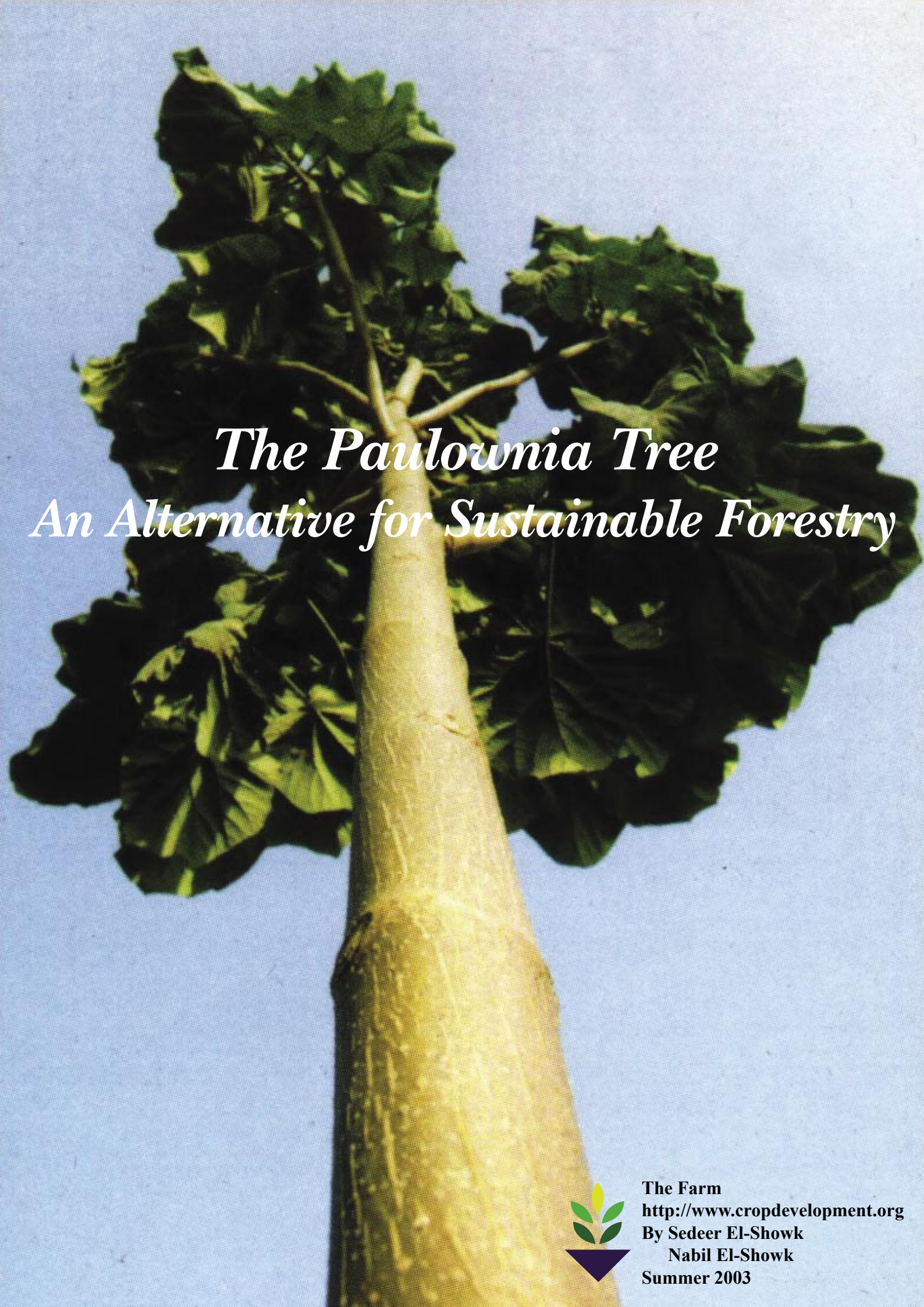

The Paulownia Tree
An Alternative for Sustainable Forestry

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Introduction

1.1 The Problem

Across the globe, urban centers and farms are expanding, often at the cost of natural forest systems, which are also the victims of an increasing demand for timber. The loss of these systems causes severe damage to region's ecosystem: soil erosion increases while soil moisture capacity and atmospheric humidity decrease. These alterations cascade through the ecosystem, resulting in increased temperature, altered and unreliable rainfall patterns and degraded soil profiles.

