and that a growth of 4.8 m in height in three growing seasons was still impressive.

Plate 8 - Picture of three year old Paulownia trees during growth season (June 30th 2015)

Plate 9 - Picture of three year old Paulownia trees during growth season (August 29th 2015)

Plate 10 - Six different varieties of Paulownia planted in 2013 at 4 x 4 m spacing emerging from dormancy after three growing seasons. (May 8th 2016)

Plate 11 - 800 Paulownia trees on 1,2 hectares coming into leaf emergence. Notice pruning done on main stem in 2014 and 2015 (May 8th 2016)

Plate 12 - Highest specimen recorded on site was 4.8 meters after three growing season, with 2014 and 2015 colder than average for the site. (May 8th, 2016)

Plate 13 - Paulownia planted in 2013 in sheltered courtyard garden near pig enclosure. Pigs were reported to readily eat fresh leaves. (May 8th, 2016)

3.1 What are the suitable Paulownia species/hybrids that can be grown in agroforestry systems in NW Europe?

3.1.1 Literature Review

The growing results and species identified having been planted on a field scale in NW Europe as per published literature and internet references have been summarised in Table 3.8.

Table 3.8 – Paulownia species grown on field scale in NW Europe

Location	Species grown	Summary
Hillsborough, Northern Ireland, UK	*P. elongata* and *P. fortunei* and hybrids/clones sourced from Spain and Morocco for biomass production.	Survival rate was generally high in the trials. However, the growth rate of the clones was not up to expectations compared to willow and poplar (Olave *et al.*, 2015).
Soulton, Wem, North Shropshire, UK	Seven Paulownia species in the trial since 2009 in a silvopastoral system.	Only *P. fortunei* survived. Growth rate was reported to be slow and woodpeckers inflicted severe damage in the extreme winter of 2010-2011. The climate could be an issue as the nearby RAF Station at Shawbury often has the coldest winter lowland temperatures in England (Aspin, 2015).

(Olave *et al.*, 2015; Aspin, 2015)

The species in the Hillsborough trial were six Spanish and three Moroccan genotypes of Paulownia *P. fortunei*, *P. elongata* sourced from Spain and Morocco and planted at separate sites as per origin. The specific species/hybrids are noted in Table 3.9.

Table 3.9 - Paulownia Genotypes in Hillsborough trial 2009-2013

Genotype Name	Hybrid Commercial Code	Origin
P. fortunei		Morocco
P. elongata × *fortunei*		Morocco
P. elongata		Morocco
P. elongata × *fortunei*	PWCOT-2	Spain
P. elongata × *fortunei* × *tomentosa*	PW-105	Spain
P. elongata × *fortunei*	PWL-1	Spain
P. elongata	PWCOT-1	Spain
P. fortunei	PWST33	Spain
P. elongata × *fortunei*	PWST-11	Spain

(Olave *et al.*, 2015)

It was reported that overall mean survival and height of the Spanish and Moroccan genotypes after three growing seasons were 70.8% and 32.2% and 1.1 m and 2.2 m respectively. The Spanish genotypes that had the highest survival rates were *P. fortunei* (95.8%) and *P. elongata* (87.5%) with both reaching 1.5 m after three growing seasons. Although the survival rate was much lower for the Moroccan specimens, one of the genotypes had the tallest growth of 2.1 m.

3.1.2 Secondary Data Review

Based on plantings around NW Europe, *P. tomentosa* was confirmed to be the most common species planted, however all other hardy species relevant for agroforestry (*P. elongata* and *P. fortunei*) had also been recorded by the Tree Register as noted in Table 3.4.

3.1.3 Interviews and Written Responses

Participants were asked the following question related to specific Paulownia species and hybrids considered most suitable for NW Europe. The high level responses are indicated below from interview comments and written responses as a summary.

Question	**Agroforestry Experts/Plantation Managers/Plant Nursery Manager** *Are there any specific Paulownia species/hybrids you think are most suitable for agroforestry? If yes, please describe why* **Agroforestry Farmer** *Which Paulownia species/hybrid do you grow and why did you choose these?*
Agroforestry Experts	No answer given (54%)

(13)	Hybrid between *P. tomentosa*, *P. elongata*, *fortunei* (46%)
Agroforestry Farmer (1)	'*P. fargesii*, *P. fortunei*. (Only ones available for purchase at the time).' (UK)
Plant Nursery Manager (1)	'Specific hybrid selected for site conditions.' (Bulgaria)
Plantation Manager (2)	'I think for N. Europe the most suitable would be a hybrid of *P. fortunei* and *P. tomentosa*.' (Germany) 'Selected for claimed cold-tolerance' (UK/Northern Europe)

3.1.4 Case Study

Case Study 1 – East Sussex, UK

Species planted on site was *P. elongata* from seed.

Case Study 2 – Ballydehob, Ireland

The six species/hybrids planted were:

- *P. tomentosa*
- *P. elongata*
- *P.* 'Shandong' (hybrid)
- *P.* 'Arctic' (hybrid)
- *P. catalpifolia*
- Unspecified sourced from Bulgaria

All plants were sourced as bare-rooted plants except for 'Artic' which was shipped as a root ball.

3.2 What are the reasons why Paulownia has not gained widespread use in NW Europe on a commercial scale yet?

3.2.1 Literature Review

The only two specific references describing an attempt in growing Paulownia on a commercial scale in NW Europe for biomass production were the trials in Northern Ireland from 2009-2013 where the results were documented by Olave *et al.* (2015) and a trial in a silvopastoral system with cattle in Shropshire, UK (Aspin, 2015) which was identified from an internet search.

Several causes were linked to the relatively slow growth rate in the Northern Ireland trial such as strong wind speeds at the sites, heavy soils with excessive moisture and lack of sunlight with very few days with clear skies.

Cold damage was also attributed to only one out of seven Paulownia species surviving on the site in Shropshire, UK.

3.2.2 Interviews and Written Responses

Participants were asked the following questions in order to gain further understanding about the possible reasons why Paulownia had not yet been considered as a commercial tree crop in NW Europe. Responses from all the participant groups were compiled for this question including those outside the focus area. The expert's focus area country has been put in parentheses where this is not stated in the response.

Question	*Why do you think Paulownia has not been considered for prior use in UK/NW Europe given its success in temperate agroforestry systems in China?* *If your area of expertise is not in UK/NW Europe, please explain why this is so for your focus area.*
Agroforestry Experts (13)	Timber industry focus on well-known species (31%) Lack of awareness, research (38%) CAP, subsidies -not Paulownia specific (15%) Invasiveness (8%) Frost (8%)
Agroforestry Farmer (1)	'Too much backward thinking in agriculture, nobody looks far enough into the future in the industry.' (UK)
Plant Nursery Manager (1)	'I don't know but maybe because there are lots of natural species and the traditional use of oak and pines is big. It is hard to compare because there are a lot of minuses in this timber, but also a lot of plusses. But for something new it takes a long time to be successful on the market. I see now for the last 2-3 years there are a lot who want to work

	with the timber.' (Bulgaria)
Plantation Manager (2)	'Because of the law in Europe. It was only possible in 2010 we could start plantations, before short-rotation plantations were not possible.' (Germany) 'Many have tried, few have succeeded…This tree crop cannot be grown as conventional forestry and each stem has to be treated as an individual. Also because the growing tips die each year skilled pruning is required to produce a straight marketable stem. There are very few of us who know how to do this' (UK/Northern Europe)

Question	*Please describe the ideal characteristics of an agroforestry tree species for UK/NW European farming systems?* *If your area of expertise is not in UK/NW Europe, please describe the characteristics for your site.*
Agroforestry Experts (13)	Compilation of all characteristics mentioned: • Low competition with grass and arable crops • Fast growth • Climate resilient, adaptable • End market • Valuable timber • Multifunctional • Non-invasive • Fodder value • Little shade • Compatible with mechanisation • Environmental benefits • Coppice ability
Agroforestry Farmer (1)	'Reasonably fast growing and vertical with not too much branching. Also deep rooting to compete for moisture in summer.' (UK)
Plant Nursery Manager (1)	Not applicable
Plantation Manager	Not applicable

(2)	

Question	**Agroforestry Experts** *Do you recommend or plan to conduct further trials/research about growing Paulownia in the future? Please describe why.* **Plant Nursery Managers and Plantation Managers** *Do you plan to expand your operation growing more Paulownia in the future? Please describe why.*
Agroforestry Experts (13)	Yes or provisionally Yes (53%) No (15%) No response (32%)
Agroforestry Farmer (1)	'Not at my age.'
Plant Nursery Manager (1)	'Yes we are expanding every year. We are getting lots of demand.'(Bulgaria)
Plantation Manager (2)	'No, due to increasing land prices we are now focusing on south Europe. The timber production is more economical there.' (Germany) 'I do not think the UK is a suitable place to grow these trees as land values are too high to justify planting with trees' (Northern Europe)

Question	**Agroforestry Expert** *Do you think there is enough information about growing Paulownia available for current and potential growers in the focus area?* **Agroforestry Farmer/Plantation Manager/Plant Nursery Manager** *Where do you seek advice and information regarding growing Paulownia?*
Agroforestry Experts (13)	No response (38%) 'Probably not but because the Chinese have been growing Paulownia for over 1000 years and there is quite a lot of information available from USA, it should be possible for EU growers to adapt what is already available.' (UK) 'Far not enough.' (Hungary) 'No' (UK) 'No, extensive trials are needed on cv evaluation for a range of sites, agronomy, and on AF systems (arable and livestock).' (UK)

	'No, everyone thinks they are discovering it. The grower I know is the first one that has gone after this commercially and actually planted it and hope to produce a product. A lot of the others have been hoping to get funding for research whereas this grower has gone ahead and done it out of his own pocket.' (Ireland) 'There is enough information in Mediterranean and subtropical countries but there is no information if this species is suitable in Ireland or cool temperate climates. The plot we produced here is the first one that has been investigated Paulownia in cooler areas. The one in NZ is also warmer than this area. There is very little information out there right now.' (UK) 'No, there is very little in fact, if any.' (UK)
Agroforestry Farmer (1)	'Use the same knowledge as for other tree species.' (UK)
Plant Nursery Manager (1)	'N/A'
Plantation Manager (2)	'We have all this information in-house.' (Germany) 'Practical experience and significant library' (UK/Northern Europe)

Question	*Assuming that the Paulownia trees can be grown successfully on field scale in local conditions, would there be any specific barriers for farmers adopting an exotic tree species in an agroforestry system compared to a local species?*
Agroforestry Experts (13)	'Not in NZ' 'Yes, the national rules which do not allow farmers to use exotic tree species in their plantations. At the moment, here in Hungary they are allowed to plant only domestic species.' 'No' (UK) 'I cannot answer this question with level of knowledge of the species.' (UK) 'It could be challenged on the basis of the need for an Environmental Impact Assessment and the possibility of importing trees pests and pathogens.'(UK) 'No doubt some conservation groups would complain – but what is a native species in UK? Practically great care would be needed in phytosanitary methods if large numbers of lines are to be introduced using vegetative methods – root cuttings – as would be needed. Use of tissue culture clones would ease health problems.'

	‘In Scotland we have to aware of the WANE Act (Wildlife and Nature Environment Act) where you need to get special permission for species which are not normally grown here. But that’s something we can get around if we were to try that.’ ‘The problem is dealing with an introduced species of timber that has never been used in the country before so a market has to be developed for that timber you see. I don’t know what those markets may be. I am not sure if there are any barriers for exotic species since I have not worked with forestry for over 29 years.’ (UK) ‘As per the current rules for forestry, there is a list of approved timber species that are eligible for grant aid, like not banana trees etc. for obvious reasons. However, when Paulownia appeared, it wasn’t on our list because it is so new yet because we just simply do not know enough about it. If the grower's research and results produce a specific cultivar that looks promising what we might do is to be more specific when we specify Paulownia as a timber producing species. So we would be looking at a specific cultivar and then look for provenance certificates. Grower has also applied for approval for a plot to be planted under our agroforestry measure growing disease-resistant elm, cherry and oak.’ (Ireland) ‘Well depending on if the species is demanding in terms of good quality land. If it requires high quality land then the farmer will be inclined to go for conventional crops. No, there are no barriers growing exotics compared to conventional tree crops in Northern Ireland with no such rules at the moment.’ (UK) ‘Yes, first thing is material if it’s invasive or not. If it’s in the list of permitted plants and it’s very important not to use invasive species. But if institutes or universities figure out some good solutions like clones that really works and not some false promises that might be good. List of permitted species is specific for countries, but there is an EU list as well.’ (Poland) ‘Main issue is disease, it has to be checked with forestry commission.’ (Scotland, UK) ‘No not really. There is a lot of freedom in what you can grow. The main thing is for them to see if there is a product. I have run

	forestry companies before in the past and we found that we could sell wooden rulers cheaper than plastic. This is just an example, you could make some interesting rulers with Paulownia.' (UK)
Agroforestry Farmer (1)	''No barriers. Some "Native" tree species have proved to be too susceptible to disease' (UK)
Plant Nursery Manager (1)	'Invasiveness of a species can be a main issue and should be managed very well. We have some small plantations with our sterile clones with 15-20 plants to monitor them and until now there is not a single plant (seeded). But anyways we have to be very careful with this. Before 10 years in Bulgaria it was mainly grown in cities but now it's everywhere.'
Plantation Manager (2)	'No, no special permission needed.' (Germany)

3.2.3 Case Study

Case Study 1 – East Sussex, UK

Farmer cited the following possible reasons why Paulownia has not yet been planted commercially on a wide scale for agroforestry in NW Europe

- No recordings of growth rates/feasibility for UK, hence possible risk
- Unknown species, farmers generally prefer to plant what they know and other farmers are also growing

Case Study 2 – Ballydehob, Ireland

The main reason provided by the grower for the limited adoption of Paulownia as a commercial crop was that it is little known other than as an ornamental tree and that markets have not yet been well established.

3.3 What are the possible risks in planting Paulownia on a wide scale in NW Europe?

3.3.1 Literature Review

A review was conducted of all published references indicating the possibility of Paulownia being invasive in the focus area. This was considered an important factor in assessing suitability since prior to introducing an exotic species into general broad scale usage in NW Europe an assessment would be required of any potential risk of invasiveness that could impact local biodiversity and wildlife.

A single Paulownia tree has been reported to be capable of producing an estimated 20 million very small seeds that are easily transported long distances by wind and water and these may germinate shortly after reaching suitable soil (Remaley, 2005). It has been reported by Zhao-Hua *et al.* (1986) that the seeds can travel up to 1 km away from the mother tree. As per a US study, the seedling establishment is optimal in disturbed areas with exposed mineral soil, a lot of sunlight, and little to no litter (Innes, 2009). Borough (1991) stated that Paulownia 'is not found in pure-even aged stands but rather as scattered individuals in forests which have been disturbed and has the typical features of "secondary" or "pioneer" rainforest species – high light demanding, fast growth, and relatively short-lived.' As per GISD (2005) in its native range, *P. tomentosa* occurs in various habitats, preferring moist to semi-dry open forests, is shade intolerant and not found in dense forests.

P. tomentosa is classified as an invasive species in the US after it was introduced in the 1800s via seeds used as packaging material from Chinese dinnerware in the 1800s (Remaley, 2005) and is considered to be 'potentially' invasive in Australia (Csurches and Edwards, 1998).

Innes (2009) stated that self-sown trees are particularly prevalent in the Eastern United States as an early succession species in disturbed habitats such as forest gaps and edges, streambanks and riparian areas, steep rocky slopes (particularly south-facing), fencerows, vacant lots, and 'wastelands.' Its classification as invasive has limited its widespread commercial use in the US. It has been disputed in a detailed account by Sutton (2016) whether it should be removed from the list of invasive species partly due to its selective site specifications for germination and spread, lack of confirmed harmful impact to native environments and taking into account its "enormous" economic benefits and its "endless" potential for agriculture.

Innes (2009) also stated that there appears to be a lower risk of invasiveness in Europe than US but that this is presently receiving research attention due to increased observances since the 1980s.

Essl (2007) has recently made an assessment of possible invasiveness risks in Central Europe, specifically Austria, Czech Republic and Germany. It was determined that seedlings of *P. tomentosa* as the hardiest and most ornamental species typically occurred in small populations of less than 10 individuals (83% of all records). These seedlings colonised primarily disturbed urban habitats and that near-natural habitats, e.g. forest clearings and riparian shrub areas were rarely colonized. Essl (2007) also noted that the average annual temperature in its native range (10–16°C) is higher than in Central Europe (7–10°C).

CABI (2013) reported that *P. tomentosa* could potentially become invasive in Europe if it continues to be planted. It has been reported by Verhaeghe (1999) that some trees have been found in disused waste grounds in Brussels and other urban localities and that although a general naturalisation has not been confirmed yet, it is expected that more observances will occur in the future.

Zhao-Hua *et al.* (1986) confirmed that the germination and seedling growth require intensive light with the consequence that Paulownia would be unable to regenerate naturally within a forest but only on exposed areas like abandoned land, felled and burnt sites where it can be considered as a pioneer species. The same study confirmed that very few dense stands of any large size have been identified and that they grow in a successional pattern.

P. tomentosa is currently on the 'amber' list of potentially invasive species in Ireland and Northern Ireland (Invasive Species Ireland, 2016) but it is not listed as invasive or potentially invasive for Great Britain, Netherlands, Belgium and Denmark.

It should also be noted that many clones developed for commercial use in Europe and worldwide are marketed as sterile which would further reduce the risk of invasiveness if these specific hybrids were introduced on a broad scale.

3.3.2 Interview/Written Responses

The following questions were asked to all participants regarding the possibility of Paulownia becoming invasive in NW Europe. The expert's focus area country has been put in parentheses where this is not stated in the response.

Question	*Do the Paulownia trees flower regularly on the site (e.g. every year)?*
Agroforestry Experts (13)	Yes (23%) No – trees on site too young (15%) No (15%) Not answered (46%)
Agroforestry Farmer (1)	'No' (planted in 2009). (UK)
Plant Nursery Manager (1)	'Clones not regularly. But if you make a comparison with our cultivators, the Spanish cultivators produce a lot of flowers. Yes every year. In Bulgaria the flowers open April-May for 6-8 weeks.'
Plantation Manager (2)	'They usually flower on the 5th year after planting.' (Germany) 'After about 3 years' (UK/Northern Europe)

Question	**Agroforestry Experts and Plant Nursery Managers** *Do you think there is a possibility of invasiveness of Paulownia in the focus area (UK/NW Europe), and are you aware of any prior research made on this?*

	Agroforestry Expert and Plantation Managers *Have you witnessed Paulownia seedlings on your farm or surrounding area from self-seeding?*
Agroforestry Experts (13)	No (8%) Unknown or Possibly (61%) Not answered (23%) Yes – if cultivar not sterile (8%)
Agroforestry Farmer (1)	'None as yet, nor suckers.' (UK)
Plant Nursery Manager (1)	'I think it could be invasive for the warmer parts of Europe. Invasiveness of a species can be a main issue and should be managed very well. We have some small plantations with our sterile clones with 15-20 plants to monitor them and until now there is not a single plant (seeded). But anyways we have to be very careful with this.' (Bulgaria)
Plantation Manager (2)	'No we never observation anything like that.' (Germany) 'None' (UK/Northern Europe)

3.3.3 Case Study

Case Study 1 – East Sussex, UK

Trees were planted in 2014 and not yet at flowering age. Invasiveness was not expected to be an issue at the local site.

Case Study 2 – Ballydehob, Ireland

Trees were planted in 2013 and not yet at flowering age. Invasiveness was not expected to be an issue at the local site.

3.4 Where are the locations growing Paulownia in NW Europe and what can be learned from these sites?

3.2.1 Literature Review

Two relevant sites were identified in NW Europe growing Paulownia on a field scale as part of the literature review.

Hillsborough, Northern Ireland, UK

As a follow-up to the report by Woods (2008), some trial plots were established at Hillsborough in Northern Ireland from 2009-2013 in order to further investigate the suitability of Paulownia for biomass production, using genotypes from Morocco (two year old bare-rooted plants) and Spain (seedlings from tissue culture).

A summary of the site conditions has been provided for reference in Table 3.10

Table 3.10 - Paulownia trial at Hillsborough, Northern Ireland (2009-2013)

Parameter	Value
Coordinates	Latitude 54.48° N, Longitude 6.08° W
Annual average summer temperature	14.5 °C
Annual average winter temperature	4.5 °C
Mean annual temperature between 2009 and 2013	8.9 °C
Maximum temperature between 2009 and 2013	24.5 °C
Minimum temperature between 2009 and 2013	-8.4 ºC
Soil pH	5.49 - 5.89
Planting distance	1.8 m x 1.8 m
Aspect	Gentle south to southwest facing slop
Protection from livestock/wildlife	Electric fencing
Fertilisers applied?	Yes, to minimise differences in plots due to soil moisture and nutrient deficiencies
Weeding management	Jute mat after applying herbicide and cultivation

(Olave *et al.*, 2015)

A detailed report of the Paulownia trial on the six sites in Hillsborough has been documented by Olave *et al.* (2015). Overall, as per this report the results in the Northern Ireland trial were not considered successful for biomass production due to the much lower than expected growth rate; the tallest genotype had a height of only 2.1 m after three years. Compared to the cost and the growth rates of other species such as willow and poplar which can reach 7 m in height in the same time period, the trial indicated that the potential of Paulownia as a biomass crop appeared to be limited in Northern Ireland.

Specifically, Olave *et al.* (2015) provided the following factors which could have attributed to the poor performance of genotypes in the trial:

- Exceptionally cold winters during 2010 and 2011 with minimum recorded temperatures of -14 °C and -7.2 °C
- Strong winds recorded at over 40 km hour-1 on several occasions, which can cause damage to young trees as stated by Barton *et al.* (2007)
- Heavy soils
- Excessive moisture and poor drainage

Species and hybrid selection was also confirmed to be a factor since there were varying degrees of growth and survival rates depending on genotype and origin. It was also noticed that the Spanish genotypes supplied as containerised plants generally performed better than the bare rooted specimens from Morocco and therefore the type of nursery stock could also have been a factor where containerised plants adapt better to a harsh climate (Olave *et al.*, 2015).

Pruning was not carried out on any of specimens since they had not reached the required height expected.

North Shropshire, UK

The only exact match for Paulownia agroforestry found in the focus area of NW Europe was an online reference from Aspin (2015) describing one specific site in North Shropshire, UK where the attempt to grow seven species in a silvopastoral system was not up to expectations. The only species that survived was *P. fortunei* and severe losses were reported due woodpecker damage in the cold winter of 2010-2011. The cold damage was reported to be likely due to the fact that the site frequently records the coldest lowland temperatures in the UK.

3.4.2 Interview/Written Responses

Due to the geographic focus of this research question, the interview/written responses have been extracted only from those participants who had either working knowledge or practical experience with Paulownia in the focus area countries in order to derive relevant information for NW Europe.

- Ireland
- United Kingdom
- New Zealand

Although New Zealand is outside the focus area, the maritime climate is comparable to cool temperate Europe and was included. Participant comments have been included to highlight important points. Percentage totals given could not always equal 100% where participants provided multiple responses.

The following questions were asked to the participants on a broad range of topics related to site and ecological requirements, agroforestry practices, planting and growing techniques and

general questions about species characteristics. The expert's focus area country has been put in parentheses where this is not stated in the response.

