Fertilization and agroforestry in Eucalyptplantations in Guangxi southern China

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Abstract

Eucalyptus spp. has got good properties in both pulp and timber production, and is very suitable for plantations due to its fast growing abilities; which can be approved by adding nutrients. The trees in a plantation are often strictly planted in rows with an un-used spacing between the rows. This spacing could be utilized by using agroforestry and give an increased socioeconomic welfare, more revenue, and a better ecological situation. The purpose with this study is to investigate how fertilizers may affect *Eucalyptus urophylla* (S.T Blake.), and if agroforestry practice is possible in *E. urophylla* plantations.

Biomass estimations were made through randomized plot samples, and nutrients analysis through leave samples. The site and the area around were also evaluated on the basis of agroforestry possibilities through interviews and literature.

The results showed high standing volumes in treatment NPK-150-B (81, 3 m^3 ha^{-1}) and NPK-300-B (82, 4 m^3 ha^{-1}), and a high volume increment over the past year in treatment NPK-100 (43, 6 m^3 ha^{-1} yr^{-1}). The best revenue in veneer was achieved in treatment NPK-150-B (47 318 RMB/ha) and treatment NPK-300-B (46 665 RMB/ha), and the best revenue in pulp was achieved in treatment NPK-150-B (35 123 RMB/ha) and treatment NPK-300-B (34 305 RMB/ha) The agroforestry survey showed possibilities of conducting agroforestry with *Eucalyptus spp.* and peanuts or cassava. The revenue in roughly numbers were 7500 RMB/ha for cassava and 1275-1530 RMB for peanuts. Nutrient analysis showed high Mn/N and Mg/N-ratios, and a decreased B/N-ratio compared to the readings done last year. Almost every N-ratio level was higher than the recommended value besides from the P/N-ratio which had a lower value.

The recommended nutrient compound should be between NPK-100 and NPK-100-B Agroforestry can be cooperated into *E. urophylla* plantations. Preferably using cassava or peanuts as intercrop species: depending on the commodity interest of the user.

Key words: Agroforestry, Biomass, *Eucalyptus urophylla*, Fertilisers, Plantations, Southern China

Explanations

Ha = Hectares, one hectare is equal too 100x100 meters

m^3 = Cubic meters which is equal too 100x100x100 cm

NK = Fertiliser composition which contains Nitrogen and Potassium

NPK = Fertiliser composition which contains Nitrogen, Phosphorus and Potassium

RMB = Chinas currency. 1 RMB is equal to 0, 8 SEK (Swedish current)

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1. Introduction

China is a relatively "young" country with a new government, with new ways of thinking. About twenty years ago most of the Chinese citizens were riding a bicycle because of government policies. The picture today is somewhat different. Now vehicles of different sorts are roaming the streets. The situation of companies abroad has also changed with a more friendly approach, and therefore more and more companies are settling down in China to make use of the market.

China is a very lucrative country with about 159 million hectares of forest lands, which covers about 16.55% of the land area (Shengxian et al 2000). China has increased their import of logs, and decreased their export volumes (China forestry Development Report, 2000), and consumption and production of paper has increased in China during the past seven years (FAO Yearbook of Forest Products, 2003). This shows that the demand of wood products is high in China, which may lead to deforestation and devastation of the lands and soils in China. The high population density in China triggers this development, due to the demand of food and wood supplies. Given the limitations of arable land (131.1million hectares 1995 source: www.iiasa.ac.at) and the density of people (Fig 1) with over 1.3 billion inhabitants and 61.4% (Fig 1) of these living in rural areas (FAO 2007), it is only fair to assume that people search for new lands to cultivate crops. Although the trend shows that people are moving into the cities, there are still a large amount of people living in rural settlements. The increase in people density also means that the population is growing, and a higher population means more mouths to feed.