This problem is particularly acute in North Africa and the Middle East, where several countries have amongst the highest relative rates of deforestation in the world. This region has been the site of intensive farming for over 2,000 years and has very little forested land remaining. As a consequence, as much as 90% of the forestry products consumed in these countries are imported.

Table 1: Percentage Averal Annual Decrease in Forested Area, 1990-1995

Global Rank	*Country*	*%*
1	Lebanon	7.8
11	Jordan	2.5
15	Syria	2.2
18	Iran	1.7
28	Algeria	1.2

Source: The Economist

Table 2: Value of forestry product imports (USD), 2001

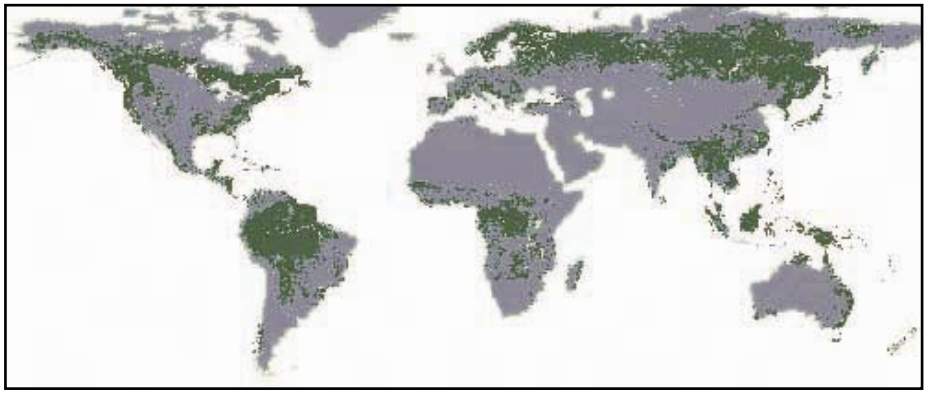
Country	*Value*
Egypt	$754,230,000
Saudi Arabia	$733,040,000
Iran	$422,401,000
United Arab Emirates	$363,705,000
Morocco	$333,717,000
Algeria	$248,714,000
Lebanon	$189,938,000
Jordan	$187,548,000
Syria	$143,020,000
TOTAL	*$3,376,313,000*

Source: FAO forestry website, FAOSTAT database

Alongside the disappearance of forests there is a continuing increase in global timber demands. A recent FAO expert consultation on Sustainable Forest Management (Rome; February 3-5, 2003) estimated that there will be a 10% rise in worldwide consumption of timber products by 2010 and a 15% rise by 2015.

While limited resources and a long history of intensive farming may accentuate the problem in North Africa and the Middle East, global rates of deforestation continue to increase, combining with a rising demand for timber products to create a critical need for managed forestation projects to satisfy a growing worldwide market.

Figure 1: Map showing Global Forest Coverage



Source: FAO forestry website (reproduced without permission)

1.2 Our Solution

The Paulownia tree provides a unique and ideal solution to this problem. It is a fast-growing, readily sustainable hardwood requiring minimal management and very little investment. Harvesting begins within 8-10 years and can continue yearly for as long as is desired, since new shoots grow from the stumps of felled trees.

We have several varieties of Paulownia in our nurseries. Beginning with a stock of P. tomentosa and P. elongata, we undertook a breeding program, selecting trees based on canopy shape, branching pattern, drought tolerance and rate of growth. After several years of research, we selected five new varieties for *in vitro* multiplication. One of the new varieties, PS, is very well adapted to timber production and is currently under production on our plantations.

Paulownia: The Tree

2.1 Description

2.1.1 History

At least six species of Paulownia are currently recognized: *P. elongata, P. fargesii, P. fortunei, P. glabrata, P. taiwaniana* and *P. tomentosa*.; it is also commonly known as Kiri. Paulownia has been cultivated in China for at least 3000 years; "A Monograph on Paulownia", by Chen Chu, was published in the Northern Song Dynasty in the year 1049 BCE. There is evidence that it was being used to build coffins around 600 BCE and was being cultivated on a large scale by no later than 200 BCE. For many centuries, the Chinese have been planting Paulownia around their homes in order to attract the phoenix and bring good luck.