Ecological Requirements

Question	*Are you aware of any reported survival rate in the first year on the site? Are the Paulownia trees generally hardy?*
Agroforestry Experts (6)	'Survival rate after 2 years usually +95% providing grass competition is controlled' (New Zealand) 'Varies between genotype. Mean survival rate for Spanish and Moroccan genotypes after three growing seasons were 70.8% and 32.2%) (UK) 'Generally hardy' (UK) No response given (50%)
Agroforestry Farmer (1)	'*P. tomentosa* survival was poor, other species seem much better'' (UK)
Plantation Manager (1)	'Varies from 60% to 90%' (UK/Northern Europe)

Question	*Are you aware of any reported significant variations in growth for the Paulownia trees in cool/wet summers?*
Agroforestry Experts (6)	'Yes –growth rate will be slower' (New Zealand) 'No, but this would be anticipated as they like hot summers.' (UK) 'The trial in Cork put on an impressive amount of growth last summer; we will have to see for this summer.' (Ireland) 'Some (genotypes) were more resistant to winter cold weather than others. And also there were a couple of sites that were more exposed than others; wind exposure caused some variations in growth between species.' (Northern Ireland, UK) 'No I am not aware of it, but it would a key issue. The day degree and soil temperatures would have an affect but that is the case for all trees as we know from this work with polythene mulches.' (UK)
Agroforestry Farmer (1)	'None' (UK)
Plantation Manager (1)	'The main problem is dry summers where inadequate irrigation has been provided.' (UK/Northern Europe)

Question	*Are you aware of any difficulties getting the Paulownia trees established on the site?*
Agroforestry Experts (6)	'None apart from keeping browsing animals off trees' (New Zealand)

	'I had low survival rate. Large foliage makes stability in strong winds / on exposed sites an issue' (UK) 'China: 2 year old saplings planted; none reported' 'They grew well but grower wasn't happy for the form so he cut them back and they grew again.' (Ireland) 'Yes I think they were quite demanding in terms of preparing the ground and also handling the plants because they were quite delicate at a young age and we had to be more careful handling these than conventional trees planted here in Northern Ireland.' 'No not really. It is still an important tree in the nursery world, it's coming back into favour as a street tree. So they would have the knowledge, this trade would be selling semi-mature trees. So they would have established it some way and manage it in a certain way so it suffers less from transplant shock, so there is already experience in that sector. That is why I am saying if you can get it to a certain height, it is safe from frost. When they are at 8/10 standard as a street tree, the apical buds never get affected. So it maintains its good form. That is why I made the suggestions about how to combat frost. Because I have watched this happen, if it has good form and is more than 2 m high, then it maintains that good form even though there are frosts around.' (UK)
Agroforestry Farmer (1)	'None' (UK)
Plantation Manager (1)	'Yes. Soil pan and did not use appropriate cultivation (this was before I was involved) Where soil moisture content is low mice eat the roots' (UK/Northern Europe)

Question	*Have you noticed or received information about any wildlife attracted to the Paulownia trees (e.g. bees, birds, other insects)?*
Agroforestry Experts (6)	Yes (33%) No (66%) 'Yes. Very attractive to bees and nectar seeking birds. In NZ the Tui, a very intelligent bird, soon learnt to bite into the base of the flower which it found too deep to access from the top.' 'Paulownia has great potential for pollinators since it gives these nice flowers. I don't think wildlife has been measured, but Buddleia is a Chinese species so even though it's not native there is no reason to think it's not attractive to pollinators. The other thing that happens to agroforestry systems when you have mulch is that you have a lot of leaf material and branch

	material that falls off, so very quickly within the tree row you end up with a very interesting litter layer, and within that litter layer is an incredible amount of invertebrates. And very quickly in my sites we have grass snakes and adder, incredible wildlife; it is almost like a beetle bank. The black polythene doesn't look very nice and it's a good thing its covered up very quickly, it does its job in the first couple of years in terms of soil temperatures and then the litter layer builds up which is fantastic for wildlife.' (UK) 'I have not noticed anything major as the flowers are very high up. I am sure bees would be up in them. Other than that I have not seen anything in particular.' (Ireland)
Agroforestry Farmer (1)	No, trees are not yet flowering – planted in 2009' (UK)
Plantation Manager (1)	No response given
Question	*What are the main factors affecting growth rates of Paulownia trees?*
Agroforestry Experts (6)	'Lack of moisture in summer, shallow soils, low temperatures' (New Zealand) 'Wind exposure!' (UK) 'Temperature during the growing season Fertility and depth of soil – must be well drained and neutral pH' (UK) 'Light and shelter. Because they have very big leaves if they are out in the wind or exposed in a high altitude because they are so big they can be ripped off.' (Ireland) 'Warm summers, light, sunshine and also exposure (shelter)' (Northern Ireland, UK) 'Temperature, particularly soil temperature.' (UK)
Agroforestry Farmer (1)	'Moisture' (UK)
Plantation Manager (1)	'Moisture and nutrients' (UK/Northern Europe)

Question	*Have there been any frost damage/deaths for the Paulownia trees on site in cold winters?* *If yes, what was the minimum temperature (if recorded)?*
Agroforestry Experts (6)	'In its natural environment (China) Paulownia does not appear to be affected by frost and, varying by species, can withstand temperatures as low as -20°C. However the climate in NZ is quite variable in spring for, while temperatures begin to rise in

	August, frosts in the North Island can occur up to December. While the climate in the South Island is more like that of Britain, out of season frosts do occur and, apart from the northern third of the island summer temperatures are mostly too low for good Paulownia growth. In summary, out of season frosts will kill new growth of Paulownia –especially in spring, but also in autumn.' 'As above, in China lead shoots are killed with severe frost (-20°C) and shoots need to be selected and trained. I am not aware of deaths of the whole tree due to cold.' 'The reason grower grows them here is that there is less frost in S. Ireland than the rest of the country due to the proximity to the sea. I have not noticed frost damage on the ones I have in the garden compared to other trees I planted such as wingnut from N. America that tend to get burned back a lot but Paulownia tends to be fine. I know they had problems up in NI with their trials up there with late frost.'(Ireland) 'Yes, we saw a lot of that in 2010 and 2011. Those years were quite cold and some varieties were susceptible to frost damage. It was during extreme winters and strong winds rather than frosts. Strong winds caused a lot of damage by breaking branches which are very sensitive. I think that type of damage is more serious than frost. Normally it did not kill the tree but more than half the stem and the tree the next spring attempt to regrow again from the root system.' (Northern Ireland, UK) 'Yes - I have seen a lot of frost damage on Paulownia in landscape situations where they just tried to use just small whips, small seedlings, so pretty soon that becomes a bush or a shrub. It is only the semi-mature and transplanted ones that maintain their form. So it is highly frost-susceptible for the form.' (UK)
Agroforestry Farmer (1)	'No' (UK)
Plantation Manager (1)	'Some but the trees usually recover by sending up new shoots' (UK/Northern Europe)

Agroforestry Practices

Question	*Was the site where the Paulownia grown certified organic?*
Agroforestry Experts (6)	No (100%)
Agroforestry Farmer (1)	Yes, with Soil Association' (UK)

Question	*Do you see any challenges growing Paulownia in an organic system?*
Agroforestry Experts (6)	No (100%)
Agroforestry Farmer (1)	'No' (UK)

Question	*What other crops had been intercropped with Paulownia on the site (if any)?*
Agroforestry Experts (6)	Grass only (50%) Grass and sheep (33%) – one site in Ireland would introduce sheep when trees get older. No response (17%)
Agroforestry Farmer (1)	'Permanent grass/clover' (UK)

Question	*Are you aware of any crops that grow particularly well/poorly with Paulownia? If yes, please describe in further detail.*
Agroforestry Experts (6)	No response (50%) **Grow poorly:** Maize (17%) **Grow well:** Winter wheat (33%) Maize (33%) 'It is incredibly sophisticated in China, they have 50 centuries of working with trees and mixed cropping, so even for maize, they have a short season maize crop that can be grown'
Agroforestry Farmer (1)	'None' (UK)

Question	*How many Paulownia trees per hectare are there on the site?* *Please describe spacing and layout (e.g. 5 m x 20 m in tree spacing/row distance).*
Agroforestry Experts (6)	'Usually about 200, stems / Ha. at varying spacing. Alternatively planted in single rows along fence lines NZ)' 'Initially 200 trees per hectare 5 m x 10 m, reducing to 5 m x 20 m and then 5 x 40.' (China) '2 m by 2 m, to be thinned' (Ireland) '1.8 m by 1.8 m' (N. Ireland)

	No specific figures given (33%)
Agroforestry Farmer (1)	'Less than 10 trees on 8 hectares' (UK)

Question	*If the site is for agroforestry, were there any benefits from Paulownia to the farming operation. If yes/no, please specify.*
Agroforestry Experts (6)	No response (66%) 'In China, yes. Paulownia is a warm temperate species, and the leaves do not senesce like poplar or willow. They stay green to until the first frost, when all leaves fall at once. They can then be collected, dried / ensiled, and fed to livestock over winter. If grazed pasture is present, and there is no hard frost, leaves will fall individually, and as they are green they may be eaten by grazing livestock – although they are bitter.' 'At Shuttleworth it was a silvopastoral system grazed with sheep.' (UK)
Agroforestry Farmer (1)	'None, as yet' (UK)

Question	*If the site is for agroforestry, did you identify any challenges growing the Paulownia trees that interfered with the other farm enterprises?*
Agroforestry Experts (6)	No response given (66%) 'Once they acquire the taste animals eat leaves (they are excellent fodder) and strip bark' (New Zealand) 'In China, summer crops became shaded and yield reduced. With first harvest at 10 years, severe shading occurred from year 5. However in UK growth rates are only ¼ of those in China.'
Agroforestry Farmer (1)	No' (UK)

Question	*Are the Paulownia leaves fed to livestock on site (if applicable)?*
Agroforestry Experts (6)	No (50%) Yes (50%) 'Yes. In China with a hard first frost, leaves fall still green. These are easily picked up, dried (or might be ensiled with additive). They can be fed to ruminants. Dried leaves need to be soaked in hot (not boiling water) to make them palatable for feeding to pigs, or the dustiness reduces feed intake. Paulownia contains *iridoid glycosides*, which are bitter but are soluble in water. When 0.5 kg of the dry leaves were soaked and fed to pigs in addition to their normal ration, instead of 500g per day they grew at 600g per day. As the pigs were fatter, the local butchers paid

	more for the whole carcass. For pigs sold to the state pig buying corporation at a flat rate price, farmers substituted Paulownia leaves for purchased wheat bran (used as a protein source), and the pigs still gained 500 g per day.' 'The intention is to feed the leaves when sheep are introduced.' (Ireland)
Agroforestry Farmer (1)	'They browse them occasionally, but not as palatable as many other tree species' (UK)

Planting and Growing Techniques

Question	*What do you see as the main challenges in growing Paulownia in the focus area that farmers need to be mindful of?* • *Market* • *Wind* • *Diseases/Pests* • *Placement (shelter?)* • *Soils* • *Maintenance* • *Other*
Agroforestry Experts (6)	'All of the issues listed can apply. I would rate pests and disease as lowest challenge. Markets may also not be such a problem as they are in NZ since the population of EU should be high enough to sustain a variety of uses.' 'Wind, Market, Pruning' (UK) 'All, but especially training for growth form to get good trunks. Soils are critical, should be deep and well drained, preferably fertile. Shelter may be important, as wind damage may be a problem, but not necessarily. A lot of management is required.' (UK) 'I would think a relatively sunny area, maybe southern aspect in a relatively sheltered location' (Ireland) 'I think the first point is to try to identify genotypes which are suitable for the focus area. The second one is to identify areas which are more suitable in terms of wind and soil protection to give those factors better condition for the growth.' (Northern Ireland, UK) 'Due to frost, the topography of the site is critical, you do not want to put it at the bottom of a slope due to a container of cold air so that makes things worse. The other question is what are you going to use (the tree) for.

	The economic product has a strong link and this needs to be determined before the silviculture. So the management can change the nature of the product. So if you wanted a quick source of biomass, you could just grow any material and quite densely, and if you wanted to have a good form, then with *P. tomentosa* especially, the main issue is that the first shoot and it grows incredibly fast is susceptible to frost, so it can then branch all over the place. In summary, four variables for greater success for growing Paulownia for the UK are: 1) Select strong cloning material 2) Management depending on market 3) Understory management with black polythene 4) Site placement'
Agroforestry Farmer (1)	'None' (UK)
Plantation Manager (1)	• Market - *Not explored* • Wind - *Can be a hazard when in full leaf* • Diseases/Pests - *Not Many* • Placement (shelter?) - *Helps protect from frost* • Soils - *Deep Free draining soils ideal* • Maintenance? - *Maintain Fences to prevent grazing* (UK/Northern Europe)

Question	*How would you recommend maintaining the understory of the Paulownia?*
Agroforestry Experts (6)	No response given (33%) Grass, mowed (33%) Plastic mulch (33%) 'For establishment, cultivate 1 m wide strip including subsoiling. Lay black plastic mulch and plant trees through the plastic. As plastic degrades, cut, spray or cultivate intra row (Note between plant cultivators for vineyards)' (UK) 'Black polythene mulching is recommended. All agroforestry work is done with farmers and we need permission from farmers and they would not permit it because they are worried about weeds. The mulching was a given thing, and then we discovered by accident what an incredible affect it had on soil temperate and subsequent growth rates. You only need half a degree centigrade in daily mean temperature to accumulate a lot of day degrees.' (UK)
Agroforestry Farmer (1)	'Permanent grass/clover' (UK)
Plantation Manager	'Destroying all vegetation for 1.5 m around base of tree is

(1)	essential' (UK/Northern Europe)

Question	*Are you aware of any diseases encountered with growing Paulownia on the site?* *a. If yes, please specify.* *b. What preventive measures can be undertaken?*
Agroforestry Experts (6)	Yes (33%) No (66%) 'Yes, *Armillaria*. Not common and probably no preventative measures tried.' (New Zealand) 'At the park in Canterbury, yes. I don't know what the disease was. It should be possible to control by plant hygiene measures - removal of fallen leaves – and by fungal sprays – difficult when tall.' (UK)
Agroforestry Farmer (1)	None' (UK)
Plantation Manager (1)	'*Anthracnose* can be a problem especially where the plant is growing poorly due to stress from absence of moisture or nutrients. The latter is the problem with an organic system on poor soils which are the ones usually used for growing trees' (UK/Northern Europe)

Question	*Are you aware of any pests encountered with growing Paulownia on the site?* *a. If yes, please specify.* *b. What preventive measures are undertaken?*
Agroforestry Experts (6)	Yes (17%) No (83%) 'The main insect affecting Paulownia in NZ is the endemic ghost moth (*Aenetes virescens*), a stem borer. If there are similar species in the focus area they could cause problems.'
Agroforestry Farmer (1)	'None' (UK)
Plantation Manager (1)	'Deer and any grazing fauna would destroy the crop but these are fenced out. Snails have infected at some plots but do not appear to be causing a problem' (UK/Northern Europe)

Question	*What other management would you recommend for the Paulownia trees to receive (e.g. pruning, fertilisation, herbicides)?*
Agroforestry Experts (6)	'Coppicing and pruning very important plus grass control first two years.' (New Zealand) 'Staking' (UK) Pruning is essential to maintain form of the main trunk. In China, the lead shoot(s) is killed by frost each year. Once frost is over, several shoots appear at the apex. One lead shoot must be

	selected, and if necessary be trained to grow vertically. Over several years the trunk then grows straight at this point.'
Agroforestry Farmer (1)	'One was very misshapen so it was coppiced to a single stem' (UK)
Plantation Manager (1)	'Pruning essential from Year 2. No herbicides. Fertiliser is used to maintain rapid growth' (UK/Northern Europe)

Question	*How old would you expect the Paulownia trees to be before harvest?*
Agroforestry Experts (6)	'Depends on site and expected usage. On good site can be milled in 7 years, on slower sites 30 plus. Faster grown Paulownia reasonable for veneer.' (New Zealand) 'In China trees are harvested from ten years old with dbh about 300 mm. The 50 year old trees in Canterbury are 400 – 500 mm dbh, so we are looking at an increase of dbh of 10 mm p.a. I suggest a denser planting, say 2.5 m x 10 or 2 x 12 m (with a 1 m alley for the trees); with thinning within the row once competition is apparent within the row. Even small diameter stems will have a high value, with initial thinning at 10 years and 50-100 mm dbh (plant 2 – 4 year old saplings)' '(The grower) said he was going to do it in a very short space of time 15-20 years after thinning them out after a few years.' (Ireland) 'At the rate they grow at the moment, if there was potential for timber that would be 10-20 years.' (Northern Ireland, UK)
Agroforestry Farmer (1)	'Too early to define' (UK)
Plantation Manager (1)	'15 years is expected' (UK/Northern Europe)

Question	**Agroforestry Experts and Plant Nursery Manager** *Do you think growers should propagate their own Paulownia trees from cuttings or seed?* *If yes, which option (seed/cuttings) is preferred?* **Agroforestry Farmer and Plantation Manager** *Do you propagate your own Paulownia trees, or plan to do so?* *If yes, would this be from cuttings or seed?*
Agroforestry Experts (6)	'If you have a good clone propagate from root cuttings but to get variation in stock, get seed from a range of sources, select best seedlings and then propagate from root cuttings. Stem cuttings have extremely low strike rate' (New Zealand) 'In principle cuttings from trees of better form has potential, with the proviso that genetic diversity needs to be retained.' (UK)

	'Seed will provide a very variable plant population and is NOT an option. The most productive in China are hybrids, with propagation by root cuttings. Paulownia clones can also easily be produced by tissue culture.' 'Once you clear the trees, the trees can coppice. Root cuttings are generally the way to go for the best trees.' (Ireland) 'Our experience is we had two types, one from bare-root cuttings from 2 year trees, the others were small tissue culture samples. Between the two, I think the tissue culture is much better than the bare root. But if you don't have facilities here to grow tissue culture material then bare roots becomes more suitable. In terms of seeds and cuttings this depends if these were sterile or not. If sterile then this would not be a problem.' (Northern Ireland, UK) 'The key thing is that in China Paulownia is propagated through root cuttings, so its clonal material so they have got a superior strain that is based on clonal propagation because that has a strong bearing on its form. So that is a key issue, if the tree is to be planted at UK it is important to have good material.'
Agroforestry Farmer (1)	'Yes, from seed' (UK)
Plantation Manager (1)	'Not at the present time' (UK/Northern Europe)

Question	*Do you have any information about expected annual growth rates (cm) for Paulownia in UK/NW Europe?* *If no, what was the average growth rate on the site you worked with?*
Agroforestry Experts (6)	'No data but would expect to be lower than NZ. Warm areas with adequate summer rain fall – >50 mm per month or irrigation would be best. In NZ trials suggest that 70 cm diameter can be reached in 12 – 20 years, depending on temperature, moisture availability and soil conditions.' '*P. tomentosa* in my garden is not one I would rely on due to its being ornamental. It grew relatively quickly the first 4-5 years then grew in girth instead with a crowned dome. Whereas if trees are grown relatively close together they will force each other up. That is why grower planted at 2 m.' (Ireland)

	'It is much lower than other fast-growing tree species planted in UK and Ireland, such as poplar or eucalyptus.' (Northern Ireland, UK) 'Based on observations and nothing scientific, I would say a minimum of 2 m/ year, a min. of 3 cm diameter increment.' (UK)
Agroforestry Farmer (1)	'When established, about 40 cm/year' (UK)
Plantation Manager (1)	'Range 10 cm to 120 cm in height' (UK/Northern Europe)

Question	*Would you consider Paulownia a low/medium/high input crop in an agroforestry system in the focus area? Please describe why.*
Agroforestry Experts (6)	'Not able to comment regarding focus area. It would be regarded as relatively high input in NZ.' 'Low - Needs no fertilisation in normal soils' (UK) 'High – due to time required to obtain good growth form in early summer; intensive management. Also quite labour intensive in the plant nursery.' (UK) 'Grower is not planning on growing them in tree shelters at all and to just thin them and let the sheep graze in between. If he can do that then it means it is very low input, I suppose one of the biggest inputs and this applies to any agroforestry system is because they are growing so far apart it means you have to do a lot of pruning. You could just start pruning after thinning out so there are fewer trees to actually prune. If landowner expects to make a windfall then pruning should not be a problem. From experience in my own garden, the timber is relatively easy to cut, it should be relatively easy to prune. I do not think fertiliser or herbicide would be required, that is why agroforestry is perfectly suited to organic farming.' (Ireland) 'At the moment high inputs there are other tree species that could perform better with less input.' (Northern Ireland, UK) 'If the right varieties and appropriate establishment, it is a low input.' (UK)
Agroforestry Farmer (1)	'Low input, the main crop is perennial grass/clover' (UK)
Plantation Manager (1)	'High input for a tree crop' (UK/Northern Europe)

Paulownia Products and Services

Question	*Can you describe any particular positives about the Paulownia tree other than the ones already mentioned?*
Agroforestry Experts (6)	'It has high potential for the development of useful medicines.' (New Zealand) 'If the leaves remain green when they fall, and are eaten by grazing livestock such as sheep or cattle, besides extending the grazing season they might act as an anthelmintic – research pending.' 'It grows quickly and could provide a return to the farmer very quickly. It is of use to grazing animals due to foliage and easy to manage provided it stays disease-resistant. Paulownia is very stable and moisture free compared to other trees. You don't need to dry it as much and can sell it on a lot quicker.' (Ireland) 'Yeah I think it is very easy to work with and regrows very quickly and it coppices very well. And also I think it is C4 plant so there is potential so it may require fewer nutrients than other species for some periods. I think it still requires more research.' (Northern Ireland, UK) 'It is one of the fastest growing species when grown in the right place but the wood density is extremely low. It must be considered as a multipurpose tree for the farmer, it is not a single product. You can make things from the leaves. Paulownia is the quintessential tree of China, just like most British people would consider the oak, like in medicine and culture. So there are probably like 500 products in China from Paulownia. One of the most exciting things they found on my project was that the leaves were that they had anti-aging properties, so it is a very interesting plant. It is the only woody plant of the *Scrophulariaceae* and they have many medicinal compounds.'
Agroforestry Farmer (1)	'None at present' (UK)
Plantation Manager (1)	'Responds well if the environmental conditions are correct and the appropriate husbandry methods are used. The timber, once grown, and a market established has enormous potential and a wide range of uses that we have hardly begun to explore or exploit' (UK/Northern Europe)

Question	*Can you describe any particular negatives about the Paulownia tree other than the ones already mentioned?*
Agroforestry Experts (6)	No (66%)

	'Potential for catastrophic disease incidence.' (UK) 'Probably the main one is that the species planted here requires a lot of investment in terms of management.' (Northern Ireland, UK)
Agroforestry Farmer (1)	'No' (UK)
Plantation Manager (1)	'The hype around this tree often attracts people with the wrong objectives' (UK/Northern Europe)

Question	*Do you have any other general comments and observations not covered in the interview?*
Agroforestry Experts (6)	'Paulownia timber has tremendous properties not found in other timber species. It is lightweight, but immensely strong AND anti-warping/twisting due to a high proportion of cross fibres. It also has fire resistant properties compared to other species. It is therefore highly desired for making musical instruments and furniture; but also for construction both as a veneer but also high structural strength. It would be ideal for engineered timber such as intricate glue-lams, as well as for cross-laminated panels in multi-storey buildings. Due to its anti-warping properties it is ideal for wooden window and door frames as well as for doors. Paulownia is grown commercially in the USA; see World Paulownia Institute LLC at www.worldpaulownia.com . They offer a turnkey operation including site evaluation, and guarantee purchase of timber. Besides seedlings (avoid) they offer plants grown by tissue culture. They have a long history, and should be able to supply disease free materials through their international programme suitable for various sites in Europe.' (UK) 'One other observation would be other potential for crops such as bioremediation and erosion control that needs to be investigated.' (Northern Ireland, UK)
Agroforestry Farmer (1)	'The research here is still in its early days. The knowledge from the research is developing as I learn more about the relationship between bovines and trees.' (UK)
Plantation Manager (1)	'To grow this crop successfully there is a requirement for investors with a long term view of seeing a return on their investment. The planting density is low compared with most other forestry crops as the cost of the individual plants is high. The labour and monetary investment input into Paulownia is very high in years 1 to 6 – cultivation, irrigation, fertiliser and pruning, none of which apply to conventional forestry - and unless capital availability is high or the investor is prepared to be patient and understands the nature of the crop and its cash-flow requirements many will drop out. It is only when numerous areas are established so that some are at the harvest stage, which can help fund those at the early growth stage, will this be a viable enterprise and an attractive investment. However, there are

	brave souls out there who share my passion for this crop and are long sighted enough to see the advantages and willing to make the commitment of growing the trees correctly and they will reap the undoubted rewards of so doing.' (UK/Northern Europe)

3.4.3 Case Study

Case Study 1 – East Sussex, UK

Some of the *P. elongata* specimens planted on the site experienced frost damage during both winters since establishment although the winters 2014 and 2015 were not particularly cold compared to average site temperatures. The forms and growth rates also differed between trees based on observation. This would indicate that plants propagated from seed have variable characteristics as already stated in the literature review. Nevertheless, despite the winter damage the survival rate was high at 90% considering that the trees were not managed intensively since the initial establishment. Growth rates appeared to be a maximum of around 1 m in height per growing season following the stem die-back from the winter and several of these specimens had multiple stems that would require pruning as part of the management.

Case Study 2 – Ballydehob, Ireland

The main limiting factor on the site was the cool spring temperatures and subsequent unusually cool summer temperatures during the growing seasons in 2014 and 2015. This was evidenced that the trees planted on top of a hill nearer to the windbreak had benefited from the microclimate and were significantly higher than the trees planted on the lower end of the field.

Frost was not a problem on this particular site and although the wind speeds could be high this had also not caused any damage to the trees. The sheep grazing under the trees to keep down the grass had not debarked any of the trees and deer and rabbits. The main challenges reported in establishment were slugs and managing the rapid grass growth around the trees.

Pruning was also confirmed to be a critical success factor when managing Paulownia for timber production and it was expected that the growth would have been higher if pruning had been carried out during the first growing season, but this was then carried out in the following growing two seasons with some of the trees cut down to the ground level to regrow.