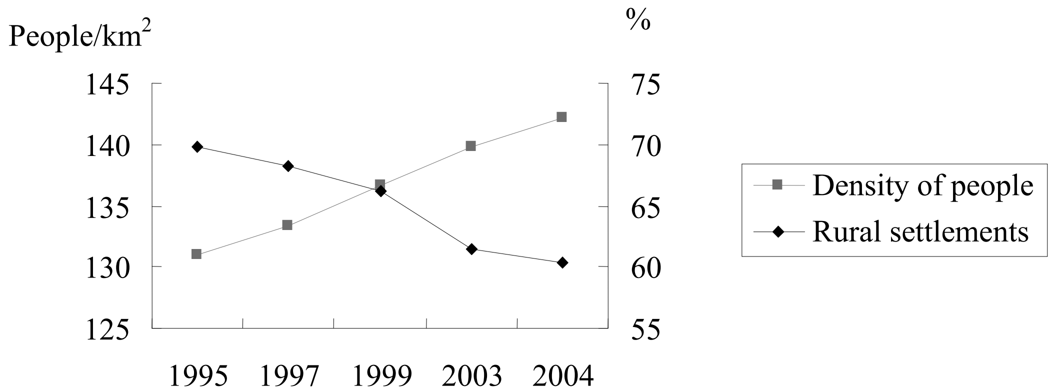


Figure 1: The rural settlements and the density of people over a time period spanning from 1995-2004 in China (FAO 1995-2007)

One way to solve this problem is to make the cultivation more effective by utilizing the arable area better. Introductions of systems that despite the limited arable area can provide food and wood products, may lead to a more sustainable use of the land, and a better economic situation for the farmer. A plantation may provide the future domestic market with enough wood products.

Forest plantations are conducted in many places of the world with different kinds of species and clones, for example in Brazil, Australia, India and China (Xiaomei et al

2007). In China the forest cover has increased with 2.2 % from 2000 to 2005 (FAO 2007), which can be compared to the 1.2 % increase in forest cover from 1900 to 2000 (FAO 2003).

There are about 31 369 000 hectares of forest plantations in China 2005, where 1000.000 hectares are situated in Guangxi where I have done my studies. This shows a potential of plantations in southern China, due to the fact that there already are plantations being conducted on a pretty large scale.

Characteristics of a plantation are;

- A stand which has an even spacing and/or is even aged (FRA, 2005).
- Plantations are normally rectangular shaped with clear borders and the area should be larger than 1 ha (Evans, 1982).
- The planted trees should be evenly distributed so most of the productive capacity is utilized (Evans, 1982).

Plantations in China - obstacles and possibilities

According to the World of agroforestry properties of *Eucalyptus spp.* is very suitable for plantations in both pulp and timber production due to its fast-growing abilities. The productivity in southern China is quite low compared to other countries. The productivity in Ethiopia, Congo and Brazil are higher, with the lowest annual growth of 13 m^3 ha^{-1} yr^{-1}in Ethiopia (13 m^3 ha^{-1} yr^{-1}- 46 m^3 ha^{-1} yr^{-1}), and the highest in Brazil (60 m^3 ha^{-1} yr^{-1}- 90 m^3 ha^{-1} yr^{-1}) with an annual growth of 90 m^3 ha^{-1} yr^{-1} (Christenson and Verma 2006). The problem with soils in south of China is that they are low in nutrients and therefore vegetation growing on the site will lose important yield volumes. This lack of nutrients could be solved by adding nutrients. Nutrients which are limited in southern China are nitrogen (N), phosphorous (P), potassium (K) and boron (B) (Barros 1991; Xu and dell 2002; Goncalves et al 2004).

Fertilizing poor sandy soils could increase the yield in plantations from today's low productivity of 24 m^3 ha^{-1} yr^{-1} (Wang and Zhou 1996) to a more satisfying growth of 40 m^3 ha^{-1} yr^{-1} (Andersson 2007) depending on what kind of fertilization program is utilized, and how the fertilizers are distributed.