Figure 2: A Paulownia tree in bloom. This is an ornamental variety; the open canopy is not suitable for timber production.

Paulownia timber was exported from China to Japan, where it was used to produce handicrafts such as *kotos* (harps) and *tansa* (wedding chests). It is a custom in parts of Japan to plant a Paulownia tree when a girl is born so that the wood may be used to fashion her wedding chest.

It was introduced into the United States in the 1800s when Paulownia seeds, which had been used as packing material for Chinese dinnerware, were released into the wild, where they flourished. These feral Paulownia growths were discovered by the Japanese in the 1970s and have since become the focus of a multi-billion dollar export project.

2.1.2 Morphology

Paulownia is a fast-growing deciduous hardwood with gray-brown lenticillate bark. The leaves have long petioles and an opposite arrangement; juvenile leaves can be as large as 80cm, with a serate margin, while mature leaves are smaller and have a smooth, wavy margin. The undersurface of the leaves is covered with a dense layer of fine hairs. The inflorescence is a pedunculate or subsessile cyme of 2-5 flowers; the fragrant, purplish white flowers have a large, two-lipped corolla, with two lobes on the upper lip and three on the lower. Paulownia is entomiphilous and can be cross-pollinated to produce numerous small, ellipsoid, membranaceous seeds with striate wings.

Figure 3: Paulownia flowers. Flower color varies with variety; the range is from light to dark purple.

Figure 4: Six month old tree. September 1999.

The Paulownia tree is extremely hardy; it has a broad range of temperature tolerance and has been known to grow at altitudes of up to 2,000m. Under optimal conditions, a 5-6m increase in height can be expected in the first growing season and an increment of 3-4cm in diameter at breast height annually. Trunk extension in Paulownia is sympodial; the rapid growth of the lateral branches, however, gives it the appearance of a monopodial growth pattern.

Paulownia is a deep rooted tree with a well developed root system. There are usually several large, dichotomously branched roots growing downwards (up to a length of 8 meters). The absorptive roots are 1-5mm thick and up to 60cm long. In sandy soils, 76% of the absorptive root system is 40cm-100cm deep; only 12% of the root is in the first 40cm of the soil. The development of the root system is heavily influenced by the soil structure; a loose, well-drained sandy soil is ideal for Paulownia.

A Paulownia plantation requires only minimal inputs from the grower; it can also be readily intercropped. A properly maintained tree will yield one cubic meter of hardwood in 8 to 10 years, after which a new stem will shoot. A single plantation can therefore be harvested several times, providing a sustainable, renewable source of timber.

2.1.3 Tissue Culture

The use of *in vitro* propagation techniques provides a supply of healthy, homogenous planting material for Paulownia. Trees planted from seed often show an altered growth habit and may be more susceptible to pests and diseases. We use only primary and axillary shoot meristems as explants for our *in vitro* cultured Paulownia plants in order to ensure true clonal propagation. Our research has shown that the best growth is achieved when the composition of the growth medium is adjusted for both the variety and the stage of growth.

Figure 5: Working with Paulownia in vitro.

2.2 Plantation/Silviculture

2.2.1 Climate

Paulownia can survive between latitudes 40°N and 40°S and at altitudes of up to 2,000m. Although the tree can withstand temperatures between -20°C and +40°C, optimal conditions for growth are between 24°C and 29°C. In regions where there is a significant seasonal variation in temperature, it is advisable to wrap young trees in grass during the winter (to protect the bark from freeze-damage) and to paint them during the summer (to protect the bark from sun-scald). Young Paulownia trees are very tall but may not have yet developed an extensive root system to provide anchorage; strong winds can cause breakage or inclined stems, which should be straightened out, propped and mounded.

Figure 6: Grazing damage to trunk.

2.2.2 Preparation and planting

No special site treatment is necessary before plantation. A southern facing exposure with some protection from wind is preferred. Young trees should be protected from grazing animals which may feed on the bark, damaging the tree and limiting growth.