3.5 Does a market for the yield (timber) currently exist in NW Europe?

3.5.1 Literature Review

Timber has historically been considered a sound long term low-risk investment in particular for species in high demand. Living Investments UK (2016) noted that the global demand for hardwood has multiplied 25 times in the last 40 years and with population growth expected to continue to increase to 9.7 billion by 2050 (United Nations, 2015) this trend will likely continue.

iPaulownia (2016) stated that the production and consumption of key wood products and wood energy could be expected to rise from the present up to 2030 following historical trends of 1-2% increases per year.

This is due to several primary factors attributed to an increase in demand for timber globally:

- Population growth to 7.5 billion in 2020 and 8.2 billion in 2030 (FAO, 2009)
- Global GDP projected to increase from US$65 trillion in 2010 to US$130 trillion by 2030 (CEPS, 2013)
- Rapid growth of developing countries, mostly in Asia; China to account for 24% of global GDP by 2030 (CEPS, 2013)
- Environmental policies reducing the amount of old growth forests marked for timber production (CBI, 2016; FAO, 2009)

Furthermore, there have been recent restrictions implemented in EU legislation to restrict the import of tropical timber originating from illegal logging (EUTR, 2016).

Paulownia has been recognised as a versatile hardwood timber with a variety of uses as described in Appendix A. Paulownia Reforestation Project (2001) stated that 'business economics makes it clear that the most desirable place to be is in the middle between a long term, decreasing supply, and a steadily increasing demand' and the company considers planting Paulownia an opportunity to be among the first to market in the US to obtain premium prices.

It has been reported by Barton *et al.* (2007) that Paulownia wood is presently supplied mainly from China, with Taiwan, Brazil, and USA contributing smaller amounts and noted that it is only USA that can supply high quality timber. In 1990 the average price paid in Japan for logs from USA was ¥217,000/m³ while those from China was only ¥47,000/ m³ which is a reflection of the high value placed on slower-grown Paulownia having a more desirable colour and texture.

The history and experiences of the market conditions and present demand for Paulownia timber have been summarised in this review for the main countries with a comparable temperate climate growing Paulownia at the present time in order to provide an indication of market conditions for potential growers in NW Europe.

China

Paulownia is well-known in East Asia and where its quality timber is in high demand (iPaulownia, 2016). Yin (2004) stated that farmers in China started to plant Paulownia on an extensive scale in the 1970s following land reforms which led to wide scale implementation of agroforestry systems in North China. Paulownia intercropping systems increased rapidly in area during the 1970s and 1980s, when Paulownia timber was widely used for house construction and furniture making as well as for export. Wenhua (2001) reported that Paulownia was an important export item and that in 1984 114,702 m^3 of Paulownia logs and 169,210 m^3 of Paulownia boards were exported, earning US$ 7.21 million and greatly increased the living standards of local farmers. However, Yin (2004) noted that the Paulownia timber market became saturated in the 1990s while the demands for fruits, nuts, crafts, panels, medicinal herbs, and other outputs became strong with the result that many other types of other fruit, nut and timber tree species have since replaced Paulownia in intercropping systems.

This was also confirmed by Briggs (2012) who reported that market saturation was one of the reasons for many farmers switching to poplar which has an advantage over Paulownia as being more tolerant of waterlogged conditions. The general mass market can therefore be considered to be variable depending on supply and demand, but Paulownia still remains one of the key agroforestry species in China due to its other associated benefits and popularity.

United States

Paulownia trees have been growing in the Eastern United States since the middle of the 1800s in the wild after they were allegedly released by accident when the seedpods were dispersed from Chinese dinnerware packaging material (Paulownia Reforestation Project, 2001).

Nix (2014) reported that Paulownia was only recently discovered as a commercial species in the US when it was noticed growing in the Blue Ridge Mountains by a Japanese timber buyer on a visit in the 1970s. The older specimens in the US having particularly high quality timber were in great demand at the time by Japanese buyers and one log was sold for $20,000 as stated by Nix (2014).

This initially led to wide scale harvesting of wild specimens, illegal harvesting from city parks and later as a commercial plantation crop as described by Preston (1983), who furthermore reported that the following oversupply of quality Paulownia exceeded the demand of the Japanese export market and prices subsequently fell. The market for high quality timber had since become more selective as per Preston (1983) and that Japanese buyers expected trees at least 35 years old with very fine annual rings and only a tiny fraction of the harvested Paulownia in plantations could meet these specifications.

Clatterbuck (2004) confirmed that the Paulownia log market in the US remains greatly dependent upon Japanese demand with high prices paid only for top-grade logs as per a grading system based on log diameter, growth ring width and the number of defects. Clatterbuck (2004) further cautioned that there is considerable market uncertainty associated with growing Paulownia plantations both in the US and overseas and mentioned factors affecting price to be log quality, distance from mill and terrain. Kays *et al.* (ND) also noted the Paulownia price factors as grading specifications, price fluctuations and subjective criteria

such as colour, number of growth rings per inch (the lower the higher the price), length of long, ring shake and stain.

Nix (2014) cautioned that the wood is 'totally ignored by domestic timber companies in the United States and speaks volumes about its economic potential' but noted however that utilisation studies by several universities including Tennessee, Kentucky, Maryland, and Virginia suggested a possible favourable market.

Kays *et al.* (ND) noted that Paulownia remains a niche market in USA where only high quality logs grown in the wild are in demand and that these can yield a higher price than quality walnut and oak. There is no large volume market domestically because supplies are not yet available.

Several nurseries and plantation companies were identified to be currently actively marketing Paulownia in USA. One of these is World Tree (World Tree, 2016) offering investors to invest in Paulownia plantations with the stated selling price of US$3-14 per board foot depending on quality. Trees of the company's strain of *P. tomentosa* 'Empress Splendor' is offered to farmers free of charge willing to grow a minimum of 8 hectares and who then receive 50% of the profit, the remaining 50% split evenly between World Tree and investors.

Another company identified was World Paulownia Institute (WPI) (World Paulownia, 2016) based in Georgia describing itself as 'world's largest producer and supplier of genetically superior Paulownia seedlings.' The company offers a buy-back program for the timber produced by growers in the local area or assistance in organising the harvest along with a buyer where the area is greater than 4 hectares. One UK forestry investment company (Willow Rivers Wealth, 2016) growing Paulownia in Panama has agreed a forward purchase contract with WPI to sell timber at US$275 per m^3. WPI would then sell the timber to buyers in Asia and Europe.

Australia

Australia has established several Paulownia plantations over the last few decades with the major planted areas located in northern New South Wales and Queensland (van de Hoef, 2003). Van de Hoef (2003) stated that the market for Paulownia timber has yet to be developed in Australia with the main consumers currently located in China and Japan. The premium Japanese market for Paulownia requires large diameter logs with consistent growth ring width of 10 mm, which to date has not been possible to achieve for most Australian grown Paulownia timber.

Europe

More recent developments have been occurring in Europe where Paulownia plantations and nurseries have become more common in Southern and Central Europe during the last decade (Paulownia Invest, 2016; Paulownia Development, 2016; Paulownia Trees, 2016; Robinia Invest, 2015; Bikfalvi, 2014; Paulownia Europa, 2012; Bio Tree, 2012).

iPaulownia (2016), a UK-based forestry investment company specialising in Paulownia reported that the current market value for Paulownia in countries like Australia and China for first quality timber has exceeded US$1,500 per m^3 and that in Europe, imported Paulownia timber is being bought for over €500 per m^3. The company expects a conservative estimate

to be 5% growth per annum from today's market value for Paulownia timber which would set the price up from €450/ m³ to €733/ m³ or an increase of €283/ m³ within the next 10 years.

Some price figures obtained from sources on the internet about the prices for Paulownia timber in Europe are given in Table 3.11. It should be noted that these figures are presented as estimates for profitability scenarios provided by companies and are therefore only indicative based on current prices.

Table 3.11 Paulownia Timber prices in Europe

Projected selling price per m³	**Country of origin**	**Source**	**Comments**
€250 - €503	Bulgaria	Robinia Invest (2015)	Harvest at Year 12, 0.8 m³ per tree
€312 - €628	Germany	Robinia Invest (2015)	Harvest at Year 12, 0.6 m³ per tree
€450	Spain	iPaulownia (2016)	Harvest at Year 10, 0.7 m³ per tree
€567	Poland	Paulownia Trees (2016)	Harvest at Year 12
€700	Romania	Paulownia Development (2016)	Price quoted as paid for Paulownia timber by Italian furniture manufacturers in 2012.

Paulownia Invest (2016) in Romania are offering another model where the trees supplied are bought back from the grower at an agreed price of 'at least' €100/tree. Based on a model of 4 m x 4 m plantings (660 trees/hectare), the company reportedly pays €65,000 in Year 6 and then the same amount for the regrowth in Year 9, Year 12 and finally €12,000 for the roots at the end of the rotation.

A recent market report (CBI, 2016) noted that the timber market in EU is in recovery after 2008 with stricter import restrictions of tropical timber and increasing awareness among European consumers of issues climate change and tropical deforestation resulting in greater demand for local timber as per recent trends and these are expected to be stronger in years to come (CBI, 2016).

3.5.2 Interview/Written Responses

The following questions were asked to all participants about the market for Paulownia timber in Europe and abroad. The experts' focus area country has been put in parentheses where this is not stated in the response.

Question	*Is there a local market in EU for Paulownia timber or are they exported? If exported, where to?*
Agroforestry Experts (13)	No response/Don't know (54%) 'As far as I know there are casual market possibilities for Paulownia in Europe (e.g. in France for production of special wood products) but there is no extended market and sales are

	upon individual agreement. Most of the Paulownia are exported to the Far East.' (Hungary) 'Could be developed in UK – e.g. peeling for plywood manufacture. Main importers are China and Japan. All the new buildings in China use Paulownia based veneer for fixed furnishings. However Paulownia timber is exported from China – see Alibaba e-commerce site (Google)' 'I don't think there would be a local market. There will be no market in Scotland for it as a hardwood species at the moment.' 'The grower said that in Germany you can buy Paulownia timber and that it is very, very good for furniture and that its very stable, he said. He showed me a piece of it that he bought in a hardware store in Germany and said that the reason why timber values value it so high and what he reckons the same is that its relatively dry so there is very little processing needed compared to other timbers. Drying out oak for example is a very laborious procedure and requires huge expertise to prevent the oak from splitting so he reckons timber purchasers will pay big money for it. Grower reckons there is big demand and potential.' (Ireland) 'I couldn't answer that but I heard they make the best surfboards in the world. It has a light weight but is very strong.' (UK) 'For me its greatest value is to use it for small artefacts because it has very special characteristics. It makes incredible musical instruments and boxes and things for the kitchen. But it is not a tree that's part of our culture, so there would need to be additional markets for it. So it is a matter of looking at it what can be used to substitute for, such as plastic because it is incredibly light. In the UK timber market we are incredibly conservative, so for construction for example, people will say they just want Douglas fir and not anything else. Even if you can prove the structural integrity of other species are the same or better, people won't accept it. So timber in the UK is an exceptionally difficult market to substitute one species for another. So much so that for any new species it's better to look at totally new niche markets.'
Agroforestry Farmer (1)	'No' (UK)
Plant Nursery Manager (1)	'As far as I know, the market is in EU. The people from Serbia and Hungary are working with a company in Slovakia, but up to now we don't have a plantation that is cut. There are indications of a market in Italy,' (Bulgaria)
Plantation Manager	'The end market is Europe but the biggest market worldwide is

(2)	Asia. Our plan is to sell within Europe, we have already contacted people who want to process the wood.' (Germany) 'Trees are not at a marketable size at present so not explored. You will have noticed that the International Timber Trade Organisation (ITTO) do not provide prices for Paulownia' (UK/Northern Europe)

Question	*Would you expect that the slower growth rate expected in UK/NW Europe improves quality of the timber compared to warmer climates?*
Agroforestry Experts (13)	No response given (38%) 'Yes. Definitely would make it more attractive to the Japanese market' (New Zealand) 'It is a complicated question as the result depends on several parameters (species/variety) How do you define quality? I think the purpose is determinative. Otherwise it would make sense to get more dense material with slower growth. There are some tests going on in Hungary on this issue too.' (Hungary) 'In China the cut timber is stripy like mahogany, paler with wider stripes. With slow growth, stripes would be narrower-could be most attractive but I have not seen any. For peeling for veneer / plywood, it might enhance appearance by introducing broad stripes – not present in veneer from fast grown Paulownia.' 'Yes- that's generally the case.' (UK) 'Possibly yes. It might even be different colour and more attractive, just different.' (Ireland) 'It requires more research to let this crop develop a bit more to see the timber potential of this tree. I wouldn't say at this time.' (Northern Ireland, UK) 'You see timber quality is a market defined variable. So for a musical instrument or kitchen things then not really an issue, the timber properties are not that critical. I mean you are not going to use Paulownia as a structural timber, it's not strong enough. So the qualities of Paulownia would look to be quite odd to most timber people, it is an unusual niche material.' (UK) 'It is better to look at products than just look at timber as a product then you get a lot of surprises. So just like optimal agroforestry management, optimal timber quality depends on product, they are not general.

	The buy-ins market is less critical of timber quality and in fact most issue under British conditions is moisture content and not timber density.' (UK)
Agroforestry Farmer (1)	'It is possible, but no experience at present' (UK)
Plant Nursery Manager (1)	'I am not sure if that will make an effect on the timber.' (Bulgaria)
Plantation Manager (2)	'Yes, definitely in Middle Europe the quality is higher than that grown in Asia.' (Germany) 'The wood will be of higher density and should attract a premium price' (UK/Northern Europe)

Question	*What is the expected or actual yield per Paulownia tree in cubic metres?*
Agroforestry Experts (13)	Don't know/No response given (77%) '150 m^3 from 200 stem/ hectare. = 0.75 m^3.' (New Zealand) 'I have no own figures, but according to the literature (in China) it is 0.2-0.6 m^3 per a 10 year old tree' 'You can be looking at 30 m^3 per hectare per year.' (UK)
Agroforestry Farmer (1)	'No idea at present' (UK)
Plant Nursery Manager (1)	'Between 0.7 and 1 m^3. But this is effective timber, without branches or bark.' (Bulgaria)
Plantation Manager (2)	'It very much depends on the clone, our clones are very *P. fortunei* dominated and they harvest around 1 m^3, so we are talking around 25 cm diameter and 1 m^3 timber. P. *elongata* for example is only 0.5 m^3 per tree but our clones have almost 1 m^3.' (Germany) '0.8 m^3 of usable timber per tree at 15 years of age' (UK/Northern Europe)

Question	**Agroforestry Experts and Agroforestry Farmer** *Do you know the current market prices for Paulownia timber (in cubic metres)?* **Plantation Managers and Plant Nursery Manager** *How would you describe the current market for Paulownia timber (good/acceptable/bad)? Do you expect it to improve?*
Agroforestry Experts (13)	Don't know/No response given (85%) 'High! US$100-500 per cu m depending on quality for making coffins / caskets, either as cut timber or panels or plywood. Ex

	Shandong. 1 cu m = 400 kg. Minimum 50 cu m. (1 container)' (UK) 'There used to be a set of shops in the UK called Reject Kitchen shops where you could get a lot of things for the kitchen cheaply. There used to be a lot of Paulownia items in that, spoons, little boxes, little shelves. I don't know where there were manufactured, probably outside EU. Market is vital; the best and most successful agroforestry systems are grown in partnership from the beginning, because of the level of complexity, the fact that what's going on is unpredictable to some extent by foresters or agronomists. The poplars for instance, you have a contract with a match producing company and they give you the materials and a guaranteed price. So for agroforestry to flourish that is the way forward. The idea of a farmer having to search around for markets is not really viable, haven't gotten the time or the expertise to do that. Far better to work from the other end, to find potential buyers and get them to issue contracts to farmers.' (UK)
Agroforestry Farmer (1)	'The market for all timber will improve in the long term' (UK)
Plant Nursery Manager (1)	'I don't know' (Bulgaria)
Plantation Manager (2)	'Good market prospective. I went to China and there are many companies that only process Paulownia woods and also many companies using Paulownia now in Europe. The prices are good and more and more companies are asking for it. I think the prices will increase like the markets for other woods.' (Germany) 'The current market in Northern Europe is non-existent. There are some users in the recreational (surf board and related) markets but the demand is not there because the supply is not available. It is a classic chicken and egg situation' (UK/Northern Europe)

Question	*What is the targeted selling price per cubic metre?*
Agroforestry Farmer (1)	'Do not know' (UK)
Plant Nursery Manager (1)	'Do not know' (Bulgaria)
Plantation Manager (2)	'That depends on the diameter and quality. We are expecting between €75-200 for the wood in Spain and between €100-280 for the wood in Germany. These are the prices from the company in China who are buying the wood for the processing company there.' (Germany)

	'£400/ m³ in 12 years' time (UK/Northern Europe)

Question	*Has the price for Paulownia timber risen or fallen over the last 2 years? Please describe. Are there price fluctuations?*
Plantation Manager (2)	'No public numbers available.' (Germany) 'Prices are difficult to establish. The Australian market is quite mature as is the American one but these sources are mainly of fast grown timber that does not attract a premium price. To make the enterprise of growing these trees viable the grower will almost certainly have to add value himself/herself by harvesting, machining and marketing because the Market in Northern Europe has no experience of this tree crop and will only offer the grower a low price until an established market and demand prevails' (UK/Northern Europe)

Question	*Do you see Paulownia increasing in popularity as a tree crop in your area over the coming years? Please describe why.*
Agroforestry Experts (13)	No answer given (38%) 'It will increase in suitable areas providing a good market can be found. As indicated earlier NZ's small population is a limiting factor' 'Yes, because there are several distributors of different Paulownia propagation materials and much information are available on the net (some pieces are even excessive/unreasonable) which motivate people to establish Paulownia plantations with a hope of a high return' (Hungary) 'It is not grown as a tree crop in UK to my knowledge. Yes, if someone develops the market. Both as an arable and livestock based agroforestry system. It needs a company such as the Poplar Tree Company to take the initiative and to guarantee a market to farmers – and for it to be adopted under EU CAP regulations.' 'Yes, because it is a multipurpose tree and climate change means every year conditions are better for it.' (UK) 'Yes - it is worth trying.' (UK) 'More and more people are showing interest. Besides the Croatian gentlemen, my boss forwarded to me another letter from someone who again thought he was going to be the first in Ireland to discover this species and he said he was interested in setting up trials. He said he reckoned that this would be a major species of tree in the future and was wondering for grant aid for trials and all of that.' (Ireland)

	'Probably not yet but depends on other studies and tests it might become more popular. I wouldn't think so at this point. It is becoming popular in other countries but here there is a cost-benefit question since it requires a lot of management compared to other species.' (Northern Ireland, UK) 'There could be, demand for quality timber is increasing.' (UK)
Agroforestry Farmer (1)	'Yes. Agroforestry will soon become of primary importance in climate modulation. And fast growing species such as Paulownia are essential' (UK)
Plant Nursery Manager (1)	'Yes, it is an interesting opportunity. You can find very shocking results online but actually it is not like that! I see now for the last 2-3 years there are a lot who want to work with the timber.' (Bulgaria)
Plantation Manager (2)	'I see the highest interest and increase from East Europe, Romania, Kosovo and Croatia. Every week we get many emails from these countries asking for plants buy. 90% of the interest comes from Eastern Europe. There are major governmental programs there that support planting Paulownia.' (Germany) 'Yes. But only if it is grown by people who take a professional approach' (UK/Northern Europe)

Question	*Do you see an increased demand expected in your focus area for locally grown high quality timber species?*
Agroforestry Experts (13)	No (23%) 'Possibly so in focus area but in NZ not unless impediments listed above can be overcome' 'Yes but demand does not necessarily equal economic opportunity' (UK) 'Yes, but it will have to compete with imports from the tropics and/or China on quality, quantity and price.' (UK) 'Yes, the demand is getting greater and greater and added interest in growing for quality.' (UK) 'We have lost a couple of timber species such as ash and Japanese larch due to *Phytophthora ramorum*, so I am hoping that if Paulownia proves successful we have lost two but may be able to replace it with another in time once we know a little bit more. The other thing about elm of course is that it would have been one of our main species for planting if it had not been for Dutch

	elm disease, as a result its very rare and the grower reckons that if he only grows a few, and that they will grow really fast and he can get premium prices. And that is what he is hoping to do with the Paulownia as well.' (Ireland) 'I think yes for sure, the demand is increasing. I think it is a matter of knowing the markets and also legislation is important. If you are in a region with an industry for processing wood products it would be good, but if you are in a region with small farmers where land is not productive and there is a water deficit it might be difficult to do.' (Poland) 'There could be, demand for quality timber is increasing.' (UK) 'Certainly in NW Europe yes, but England is a very peculiar place in terms of quality timber. Like I said it is an extremely conservative market. So in France the most valuable high quality timber is wild pear, *Pyrus Communis*. Here in England if we tried to sell that people would laugh at us. It is a funny thing that the high quality timber market is quite bizarre, most people would just prefer to carry on with imported tropical timbers like they are used to. I think because England was a great world power, we never worried about growing quality timber from our own sources because we knew we could always get it imported. The imports of trees into England has not changed for hundreds of years, we got rid of all our forests and we got a lot of high value agricultural land and we don't want to bring forests back and we are content to source our timbers elsewhere. That is the current situation, apart from a few enthusiasts who are trying to change things.'
Agroforestry Farmer (1)	'I cannot talk about that because I have lost contact with what is happening at the present time.' (UK)
Plant Nursery Manager (1)	'Yes it will. I can see for Bulgaria there are too many plantations cut without any new ones made. So after 10 years it will be a big problem and there is going to be a boom in starting plantations and Paulownia will be very well placed.
Plantation Manager (2)	'Yes' (Germany) 'Probably but there are still vast reserves of timber in the world and one other factor affecting the price is increased use of recycled timber' (UK/Northern Europe)

3.5.3 Case Study

Case Study 1 – East Sussex, UK

The farmer had no information at present about the market prices for Paulownia timber since it was still early in the growing cycle to see how long it would take for the trees to grow to maturity.

Case Study 2 – Ballydehob, Ireland

The grower had no information about the market prices for Paulownia timber since it was still early in the growing cycle to see how long it would take for the trees to grow to maturity.

3.6 What are the main factors preventing farmers from adopting agroforestry systems in NW Europe that Paulownia could mitigate?

3.6.1 Literature Review

The starting point to answer this research question involved identifying from the literature review general reasons why farmers have indicated reservations about planting trees in their farming systems. The focus within this broad subject was to identify the specific reasons where Paulownia could play a mitigating role to counteract them.

The general reasons found from a US study but relevant to this research why farmers are reluctant to adopt agroforestry as highlighted by Valdivia *et al*. (2012) were:

1. Lack of tree management experience
2. Cost of establishing/managing trees
3. Lack of technical information
4. Time required to manage trees
5. Too much effort required for clearing the land
6. Trees being an obstacle for farm equipment
7. Inadequate market prices for timber
8. Long term return on investment
9. Negative effect on arable cropping and livestock operations due to shading

Briggs (2012) also highlighted two other possible barriers preventing broad implementation of agroforestry systems specific to Europe:

10. Short-term tenancy contracts discouraging planting tree crops
11. Ambiguous CAP payments system whether tree planting affects subsidies

3.6.2 Interview/Written Responses

The following questions were only asked to participants involved in agroforestry irrespective of focus area. The expert's focus area country has been put in parentheses where this is not stated in the response.

Question	*What do you think are the main reasons why agroforestry in general is not more common in UK/NW Europe?* *If your area of expertise is not in UK/NW Europe, please explain for why this is so for your focus area.*
Agroforestry Experts (13)	'Lack of vision, lack of suitable markets.' (New Zealand) 'Lack of knowledge even about the existence of such systems and fear of the risk of shifting to another technology, legislative burdens (incoherent rules, legislative barriers, administrative burdens etc.)' (Hungary) 'Because most farmers do not understand trees and most tree people do not understand farming. Maybe the grant system too.'