The trees in a plantation are often strictly planted in rows with a gap between the rows, which is not used ever during the process. This spacing could come to work for the users benefits, and not just be an empty hole. By combining tree species with crops/animals this gap can be utilized in favor to the user and bring him/her more revenue, an increase in socioeconomic welfare and a better ecological situation. Instead of having a monoculture practice more biodiversity can be introduced. Agroforestry can be utilized by the farmer or on a larger scale by big companies. Combinations and different systems can be modified to serve the ultimate purpose. If it is to reduce soil erosion (Appendix) improve nutrients in the soil (Appendix) or reduce wind damages (Appendix).

An introduction of agroforestry could provide with (Appendix; interviews);

- Self-sufficiency of farmsteads with wood and non-wood forest products
- Diversification of production which creates a kind of buffer if one crop should fail.
- Better use of the space.
- Food security for the locals.
- Improved protection against erosion and increased soil fertility (Buck et al 1998)
- Less fertilizer needed (Buck et al 1998).
- Protection for the animals and crops living underneath the trees against wind, warm and cold weather.
- Sustainable use of lower quality sites for agricultural productions.
- Extra revenue and early cash flow in an early stage of a project.
- Economical security to be able to start a new project up.
- A quick output before harvesting the trees, which could pay for maintenance, labour, machines and transport, if grazing animals were used.
- Job opportunities during a longer part of the rotation period.

Intercropping with perennial wood species and agricultural crops are being practiced on about 3 million ha in China (FAO 2005). Agroforestry has a long history in China, and can be recorded back as far as 1700 years when shortage of timber inspired to plant palm trees around the farms (Li and Xu 2007). This did not only prove useful in timber production but also increased the yield of the crops (Li and Xu 2007). An introduction of livestock and crops was recommended during the Han dynasty 800 years ago, and intercropping crops with Chinese fir has been recorded 300 years ago (Zhaohua et al 1991).

Revenue properties of agroforestry

Agro forestry can be used to raise the revenue on agricultural lands. The combination of trees and crops may open up new ways to conduct both silviculture practices and agricultural practices. This could result in ways to increase the economic standard for the user, due to a larger commodity selection. One example of this is the integration of the paulownia tree (*Paulowniaceae spp.*) with wheat, cotton or maize. The lacquer tree (*Toxicodendron vernicifiuum*) is also a tree which can provide with both non-timber and timber products (Long et al 2003; www.worldagroforestrycentre.org).

Socio economical issues of agroforestry

Agroforestry is mostly conducted in countries where the socioeconomic standard is a bit scarce. Agroforestry is mainly used to raise the socioeconomically level for the individual, due to more commodities to sell and a better use of his/her land. The socioeconomic standard in China is a bit diverse. In the big cities the economy is flourishing while the rural settlements are suffering from poverty. Some of these people have an annual income of less than 1500 RMB (200 USD) (World Agroforestry Centre, Beijing Office 2007). The ways that agroforestry could change this is to give the farmer more and better work opportunities and better income from farming. By introducing agroforestry into plantation forestry the research and knowledge of this system might increase for specific areas. If companies start to conduct agroforestry they will need workers to help them with the planting, maintenance and harvest of the crops.

Ecological properties of agroforestry
Leaching of nutrients is a problem in areas where the nutrient supply is short. If there are more vegetation to collect the nutrients from the fertilization, more nutrients will be bound into the vegetation biomass. With means that fewer nutrients will leach out from the system and the nutrients can be utilized more efficiently. The organic matter in the soil may also increase with increased organic matter provided to the soil. The roots and the residue from the vegetation could help prevent soil erosion and soil degradation (Appendix). Along the years the soil will become more and more stabile, and this may also reduce the soil erosion risks and it may also increase the amount of nutrients in the soil. This could be an advantage in ecological aspects, where soil and nutrients are leached out from the system due to erosion. If more shadow tolerant species could be introduced into to the system a more sustainable ecological situation with less monoculture could be reached (http://archive.idrc.ca).