The site should be pre-irrigated to moisten the soil and reduce the amount of labour required. Holes should be dug at 5m x 4m or 5m x 3m, providing 500-700 trees per hectare (if the site will be used for intercropping, planting density should be no more than 500 trees per hectare and may be as low as 300 trees per hectare, at 3m x 6m); the hole should be 70-80cm on each side and 50-60cm deep. Be sure to separate the topsoil from the subsoil during removal; the nutrient-rich topsoil should be returned first.

The trees should be planted at the beginning of spring. Plantation should be deep enough to provide good anchorage for young trees. After planting, 15-20cm of soil should be heaped around the sapling. The sapling should be at least one year old and have an established root system in order to minimize losses.

2.2.3 Soil

Paulownia is very tolerant of adverse soil conditions but is sensitive to water logging. Heavy peat or sandy soils work well; clay and rocky soils do not. Loose, well-drained soils with a pH between 5 and 8 are ideal. Paulownia can grow well even in highly saline soils and in nutrient poor soils, where its ability to selectively absorb Ca^{++} and Mg^{++} ions gives it an advantage. As a consequence of its hardiness, Paulownia has been used with great success in mine reclamation projects.

2.2.4 Irrigation

As mentioned above, Paulownia is very sensitive to flooding and requires good drainage. It needs between 500mm and 2,600mm of rainfall annually, although it can tolerate less if the majority of the rainfall is during the growing season. Saplings should be irrigated on the day they are planted and again a few days later. The tree should be well irrigated until it establishes a sufficient root system; mulching can help minimize losses due to evaporation during the warm season. Paulownia is not very sensitive to atmospheric humidity.

2.2.5 Weeding

The Paulownia tree is a light-loving pioneer plant; slight shade can cause deformation in saplings and 70% shade may be fatal for younger trees. It is imperative to practice effective weeding for the first year so that weeds do not overgrow the young trees; mulching is highly recommended.

2.2.6 Coppicing & Pruning

Coppicing is the process of cutting a tree back to ground level in order to promote the formation of a new shoot. Paulownia is a prolific shooter; it is therefore recommended that trees be coppiced, preferably during the second year. Trees should be coppiced in the late spring, just before the beginning of the growing season. Short trunked seedlings or seedlings with poorly formed trunks should be cut just above the third bud during spring of the second year, just before the emergence of new leaves; a new, straight, well-formed trunk will shoot from the lower buds. Allow several of the buds to grow out before selcting the best one.

Figure 7: A coppiced trunk with new shoots.

Figure 8: Trees pruned in the growing season; only the crown branches remain in winter. Bekkaa Valley, Lebanon; December 2001.

Pruning should begin in the second or third year and should be performed throughout the growing season as new branches emerge. Unnecessary lateral branches should be removed; the branches of the crown, however, should not be cut during the year of their emergence, as they will form the sympodial extension of the trunk. Only the first 7-8 meters of the stem need to be kept clear of branches; after this the canopy can be allowed to assume its natural shape.

Always use a sharp, clean blade when pruning or coppicing and cover any large wounds with cloth to prevent infestation by fungi.

2.2.8 Diseases

Paulownia is not very susceptible to infection by diseases and pests; the plant is very resilient and is usually not severely affected. The most noteworthy diseases of Paulownia are described below, along with recommended treatments.

Witches Broom

Witches Broom is an infectious mycoplasmic disease which impairs the growth of mature trees and may be fatal to juveniles.

Symptoms

Branches: Axillary and accessory buds sprout in great quantities, forming bunches of small twigs which do not fall off during the winter (this is the "witches broom").
Trunk: Internode lengths are condensed.
Leaves: Blades wrinkle and become small, thin and yellow with clear veins.
Flower: Petals become leaf-like.

Recommended Treatment

Affected trees should be removed from the plantation site and burned. Affected branches on otherwise healthy trees should be cut off and burned; the wounds should be treated with an ointment of terramycin and Vaseline (1:9) and wrapped with cloth.

Anthracnose

Anthracnose is a major fungal disease affecting saplings; it is usually non-lethal. The spores germinate at 25°C and 90-100% relative humidity.