	(UK) ‘Several issues come to bear such as tree roots blocking drains, tenants can often not plant trees, previously the CAP payment system was a deterrent, restricting future land uses (once a block of trees are planted on a farm there must always be trees to the equivalent area)’ (UK) ‘• Lack of understanding of the benefits amongst agricultural sector in the UK • Lack of understanding of the benefits amongst foresters • Lack of historical references for agroforestry - forestry and agriculture have been separate and distinct disciplines in the UK • Large scale mechanisation of agriculture which is easier without a tree component’ ‘As everywhere in the world, farmers cut down the forest / woodland to grow crops and keep livestock. As it is not yet a mainstream activity, farmers do not think of planting trees in the land that they or their forebears have cleared of trees!’(UK) ‘Agroforestry in UK isn’t seen as a major player, and a lot of research on tree species has been in conifers.’ ‘The problem I see is that farmers do not want to be involved with growing two crops on the same land. Certainly in Britain, farmers act very positively to the grant structure. I think the grants are changing now in Britain and certainly in Northern Europe and it must have changed quite a lot since I was involved in agroforestry. I think you should look very seriously at the grant situation. Also they have to look at the mechanisation of their land when it was taken into agroforestry. If you are looking at very big equipment in harvesting cereals for instance, they won’t fit into an agroforestry scene. You have to go down to equipment that is a lot smaller and possibly less efficient economically.’ ‘The agroforestry measure we have at the moment comes under forestry. As time go on we are looking for a continuous cover where the trees are thinned out but never clear-felled, this is what we are hoping for that a certain amount of light will be getting through.’ (Ireland) ‘One I think is there is no forestry culture in both climates compared to continental Europe. A second one I think is over many years the farming sector is driven by the conventional activities such as main crop production and grass for different types of animals. And forestry has been seen as a separate enterprise rather than a combination of agriculture.’ (UK)

	'Because of the legislation, it's not allowed for this land use, that the main reason. I think also farmers are difficult to convince to cultivate two crops than one on the same land unit, it's a question of business ideas that it's maybe competitive. We need more research and to spread awareness on that.' (Poland) 'Land tenure, other main issue is CAP subsidies. Until 2015 agroforestry was not eligible for subsidies. This has changed now and is now 100 trees per hectare in 2015.' (UK) 'I think the main reason is the CAP. The CAP does not present incentives for innovation so with the current stock of landowners who has preserved the wrong kind of people for managing land in a resilient way. As well as giving ridiculous subsidies it gives artificially high land prices so the people who want to do new things can't. There is tremendous interest in young people who want to get into resilient horticulture and agriculture but they can't because of land prices. On that note, that's a general European observation, but England is the worst in Europe since England refused to take the agroforestry option, so there is no incentive for a farmer in England but there are in Scotland, Ireland and France. England is a terrible place to do agroforestry because you don't get any of the grants.' (UK)
Agroforestry Farmer (1)	'No vision amongst farming leaders or politicians' (UK)

Question	*Do you see agroforestry becoming more widespread in UK/NW Europe? Please elaborate.* *If your area of expertise is not in UK/NW Europe, please explain for why this is so for your focus area.*
Agroforestry Experts (13)	No response (15%) 'Not unless impediments listed above can be overcome.' (New Zealand) 'Agroforestry is more widespread in SW-Europe than in Central Europe. Although, in the last years, thanks to the European agroforestry projects it became more known in the Central European region, and more and more farmers become aware of the benefits and establish agroforestry systems, it is a very slow process and takes decades until being widespread. I couldn't assess the figures of progress of agroforestry in SW-Europe, but assume that is more widespread today compared to 10-20 years ago.' (Hungary) 'Yes as the EU grant system bribes farmers to do more' (UK) 'Uncertain' (UK)

	'I would see the integration of trees in to farming systems becoming more widespread, although this may not be the sort of intimate tree/crop and tree/livestock mixes usually identified as agroforestry. This could include increased use of trees in farming systems for shade and shelter, mitigating water runoff and pollution abatement. This seems likely to be most evident in the livestock sector. In arable farming, annual cropping and the high degree of mechanisation seems likely to deter uptake. Adaption in horticulture (mostly for shelter) may become more prevalent as shelter is seen as important in reducing water loss.' (UK) 'There is increasing interest in agroecology in all its forms, so yes, I am quietly optimistic. There is a great need to "Mainstream Permaculture". It will only come about when the economics encourage it, and/or CAP requires it. There is extensive agroforestry in France and Spain.' (UK) 'There is added interest in it, yes.' (UK) 'I think agroforestry has increased in popularity and it is possibly being encouraged by the grant structure. Obviously you would also need to choose the right land. We would select it on Grade 2 and 3 listed soils, I don't think we would want to go into difficult land at all. It is challenging enough without struggling with difficult topography.' (UK) 'Yes-provided that it's sold via demonstration plots. Conditions will vary from country to country. There is definitely increasing interest and I receive inquiries about farmers wanting to plant fruit trees etc. I think it could be very big thing over time. I always felt with forestry there is so much land used just for timber and with the first thinning there is very little value, maybe just for firewood. I have a small plantation of timber (oak) and now after 20 years I can just start to thin but the diameter is so low that it can be just used for firewood and 20 years is a long time to lock up the land whereas with agroforestry farmers have the flexibility and can get in there and grow crops and there is more light and less pressure on the trees and they can take their time to grow. Compared to forestry, farmers can use the land in the short-term and that's the huge advantage that its very flexible' (Ireland) 'I hope so, but I have doubts that it will become more attractive

	in years to come. I will be inclined to think that more woodland or other types of planting trees will be more attractive to farmers than agroforestry. I hope I am wrong but it will take longer time for agroforestry to be established in UK and Ireland.' (UK) 'For Poland generally yes. It is my focus now how to improve this and one of my ideas is to spread it on organic farms because they can deliver innovative products. For energy it would be difficult because of legislation. For organic crops if we can reach farmers and other stakeholders we can reach it quite well provided it is adapted to local conditions. 'I hope so, there is increasing interest.' (UK) 'Yes, because of the momentum in France now at all scales, it has always been there on the small scale but now also on the bigger scale. There is actually a pecuniary effect that the English farmers will take a look at what the big French farmers are doing more than any research or advice in England. So it can have a big knock-on effect. There was this amazing statement in England on TV that the French were working on this big thing called agroecology and part of the agroecology was agroforestry and it was all happening in France and we should learn from it, and that was very interesting.' (UK)
Agroforestry Farmer (1)	'Monoculture has proved to be a failure. Use of trees to affect micro/macro climate is essential' (UK)

Question	*What do you think could be done by external parties (researchers, government and other organisations) to further promote agroforestry systems in UK/NW Europe?* *If your area of expertise is not in UK/NW Europe, please explain what could be done in your focus area.*
Agroforestry Experts (13)	'Communicate, communicate, communicate –applies worldwide' (New Zealand) 'There are several activities that may be useful but according to my experience the most effective way is to talk personally with stakeholders and show them effectively, by existing examples the economic and ecological benefits of AF. Then, when there are some pioneers, the fastest way of spread of a technology is when farmer learns from each other.' (Hungary) 'Long term funded trials are vital and also impossible with current national & EU funding systems.' (UK) 'Demonstrations with key farmers' (UK) 'We need to find systems and ways of integrating trees in farming systems which match the evolution from current

	systems, rather than imposing highly systematised alley cropping and similar systems. There is an enormous need to knowledge transfer and understanding of tree management amongst agriculturalists.' (UK) 'China- it is accepted they have no lands for forestry, hence the interest in agroforestry. However, even the Paulownia wheat agroforestry system requires continuous extension of its benefits to farmers to ensure the system is continued. It requires an organisation or company to take the whole input / production / marketing chain forward, including R & D / Innovation and Knowledge transfer in order to develop processing and markets for the timber produced with guaranteed minimum returns to farmers, plus organise all the inputs. That organisation then has to prepare and implement a whole "quality assurance scheme". It would also help to combine schemes for both the agricultural and the forestry components into a win / win scheme – such as forest fowls (eggs and meat) with the tree component. With high value timber, the organisation / company should develop local saw milling / plywood manufacturing – it doesn't need to be massive high tech' (UK) 'There are grants for agroforestry in Scotland but not in England. Lots of interest but there needs to be grants to make it happen. There has been lots of research done from 1988 but few have taken it on. Funding is getting harder for all forms of research. Unfortunately agroforestry is seen as the tail wagging the dog, i.e. very, very small. Focus needs to be on benefits, for example in Wales hills with trees had 67 times better infiltration of surface water and could save millions of pounds in concrete in holding water catchment.' (UK) 'I don't know. Grant structure change is already happening and being promoted by organisations that are in favour of agroforestry.' (UK) 'I have gone to a couple of events with EURAF and over the course of 2-3 days I was being bombarded with lots of scientific research about detailed interactions with wind, wildlife and all of that. But I think if agroforestry has got to work I honestly feel that the marketing needs to take place from selling of the concept far, far more than up to now. Up to now it has struck me as being more of an academic thing than a land use thing in that it seems there are a lot of people doing projects on it and very few people actually practicing it, you know on the ground. For example, no one here in Ireland had a real demonstration plot up to about four years ago. We set up an agroforestry plot about

	four years ago with ash and oak. But I find that if I talk about it to colleagues or to foresters it means almost nothing, it is hard to paint the picture for them. The best thing for them to do is to meet a farmer, a landowner who is actually producing animals and timber; its far, far better that a landowner is convinced of its worth and can see the productivity of it and they say it can be up to 50% more productive than pure forestry or pure agriculture and that's the sort of thing that will get farmers to take it up. But really now we have to get to the second stage to get to the point where we have learned an awful lot about agroforestry and its interactions with various different things, we now need to sell it to landowners and get them convinced because there are an awful lot of environmental benefits it intercepts, water runoff, nutrients, increases biodiversity, we have the research we know all these things and we know that climate change is coming. This is why it's so important for farmers to plant, but don't get me wrong there has to be lots more research since there is so much we don't know.' (Ireland) 'I think more engagement with the private sector. I think the private sector (farmers) has to be close to the forestry sector. And the agrifoods sector should be close to the research. I wouldn't include the policy; it is more between private sector and research.' (UK) 'I think including agroforestry in EU policy then we can convince governments and farmers this is a good thing to spread. We try to do this via EURAF is to also convince companies to engage in these products and activities. If it means on the country level, this should be spread by regional associations. We need to be engaged in more projects and case studies to show that it's working in some proper conditions. I think first we need to convince politics, then we convince farmers via experience.' (Poland) 'Provision of evidence to show increase in efficiency and productivity and impact on the environment, and also the demand for the products.' (UK) 'The other thing to think of in Europe is the subliminal effect of the CAP. That has completely ruled out any entrepreneurship in farmers and it has also preserved a set of people who should probably have moved out of farming. So the CAP effect has a very negative effect of resilience and adaptability in general. You got people to basically manage the grounds really, there is no great incentive for yield or quality, and it's all based on area. I think the most important thing is for the government to support innovation in business towards the green economy. So the idea

	to substitute all the high fossil fuel costs with low cost materials. So there should be grants for anyone who produces products to substitute plastic for anything to produce nuts and fruits, so linked to resilience. There should be incentives for business incubators, it should be driven by the markets but there should be incentives from the government to a green economy. The green economy should then steer towards innovative land use to people with more connection to land. Certainly not the other way around, with more money for research grants for people to find the use, it's the market that needs to be stimulated by incentives for a new green economy. Also, changes in the legal thing, changes in policy to stop the production of environmentally negative packaging and products. The model would be Germany such as their policies in renewable energy. You need the carrot and the stick. So policy and procedural reform towards resilience, taking into account about the forest footprint.' (UK)
Agroforestry Farmer (1)	'It comes from below that level, from farmers like myself experimenting. Knowledge feeds upwards, rather than downwards' (UK)

Question	*Would you recommend farmers in UK/NW Europe growing Paulownia as an agroforestry tree species? If yes/no, please describe why?*
Agroforestry Experts (13)	Yes – Provisionally (38%) Too early to say (15%) No response/opinion given (46%)
Agroforestry Farmer (1)	'Yes. It is a very important tree in agroforestry' (UK)

3.6.3 Case Study

Case Study 1 – East Sussex, UK

Farmer cited the following general reasons why he believed agroforestry is still not yet widespread in UK.

- Unclear rules whether trees qualify for CAP payments
- Lack of knowledge about trees among many farmers
- Concerns about mechanisation possibly complicated by trees

Case Study 2 – Ballydehob, Ireland

Grower cited the following general reasons why he believed agroforestry in general is still not yet widespread in Ireland.

- Little promotion about the benefits of agroforestry to farmers
- Concerns about subsidies and bureaucracy when getting trees established

4 Discussion

This section draws on the results from the research methods used in this study to assess the suitability of Paulownia as an agroforestry species for NW Europe. The findings of each respective research method have been discussed separately under the relevant research question set out to be answered at the beginning of the study.

4.1 What are the suitable Paulownia species/hybrids that can be grown in agroforestry systems in NW Europe?

4.1.1 Literature Review

The nine genotypes selected for the two UK sites, *P. fortunei* and *P. elongata* in Northern Ireland, and *P. elongata* as the only surviving species from the Shropshire site are from the same species commonly planted in China for agroforestry and for plantations worldwide due to their form and fast growth rate. One of the Spanish genotypes (PW-105) also had genetics from *P. tomentosa*, but nevertheless performed relatively worse than the others in terms of survival and growth the trials (Olave *et al.*, 2015).

It was gathered from the trials in Northern Ireland that there is no clear indicator of a species or hybrid that performs exceptionally well on a field scale, however the genotypes selected for both sites could not be considered to be optimal for this study's focus on agroforestry. The genotypes in Northern Ireland trial were sourced from Morocco and Spain, both countries with very different climatic conditions than the target site. It is likely that this was one factor to account for the poor results, whereas genotypes bred for a cooler climate would have performed better.

The seven Paulownia species grown on the Shropshire site were all propagated from seed which is not generally the favoured means of propagating Paulownia. Woods (2008) and Bergmann (2003) reported that stronger specimens are generally propagated from root cuttings, which is also the most common means of propagation in China as reported by Zhao-Hua *et al.* (1986) who stated that seed propagation is only recommended when sourced from strong specimens. It was surprising that only *P. fortunei* survived since it has the lowest tolerance for cold temperatures at 5°C to -10°C as per Zhao-Hua *et al*. (1986) which could be due to poor seed quality from the other species and not climatic factors accounting for their losses.

Finally, although the Northern Ireland trial has been informative as a local reference for growing conditions and possible limitations with Paulownia, its focus was on growing the tree for biomass purposes and not in an agroforestry context growing Paulownia as timber in wide spacing as per main aim of this project.

Both sites have been documented to have generally stronger winds and colder temperatures than many areas in the focus area of NW Europe and hence may not be considered representative of overall success.

4.1.2 Secondary Data Review

The secondary data review indicated that *P. tomentosa* has been the most commonly planted species as an ornamental tree in the NW Europe to date. *P. tomentosa* is the species registered in all the recordings in GBIF (2013), Monumental Trees (2016a) and 84% of the recordings in Tree Register (TROBI, 2016).

Two main factors would account for the prevalence of *P. tomentosa* in the focus area. First, this is the most ornamental species generally planted due to its form and attractive flowers. Second, this is also the hardiest species which can tolerate temperatures down to -20°C whereas the other two main species *P. elongata* can withstand -15°C to -18°C and *P. fortunei* from -5°C to -10°C (Zhao-Hua *et al.*, 1986).

Due to the hardiness of *P. tomentosa* and its recorded longevity in NW Europe, the secondary data review indicated that root cuttings or seed from strong genotypes within this species could be a good starting point for propagation material in broad scale agroforestry trials.

4.1.3 Interviews and Written Responses

More than half the agroforestry experts interviewed (54%) had no specific recommendation for a suitable Paulownia species in an agroforestry system for NW Europe. This could be attributed to no prior recorded experiments having been made with this species on a field scale in agroforestry for the focus area. The remainder of the agroforestry experts (46%) and the plant nursery manager (Bulgaria) interviewed recommended a suitable hybrid between *P. tomentosa*, *P. elongata* and *P. fortunei*.

This corresponds well with the literature review where it was noted that it is important to select a suitable species/hybrid for specific site conditions (Ayan *et al.*, 2003; Wenhua, 2001). One plantation manager (Germany) advised that the most suitable selection for Northern Europe would be a hybrid of *P. fortunei* and *P. tomentosa* and the other plantation manager with expertise in Northern Europe suggested a cold hardy hybrid would be optimal for the focus area.

4.1.4 Case Studies

The site in West Sussex (Southeast UK) had grown *P. elongata* from seed. Although survival rate was generally high at 90% there was variable growth rates and frost damage amongst the specimens which would most likely be linked to variable seed quality. The farmer's intention for the future was to take root cuttings from the strongest specimens instead of seed propagation. This is also the preferred method in China as per Zhao-Hua *et al.* (1986).

The site in Ballydehob (Southwest Ireland) had grown the following six species/hybrids:

- *P. tomentosa*
- *P. elongata*
- *P.* 'Shandong' (hybrid)
- *P.* 'Arctic' (hybrid)
- *P. catalpifolia*
- Unspecified sourced from Bulgaria

There were no specific species/variety that had performed exceptionally better than the others and the grower indicated it was hard to tell the difference between each tree once they were in leaf. The variety 'Arctic' was planted a year later than other varieties and the shipment had been delayed in customs which had affected the plants.

Although no specific hybrids have been identified as part of the research methods used, the overall trend in responses and observations indicate that the most likely optimal Paulownia species for NW Europe would be a hybrid between all or two of the main species *P. tomentosa*, *P. elongata* and *P. fortunei*. Root cuttings, container grown plants or bare-rooted plants would be the preferred propagation source whereas seed propagation from a single species would be comparatively more risky due to the uncertain end results.

4.2 What are the reasons why Paulownia has not gained widespread use in NW Europe on a commercial scale yet?

4.2.1 Literature Review

The scarcity of published literature on growing Paulownia on a commercial scale in the focus area confirmed that the species remains relatively unknown and it is likely that the lack of published information about it would explain the few current attempts to introduce it on a commercial scale.

The use of Paulownia in Central and Southern Europe in timber plantations in the nearest proximity to NW Europe has been a relatively recent occurrence since the 1990s and it is still relatively unknown in Europe as a species. The literature review however indicated that this is changing and that plantations and agroforestry sites are being established in closer geographic proximity to the focus area such as in Germany (Robinia Invest, 2015) and Poland (Paulownia Trees, 2016). The results and experiences of the only two identified trials in Northern Ireland (Olave *et al.*, 2015) and Shropshire, UK (Aspin, 2015) have been considered too recent to account for the low adoption of Paulownia in the focus area.

4.2.2 Interviews and Written Responses

Interview responses received from agroforestry experts confirmed the indications from the literature review that a main reason why Paulownia is not yet widely grown has been due to its novelty. 31% attributed its low adoption to the timber industry's focus on well-known species and 38% due to lack of awareness and research into its suitability.
A significant percentage linked its low adoption due to general factors such as CAP subsidies discouraging agroforestry. Invasiveness and frost were two other reasons, however these are also indirectly linked to lack of awareness since hardy Paulownia species do exist and there are management measures that can be taken to reduce frost damage. There are sterile clones available and the climatic conditions in NW Europe with low summer temperatures comparative to its native range would not be favourable to self-seeding.

The farmer visited in East Sussex (UK) cited two main reasons also mentioned by the agroforestry experts; that there have been no recordings of growth rates or suitability for UK and that many farmers would be hesitant to plant a little known species and instead prefer to plant what they know and others farmers are also growing.

The grower in Ballydehob (Ireland) also indicated that it was because the trees were relatively unknown as a commercial crop and that growers in Ireland preferred to plant species that they were used to.

The agroforestry farmer (UK) attributed this to a general lack of future thinking in agriculture. The views expressed by the agroforestry experts were confirmed by the plant nursery manager (Bulgaria) interviewed who also indicated that this was likely due to the timber industry's preference for native species such as oak and pines is big and that it is hard to compare these to Paulownia since its timber has different properties, some positive and some negative.

The plantation manager (Bulgaria) noted however that its usage is increasing in Europe and there is increased demand, however this response was specific to Central and Southern Europe, not the focus area.

One plantation manager (Germany) indicated that it could be because of legal issues that short rotation forestry was not possible in Europe until 2010. Another plantation manager with experience in UK/Northern Europe mentioned that its management requirements do not make it suitable for conventional forestry due to Paulownia trees requiring individual attention due to annual frost damage and the skill required for this pruning which few people possess in NW Europe. However, there is documentation available describing the pruning regime (Zhao-Hua *et al.*, 1986) and this personal attention would possibly be easier in an agroforestry setting where the density per hectare is much lower at less than 100 trees (5 m x 20 m) compared than a forestry setting at about 600 trees per hectare (4 m x 4 m).

The reason for Paulownia's limited use to date could not be due to its species characteristics where it appears to meet most of the criteria that the agroforestry experts mentioned as an ideal agroforestry species for NW Europe in the interviews and written responses:

- Low competition with grass and arable crops
- Fast growth
- Climate resilient, adaptable
- End market
- Valuable timber
- Multifunctional
- Non-invasive
- Fodder value
- Little shade
- Compatible with mechanisation
- Environmental benefits
- Coppice ability

The main attributes on this list where Paulownia may not qualify is fast growth, end market and non-invasiveness and these issues will be addressed in discussing the separate related research questions.

The primary attribute noted by the agroforestry farmer (UK) as being 'reasonably fast growing and vertical with not too much branching…deep rooting to compete for moisture in summer' all apply to Paulownia based on extensive usage in agroforestry systems in China.

As a result of these positive attributes for agroforestry, 53% of agroforestry experts indicated that they would like to pursue further studies about Paulownia in the focus area with slightly less than half (46%) indicated negative or provided no response. The lack of responses could also be attributed that Paulownia was not a species the experts had any experience in working with.

The plant nursery manager (Bulgaria) planned to expand its Paulownia production in response to the increasing demand. The plantation manager (Germany) indicated that his focus for future plantations would be in Spain where timber production is more economical. This same sentiment was expressed by the plantation manager (Northern Europe) that land was too expensive in UK for forestry. However, the aim of this study was focused on agroforestry where a farmer would use their existing land to establish alley crops and not solely for timber production and consequently the plantation managers' preference for

Southern Europe cannot be considered as an indicator that Paulownia is not suitable for an agroforestry setting which would be managed differently than a plantation.

The current lack of information about Paulownia available for prospective growers was also confirmed to be a primary reason accounting for its low adoption. 38% provided no response when asked if enough information was available to prospective growers but the remainder (62%) indicated there is a gap in knowledge. It was noted however the experience accumulated growing Paulownia in China over the last 2600 years and more recent information from the US should make it possible for EU growers to adapt to local conditions if such information became more widely available.

Participants were asked if there were any legislative barriers preventing farmers from adapting an exotic species like Paulownia compared to a native species for commercial use. The answer was negative for New Zealand, Germany and positive for Hungary and Poland, with the following indications given for certain areas in the focus area.

Northern Ireland (UK): No barriers mentioned
Scotland (UK): Compliance would need to be checked via WANE **(**Wildlife and Natural Environment (Scotland) Act 2011**)**
England (UK): To be checked with Forestry Commission
Ireland: Species would need to be on an approved timber list for grant aid

No participants were interviewed with experience in Denmark, Netherlands and Belgium so these countries would need further review.

However, it was also mentioned that many Paulownia nurseries are selling sterile clones so this would be a possible way to address invasiveness concerns by putting specific sterile cultivars on the approved list.

In summary, the main reasons why Paulownia is not yet a common commercial species in NW Europe is less due to its lack of proven suitability, inherent species characteristics and possible invasiveness concerns but more to its novelty and little known potential and awareness amongst growers.

This is beginning to change however in recent years since it meets many of the requirements for an ideal agroforestry tree as has been recognised and confirmed by a majority of agroforestry experts who would like to pursue further trials and studies into its potential use in NW Europe.

4.3 What are the possible risks in planting Paulownia on a wide scale in NW Europe?

4.3.1 Literature Review

It appears from the literature review that countries in close geographical proximity to the focus area however with a continental climate with warmer summers such as Germany, Czech Republic and Austria have had few recorded occurrences of self-planted Paulownia seedlings and most of these have been confined to urban areas where temperatures would be warmer than in rural areas. Belgium is the only country in the focus area where a study has been carried out about the possible invasiveness of Paulownia (Verhaeghe, 1999) and it was reported some trees had been found in disused waste grounds in urban localities but that naturalisation has not been confirmed yet. It must also be noted that *P. tomentosa* has been planted in parks and as a street tree in NW Europe since 1830 (Hu, 1959) and it has not become naturalised. One main reason for this would be linked to its germination requirements of intensive light conditions and warm temperatures (Zhao-Hua *et al.*, 1986) which is not so common in NW Europe.

This preference for urban settings is indicative that Paulownia prefers a warmer microclimate and is therefore not deemed to be a nature conservation issue yet in continental Europe. Nevertheless, the increased occurrence of self-seeded plants as reported by Essl (2007) could indicate that a gradual spread into more natural habitats should be closely monitored in light of climate change.

4.3.2 Interviews and Written Responses

Agroforestry experts were asked about the possibility of Paulownia becoming invasive in NW Europe and 69% indicated that this is a possibility with the remaining 31% provided no response. The agroforestry farmer (UK) reported that his plants were too young to flower. The plantation manager (Germany) had not noticed any occurrences of self-sown plants on their sites and the plantation manager (Northern Europe) responded negatively to the possibility of invasiveness. The plant nursery manager (Bulgaria) indicated that Paulownia could possibly become invasive for the warmer parts of Europe.

In order to determine the likelihood of invasiveness, interviewees were asked whether the trees would flower yearly. 23% responded that the trees did flower yearly, 46% provided no response, 15% indicated negative due to the trees being too young and 15% indicated negative without comments. The agroforestry farmer (UK) reported that the trees had not yet flowered since they were planted in 2009 and the plantation manager (Germany) confirmed that trees usually flower in the fifth year of planting. The plant nursery manager (Bulgaria) reported that flowering depends on the cultivar used and that the clones sold are often sterile but that this needs to be monitored carefully.

In summary, it would appear from the literature review and interviews that there is a low risk of invasiveness due to climatic conditions in NW Europe, even more so if sterile clones were to be planted as general practice. Invasiveness however could be more likely to be a possibility in later years due to climate change so this is another factor to be taken into consideration.

4.4 Where are the locations growing Paulownia in NW Europe and what can be learned from these sites?

4.4.1 Literature Review

The literature review for this research question was limited to the only two identified sites with published information available.

Hillsborough, Northern Ireland UK

Northern Ireland could be considered to be one of the most difficult locations growing Paulownia in the study focus area due to its site and climatic conditions.

In addition to all the reasons cited by Olave *et al.* (2015), namely exceptional cold winters in 2010-2011, strong winds, heavy soils and poor drainage, Northern Ireland has lower summer temperatures and less sunlight than most of the focus area, so therefore a combination of these climatic factors could be attributed to why the growth rates were not as per expectations.

Species and hybrid selection was also confirmed to be a main factor with significant variances in growth and survival rate between genotypes, which corresponds with the findings of Bergmann (2003) from trials in USA and in Turkey from trials reported by Ayan *et al.* (2003).

It would therefore be important to carefully select optimal site conditions and an appropriate hardy species/hybrid for the given site to cope with harsher climatic conditions than its native range.

North Shropshire, UK

The Paulownia species planted on the silvopastoral site in Shropshire did also not perform up to expectations. One likely reason for this is the propagation method via seed which as per the literature review (Woods, 2008; Bergmann, 2003) results in variable quality. In China this is only done from superior phenotypes as stated by Zhao-Hua *et al.* (1986). Interestingly, the *P. tomentosa* survival was reported to have had the poorest performance although this is the hardiest species and this could be attributed to seed quality since mature *P. tomentosa* specimens exist as ornamental trees throughout NW Europe.

The seven species in the trial was not mentioned except that the only species that survived was *P. fortunei*. The severe losses were reported due to woodpecker damage in the cold winter of 2010-2011. The cold damage was reported to be likely due to the fact that the site often has the coldest lowland temperatures in the UK (Aspin, 2015).

Additionally, the site was also not sheltered from the prevailing western winds, which is another likely factor for the slow growth and low survival rates. The site also has generally low rainfall with insufficient moisture for good grass growth in midsummers.

In summary, the propagation method/origin of the Paulownia specimens and the climatic and site conditions for these two sites could be considered to have significantly below optimal growing conditions compared to the general conditions in the focus area. The small sample

of field scale sites identified in the literature review (2) would be insufficient in themselves to provide a general overview about suitability although the reasons why the trials did not perform as well as expected could be considered instructive to ensure that a careful propagation method/nursery stock and site is chosen in light of the requirements of the Paulownia species.

4.4.2 Interviews and Written Responses

A review of the responses received regarding experiences with Paulownia from participants in NW Europe have been categorised in four main sections.

- Ecological Requirements
- Agroforestry Practices
- Planting and Growing Techniques
- Paulownia Products and Services

Ecological Requirements

There were differing views expressed by agroforestry experts about whether it was difficult to establish Paulownia on a site. The trial in Northern Ireland stated that the trees were quite demanding in terms of preparing the ground and also handling the plants because they were quite delicate at a young age and had to be handled more delicately than conventional trees planted locally.

Recommendations included planting trees that are over 2 years old to minimise frost damage, fencing for livestock and ensuring that the site is well-sheltered to provide wind protection. The agroforestry farmer (UK) however reported no difficulties in the initial establishment. Survival rates in the first year were considered high in NW Europe as per the agroforestry experts, but it was noted that this is dependent on species and hybrid; this was also confirmed by the agroforestry farmer (UK) who had varying success with different species.

It was generally anticipated by agroforestry experts that the cooler summer temperatures in the focus area compared to its native range would mean slower growth rates. One recommended mitigating measure to increase soil temperatures was putting black polythene mulches under the trees.

In terms of wildlife benefits, none of the agroforestry experts interviewed or the agroforestry farmer (UK) had confirmed sightings of bees or other beneficial wildlife around the Paulownia trees, although the species is well-regarded as a nectar source for bees in China. This would most likely be due to the young age of the most trees planted commercially and that the flowers are on the higher branches and thus not noticeable. It was confirmed from the NZ sites however that bees and some nectar-seeking bird species were attracted to the trees which indicates that this could also likely be a bee plant in NW Europe when they flower around May. The addition of polythene mulch was also reported to attract beneficial wildlife as a result of the accumulated litter under the trees so this would be a side benefit in addition to increasing growth rates and weed control.

In terms of resistance to cold temperatures and frosts, several of the agroforestry experts interviewed mentioned that although Paulownia species could withstand cold winter temperatures with *P. tomentosa* in particular down to -20°C, the occurrence of frosts during the growing season especially in spring can kill the lead stem, although the tree would then

regrow again from the root system. The resistance to frost however varies on the genotype and the site in Northern Ireland indicated that strong winds were likely to be a bigger cause for concern than late frosts. There were several preventative measures for frost identified in the literature such as painting the stems with lime and using nylon wrapping (Zhao-Hua *et al.*, 1986) and polythene mulch would also help moderate the temperature. Site placement would also clearly be a factor where a south-facing slope with shelter would help mitigate the risk of frost and winds.

Agroforestry Practices

All the responses received from the agroforestry experts and farmer with specific experience in NW Europe and a comparable climate (New Zealand) were in agreement that there should no barrier to growing Paulownia in an organic system. The only agroforestry farmer (UK) has been growing Paulownia as a trial on certified organic land since 2009.

All the sites identified were growing grass between the trees. One site (UK) had cattle grazing near the trees and intention was reported from another site (Ireland) to introduce sheep when the trees were taller. No site data was available on the potential of intercropping with arable crops commonly grown in NW Europe since such systems have not yet been identified or implemented.

The tree spacing on both sites could not be considered indicative for general agroforestry practices in NW Europe since the site in Northern Ireland at 1.8 m x 1.8 m was for biomass purposes and the site in Shropshire had less than 10 trees on 8 hectares.

There were no specific benefits mentioned to growing Paulownia in a local agroforestry setting reported by either the experts or the farmer (UK) with 66% not providing any response and the farmer indicating that the trees were still too young.

The only specific agroforestry site (UK) reported that the cattle browsed the Paulownia leaves occasionally but that they were not considered as palatable as many other tree species. This corresponds with the literature review from experiences abroad (Barton *et al.*, 2007) where Paulownia have been recorded as a source of livestock feed in China and the agroforestry experts interviewed also confirmed the benefits of using the leaves as fodder. This could be considered a main reason to introduce Paulownia in a silvopastoral system due to their high protein content at 22.6% (El-Showk and El-Showk, 2003) compared to the other common NW European fodder tree species reported by Luske and van Eekeren (2014) as indicated in Table 1.3.

Experiments from abroad also indicate that in systems without livestock, Paulownia leaves provide useful mulch and nutrients to feed the subsequent arable crop (Mughal and Jalbani, 1997).

In terms of managing the understory recommended by the agroforestry experts, 33% provided no opinion, 33% recommended mowed grass and 33% advised plastic mulch. The agroforestry farmer (UK) recommended permanent grass/clover as the understory.

Management measures recommended by agroforestry experts interviewed were the following in the early years of planting:

- Coppicing and pruning
- Grass/weed control first two years.

- Staking

Pruning was also confirmed in the literature review to be particularly important to ensure a straight trunk if the end market was intended to be for timber and detailed instructions by Zhao-Hua *et al.* (1986) are available based on best practices in China.

The main factors for good growth rates were identified by agroforestry experts to be the following:

- Sufficient moisture in summer
- High temperatures (soil in particular)
- Wind protection
- Deep and well-drained soils
- Soil fertility
- Neutral pH

The agroforestry farmer (UK) highlighted sufficient moisture in summer as the main factor. These responses generally correspond with the literature review findings, although it has also been noted by several sources that Paulownia could grow well on nutrient-poor soils (Hall, 2008; Woods, 2008; El-Showk and El-Showk, 2003).

General management advice from agroforestry experts interviewed to growers included the following core factors to be mindful of:

- Ensuring there is wind shelter
- Planting at suitable topography – Do not put at bottom of a slope due to colder air
- Selecting a sunny site
- Determining market for the timber before growing
- Pruning/Management required for maintaining good form for timber
- Planting in deep and well-drained soils
- Selecting suitable genotypes for focus area

Possible drainage problems on sites prone to waterlogging in the focus area could also be mitigated by planting the trees on ridges as is commonly done in China as stated by Zhao-Hua *et al.* (1986) and in Australia (TGG, 2011a).

With regard to the management, agroforestry experts were asked for their reviews whether Paulownia could be considered as a low/medium/high input crop and the results were 50% indicating high input and 50% indicating low input with the following justifying comments.

Low Input
-No fertilisation needed in normal soils
-Timber relatively easy to cut, hence easy pruning
-Low input if right varieties are chosen

High Input
-Considered high input for NZ
-Time is required to obtain good growth in early summer and this requires intensive management

-Trees will grow far apart in an agroforestry system and hence a lot of pruning required
-High input compared to the species in Northern Ireland that perform better with less input

The agroforestry farmer (UK) indicated that the trees planted were low-input, however his main crop was perennial grass/clover and there was not indicated any intention to manage the trees for timber.

The plantation manager (UK/Northern Europe) indicated Paulownia was a high-input tree crop for high quality timber due to its pruning requirements in the first 6 years.

When asked about the preferred propagation method, all the agroforestry experts interviewed were in agreement that root cuttings from strong genotypes with good form were recommended for timber purposes. Seed propagation was considered risky with variable quality and was not recommended. However, the agroforestry expert in Northern Ireland specified that container plants from tissue cultures performed better compared to root cuttings when planted on the local site.

The literature review specified one possible disadvantage to root cuttings compared to seed propagation as noted by Zhao-Hua *et al.* (1986) was that the roots tended to be better developed in seedlings compared to seedlings propagated by root or stem cuttings with faster growth and stronger trees with less susceptibility to heartwood-rot. A strong root system would clearly be an advantage on sites with strong winds, but it would seem that the advantages of root cuttings outweigh this advantage for the focus area where the greater priority is for stronger specimens to withstand the climatic conditions.

The specimens planted by the agroforestry farmer (UK) were all propagated from seed which could be a likely factor in explaining why the survival rate for the various species was generally low.

Planting and Growing Techniques

33% of agroforestry experts interviewed reported occurrences of diseases in local specimens and 66% did not. *Armillaria* (honey fungus) was reported in NZ although this was not commonly found on Paulownia and no preventative measures were tried. This fungus is also present in NW Europe and can affect many native tree species as well. There was another report of a disease affecting a tree in a park in Canterbury (UK) but no further details were available. No mention was found about the major diseases commonly encountered with Paulownia in China, in particular Witches Broom. The agroforestry farmer (UK) had encountered no disease problems although it was noted that the trees were still young.

In terms of pests encountered, 17% of agroforestry experts had encountered pests with Paulownia and 83% had not. The only occurrence of pests was from one agroforestry expert in NZ, where the main insect affecting Paulownia in NZ is the endemic ghost moth (*Aenetes virescens*). There are species belonging to the same *Hepialidae* family in the NW Europe and hence there exists a possibility this would affect trees planted in the focus area, however Barton *et al.* (2007) reported no serious damage to the trees planted in New Zealand. Experts and growers outside the focus area reported damage to young trees from deer, rabbits, voles and pigeons which could also be expected to happen in NW Europe hence protection in the early years would be advisable.

The expected time frame from growing to harvest for timber differed widely amongst the agroforestry experts interviewed ranging from 7 years to 30 years. The high estimate of 30 years still compares favourably with the optimum rotation age for other common timber species grown in NW Europe as noted in Table 4.1.

Table 4.1 – Rotation age for timber species in UK

Species	**Rotation age in years**
Ash	90
Beech	120
Birch	50
Cherry	70
Larch	50
Oak	150
Paulownia	**30**
Pine	60/70
Spruce	50/60
Sweet chestnut	90
Sycamore	75

(Adapted from Richards *et al.*, 1988)

Agroforestry experts were asked about expected growth rates per year in NW Europe and it was noted that the growth rates were far below the optimal growth rates recorded in China and warmer countries at over 2 m a year. In Northern Ireland, the best-performing specimens reached 2.1 m in height after three growing seasons, which was much less compared to other species grown locally for biomass such as eucalyptus and poplar. It was also expected that the growth rates in NW Europe would likely be less than in NZ since growth is dependent on warm summers with rainfall greater than 50 mm per year. Based on NZ experiences, a tree could reach 70 cm diameter in 12-20 years.

The agroforestry farmer (UK) reported that the *P. fortunei* specimens grew around 40 cm/year once established, however this could not necessarily be considered indicative based on one site and the propagation source from seed.

Paulownia Products and Services

Interviewees were also asked to provide any positives or negatives about Paulownia outside the topics covered in the interview.

Positives

- High potential for the development of useful medicines and possibly anti-aging properties
- Leaves remain green when they fall, can be eaten by cattle and may have anthelmintic properties
- Quick growing tree that can provide a return to farmer relatively quickly
- Timber is stable and moisture free compared to other trees and hence need less drying and processing and be sold quicker
- Multipurpose tree that should not be considered as a single product
- C4 species that require less nutrients than other tree species

- Unique timber properties not found in other species
    - Light weight and strong
    - High proportion of cross fibres
    - Relatively fire-resistant
    - Anti-warping/twisting
    - High structural strength
- Potential for bio-remediation and erosion control

Negatives

- Potential for catastrophic disease incidence.
- Species investment in terms of management

The agroforestry farmer (UK) had no specific positives or negatives indicating that it was too early to tell based on the age of his trees.

All the above positive attributes were also identified in the literature review from various sources, although further research is still required for the medicinal properties and it remains to be determined whether the tree would be quick growing under field conditions in NW Europe. However, even if Paulownia is slow-growing, this would likely result in higher quality timber and it yields many other useful products and services as highlighted in the literature review.

4.4.3 Case Study

Case Study 1 – East Sussex, UK

The results of a field scale trial indicated that *P. elongata* could grow to a significant height of up to 1 m a year with a high survival rate of 90% over two growing seasons. Frost damage however was a common occurrence and growth rates also varied between specimens. The sandy soil type and warmer climate compared to Northern Ireland and North Shropshire (UK) is also a likely factor indicating why the growth rates were higher on this site, even under little management since establishment. It was shown that height could vary between specimens propagated from seed; however the seed source being from Lithuania could be a factor explaining why these specimens performed better than the genotypes sourced from Spain and Morocco as per the trials reported by Olave *et al.* (2015). Although initial results appeared generally positive, two growing seasons however would still be too early to assess long term viability of the trees especially considering that the 2014 and 2015 winters have been comparatively mild in the UK.

Case Study 2 – Ballydehob, Ireland

The site at Ballydehob indicated that tree growth of around 1 m a year per growing season is possible with some specimens reaching 4.8 m in height after three growing seasons especially considering that the latter two were colder than expected. Site placement rather than species/varieties had a greater effect on growth rates with the trees nearer the windbreak benefiting from the warmer microclimate. This observation matches the experiences in China as reported by Woods (2008) and Barton *et al.* (2007) and with poplar typically planted as the first wind barrier on exposed sites.

Cool spring temperatures were believed to the limiting factor where a minimum of 15°C would be required to allow the trees a good growing season.

Paulownia trees appeared to be compatible with silvopastoral systems in the focus area since no damage was reported from the sheep. The sheep would also eat the leaves when they were fed to them and the grower's pigs were also reported to eat the fresh leaves with satisfaction.

The grower was generally positive about the performance of the Paulownia trees as per the initial growing season but indicated that long term success for the site was too early to indicate based on the last two seasons growth.

4.5 Does a market for the yield (timber) currently exist in NW Europe?

4.5.1 Literature Review

There was no indication from the literature review that there is a significant local market for Paulownia timber in NW Europe at the present time. However, the projected global trend of population growth indicates that there will be an increased global demand for hardwood worldwide. The expected rise of China as the world's biggest economy could indicate a possible lucrative export market for high quality Paulownia timber due to little available supply for high-grade timber in China or abroad. The slower growth rates in NW Europe could fill a niche for this market to the high end of the market in China with the expanding middle class as per the Chinese government's aim to expand consumption percentage in GDP from 36% in 2005 to 50% by 2025 (Woetzel *et al.,* 2009). It was identified in the literature review that the Paulownia trees grown on plantations in the USA and Australia were unlikely to meet the high specifications of the Japanese market and hence NW European growing conditions may be more favourable. However, there is no guarantee that exporting countries will continue to find a ready market for Paulownia in the Far East unless they satisfy requirements at the upper end of the market.

On a European level, high quality timber produced sustainably on a local level would also be expected to increase due to the recent occurrence of ash dieback and ongoing tropical deforestation restricting imports and therefore Paulownia as a species could possibly fill this gap in suitable areas (El-Showk and El-Showk, 2003; Paulownia Reforestation Project, 2001). Compared to other fast growing timber species such as eucalyptus and poplar, Paulownia produces the highest quality timber (Paulownia Reforestation Project, 2001). It was reported by one grower in Romania that Paulownia wood is in demand by Italian furniture makers reportedly paying up to €700 per m³ (Paulownia Development, 2016).

These trends indicate there could be a potential for a niche market either internationally or regionally to be developed for NW Paulownia growers, albeit with some uncertainty. In case of negative price fluctuations in a given year, farmers could decide to leave their crop standing and it would still increase in value, which would not be possible for an annual crop.

Price estimates identified in the literature review were highly variable and quoted across many different European countries and none within the focus area. The closest geographic location was Germany with a plantation grower Robinia Invest (2015) indicating prices ranging from €312 to €628 per m³ at harvest at Year 12 with an estimate of 0.6 m³ per tree under plantation conditions.

Therefore, if the minimum of 50 trees are planted per hectare (5 m x 40 m spacing), it would be possible to obtain a yield 30 m³/tree of timber with a gross yield ranging from €9360 - €18,840 per hectare after 12 years. CAP regulations would allow up to 100 trees per hectare to remain eligible for subsides therefore if the trees were planted at 5 m x 20 m spacing, the gross yield would be €18,720 - €37,680/hectare after 12 years.

Furthermore, farmers may have a competitive edge in this market over plantation growers; as per reports on the intensive management of the agricultural crops in the intercropping system based on the alley cropping system in China could provide better growing conditions for Paulownia than in a pure Paulownia plantation Zhao-Hua *et al.* (1986). This was also confirmed in a report by an Australian grower TGG (2011a) that Paulownia establishment is

similar to agricultural operations following ploughing and cultivation resulting in better performance than under plantation management. Consequently it could be reasonably expected that the trees would also grow faster in an agroforestry system in NW Europe than in a plantation system.

4.5.2 Interviews and Written Responses

54% of the agroforestry experts interviewed had no information about whether there was a local market in the EU for Paulownia timber.

There were indications given about some niche market possibilities in France, Germany and Italy for furniture, kitchen items, surf boards and musical instruments. However, the main market for the timber was in China and Japan. One expert noted that Paulownia wood is relatively easier to work with than oak and once its qualities become well-known in Europe there could be a potential for a big local demand. It was also mentioned that all new buildings in China used Paulownia based veneer for fixed furnishings. Since the Chinese middle class is rapidly increasing, it could be reasonably expected that an export market could exist in the near future for high quality timber produced in Europe.

Experts in UK generally and Scotland specifically indicated that would be no local processors willing to buy Paulownia wood due to the conservative nature of the UK local timber market, but that possibly a market could be developed for veneer in plywood manufacture.

It would appear that as per the US experience the initial market could be for niche products made in Europe since there is no demand for mass production of the timber.

The export market would need to be explored further for China and Japan, but it is too early to tell if quality of the timber produced in NW Europe would meet the high specifications expected by those countries to obtain premium prices. There were many references found on www.alibaba.com (Chinese e-commerce website) with containers of Paulownia timber produced in China for export where the prices range from US$300 - $980 per m^3.

The plant nursery manager (Bulgaria) advised that the end market for Paulownia from the plantations in Southern Europe he was aware of was in the EU (Italy). The indication of a market in EU was confirmed by the plantation manager (Germany) who had also secured an end market in the EU, but noted that the biggest market for Paulownia wood is still in China.

In response to the question whether the slower growth rates expected in NW Europe would improve the quality of the timber, 38% had no response, and the remaining 62% indicated that generally this would be the case, depending on ‘quality’ as defined by the end market. However, it was also noted that timber quality is also dependent on the species/varieties chosen and the management of the trees. Since no records have been found of the timber quality for existing trees harvested in NW Europe, it is not possible to confirm that the quality would be higher.

This was confirmed by the agroforestry farmer (UK) who indicated this would be possible but there was no proven experience of this at present. The plant nursery manager (Bulgaria) indicated he was not sure that slow growth would have an effect on the timber, whereas the plantation manager (Germany) confirmed that the quality of the Paulownia timber in Central Europe would ‘definitely’ be of higher quality than the timber grown in Asia with the same confirmed by the plantation manager with experience in UK/Northern Europe.

In terms of expected or actual yields in m³, 77% of agroforestry experts did not know, but the remainder provided indicative figures between 0.2 - 0.6 m³ for a 10 year old tree. The plant nursery manager (Bulgaria) estimated between 0.7 and 1 m³ per tree as effective timber, without branches or bark. The plantation manager (Germany) stated that the yield would be very dependent on the clone, and that for example *P. elongata* typically could yield 0.5 m³, but certain clones dominated by *P. fortunei* could yield up to 1 m³.

In response to knowledge about the current market prices for Paulownia timber, 85% of agroforestry experts had no information. One estimate was given of between US$100-500 per m³ as per container sales from China. It was highlighted by one agroforestry expert (UK) that it was important for successful agroforestry systems that a market had to be determined prior to growing the timber since farmers would not have the time to search for a market. The agroforestry farmer (UK) indicated that all timber prices could be expected to rise in the future, which also corresponds with the literature review findings.

This was also confirmed by the plantation manager (Germany) indicated that the market prospective was good. He had noticed that many companies are presently processing only Paulownia wood and also many companies in Europe are now starting to use Paulownia and that demand is increasing. The targeted selling price for the wood produced was between €100 – €280 for wood produced in Germany and €75-€200 for wood produced in Spain. These estimates for Germany are significantly lower than the ones stated by another German plantation Robinia Invest (2015) which indicated prices from €312 to €628 per m³.

The plantation manager (UK/Northern Europe) summarised that 'the current market in Northern Europe is non-existent. There are some users in the recreational (surf board and related) markets but the demand is not there because the supply is not available. It is a classic chicken and egg situation.'

There were varying opinions expressed amongst agroforestry experts whether Paulownia was likely to become more widespread as a tree crop in their respective focus areas over the coming years with 38% providing no views on this. It was mentioned that for New Zealand the small population was a limiting factor but that increase is likely if a suitable market could be found.

On a general note, timber prices have been increasing worldwide and Paulownia has several main advantages being a multipurpose tree producing high quality timber and that more people are starting to show interest in growing the species, for example in Ireland. Its popularity in NW Europe could also possibly increase as agroforestry moves into the mainstream and since climate change could mean more favorable growing conditions for the species.

Other agroforestry experts were not positive about its increasing popularity in the focus area since there is no market for the timber at the moment and that it would be a cost-benefit issue since Paulownia requires a lot of management compared to other species. Plantation growers were in agreement that Paulownia requires a high degree of management to produce quality timber and farmers would need to be mindful of this before planting with the expectation to harvest quality timber. Nevertheless, managing 50-100 trees per hectare in the initial years of establishment until the trunk size reaches the required height would involve less work than closely spaced trees in a monoculture planted at 600 trees per hectare.

It was noted by the plant nursery manager (Bulgaria) that there are many unrealistic figures and expectations for Paulownia available online and that the reality is quite different, however he confirmed that in the last 2-3 years there have been more contacts from customers who want to work with the timber. The plantation manager (Germany) verified this trend that he receives many contacts every week from East Europe (Romania, Kosovo, Croatia) where 90% of the interest comes from at present, which is likely due to governmental programs there supporting planting Paulownia.