Symptoms

Leaves: Affected blades have pale spots which enlarge into brown, circular spots surrounded by yellow-green tissue. The spots later crack in the center and the infected leaves drop early. Heaps of red conidia often appear on the spots after rainfall or in humid climates.

Recommended Treatment

Anthracnose can be prevented from overwintering by raking and destroying fallen leaves and twigs and pruning dead branches out of the tree. In cases where the disease causes repeated defoliations or infestation occurs on plants which are otherwise stressed, a chemical treatment of thiophanate-methyl, mancozeb, Bordeaux mixture or other copper fungicides can be used. The first spray should be applied in the spring when the buds begin to swell, followed by two to three additional sprays at 10-14 day intervals.

2.3 Uses

Paulownia has been used extensively for intercropping in rural sites in China. The Chinese Academy of Forestry reports that intercropping with Paulownia can 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 0-50cm was found to be 19.4% higher than at control sites. Furthermore, Paulownia has a moderating effect on the climate: the reduction in wind speed during the winter can increase the temperature by 1°C while the shade provided in the summer can decrease the temperature by the same amount.

A small Paulownia plantation can help establish sustainability for small rural communities. The trees can serve as a sustainable source of lumber, firewood and coal. The wood also serves as a good material for composting; it is both rich and rapidly renewable. Paulownia leaves are rich in nitrogen and highly palatable; once accustomed to them, livestock will preferentially feed on Paulownia leaves. When used appropriately, Paulownia can help mitigate the effects of human habitation on the environment by providing a steady, sustainable supply of important resources.

Figure 9: Two month old Paulownia. Note the large leaves that form during the first year.

Table 3: Analysis of the content of 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

Source: Leaf analysis by Industry Institue

Paulownia is a pioneer plant which rapidly removes minerals from soil and has a high tolerance for adverse conditions. This rare combination of characteristics makes it ideally suited for projects such as mine reclamation and waste water management projects.

Paulownia timber is light yet strong, has a beautiful grain and does not rot, as well as being a good thermal insulator. This remarkable combination of qualities has resulted in the use of Paulownia timber for a wide range of purposes, such as:

- Musical instruments. Paulownia wood has very good resonance qualities; it is used to make a variety of musical instruments in China and Japan.

- Construction. Thanks to its light weight and resistance to decay, Paulownia is an ideal wood for use in structural pieces, such as roof beams, door, windows, partition boards, ceilings and inner roofs. Paulownia roof beams in a 100 year old temple in Szechuan Province, China are still in good condition. The wood is also used in making packing boxes; the lightweight boxes can carry a larger volume of cargo and are damage resistant.
- Handicrafts & Furniture. Paulownia timber is easy to work, does not deform and accepts stains easily. It is extensively used in the construction of chairs, tables, chests, tea boxes, fruit boxes and grain storage.
- As a consequence of its low thermal conductivity, Paulownia wood wool is ideal as an insulation material in cooling systems. Beehives made from Paulownia wood are lightweight and well-insulated and achieve a higher yield of honey.
- Plywood. Plywood made from 7 year old Paulownia is comparable with plywood from 40-50 year old poplar.
- Charcoal.
- Pulpwood.

Paulownia: The Timber

3.1 Harvesting

Harvest can begin when the trees are 8 to 10 years old; a 10 year old Paulownia tree can be expected to provide an average of 300 board-feet of timber. Trees will continue to increase in volume and value as they age; 18 year old *P. fortunei* trees in China yield an average 6.5m^3 with a diameter-at-breast-height of 1m. Paulownia should be harvested in the autumn and winter. Timber harvested during the growing season may contain large quantities of polyphenolic compounds which will react with stains to develop spots after several years.

The price of Paulownia timber varies with the quality of the wood. Timber FOB China may range from $250 (Grade E) to $550 (Grade A1) per cubic meter, while high quality timber from Australia may cost as much as $2,000/$m^3$. The table below may be used as a rough guide for determining timber quality.