77% of agroforestry experts interviewed expressed likelihood that there will be an increased demand for locally grown high quality timber species in the future. It was highlighted however that increased demand does not necessarily equal economic opportunity and that Paulownia timber produced locally would need to be competitive in quality, quantity and price with timber produced in China or more tropical climates.

Another main reason for the expected increased demand and possible niche for Paulownia in NW Europe is that the focus area has recently lost two major timber species (Elm and Japanese Larch) due to Dutch Elm Disease and *Phytophthora ramorum* and that ash trees are currently in decline due to ash dieback across the continent and now occurring in UK as well. The plant nursery manager (Bulgaria) also expected increased demand in Bulgaria due to lack of replacement for existing cut plantations and Paulownia could play a major role in the future.

In summary, the market for Paulownia timber in NW Europe appears non-existent at the present time but there are several indications for increasing demand from international and local markets for a possible niche to be occupied in the long-term perspective. Farmers would need to have realistic expectations about prices and the effort required in management to obtain a successful timber harvest.

Nevertheless, Paulownia offers many products and services as covered in the literature review that even if there is no market for the timber, the trees could still play an important role to provide livestock fodder and ecosystem services with little adverse impact to the livestock and arable farming systems and should thus be seen as a valuable ‘multi-purpose’ species.

4.6 What are the main factors preventing farmers from adopting agroforestry systems in NW Europe that Paulownia could mitigate?

4.6.1 Literature Review

Paulownia species have several attributes that could possibly address some of the barriers to agroforestry adoption as identified by Valdivia *et al.* (2012) and Briggs (2012).

Reasons cited by Valdivia *et al.* (2012) were:

1. Lack of tree management experience
2. Cost of establishing/managing trees
3. Lack of technical information
4. Time required to manage trees
5. Too much effort required for clearing the land
6. Trees being an obstacle for farms equipment
7. Inadequate market prices for timber
8. Long term return on investment
9. Negative effect on arable cropping and livestock operations due to shading

Long term return on investment. Paulownia is one of fastest-growing tree species in the world (Woods, 2008) under optimal growing conditions; trees could be ready for timber harvest at estimated 12 years based on projections from a plantation site in Brandenburg, NE Germany which is in close proximity to NW Europe (Robinia Invest, 2015), albeit with a more continental climate and warmer summers. Nevertheless, assuming the time to harvest would take twice as long in NW Europe at 24 years, this still compares favourably to other valuable hardwood species such as oak which takes 150 years or cherry which takes 70 years under UK growing conditions as reported by Richards *et al.* (1988).

Inadequate market prices for timber. There have been positive indications from US reports that slower-growth Paulownia would give higher prices (Clatterbuck, 2004), however with the caveat that demand for top-quality wood is subject to an elastic supply curve and premium prices cannot therefore be assured. Paulownia timber being relatively unknown in NW Europe could be a key initial disadvantage, but it must also be noted that agroforestry using native and well-tried species still remain outside the mainstream of NW agricultural systems with agroforestry systems ranging only from 3.4% - 10.1% of UAA in the focus area countries (Den Herder *et al.*, 2015). Nevertheless, there is an export market and the increase in Paulownia plantations being established in South and Central Europe indicate that there is an increased demand for local use of this timber.

Negative effect on arable cropping and livestock operations due to shading. Paulownia has been well-documented to complement well with agricultural operations providing no adverse effect and benefits to arable cropping (Yin, 2004; Wenhua, 2001; Zhao-Hua *et al.*, 1986). There is no reason to indicate it could not work equally well in silvopastoral systems if the trees were fenced off in the initial years and the grass was mowed regularly to prevent competition. The case study in Ballydehob indicated that fencing may not be required for sheep grazing since they do not damage the trees provided that sufficient grass is available.

Trees being an obstacle for farms equipment. As stated by Briggs (2012), contemporary alley cropping systems in Europe would typically have spacing between rows of at least 24 m

to allow for machinery. Also, planting a maximum of 100 trees per hectare would be advisable to stay within the maximum limits set for CAP subsidies. Paulownia intercropping systems would be compatible with modern farm machinery using this model.

Paulownia species could also address possible barriers specific to NW Europe as stated by Briggs (2012).

Short-term tenancy contracts discouraging planting tree crops. The shorter growth period for Paulownia compared to other tree species could help mitigate this factor but it would depend on the length of the tenancy contract and specific agreements in place. It is important to note that the same problem existed in China up until the 1970s when agricultural reforms allowed farmers ownership of the tree crops that the rapid expansion of agroforestry increased tree cover on the North China Plain from 5% in 1973 to 13% at the turn of the last century as documented by Yin (2004).

Land reform and longer tenancy agreements with provision for farmer ownership of the tree crops would therefore be essential to increase the implementation of agroforestry into the mainstream as part of the transition process to sustainable agricultural systems in UK/NW Europe.

Ambiguous CAP payments system whether tree planting affects subsidies. Paulownia species planted in intercropping systems in China are typically planted at a low density. As per Yin (2004), 70% of the area surveyed was in the range from 5 x 20 m to 5 x 50 m. Even if the trees were planted at 5 x 20 m as the maximum density assumed to be suitable for NW Europe in order to give the crops maximum sunlight exposure and allow machinery access, this would still remain within the limits of eligibility for CAP payments where a maximum number of trees is set to 100 per hectare (EU, 2014).

4.6.2 Interview and Written Responses

Current general barriers to agroforestry in NW Europe

Agroforestry experts were asked what they considered to be the main reasons why agroforestry in general is not more common in NW Europe. A diverse range of responses were received and sorted in terms of most frequent reasons cited:

- CAP payments system ambiguous, agroforestry was not eligible for subsidies until 2015
- Lack of knowledge about agroforestry amongst farmers and government
- Traditional mentality amongst many farmers that trees are a problem in operations
- Mechanisation makes farming more difficult with a tree component
- Legal separation of agriculture and forestry for subsidies
- Lack of vision
- Recent trend of simplification of farming operations, monoculture
- No forestry culture amongst farmers in NW Europe compared to continental Europe
- Lack of suitable markets

Future outlook for agroforestry in NW Europe

Agroforestry experts were asked for their views whether agroforestry is likely to become more widespread in NW Europe. 15% provided no response, and with a few people expression uncertainty, the overall outlook was generally positive due to the following reasons cited:

- EU research into agroforestry has increased in recent years
- Change in CAP payments since 2015 reducing prior uncertainties about eligibility for agroforestry
- Recent wide scale implementation of agroecological initiatives in France providing an example to neighbouring countries with similar farming systems
- Increasing realisation amongst land owners that land can be utilised better combining trees and arable crops/livestock instead of a monoculture

In order to further increase uptake, there were several mentions amongst participants of the importance of setting up demonstration plots since farmers would be more likely to adopt an agroforestry system if it is seen to work for other farmers. This has also been recognised by researchers (Cirrou and Hannachi, 2014) and an increasing number of agroforestry demonstration sites are presently being established throughout Europe (EU, 2016). There is a Paulownia demonstration site in Hungary (Vityi *et al.*, 2015) growing Paulownia in alleys with lucerne as an intercrop with the intention to use the Paulownia leaves for animal fodder but there are as of yet no demonstration sites researching Paulownia for agroforestry in NW Europe.

Agroforestry experts were also asked for their opinion about what could be done by external parties (researchers, government and other organisations) to further promote agroforestry systems in NW Europe. Various views were expressed and these have been sorted below in order of most common themes:

- Demonstration sites with key farmers
- Knowledge transfer/increased communication between stakeholders and better marketing about economic and ecological benefits of agroforestry (e.g. flood control for water run-off on hills)
- Organising a process of ownership to take the whole input / production / marketing chain forward
- Increased engagement with private sector
- Long term funded research trials
- Granting structure is still a problem for some areas (e.g. Scotland has agroforestry measures, but England does not)
- CAP reform to encourage innovative systems instead of maintaining status quo

The agroforestry farmer (UK) expressed his view that change in agricultural systems ‘comes from below that level, from farmers like myself experimenting. Knowledge feeds upwards, rather than downwards’, an idea that was echoed by several of the agroforestry experts as well that the theoretical underpinnings of agroforestry have become quite well established at this time and that the next stage would involve more practical steps by farmers to implement workable systems as an example for others to adopt and emulate. This step is clearly dependent on the grant structure facilitating such as a transition and this is already in progress (EU, 2014).

Future outlook for Paulownia-intercropping systems in NW Europe

Agroforestry experts were asked if based on existing knowledge they would be able to recommend farmers in NW Europe growing Paulownia as an agroforestry species. 38% answered yes provisionally, 15% said it was too early to tell and 46% did not provide a response or opinion. The high proportion of uncommitted answers could be attributed to lack of current trials and that Paulownia experience was a preference but not a prerequisite for participation in the study; many experts had not worked with the species before and could therefore not provide a qualified response.

There were however no opinions against the possibility of using Paulownia, and the provisionally affirmative responses were dependent on further research into the following areas:

- Disease resistance
- Invasiveness
- Hardiness
- Suitable species/hybrids
- Market demand
- Governmental regulations

The agroforestry farmer (UK) interviewed indicated that he would support further trials since it is a very important species for agroforestry and an interest was also expressed during the case study visit in UK to grow more Paulownia due to their positive attributes.

In short, there remains many 'unknowns' but Paulownia agroforestry species were acknowledged to have many attractive features that would warrant further investigation and research.

4.6.3 Case Studies

Case Study 1 – East Sussex, UK

The reasons cited by the growers who participated in the case studies in UK and Ireland inhibiting the adopting agroforestry in the focus area were:

- Unclear rules whether trees qualify for CAP payments
- Lack of knowledge about trees amongst many farmers
- Concerns about mechanisation possibly complicated by trees
- Little promotion about the benefits of agroforestry to farmers
- Concerns about subsidies and bureaucracy when getting trees established

None of these reasons other than possibly mechanisation concerns can be mitigated by Paulownia but would instead need to be addressed as part of a larger framework of increased research and dissemination of knowledge to farmers about the benefits of agroforestry systems and their eligibility status for subsidies. These same reasons mentioned also correspond with the findings of agroforestry experts in the focus area.

4.7 Limitations of Study

The following limitations of the research instruments used as part of this study must be considered in assessing the validity of its conclusions and recommendations.

Literature Review

Given its low profile in NW Europe, a significant portion of the information about Paulownia was published in languages other than English. It was identified that there existed extensive publications in Mandarin but also other published references were available in Hungarian and French which were not possible to review wherever these had not been translated to English. The compiled published references may not therefore present a complete picture since this study was limited to publications and references in English.

Furthermore, some of the publications which were not from academic sources would likely contain a greater degree of bias due to commercial interests. This was recognised and any claims which were not verifiable by peer-reviewed literature would be indicated as such by referring to the reference as a commercial entity.

Secondary Data Review

Given the worldwide distribution of Paulownia and its common use as an ornamental tree around the world, extensive recordings of individual plantings around the world were available and easily accessible. The limitations identified were that the majority of these plantings in NW Europe were *P. tomentosa* as the most common ornamental tree. Although this species would be a likely candidate for agroforestry in NW Europe due to its hardiness, it is also generally not the preferred choice in other countries for agroforestry or plantations because of its trunk structure and branching pattern. Wherever possible, the study would document occurrences per species in a specific area but the prevalence of one species would not necessarily indicate that this was the most suitable for commercial use.

Also, it was noticed that the documented records in the selected databases were not comprehensive in detail or scope within the entire focus area of NW Europe and therefore a general search was also conducted to find additional references of plantings in the focus area but exclusions were expected if these references were not published online.

Interviews and Written Responses

Given that the focus area of the study consisted of several countries in NW Europe, it was also recognised that the management, climatic variances, site conditions and microclimate would also play a major role in determining recorded successes or failures; this was also analysed as part of the study, with particular emphasis given on case studies to assess actual plantings first hand. Furthermore, the species selected and the management effort and expertise of the growers were also recognised to be a factor in success outside the climatic limitations.

The samples of the four participant groups totalling 17 interviewees (13 experts, 1 farmer, 1 plant nursery manager, 2 plantation managers) may also not have been representative enough to adequately address the research questions.

The option of providing a written response was given to obtain a higher participation ratio, and although these responses could contain either less or more detail compared to an interview, this method had another disadvantage that it would not allow probing or follow-up questions.

Case Studies

Since the interest in growing Paulownia on a commercial scale is still very recent in NW Europe, it was expected prior to the study that it would be difficult to find existing sites for agroforestry specifically and if some were found, the trees on site would still be very young and thus a complete overview of a successful growing cycle from planting to harvest could not be determined at the time of this study.

Furthermore, the site visits would be limited to a few hours therefore limiting the amount of in-depth fieldwork possible as per the ideal, although as stated by Patton (2015), in actual practice short site visits are the common approach

Finally, success or failure for one specific site could not be considered to be an indicator that it will work in a country or the region as a whole. Only two case studies in UK and Ireland were identified and visited within the project time frame; although it would not be possible to generalise for either these countries or the focus area of NW Europe as a whole based on such a small sample, it was anticipated that useful lessons could still be drawn from reporting the experiences of these sites.

Market Research

It was considered important to establish as part of this study whether an established market was presently available for the Paulownia timber as an added incentive for farmers to invest in growing a novel crop species. However, given that Paulownia is still largely unknown as a timber crop in NW Europe it was expected that data about prices and end market would be scarce and this was confirmed. The major markets for Paulownia at the present time are in China and Japan and these countries are also where the majority of high-quality Paulownia timber is exported from the US. The preference for the study would have been to find a local market for the timber and to identify buyers within the EU, but limited published information was found.

It was also recognised that timber prices can fluctuate over the years and that the selling prices historically and today could only give an indication of future trends just like any other crop. Prices quoted in this study for Paulownia timber should be considered indicative only based on the present conditions; trees planted today would not be harvested until 15-20 years in the future and some level of uncertainty should be expected.

5 Conclusion and Recommendations

Paulownia species have greatly increased in popularity as an agroforestry and plantation crop in China and worldwide over the last three decades. The adaptability of the three hardiest species being able to grow under a wide range of climatic and site conditions in addition to their many products and services have justified their widespread usage as valuable tree species for human use.

P. tomentosa, *P. fortunei* and *P. elongata* are the most common agroforestry and plantation species for temperate climates and all these three species and associated hybrids/varieties have been confirmed by this study to grow in the cool temperate climate of NW Europe under field conditions with generally high survival at over 95%, growth rates in height recorded at 4.8 m after three growing seasons; the species have been reported to be minimally affected by disease but requiring some pest control like for other trees.

The ecological requirements and best practices in planting and growing techniques have been well documented from published literature references worldwide which are also applicable to the climatic conditions of NW Europe. It has been also been confirmed from this study that a propagation method of root cuttings or the purchase of bare-rooted or containerised plants would be preferable over seed propagation.

Various species and hybrids were reviewed as part of this study but no clear preference was identified from results over three growing seasons to indicate the most suitable species for agroforestry with quality timber as the end crop in the focus area.
In addition to selecting the most suitable species/hybrid, the selection of a sheltered, warm site with light free-drained soils was also identified to be a critical success factor to obtain the best growth and survival rates. Paulownia trees in NW Europe will not grow as fast as under more optimal conditions found elsewhere in the world but for timber production fast growth rate would not necessarily be desirable for the best quality product.

Climatic suitability for Paulownia in NW Europe has been established given the data gathered in this study over three growing seasons when the purpose is for agroforestry and not biomass production where other tree species would perform better.

However, Paulownia is a high-input tree crop that benefits from giving each tree individual attention and pruning over the growing season especially when there is frost dieback on the main stem; growers need to be aware that time and effort would be required in the early years of establishment in order to obtain a good trunk for quality timber.

The market for Paulownia timber in Europe is still in its very early stages but growers in Southern Europe have been projecting timber prices up to €700 per m^3 and there are reports of increasing local interest by manufacturers. Paulownia is highly valued in East Asia especially for slow grown wood and NW Europe may be able to fill a niche in this market for the growing economies in the Far East expected over the coming decades. Nevertheless, it would be best to view Paulownia more as a multi-purpose crop providing fodder, better microclimate, pollination, carbon sequestration, bioremediation, landscape aesthetics and other products and services instead of its value as a timber crop alone.

The likelihood of invasiveness has been deemed to be low in NW Europe considering that *P. tomentosa* has been planted as an ornamental for almost two hundred years and no naturalisation has yet been recorded. The conditions for germination would be much better in urban areas than under field conditions as per studies made in USA, Austria and Belgium. The risk of possible future naturalisation in NW Europe would be reduced further when planting sterile clones readily available on the market.

Paulownia species have advantageous characteristics over many other species for agroforestry systems and therefore could address many of the identified concerns farmers have regarding the adoption of agroforestry. Furthermore, the recommended low planting density would enable farmers to remain eligible for CAP subsidies.

The conclusion of the study indicates that Paulownia species would be worthwhile candidates to be incorporated in NW European agroforestry systems due to their many positive characteristics and would like to recommend the following proposals for future action:

- Establishment of field trials into Paulownia species/hybrids considered most suitable for agroforestry under local climatic conditions
- Root cuttings to be taken from strong existing specimens in NW Europe to form basis of a breeding programme for Paulownia species likely to cope with local climatic conditions
- Collaboration with overseas researchers in China and other temperate climates to identify the most suitable varieties for NW Europe
- Dissemination of knowledge to farmers about Paulownia as a tree crop and its associated benefits to encourage further private initiatives
- Identification of manufacturers and businesses in EU interested in Paulownia wood and the setting up of networks between farmers interested in growing the crop
- Research into possible risks of disease spreading from Paulownia affecting other tree species in NW Europe

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7 Appendices

Appendix A – Uses for Paulownia wood

Construction	Interior framing, including door and window frame
	Architraves
	Cabinet making
	Wall panelling and folding partitions
	Plywood, particleboard, and flake-board
	Furniture, especially with doors and drawers
	Automobile and yacht interiors
	Panelling and partitions in airplanes and ships
	Boat construction and paddles
	Beehive construction (resistant to cracking and warping, good insulation, lightweight)
Containers	Decorative containers (pails, jewellery boxes, bowls, etc.)
	Humidors and cigar boxes
	Lining for safe deposit boxes
	Coffin construction.
	Pallets, boxes and crates (lightweight airfreight crating minimizes shipping costs)
	Packing material (natural insulation, biodegradable packing, no odor or taste)
	Food and gift packing (cuts thin, light and strong, free from odour or flavour: could pack specialty foods such as cheese, fruit, coffee, etc.)
Other uses	Arts and crafts: small stock (from crown of tree) used for paint brush handles, pencils, charcoal bars for sketching, etc.
	Shoe and sandal manufacturing
	Inscription plaques
	Filtration material for evaporation coolers

Hall (2008)

Appendix B - Interview Guide

Research Project Title	An investigation into the suitability of Paulownia as an agroforestry species for UK & North-western European farming systems
Researcher	Janus Bojesen Jensen Msc in Organic Farming, SRUC S20003159 **Contact details** janusb@hotmail.com +44 (0) 7748109530
Questionnaire Completed by	

Dear Participant,

I would like to thank you for your time completing the below questionnaire.

Please contact me if any of the questions are unclear or you would like further information.

Please let me know upon completion if you would like a copy of the final report and I will send you a copy in June 2016.

All responses will be anonymised and kept confidential in the report.

Code	Question	Response	Participant Group
BCK01	**Agroforestry Expert/Agroforestry Farmer** Please describe briefly your background and involvement with agroforestry. • Place of work • Years of experience • Countries/focus area • Specific area within agroforestry **Plant Nursery Manager/Plantation Manager** Please describe your operations a. Place of work b. Date of establishment c. Countries you are selling to? d. End market (plantations, or farmers?)		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
BCK02	Have you worked directly with Paulownia trees before?		Agroforestry Farmer Agroforestry Expert
BCK03	Do you have any indications from experience or past research made to provide information regarding whether growing Paulownia would be suitable for agroforestry in UK/NW Europe (Ireland, Belgium, Netherlands and Denmark)? • If you answered **No** to both Questions BCK02 and BCK03, please skip to all questions with **AGR** and **PLW** Codes. • If **Yes**, are you aware of any existing agroforestry sites in the focus area? If not, in close proximity or similar climate? Please provide details.		Agroforestry Farmer Agroforestry Expert

Code	Question	Response	Participant Group
	• If **Yes**, are you aware of any existing plantation sites in the focus area? If not, in close proximity or similar climate? Please provide details.		
AGR01	**Agroforestry Expert** Please give a description of the Paulownia site and its enterprises (e.g. location, hectares, arable, mixed, livestock only)? **Agroforestry Farmer** Please give a brief description of your farm and its enterprises (e.g. location, hectares, arable, mixed, livestock only)?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
AGR02	Was the site where the Paulownia grown certified organic?		Agroforestry Farmer Agroforestry Expert
AGR03	Do you see any challenges growing Paulownia in an organic system?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
AGR04	What other crops had been intercropped with Paulownia on the site (if any)?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
AGR05	Are you aware of any crops that grow particularly well/poorly with Paulownia? If yes, please describe in further detail.		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
AGR06	**Agroforestry Expert/Agroforestry Farmer/Plant Nursery Manager** How many Paulownia trees per hectare are there on the site?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager

Code	Question	Response	Participant Group
	Please describe spacing and layout (e.g. 5 X 20 m in tree spacing/row distance). **Plantation Manager** How many Paulownia trees per hectare would you consider ideal for plantation growing? Please describe spacing and layout (e.g. 5 X 20 m in tree spacing/row distance).		
AGR07	**Agroforestry Expert** If the site is for agroforestry, were there any benefits from Paulownia to the farming operation. If yes/no, please specify. **Agroforestry Farmer** Have the Paulownia trees provided benefits to your farming operation? If yes/no, please specify?		Agroforestry Farmer Agroforestry Expert
AGR08	**Agroforestry Expert** If the site is for agroforestry, did you identify any challenges growing the Paulownia trees that interfered with the other farm enterprises? **Agroforestry Farmer** Do you have any challenges growing the Paulownia trees that interfere with your other enterprises?		Agroforestry Farmer Agroforestry Expert
AGR09	**Agroforestry Expert** Are the Paulownia leaves fed to livestock on site (if applicable)? **Agroforestry Farmer** Do you feed the Paulownia leaves to your livestock		Agroforestry Farmer Agroforestry Expert

Code	Question	Response	Participant Group
	(if applicable)?		
PLW01	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Are there any specific Paulownia species/hybrids you think are most suitable for agroforestry? If yes, please describe why. **Agroforestry Farmer** Which Paulownia species/hybrid do you grow and why did you choose these?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW02	Please specify the country and describe the site conditions where the Paulownia were grown: • Soil type • Altitude • Orientation • Temperature range, other climatic factors • Slope • Water table • Shelter		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW03	Which year did you start growing Paulownia on the site?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW04	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Are you aware of any difficulties getting the Paulownia trees established on the site? **Agroforestry Farmer** Did you have difficulties getting the trees established		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager

Code	Question	Response	Participant Group
	on the site? If yes, please describe.		
PLW05	**Agroforestry Expert** Are you aware of any reported survival rate in the first year on the site? Are the Paulownia trees generally hardy? **Agroforestry Farmer** What is the survival rate in the first year on the site? Are the Paulownia trees generally hardy? **Plant Nursery Manager/Plantation Manager** What is the survival rate in the first year for nursery plants? Are the Paulownia trees generally hardy?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW06	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Are you aware of any reported significant variations in growth for the Paulownia trees in cool/wet summers? **Agroforestry Farmer** Have you noticed significant variations in growth for the Paulownia trees in cool/wet summers?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW07	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** How would you recommend maintaining the understory of the Paulownia? **Agroforestry Farmer** What is grown in the understory of the Paulownia trees?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW08	**Agroforestry Expert/Plant Nursery**		Agroforestry Farmer

Code	Question	Response	Participant Group
	Manager/Plantation Manager Have you noticed or received information about any wildlife attracted to the Paulownia trees (e.g. bees, birds, other insects)? **Agroforestry Farmer** Have you noticed any wildlife attracted to the Paulownia trees (e.g. bees, other insects)?		Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW09	Do the Paulownia trees flower regularly on the site (e.g. every year)?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW10	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Are you aware of any diseases encountered with growing Paulownia on the site? a. If yes, please specify. b. What preventive measures can be undertaken? **Agroforestry Farmer** Are diseases encountered with growing Paulownia? a. If yes, please specify. b. What preventive measures are undertaken?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW11	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Are you aware of any pests encountered with growing Paulownia on the site? a. If yes, please specify. b. What preventive measures are undertaken? **Agroforestry Farmer**		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager

Code	Question	Response	Participant Group
	Are pests encountered with growing Paulownia? a. If yes, please specify. b. What preventive measures are undertaken?		
PLW12	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** What other management would you recommend for the Paulownia trees to receive (e.g. pruning, fertilisation, herbicides)? **Agroforestry Farmer** What other management do the Paulownia trees receive (e.g. pruning, fertilisation, herbicides)?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW13	What are the main factors affecting growth rates of Paulownia trees?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW14	Is there a local market in EU for Paulownia timber or are they exported? If exported, where to?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW15	Would you expect that the slower growth rate expected in UK/NW Europe improves quality of the timber compared to warmer climates?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW16	How old would you expect the Paulownia trees to be before harvest?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW17	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Do you think there is a possibility of invasiveness of		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager

Code	Question	Response	Participant Group
	Paulownia in the focus area (UK/NW Europe), and are you aware of any prior research made on this? **Agroforestry Farmer** Have you witnessed Paulownia seedlings on your farm or surrounding area from self-seeding?		Plantation Manager
PLW18	Have there been any frost damage/deaths for the Paulownia trees on site in cold winters? If yes, what was the minimum temperature (if recorded)?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW19	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** What do you see as the main challenges in growing Paulownia in the focus area that farmers need to be mindful of? -Market -Wind - Diseases/Pests - Placement (shelter?) - Soils -Maintenance -Other **Agroforestry Farmer** Are there any other challenges you have found growing Paulownia? • Market • Wind		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager

Code	Question	Response	Participant Group
	• Diseases/Pest • Placement (shelter?) • Soils • Maintenance?		
PLW20	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Do you think there is enough information about growing Paulownia available for current and potential growers in the focus area? **Agroforestry Farmer** Where do you seek advice and information regarding growing Paulownia?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW21	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Would you consider Paulownia a low/high/medium input crop in an agroforestry system in the focus area? Please describe why. **Agroforestry Farmer** Would you consider Paulownia a low/high/medium input crop in your operations? Please describe why.		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW22	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Where were the Paulownia trees from the site obtained from? Why did you choose this source? **Agroforestry Farmer** Where did you obtain the Paulownia trees from?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager

Code	Question	Response	Participant Group
	Why did you choose this source?		
PLW23	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Do you think growers should propagate their own Paulownia trees from cuttings or seed? If yes, which option (seed/cuttings) is preferred? **Agroforestry Farmer** Do you propagate your own Paulownia trees, or plan to do so?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW24	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Do you have any information about expected annual growth rates (cm) for Paulownia in UK/NW Europe? If no, what was the average growth rate on the site you worked with? **Agroforestry Farmer** What is the average growth rate for Paulownia (in cm) per year?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW25	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Why did you start growing/researching about Paulownia? **Agroforestry Farmer** Why did you start growing Paulownia?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW26	What is the expected or actual yield per Paulownia		Agroforestry Farmer

Code	Question	Response	Participant Group
	tree in cubic metres?		Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW27	**Agroforestry Expert** Do you know the current market prices for Paulownia timber (in cubic metres)? **Agroforestry Farmer/Plant Nursery Manager/Plantation Manager** How would you describe the current market for Paulownia timber (good/acceptable/bad)? Do you expect it to improve?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW28	What is the targeted selling price per cubic metre?		Agroforestry Farmer Plant Nursery Manager Plantation Manager
PLW29	Would you recommend farmers in UK/NW Europe growing Paulownia as an agroforestry tree species? If yes/no, please describe why?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW30	Do you see Paulownia increasing in popularity as a tree crop in your area over the coming years? Please describe why.		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW31	**Agroforestry Expert** Do you recommend or plan to conduct further trials/research about growing Paulownia in the future? Please describe why. **Agroforestry Farmer/Plant Nursery Manager/Plantation Manager** Do you plan to expand your operation growing more		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager

Code	Question	Response	Participant Group
	Paulownia in the future? Please describe why.		
PLW32	Can you describe any particular positives about the Paulownia tree other than the ones already mentioned?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW33	Can you describe any particular negatives about the Paulownia tree other than the ones already mentioned?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
PLW34	Has the price for Paulownia timber risen or fallen over the last 2 years? Please describe. Are there price fluctuations?		Agroforestry Farmer Plant Nursery Manager Plantation Manager
EXP01	Why do you think Paulownia has not been considered for prior use in UK/NW Europe given its success in temperate agroforestry systems in China? If your area of expertise is not in UK/NW Europe, please explain for why this is so for your focus area.		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
EXP02	**Agroforestry Expert/Plant Nursery Manager/Plantation Manager** Please describe the ideal characteristics of an agroforestry tree species for UK/NW European farming systems? If your area of expertise is not in UK/NW Europe, please describe the characteristics for your focus area.		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
EXP03	What do you think are the main reasons why agroforestry in general is not more common in UK/NW Europe?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager

Code	Question	Response	Participant Group
	If your area of expertise is not in UK/NW Europe, please explain for why this is so for your focus area.		
EXP04	Do you see agroforestry becoming more widespread in UK/NW Europe? Please elaborate. If your area of expertise is not in UK/NW Europe, please explain for why this is so for your focus area.		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
EXP05	Do you see an increased demand expected in your focus area for locally grown high quality timber species?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
EXP06	What do you think could be done by external parties (researchers, government and other organisations) to further promote agroforestry systems in UK/NW Europe? If your area of expertise is not in UK/NW Europe, please explain what could be done in your focus area.		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
EXP07	Assuming that the Paulownia trees can be grown successfully on field scale in local conditions, would there be any specific barriers for farmers adopting an exotic tree species in an agroforestry system compared to a local species?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager
EXP08	Do you have any other general comments and observations not covered in the questionnaire?		Agroforestry Farmer Agroforestry Expert Plant Nursery Manager Plantation Manager

Appendix C – Tree Register - Paulownia Specimen Trees in UK and Ireland

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	Tomentosa	26	236		1990	Westonbirt Arboretum	Tetbury	Gloucestershire	England	Specimen Avenue; died in 1990. Much taller than any others known.
	tomentosa 'Lilacina'	21	229		2006	Dunster Castle	Minehead	Somerset	England	Bank above Mill Walk. Very pale lilac-blue flowers.
	Tomentosa	21	411		2013	Bute Park Arboretum	Cardiff	Glamorgan	Wales	N of Summerhouse Kiosk. Fine healthy tree.
	Tomentosa	20.5	236		2000	Mount Congreve	Waterford	Co. Waterford	Ireland	
	Tomentosa	20	217		2001	Islandmore, Croom	Limerick	Co. Limerick	Ireland	Pleasure Gardens
	Tomentosa	20	204		2006	Greencombe, Porlock	Porlock	Somerset	England	Top of woodland garden, E
	Tomentosa	20	163		1987	Glasnevin National Botanic Gardens	Glasnevin	Co. Dublin	Ireland	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	Tomentosa	20	119		2001	Bushy Park (Teddington)	Hampton Wick	Greater London	England	Woodland Gardens; Pheasantry Plantation; Duck Glade; N of stream by biggest Taxodium; drawn up.
2001	*Fargesii*	20	130		2015	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	Woodland Glade. Presumably genuine tree from SICH 1789. Bryan Roebuck 2015.
	Tomentosa	18.5	245		1983	Chilham Castle	Canterbury	Kent	England	
1967	*tomentosa 'Lilacina'*	18	198		2005	Broadleas Garden	Devizes	Wiltshire	England	Top of Dell
	tomentosa 'Lilacina'	18	179		1987	Wisley RHS Garden	Woking	Surrey	England	Gone by 2001
	Tomentosa	18	242		1983	Chilham Castle	Canterbury	Kent	England	Zoo below terrace. Lost.
	tomentosa	18	236		1950	Ashridge College	Berkhamsted	Hertfordshire	England	Greville with PHB Gardner
	tomentosa	18	141		1975	Birr Castle	Birr	Co. Offaly	Ireland	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
2002	*fargesii*	18	132		2015	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	S of Berberis Dell, by main path. Presumably authentic tree from SICH 2019. Bryan Roebuck 2015.
	tomentosa	17.5	188		2006	Sir Harold Hillier Gardens	Romsey	Hampshire	England	Upper Brentry 200
	tomentosa	17.5	123		2003	Headfort estate	Kells	Co. Meath	Ireland	Demesne. Woodland clearing.
	tomentosa	17.3	160		1997	Penjerrick	Falmouth	Cornwall	England	Upper garden.
	tomentosa	17	214	0.9m	1911	Westonbirt School	Tetbury	Gloucestershire	England	A Chapman in E & H. Lodge.
	tomentosa	17	170		2006	Endsleigh	Tavistock	Devon	England	W bank of Dell stream above round pool. Height estimated.
	tomentosa	17	160		2000	Birr Castle	Birr	Co. Offaly	Ireland	Millennium Garden; fair condition by 2000.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
1997	*sp.*	17	104		2006	Lamellen	Wadebridge	Cornwall	England	Bottom of drive. Keith Rushforth collection, planted probably in 1997 and grew slowly for two years, then produced a sprout which grew 6m in 2 years and 17m in 7 years. Perfectly straight.
	fortunei	17	207		2001	Hampton Court (London)	Hampton Wick	Greater London	England	Lion Gate border (W tree; G0255). As label in 2001 (AFM recorded it as *P. tomentosa*).
	fortunei	17	188		2001	Hampton Court (London)	Hampton Wick	Greater London	England	Lion Gate border; E tree (G0256). As label.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	16	251		2011	Hampton Court (London)	Hampton Wick	Greater London	England	Home Park; between Hampton Wick gate and Hampton Wick Pond.
	tomentosa	16	245		1978	Bath Botanical Gardens	Bath	Somerset	England	Blown 1982.
1951	*tomentosa*	16	214		1988	Withersdane Hall	Ashford	Kent	England	
	tomentosa	16	207		1988	Mottisfont Abbey	Romsey	Hampshire	England	
	tomentosa	16	205		2009	Kettering Crematorium	Kettering	Northamptonshire	England	In overgrown NE boundary. Second smaller trunk from the base. Thinning by 2009.
	tomentosa	16	204		1906	Wilton House (Wiltshire)	Salisbury	Wiltshire	England	
	tomentosa	16	190		2013	Singleton Park, Swansea	Swansea	Glamorgan	Wales	Ornamental Gardens; N of main axis path near E end (post 14).

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	16	182		1985	Ravenscourt Park, Hammersmith	Hammersmith	Greater London	England	
	tomentosa	16	182		1980	Goodwood	Chichester	West Sussex	England	High Wood
	tomentosa	16	148		1984	Cockington Court	Torquay	Devon	England	Lake garden.
1992	*elongata*	16	106		2014	Westonbirt Arboretum	Tetbury	Gloucestershire	England	Specimen Avenue/Holford Ride
	tomentosa 'Lilacina'	15	213		2006	Mapperton Manor	Beaminster	Dorset	England	Bottom of Arboretum, mid S
1992	*tomentosa 'Lilacina'*	15	185		2013	Bute Park Arboretum	Cardiff	Glamorgan	Wales	Behind Summerhouse Kiosk; as planted
	tomentosa	15	290	1.1m	2010	Castle Mary	Cloyne	Co. Cork	Ireland	Fork at 4m
	tomentosa	15	277		2006	Northernhay Gardens, Exeter	Exeter	Devon	England	E entrance, on bank. Fine tree with 3m bole.
	tomentosa	15	242		1995	Linton Park (Kent)	Maidstone	Kent	England	SW; decaying by 1995
1946	*tomentosa*	15	236		2005	Corsham Court	Chippenham	Wiltshire	England	E of fountain garden

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	15	223		2004	Cardiff Castle	Cardiff	Glamorgan	Wales	Under castle wall, NW. Stems almost fused.
	tomentosa	15	215		2012	Glasnevin National Botanic Gardens	Glasnevin	Co. Dublin	Ireland	Historically recorded as 'var. lanata'.
	tomentosa	15	214		1983	Battersea Park	Battersea	Greater London	England	N garden
	tomentosa	15	207		1997	Watergate House, West Marden	Petersfield	West Sussex	England	E of barn, healthy
	tomentosa	15	204		1976	Rowallane	Ballynahinch	Co. Down	Ireland	
	tomentosa	15	200	0.8m	2009	Larch Wood, Beachamwell	Swaffham	Norfolk	England	Old Larch Wood; E of footpath, mid. Possibly a rarer form? Very downy.
	tomentosa	15	188		2000	Whittington College, Felbridge	East Grinstead	Surrey	England	Back lawn, S
	tomentosa	15	174		2006	Lanhydrock	Bodmin	Cornwall	England	Top of Woodland

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
										Garden
	tomentosa	15	167		1958	Myddelton House	Enfield	Greater London	England	Blown
	tomentosa	15	154		2004	Ness Botanic Gardens	Neston	Cheshire	England	Below Heather Garden. Sparse by 2004 and much mined by woodpeckers.
	tomentosa	15	97		1979	Penjerrick	Falmouth	Cornwall	England	
	tomentosa	15			1928	Bosahan	Helston	Cornwall	England	
	fortunei	15	126		2009	Larch Wood, Beachamwell	Swaffham	Norfolk	England	Garden; N edge, mid W. Early, pale flowers, though not confirmed for species.
1992	*fortunei*	15	99		2014	Westonbirt Arboretum	Tetbury	Gloucestershire	England	Rattrays
1986	*fargesii*	15	246		2013	Hergest Croft	Kington	Herefordshire	England	Haywood Common; E side of path to Park Wood.
	tomentosa 'Lilacina'	14	242		2000	Rowallane	Ballynahinch	Co. Down	Ireland	The Hospital

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
1994	*tomentosa 'Lilacina'*	14	110		2014	Bradenham Hall	Dereham	Norfolk	England	W of Vista, upper mid (6A)
	tomentosa	14	275		2010	Ballyhooly Castle	Fermoy	Co. Cork	Ireland	
	tomentosa	14	273	1.8m	1911	Linton Park (Kent)	Maidstone	Kent	England	
	tomentosa	14	264		2013	Northernhay Gardens, Exeter	Exeter	Devon	England	E entrance, bank
	tomentosa	14	239		1997	Stansted Park (Sussex)	Havant	West Sussex	England	Arboretum, NW, healthy
	tomentosa	14	229		1892	Ashtead Park	Leatherhead	Surrey	England	
	tomentosa	14	220		2005	Insole Court	Cardiff	Glamorgan	Wales	Top of Rose Garden
	tomentosa	14	207	1.3m	2003	Notley Abbey	Thame	Buckinghamshire	England	Richard Garnett 2003.
1975	*tomentosa*	14	201	0.6m	2008	Surrey University Campus	Guildford	Surrey	England	Cathedral Court Reception shrub bed. Planted on the retirement of Dr D Leggett, 1975.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	14	200		2006	Lanhydrock	Bodmin	Cornwall	England	Top of woodland garden. Height approximate.
	tomentosa	14	185		1952	Spains Hall (Finchingfield)	Thaxted	Essex	England	'Completely bored out by woodpeckers'
	tomentosa	14	176		1951	Elsenham Hall	Bishop's Stortford	Essex	England	'Completely bored out by woodpeckers'
	tomentosa	14	176		1993	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	
	tomentosa	14	173		1988	Winchester	Winchester	Hampshire	England	Cathedral Close
	tomentosa	14	167		2004	Mount Edgcumbe Country Park	Plymouth	Cornwall	England	English Garden lawn
	tomentosa	14	164		2009	Oxford University: Magdalen College	Oxford	Oxfordshire	England	By New Building

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	14	160		2009	Larch Wood, Beachamwell	Swaffham	Norfolk	England	Old Larch Wood; E of footpath, mid. Possibly a rarer form? Very downy.
	tomentosa	14	154		2006	Caerhays Castle	St Austell	Cornwall	England	Below Quarry Path
1958	*tomentosa*	14	148		1978	Ranston	Blandford Forum	Dorset	England	
	tomentosa	14	145	?	1988	Forde Abbey	Chard	Dorset	England	
	tomentosa	14	145		1996	Canons Park, Edgware	Edgware	Greater London	England	Error for the Catalpa speciosa? W of King George V Gardens.
	tomentosa	14	141		2004	Penjerrick	Falmouth	Cornwall	England	Top of garden
	tomentosa	14	110		1970	Hampton Court (London)	Hampton Wick	Greater London	England	Nursery.
1987	*fortunei*	14	206		2006	Peasmarsh Place (Sussex)	Rye	East Sussex	England	Opposite front door. Beautiful domed tree, which flowers profusely before the leaves expand.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	fargesii	14	192		2014	Oxford Botanic Garden	Oxford	Oxfordshire	England	South garden, by rockery. Labelled as *P. tomentosa* - ? Planted around 1950.
	tomentosa	13.7	129		2006	Sir Harold Hillier Gardens	Romsey	Hampshire	England	Upper Brentry 200
1979	*x taiwaniana*	13	99		2010	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	Woodland glade/Cedar Avenue. A sucker or side-stem remains in 2010 from the original tree.
1961	*tomentosa 'Lilacina'*	13	280	0.8m	2004	Bristol University: Churchill Hall	Bristol	Gloucestershire	England	NW; forks at 1.5m. In poor health by 2004.
	tomentosa 'Lilacina'	13	141		2006	Knoll Gardens, Hampreston	Wimborne Minster	Dorset	England	Rhododendrons by house. Estimated; fruiting abundantly.
	tomentosa 'Lilacina'	13	116		1987	Birr Castle	Birr	Co. Offaly	Ireland	Gone by 2000.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	13	236		2002	Royal Victoria Gardens, North Woolwich	North Woolwich	Greater London	England	W entrance, N border
	tomentosa	13	198		2001	Cheam Park	Cheam	Greater London	England	W edge, S
	tomentosa	13	196		2013	King Edward Memorial Park, Shadwell	Stepney	Greater London	England	NE
	tomentosa	13	192		2001	Fitzgerald Park, Cork	Cork	Co. Cork	Ireland	
	tomentosa	13	189		2012	Fareham	Fareham	Hampshire	England	West Street pedestrian precinct, by La Senza
	tomentosa	13	185		2002	South Pavilion, Wotton Underwood	Aylesbury	Buckinghamshire	England	By main house; 12 spread; measured by Richard Garnett.
	tomentosa	13	183		2013	Swansea University Botanic Garden	Swansea	Glamorgan	Wales	Centre

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	13	160		1987	Batsford Arboretum	Moreton in Marsh	Gloucestershire	England	
	tomentosa	13	135		1999	Kearsney Abbey	Dover	Kent	England	SW, wood edge
	tomentosa	13	129		1979	Joyce Green	Dartford	Kent	England	
1975	*tomentosa*	13	128		2011	Ballinacarriga House	Kilworth	Co. Cork	Ireland	Storm-damage
	tomentosa	13	123		1984	Greenwich Park	Greenwich	Greater London	England	
	tomentosa	13	123		1981	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	
	fortunei	13	126		2007	Arundel	Arundel	West Sussex	England	Garden yard in Maltravers Street. Very vigorous young tree, estimated.
	fortunei	13	84		2006	Caerhays Castle	St Austell	Cornwall	England	N end of Hot Head, in dense young group
	tomentosa	12.7	242		2000	Mount Congreve	Waterford	Co. Waterford	Ireland	
1968	*tomentosa*	12.5	104		1980	Freshford Hall	Bath	Somerset	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	fortunei	12.5	126	0.8m	2014	Pine Lodge, Cuddra	St Austell	Cornwall	England	Water Garden lawn
	tomentosa	12	254		2000	Bibury Court	Cirencester	Gloucestershire	England	Hotel garden. Measured by Ted Palmer.
	tomentosa	12	210		1969	Paignton Zoo	Paignton	Devon	England	
	tomentosa	12	188		1913	Mount Usher	Wicklow	Co. Wicklow	Ireland	
	tomentosa	12	179		1980	Goodwood	Chichester	West Sussex	England	High Wood
	tomentosa	12	173		1995	Westgate Gardens, Canterbury	Canterbury	Kent	England	Hedge of garden on E side. Girth estimated.
	tomentosa	12	145		1999	Angley House	Cranbrook	Kent	England	By garage
1965	*tomentosa*	12	141		1984	Walcombe, Wells	Wells	Somerset	England	Moved 1969. Top out.
	tomentosa	12	138		1982	Osterley Park	Hounslow	Greater London	England	
	tomentosa	12	132		1996	Springfield Park, Stoke Newington	Stoke Newington	Greater London	England	White Lodge path
	tomentosa	12	132		2004	Beech Park, Clonsilla	Clonsilla	Co. Dublin	Ireland	
	tomentosa	12	132		1957	Nymans	Haywards Heath	West Sussex	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	12	129		1973	Tortworth Court Hotel	Thornbury	Gloucestershire	England	Triangle.
	tomentosa	12	126		1994	Withdean Park, Brighton	Brighton	East Sussex	England	SW, best
	tomentosa	12	113		1990	Syon Park	Brentford	Greater London	England	Orangery
1982	*tomentosa*	12	110		2000	Tullynally Castle	Castlepollard	Co. Westmeath	Ireland	
	tomentosa	12	104		1982	Bath Botanical Gardens	Bath	Somerset	England	
	tomentosa	12	101		1967	West Dean House	Chichester	West Sussex	England	
	tomentosa	12	97		1985	Spetchley Park	Worcester	Worcestershire	England	
	tomentosa	12	57		1932	Borde Hill	Haywards Heath	West Sussex	England	Garden
	tomentosa	12	41		1989	Carclew estate: Trevorick	Falmouth	Cornwall	England	
2005	*sp.*	12	105		2014	Tregrehan	St Austell	Cornwall	England	N side of field N of garden. From E China.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	sp.	12	99		2014	Westonbirt Arboretum	Tetbury	Gloucestershire	England	E of W side of Circular Drive. No label.
2000	*kawakamii*	12	125		2014	Tregrehan	St Austell	Cornwall	England	Lower slope at S end. EN 4600.
	fortunei	12	115		2013	Bute Park Arboretum	Cardiff	Glamorgan	Wales	Old Man's Wood near toilet block. Flowering on 1st May 2005.
	tomentosa	11.5	204		2003	Malahide Castle (Talbot Botanic Garden)	Malahide	Co. Dublin	Ireland	Edge of lawn between castle and courtyard
	tomentosa	11.5	141		2000	Birr Castle	Birr	Co. Offaly	Ireland	Mount Palmer
	tomentosa	11.5	107		1969	Hergest Croft	Kington	Herefordshire	England	
	tomentosa	11.5	104		2000	Abbeyleix House	Abbeyleix	Co. Laois	Ireland	Garden
	tomentosa 'Lilacina'	11	107		2005	Broadleas Garden	Devizes	Wiltshire	England	Dell S of lawn. Recorded as P. *tomentosa* by AFM but seeming the same as the other *P.*

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
										*f*argesii.
	tomentosa 'Alba'	11	198	1m	1962	Leonardslee	Horsham	West Sussex	England	Below House
1980	*tomentosa*	11	229	0.7m	2014	Scorrier House	Redruth	Cornwall	England	Garden below pinetum
	tomentosa	11	229		1906	Swanmore Cottage, Swanmore (Hampshire)	Bishop's Waltham	Hampshire	England	
	tomentosa	11	220		1994	Preston Rockery, Brighton	Brighton	East Sussex	England	By depot
	tomentosa	11	201		2009	London Road Cemetery, Kettering	Kettering	Northamptonshire	England	S (N tree). A little ivy.
	tomentosa	11	192		2012	Lesnes Abbey	Belvedere	Greater London	England	S of ruins
	tomentosa	11	192		1997	Joyce Green	Dartford	Kent	England	E side of Ward 10, S of two