Table 4: Guide for grading Paulownia logs

Small End Diameter (inches)	***Growth rings per inch***				
	8	6	4	4	<4
20+	A1	B1	C1	D	E
16-19	A2	B2	C2	D	E
12-15	A3	B3	C3	D	E
8-11	A4	B3	C4	D	E

Grade A wood must be free of defects; grade B wood may have 1 defect; grade C and D wood may have 2 defects; wood with 3 or more defects is grade E.

3.2 Description of Wood

It is light yet strong, dries easily, has a beautiful grain, does not warp, deform or suffer other effects of high humidity and will not split or crack when nailed. It dries quickly: it can be kiln dried in 24-48 hours and air dried in 30-60 days. The straight-grained, pate yellow to pate red, odorless wood is easy to plane, saw or carve without danger of chipping and readily accepts stains, paint and glue. When stained, Paulownia wood appears very much like mahogany. Physically, the timber ranks between balsa and poplar; it is perhaps best compared with American Ash. Paulownia timber rivals Black Walnut in price.

Paulownia wood has a low thermconductivity (0.063-0.086 kcal x m^{-1} x hr^{-1} x C^{-1}) and is naturally resistant to fire and decay. Fallen Paulownia trees in the Hong Ya Forestry Farm (Szechuan Provincial Research Institute of Forestry, China) were found to have lost only 1cm of wood to decay in 15 years. The heartwood region in Paulownia is wide with a fine texture.

3.3 Technical specifications of the Wood

Table 4: Technical specifications of the timber

Density	*(at 10% moisture content)*	17.91
Specific Gravity		0.265
Shrinkage Coefficient	Specific Gravity	0.21-0.27
(green to oven dry)	Radial	1.1-2.0
	Tangential	2.1-3.5
Binding Properties	Modulus of rupture	5740
(at 12% moisture content)	Modulus of elasticity (x10)	0.838
Chemical Composition	Cellulose content	46%-49%
	Hemicellulose Pentozan	22%-25%
	Lignin content	21%-23%

Source: Caronlina Pacific International, Inc webpage. (reproduced without permission)

Paulownia has an average specific density of 0.28; this compares with values of 0.40 for Eastern Cottonwood, 0.37 for Basswood and 0.42 for Poplar.

Conclusion

Paulownia enjoys several virtues that combine to create its unique appeal:

- ✓ It is a fast growing tree and requires very little maintenance after the first few years.
- ✓ The timber is high quality, rivalling Black Walnut in price.
- ✓ The grower does not need to invest in new plants after harvesting. Paulownia is a prolific sprouter; a new tree will shoot from the severed stump, allowing a single plantation to be harvested several times.
- ✓ Intercropping with Paulownia creates an improved micro-climate and soil structure, increasing yields.
- ✓ The wood has an excellent weight/strength ratio.
- ✓ The wood is beautiful, easy to work, does not warp or crack and is resistant to rot.

Paulownia was recently used in a 'social forestry' program in China. In response to an insufficient timber supply and continuing soil losses to erosion, the project aimed to achieve a 'desired standard of greening'. Small-scale Paulownia plantations were established near villages, along roads and for the rehabilitation of over-mined sites. Farmers were encouraged to use Paulownia for intercropping. In only 15 years, Paulownia has been established on over 3 million hectares of farmland, resulting in increased yields and timber supply, an improved micro-climate and a decrease in soil degradation.

There has been a growing interest in Paulownia in the Western world since the 1970s. As the value of Paulownia wood has become recognized in the West, lumber companies have turned to it to help satisfy local demand, as well as for export. In the 1980s and 1990s, growers in the United States and Australia planted thousands of hectares to help meet this new demand; their first harvests were in the late 1990s.

The Paulownia tree is uniquely suited to today's needs. In the face of rising demands for timber and dwindling forests, it provides a low cost, environmentally friendly and sustainable source of lumber. Large scale reforestation projects or smaller scale 'social forestry' programs can use Paulownia to acheive their goals more quickly, thanks to its rapid growth. Countries which lack large forested areas and must therefore import timber can use Paulownia to help establish a local supply; it is a hardy pioneer plant and will succeed in areas where other forest species might not. If properly managed, Paulownia plantations can help alleviate many of the environmental and economic hardships faced by developing countries today.