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	11	188		2006	Puckpool Park, Ryde	Ryde	Isle of Wight	England	Rose garden, under fortifications
	tomentosa	11	183		2006	Daws Hall, Lamarsh	Sudbury	Essex	England	SW of duckpond. Many of its seedlings are in the garden.
	tomentosa	11	182		1983	Victoria Park, Bideford	Bideford	Devon	England	
	tomentosa	11	182		2003	Howard Davis Park	St Helier	Jersey	Channel Islands	E edge
	tomentosa	11	182	0.5m	2003	Southover Grange Gardens	Lewes	East Sussex	England	S courtyard of Grange. Taped under fork.
	tomentosa	11	182		1968	Shelton Abbey	Arklow	Co. Wicklow	Ireland	
	tomentosa	11	168		2013	Philip Mourant Centre, Trinity	Trinity	Jersey	Channel Islands	Old garden
	tomentosa	11	167		1983	Castle Ashby parish church	Northampton	Northamptonshire	England	
1975	*tomentosa*	11	145		1995	Bishop's Palace, Wells	Wells	Somerset	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	11	138		1999	Gillingham Park (Medway)	Gillingham	Kent	England	NE
	tomentosa	11	135		1975	Madresfield Court	Great Malvern	Worcestershire	England	
	tomentosa	11	126		1982	Waterlow Park	Highgate	Greater London	England	W of rose garden.
	tomentosa	11	123		1983	Highdown, Goring	Worthing	West Sussex	England	Lost
1946	*tomentosa*	11	119		1999	Fota Arboretum	Cork	Co. Cork	Ireland	
	tomentosa	11	119		1992	Englefield Park (Theale)	Reading	Berkshire	England	Church Garden. Not noted in 2007.
	tomentosa	11	101		1928	Penrose estate (Helston)	Helston	Cornwall	England	
	tomentosa	11	94		1985	Trelissick	Truro	Cornwall	England	
	tomentosa	11	88		1981	Kensington Gardens	Kensington	Greater London	England	N of Palace
	tomentosa	11	88		1993	Ness Botanic Gardens	Neston	Cheshire	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	11	82		1981	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	S of nursery.
	tomentosa	11	72		1981	Kensington Gardens	Kensington	Greater London	England	
1955	*tomentosa*	11	69		1970	Casa di Sole	Salcombe	Devon	England	
1995	*kawakamii*	11	155		2010	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	By Water Lily House. ETOT 41.
	fargesii	11	143		2014	Bristol Zoo Gardens	Bristol	Gloucestershire	England	Lawn above Herbaceous Border
1992	*elongata*	11	95		2014	Westonbirt Arboretum	Tetbury	Gloucestershire	England	E Specimen Avenue, on N side
1964	*tomentosa 'Lilacina'*	10.5	63		1977	Westonbirt Arboretum	Tetbury	Gloucestershire	England	
	tomentosa	10.5	122		2004	Blarney Castle estate	Cork	Co. Cork	Ireland	Lawn
	tomentosa	10.3	119		2001	Caragh Lodge Hotel	Killorglin	Co. Kerry	Ireland	Island bed right of house
	tomentosa	10	218	0.6m	2013	Grove, The, St Lawrence	St Lawrence	Jersey	Channel Islands	Northern and largest of three on Paulownia

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
										Lawn
	tomentosa	10	217		2014	Clarence Park, St Albans	St Albans	Hertfordshire	England	SW. Slanting bole.
	tomentosa	10	210	1.2m	2009	London Road Cemetery, Kettering	Kettering	Northamptonshire	England	S (S tree)
	tomentosa	10	207	1m	2001	Victoria Embankment Gardens (London)	Westminster	Greater London	England	Whitehall Gardens, NE
	tomentosa	10	204		1995	Turkey Court, Maidstone	Maidstone	Kent	England	N side of lower pond
	tomentosa	10	198		2001	Battersea Park	Battersea	Greater London	England	N of Fountain Pond
	tomentosa	10	185	1.2m	2009	London Road Cemetery, Kettering	Kettering	Northamptonshire	England	N (N tree). Thin.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	10	163		2003	Malahide Castle (Talbot Botanic Garden)	Malahide	Co. Dublin	Ireland	Graveyard
	tomentosa	10	157		1995	Sevenoaks	Sevenoaks	Kent	England	Front garden of 86 Oakhill Road, diameter estimated; fine tree.
	tomentosa	10	151		1997	Hurst Mill, Harting	Petersfield	West Sussex	England	Below house. Thirty years old, dying back
	tomentosa	10	145		1996	Leonardslee	Horsham	West Sussex	England	Below Restaurant
	tomentosa	10	132		1999	Gordon Pleasure Gardens, Gravesend	Gravesend	Kent	England	
	tomentosa	10	119		1988	Jenkyn Place	Alton	Hampshire	England	
	tomentosa	10	116		2003	Steephill, St Saviour	St Saviour	Jersey	Channel Islands	Lawn SW of drive; largest of several seedlings from the late big tree.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
1956	*tomentosa*	10	113		1986	Cambridge University Botanic Garden	Cambridge	Cambridgeshire	England	
	tomentosa	10	113		2000	Snowdenham House	Godalming	Surrey	England	Far SW, misshapen
1980	*tomentosa*	10	112		2011	Castlemartin	Kilcullen	Co. Kildare	Ireland	By swimming pool
1970	*tomentosa*	10	110		1996	Hemsted Toll	Cranbrook	Kent	England	Behind cottage
	tomentosa	10	97		1989	Cambridge University Botanic Garden	Cambridge	Cambridgeshire	England	Director's house.
	tomentosa	10	97		2002	Hunter's Hotel, Rathnew	Wicklow	Co. Wicklow	Ireland	Fruit garden
	tomentosa	10	94		1973	Bayfordbury	Hertford	Hertfordshire	England	
	tomentosa	10	91		1990	Steephill, St Saviour	St Saviour	Jersey	Channel Islands	
	tomentosa	10	72		1996	Ladbroke Square (Notting Hill)	Notting Hill	Greater London	England	E side
	tomentosa	10	69		1997	Tarn, The, Mottingham	Eltham	Greater London	England	N side of lake, near bridge.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	10	63		1980	Stourhead	Warminster	Wiltshire	England	E.
	tomentosa	10	25		1981	Claverton House	Bath	Somerset	England	Beside house
2001	*sp.*	10	67		2014	Tregrehan	St Austell	Cornwall	England	West woods, far S. From Fujien.
1995	*kawakamii*	10	71		2006	Rosemoor RHS Garden	Great Torrington	Devon	England	Back lawn
	kawakamii	10	68		2014	Westonbirt Arboretum	Tetbury	Gloucestershire	England	Mid Broad Drive, to W
1992	*kawakamii*	10	60		2010	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	N of Cedar Vista, near woodland glade. ETOT 41.
1988	*fortunei*	10	63		2002	Westonbirt Arboretum	Tetbury	Gloucestershire	England	E Holford Ride, S
1988	*coreana*	9.7	66		2009	Sir Harold Hillier Gardens	Romsey	Hampshire	England	AA 100
	tomentosa 'Lilacina'	9.5	119		1978	Talbot Manor, Fincham	Downham Market	Norfolk	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa 'Lilacina'	9.5	75		1980	Sir Harold Hillier Gardens	Romsey	Hampshire	England	Brentry
	tomentosa	9.5	47		1980	Merthyr Mawr House	Bridgend	Glamorgan	Wales	Chapel.
1956	*tomentosa*	9	232	?	1989	Cambridge University Botanic Garden	Cambridge	Cambridgeshire	England	
	tomentosa	9	220		1999	Updown House, Betteshanger	Sandwich	Kent	England	SW of walled garden; shapely tree
	tomentosa	9	220		2001	Myddelton House	Enfield	Greater London	England	S of 'Lunatic Asylum'
	tomentosa	9	204		2001	Battersea Park	Battersea	Greater London	England	S of bandstand
	tomentosa	9	195	1.2m	1997	Joyce Green	Dartford	Kent	England	E side of Ward 10, N of two
	tomentosa	9	195	1.7m	1997	Chichester	Chichester	West Sussex	England	Tower Close, lawn. Taped above swelling.
	tomentosa	9	192		2001	Battersea Park	Battersea	Greater London	England	S of bandstand

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	9	192	1.3m	2009	London Road Cemetery, Kettering	Kettering	Northamptonshire	England	N (S tree)
	tomentosa	9	182		2001	Regent's Park	Paddington	Greater London	England	Broad Walk mound
1961	*tomentosa*	9	179		2004	Bristol University: Churchill Hall	Bristol	Gloucestershire	England	NW
	tomentosa	9	179		2004	Hull University: Thwaite Hall	Kingston upon Hull	Yorkshire	England	Lawn near lake. Forked from the base.
	tomentosa	9	179	1.1m	2004	Beacon Park, Lichfield	Lichfield	Staffordshire	England	N of Beacon Street. Flowering profusely in 2004.
	tomentosa	9	176		1985	Trengwainton	Penzance	Cornwall	England	
	tomentosa	9	176		1994	Preston Rockery, Brighton	Brighton	East Sussex	England	By depot
1956	*tomentosa*	9	170	0.5m	1989	Cambridge University Botanic Garden	Cambridge	Cambridgeshire	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	9	167		1997	Joyce Green	Dartford	Kent	England	Lawn SW of Staff Carpark, dying back
	tomentosa	9	163		1989	Nonsuch Park, Ewell	Ewell	Surrey	England	Epsom Road.
	tomentosa	9	160		2003	Sheffield Park Garden	Haywards Heath	East Sussex	England	From Himalayan Walk towards Waterfall. Some dieback by 2003. 180 on plan.
	tomentosa	9	138		2007	Rosemount, Farran	Farran	Co. Cork	Ireland	Drive; excellent condition
	tomentosa	9	132		1995	Borde Hill	Haywards Heath	West Sussex	England	Garden, 9-Ae01 (if same tree)
1956	*tomentosa*	9	119		1989	Crittenden	Paddock Wood	Kent	England	Gale damaged.
	tomentosa	9	119		1990	Knap Hill Nursery	Woking	Surrey	England	
	tomentosa	9	119		2001	Manor Park Cemetery, Aldersbrook	Manor Park	Greater London	England	Mid; young.
	tomentosa	9	110		1982	East Park, Southampton	Southampton	Hampshire	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	9	101		1993	Alexandra Park, Hastings	Hastings	East Sussex	England	S of Pumping station.
2005	*tomentosa*	9	100		2014	Batsford Arboretum	Moreton in Marsh	Gloucestershire	England	Entrance path by N corner of walled garden. 'Fast Blue'.
	tomentosa	9	97		2002	Creagh House, Skibbereen	Skibbereen	Co. Cork	Ireland	In wood
	tomentosa	9	88		1990	Knap Hill Nursery	Woking	Surrey	England	
1976	*tomentosa*	9	79		1984	Hall Place, Leigh	Tonbridge	Kent	England	
	tomentosa	9	75		1981	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	S of nursery.
	tomentosa	9	75		1989	Johnstown Castle	Wexford	Co. Wexford	Ireland	NW.
1956	*tomentosa*	9	69	?	1989	Cambridge University Botanic Garden	Cambridge	Cambridgeshire	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	9	66		1978	Talbot Manor, Fincham	Downham Market	Norfolk	England	E end of garden; seedlings survive in 2008.
	tomentosa	9	66		1989	Cambridge University Botanic Garden	Cambridge	Cambridgeshire	England	Border.
	tomentosa	9	63		1983	Old Rectory, The, Much Hadham	Bishop's Stortford	Hertfordshire	England	Not seen in 2001.
1978	*tomentosa*	9	57		1992	Shugborough	Stafford	Staffordshire	England	
	tomentosa	9	50		1980	Goodwood	Chichester	West Sussex	England	
1888	*tomentosa*	9			1908	Trevarno Estate Gardens	Helston	Cornwall	England	
	sp.	9	41		2009	Thenford House	Brackley	Northamptonshire	England	S of Heselhenge, W from stream. In vigorous group from KR 3865.
2006	*kawakamii*	9	58		2015	Wakehurst Place	Haywards Heath	West Sussex	England	Works border on N side of Southern Hemisphere Garden. ETOT 41.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
1993	*fargesii*	9	184	0.8m	2013	Hergest Croft	Kington	Herefordshire	England	Haywood Common, E of path to Park Wood
1979	*coreana*	9	121		2014	Cambridge University Botanic Garden	Cambridge	Cambridgeshire	England	S end of Woodland Garden by lake
	tomentosa 'Lilacina'	8.5	107		2000	Castlewellan National Arboretum	Newcastle	Co. Down	Ireland	
	tomentosa	8.5	113		2003	Malahide Castle (Talbot Botanic Garden)	Malahide	Co. Dublin	Ireland	Approach to castle on left
	tomentosa 'Lilacina'	8	138		2001	Chelsea Physic Garden	Chelsea	Greater London	England	SE. Unconfirmed - small leaves.
	tomentosa 'Lilacina'	8	132	0.8m	2008	Talbot Manor, Fincham	Downham Market	Norfolk	England	Arboretum, E extension; mid. Unconfirmed - striking low dense habit.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa 'Lilacina'	8	72		2003	Oaklands, St Peter	St Peter	Jersey	Channel Islands	N end of Hemlock Field; rather crowded. Seed 1986.
	tomentosa	8	248		1993	St Leonards-on-Sea	Hastings	East Sussex	England	Old St Johns Road garden centre. Nearly dead 2001.
	tomentosa	8	217	1.2m	1999	Aylesford School	Maidstone	Kent	England	
	tomentosa	8	178		2015	Ladybarn Park, Withington	Manchester	Lancashire	England	N side. Retrenching.
	tomentosa	8	170		1999	Broadstairs	Margate	Kent	England	Pierremont Gardens, High Street
	tomentosa	8	159		2012	Burton Agnes Hall	Driffield	Yorkshire	England	Walled Garden - Jungle
	tomentosa	8	136		2015	Chepstow	Chepstow	Monmouthshire	Wales	Riverside gardens; roadside
	tomentosa	8	134		2015	Chepstow	Chepstow	Monmouthshire	Wales	Riverside gardens; mid
	tomentosa	8	123		1979	Langleys, Great Waltham	Chelmsford	Essex	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	8	119		2002	Easton Grey House	Malmesbury	Wiltshire	England	Drive; poor health in 2002
	tomentosa	8	107		1912	Caldrees Manor	Sawston	Cambridgeshire	England	
	tomentosa	8	101	1m	1994	St Leonards-on-Sea	Hastings	East Sussex	England	Carpark for old Hastings College, Archery Road
	tomentosa	8	82		1996	South Lodge, Horsham	Horsham	West Sussex	England	By Wellingtonia. Broken.
	tomentosa	8			1911	Scorrier House	Redruth	Cornwall	England	
	tomentosa	8			1906	Castle Kennedy	Stranraer	Dumfries & Galloway	Scotland	'Poor-looking'
1998	*sp.*	8	53		2006	Lamellen	Wadebridge	Cornwall	England	Up bank from lower drive. KR3866 (1998).
	kawakamii	8	145		2006	Wisley RHS Garden	Woking	Surrey	England	Battleston Hill. Recorded by Bryan Roebuck. Felled 2006.
	kawakamii	8	72	1.1m	2001	Chelsea Physic Garden	Chelsea	Greater London	England	S path. Now managed by annual cutting.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
2000	*kawakamii*	8	62		2014	Tregrehan	St Austell	Cornwall	England	Walled garden. EN 4600.
	kawakamii	8	52		2006	Cotehele estate	Saltash	Cornwall	England	Valley garden; N side, mid. One of several young plants (most not labelled).
	fortunei	8	85		2001	Chelsea Physic Garden	Chelsea	Greater London	England	S path
	fortunei	8	73		2009	Larch Wood, Beachamwell	Swaffham	Norfolk	England	Garden; S, mid E
	fortunei	8	69		2003	Kilmokea Gardens	Campile	Co. Wexford	Ireland	By Acer rufinerve
1977	*coreana*	8	113		2010	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	Woodland glade. From the original collection by Sir Harold Hillier.
	coreana	8	60		1997	Wakehurst Place	Haywards Heath	West Sussex	England	E of pinetum, edge of lawn
	catalpifolia	8	41		2014	Congrove Arboretum	Keynsham	Gloucestershire	England	Bank NE of house. Growing very fast.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	7.7	88		2002	Lisnavagh Gardens	Tullow	Co. Carlow	Ireland	House
	tomentosa	7.5	157		1982	Singleton Park, Swansea	Swansea	Glamorgan	Wales	
	tomentosa 'Lilacina'	7	62	1.1m	2006	Peasmarsh Place (Sussex)	Rye	East Sussex	England	Opposite front door. Regeneration from base.
	tomentosa 'Lilacina'	7	57		1990	Newcastle House, Bridgend	Bridgend	Glamorgan	Wales	Probably the young tree (from sprout) in the West Garden, labelled *tomentosa* in 2004?
	tomentosa	7	138	1.1m	2005	Swaffham Bulbeck	Cambridge	Cambridgeshire	England	Newnham House, 48 Commercial End.
	tomentosa	7	135		1993	Alexandra Park, Hastings	Hastings	East Sussex	England	Main gates. Dying back.
	tomentosa	7	129		1996	Bermondsey	Bermondsey	Greater London	England	St Olaves Estate, Druid Street. By

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
										London Mission.
	tomentosa	7	97		1978	East Park, Southampton	Southampton	Hampshire	England	
	tomentosa	7	94		1978	Borde Hill	Haywards Heath	West Sussex	England	Garden; 'Lilacina'
	tomentosa	7	53		1985	Lincoln's Inn: New Square	Holborn	Greater London	England	
1961	*tomentosa*	7	50		1972	West End House, Wickwar	Chipping Sodbury	Gloucestershire	England	
	tomentosa	7	50		1984	Knightshayes	Tiverton	Devon	England	
	tomentosa	7	47		1961	Windsor Great Park (Surrey)	Egham	Surrey	England	Above Valley Gardens
	tomentosa	7	25		1998	Matson Ground, Windermere	Windermere	Cumbria	England	
	tomentosa	7	13	1.4m	2002	London Road Cemetery, Kettering	Kettering	Northamptonshire	England	London Road Cemetery.
	catalpifolia	7	35		2014	Evenley Wood Garden	Brackley	Northamptonshire	England	Stream Garden

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa 'Lilacina'	6	66		1987	Cruikshank Botanic Garden	Aberdeen	Aberdeenshire	Scotland	Not seen in 2004.
1995	*tomentosa 'Lilacina'*	6	57		2009	Bodenham Arboretum	Kidderminster	Worcestershire	England	S fence of Poplar Dingle.
1987	*tomentosa 'Lilacina'*	6	25	0.5m	1996	Stratfield Saye	Tadley	Hampshire	England	N. Pinetum. Planted by Anglo-Spanish Society as *P. fargesii.*
	tomentosa	6	50		1981	Regent's Park	Paddington	Greater London	England	Tennis court
1986	*tomentosa*	6	38		1990	Clarkson House (St Helier)	St Helier	Jersey	Channel Islands	
	tomentosa	6	28		1912	Hursley Park, Winchester	Winchester	Hampshire	England	
	tomentosa	6	28		1912	Norris Castle, East Cowes	Cowes	Isle of Wight	England	
	tomentosa	5.75	60	1.3m	1998	Faaie Mooar	Ramsey	Isle of Man	Isle of Man	Bottom of lawn to N of house; flowering well in 1998.
1975	*tomentosa 'Lilacina'*	5.5	31		1981	Powis Castle	Welshpool	Powys	Wales	Garden.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa	5.5	53		1980	Longstock Park and Water Gardens	Andover	Hampshire	England	
	tomentosa	5.5	38		1984	Sandling Park	Hythe	Kent	England	Shrubbery bank below tennis court lawn, N. Suckers remain in 2010.
	sp.	5	75		2014	Edinburgh Royal Botanic Garden	Inverleith	Edinburgh	Scotland	E edge near N end, in dense shrubbery - label not seen.
1980	*fortunei*	5			1992	Sir Harold Hillier Gardens	Romsey	Hampshire	England	AA100; recorded by Mike Wilson. Collected in Chekiang.
1977	*coreana*	5	28		1984	Wakehurst Place	Haywards Heath	West Sussex	England	Top pinetum.
1977	*coreana*	5	25		1984	Wakehurst Place	Haywards Heath	West Sussex	England	Top Pinetum.
1983	*tomentosa*	4.5	6	?	1988	Oxford University: St Catherine's College	Oxford	Oxfordshire	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
1977	*coreana*	4	13		1981	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	South of nursery. From the original collection by Sir Harold Hillier.
1902	*tomentosa*	3.7			1912	Ickleton Granges	Sawston	Cambridgeshire	England	Seedling from Caldrees trees.
	tomentosa	3.5	19		1986	Castle Howard (Yorkshire)	Malton	Yorkshire	England	
1978	*tomentosa*	3.2	22	0.8m	1995	Bridge Gardens, Hungerford	Hungerford	Berkshire	England	
	tomentosa	3	38		1988	Minterne House	Dorchester	Dorset	England	
1993	*tomentosa*	3			1993	Alexandra Park, Hastings	Hastings	East Sussex	England	S of herbacious beds.
1978	*coreana*	3	9		1981	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	South of nursery. From the original collection by Sir Harold Hillier.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
2001	*tomentosa*	2.5	12		2004	Parkside Training Centre, Prestwich	Manchester	Lancashire	England	
1990	*tomentosa*	2			1993	Alexandra Park, Hastings	Hastings	East Sussex	England	N of bowling green
	kawakamii	2			2012	Thedden Grange	Alton	Hampshire	England	Lawn S of drive. 'Sapphire Tree' from Kew.
	elongata	2			2014	Congrove Arboretum	Keynsham	Gloucestershire	England	Bank NE of house
1992	*tomentosa*	1.7			1998	Wootton: 77a Hall End	Bedford	Bedfordshire	England	Alice Holt seedling.
	elongata	1.5			2014	Evenley Wood Garden	Brackley	Northamptonshire	England	Bond Street area
2005	*elongata*	1			2008	Sir Harold Hillier Gardens	Romsey	Hampshire	England	Plant Centre Field 500; one of two 2005 accessions.
	tomentosa		320		2013	Edmondsham	Verwood	Dorset	England	Edge of parish churchyard. Robin Walter 2013.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
1888	*tomentosa*		261		1955	Whitbourne Hall	Bromyard	Herefordshire	England	Seed gathered in the Vatican gardens in 1888 by Sir R Harrington. '32' input for metric height in 1955 - feet?
	tomentosa		195		2015	Brockwood Park School	Andover	Hampshire	England	
	tomentosa		195		1983	Battersea Park	Battersea	Greater London	England	
	tomentosa		192		1995	Pinner Village Gardens	Pinner	Greater London	England	Centre. 16m recorded by PJB.
	tomentosa		188		1993	Hinton Ampner	New Alresford	Hampshire	England	
	tomentosa		176	1m	1920	Regent's Park	Paddington	Greater London	England	Mound by Broad Walk (S)
	tomentosa		160		2007	Sherbourne (Warwick)	Warwick	Warwickshire	England	Sherbourne Fishing Pool
	tomentosa		160		1995	Pinner Memorial Park	Pinner	Greater London	England	Pine plantation. 18m recorded by PJB.
	tomentosa		145		1920	Camberwell Green	Camberwell	Greater London	England	14.5m spread.

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa		135		2007	Eathorpe Hall	Leamington Spa	Warwickshire	England	Garden. Tall.
	tomentosa		125	1m	2005	Marks Hall, Coggeshall	Braintree	Essex	England	Near estate office
	tomentosa		122		2006	Reed Business School	Chipping Norton	Warwickshire	England	
	tomentosa		113	0.9m	1913	Tyninghame House	East Linton	East Lothian	Scotland	Mr Brotherton in E & H
	tomentosa		113		2006	Upton House, Edge Hill	Banbury	Warwickshire	England	Near bog garden
	tomentosa		97		1999	Beale Arboretum	Enfield	Greater London	England	
	tomentosa		94		1982	Osterley Park	Hounslow	Greater London	England	Died back. Tree behind house (Pleasure Grounds) in 2002?
1956	*tomentosa*		88		1989	Cambridge University Botanic Garden	Cambridge	Cambridgeshire	England	

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	tomentosa		66		1964	Borde Hill	Haywards Heath	West Sussex	England	Below Kitchen Garden, 18-I07, var lanata.
1987	*tomentosa*		60		1997	Rosemead, Rowledge	Farnham	Surrey	England	Beyond larches, left edge of path. Flowered for first time 1997!
1994	*tomentosa*				2009	Bradenham Hall	Dereham	Norfolk	England	6A; 'Lilacina'
	tomentosa				2006	Hodsock Priory	Worksop	Nottinghamshire	England	Interesting old tree (Good Gardens Guide)
1975	*kawakamii*				1975	Kew: The Royal Botanic Gardens	Richmond-upon-Thames	Greater London	England	Introduced to Kew from China in 1975 (Clarke, 'Supplement' to Bean, 1988).
	kawakamii				2014	Grange Farm Arboretum, Sutton St James	Spalding	Lincolnshire	England	Species list

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
	fortunei				2014	Grange Farm Arboretum, Sutton St James	Spalding	Lincolnshire	England	Species list
	fargesii				2014	Evenley Wood Garden	Brackley	Northamptonshire	England	Species list
	elongata				2014	Grange Farm Arboretum, Sutton St James	Spalding	Lincolnshire	England	Species list
	elongata				2010	Wisley RHS Garden	Woking	Surrey	England	Two accessions
2011	*coreana*				2011	Bushy House (Teddington)	Hampton Wick	Greater London	England	New planting, from Bedgebury
	coreana				2014	Grange Farm Arboretum, Sutton St James	Spalding	Lincolnshire	England	Species list
	catalpifolia				2009	(unrecorded)		*unknown	*unknown	'Freely available in commerce' (John Grimshaw, 'New Trees',

Planted	Species	Ht /m	Girth /cm	@	Year	Property	Town	County	Country	Comments
										2009, p547).

(TROBI, 2016)