This study is a presentation about fertilizers impact on growth, and how agroforestry can be introduced into regular farming and more commercial silviculture. The study explores what effects fertilizing has on the growth and the density of the trees and which distribution system of the fertilizers is the most efficient one. I have also explored if agroforestry can be added into *Eucalyptus spp*. plantations to make it more efficient and more attractive for the people involved with *Eucalyptus spp.* plantations.

1.1 Theory and hypotheses

This study is a presentation about fertilizers impact on growth, and how agroforestry can be introduced into regular farming and more commercial silviculture. The study explores what effects fertilizing has on the growth and the density of the trees and which distribution system of the fertilizers is the most efficient one. The fertilizing results will also be compared with the results from Andersson (2007) who has done the same measurements one year before. It has also been explored if Agroforesdtry can be added into *Eucalyptus spp*. plantations to make it more efficient and more attractive for the people involved with *Eucalyptus spp.* plantations.

Theory
Broadcasted distribution of fertilizers gives a better result than string distribution of the fertilizers. Fertilized areas will have an increased effect on the biomass, but a decreasing effect on the density.

Agroforestry systems can be used in a *Eucalyptus spp.* plantation with good results. And by using locals to help with maintenance entice the locals to have a better attitude towards silviculture, and increase the socioeconomically welfare. This could in the long run encourage cooperation between local farmers and forest companies in the area.

2. Material and methods

2.1 Description of the agroforestry study

The agroforestry study consists of information gathered from literature. The sources consist of books, conducted studies, and web pages. Different interviews have also been conducted, based on a provided questionnaire.

Agroforestry in China

- Where in China is Agroforestry mostly used?
- Is it frequently used in China?
  If not – Why isn't it frequently used?
- What kind of Agroforestry systems do they usually use?
- What kind of crop/tree or animal combinations do they use?
- What does the user hope to gain by conducting Agroforestry?

***Eucalyptus spp.* in an Agroforestry scenario**

- Is it possible?
- What do you need to think about to be able to use it efficiently in an Agroforestry system?
- Future possibilities of *Eucalyptus spp.* in Agroforestry?
- Do you think that forest companies can use Agroforestry in their silviculture management to make it more effective? (for example: to get more revenue out of the forest by using agroforestry, to make the trees grow faster by combining *Eucalyptus spp.* with nitrogen fixing species, reduce competition from weeds, get a god relation with the local farmers by letting them take part of the forestland and therefore increase the willingness to let the forest companies utilize or even buy their land for silviculture purposes)
- Recommendations of any other trees/crops combinations that you could use in an Agroforestry system in a silviculture point of view.

Farmers and researchers were asked to answer the questionnaire. With the help from a translator the answers were then translated into English.

2.2 Site description for the experiment

The trial is taking place in southern China, in the Guangxi Zhuang Autonomous region (Pic 1), 90 km from Beihai in Baisha. The Eucalypt plantation is located in the regions Leizhou Penisula and Hainan Island. The climate in these regions is humid semi hot tropical climate with warm and humid ocean climate. The mean annual temperature is ca. 23°C, where the temperature is 14.8°C in the coldest month and 28.9°C in the warmest month. The average annual precipitation is ca 2100mm (FAO 1987). The vegetation is tropical evergreen rain forest and subtropical deciduous forest (Andersson 2007). The soil is of a Ferric Acrisol type which is a well drained soil. The texture varies from loamy sand topsoil overlying sandy loam to sandy clay loam in the subsoil (Vlek et al 2004).

Picture 1; A map of China, the red area is the province Guangxi where the trials are taking place (www.wikipedia.org).

2.3 Description of experiment

The study done about the fertilizing trial, were an independent study and not linked to agroforestry. On the experimental site NPK fertilizers are used on two *Eucalyptus urophylla* (S.T Blake.) clones DH32-29 and GL-GU9 in a plantation prepared by a bulldozer in January 2005. The distance between the rows is 4m, and the planting holes have a spacing of 2 x 4m.

Seven different treatments and a control treatment are being monitored which are divided into four different blocks with a size of 32 x 32 m (Fig 2). The measurements are being conducted on an inner area of 300m^2 marked by the grey area in Figure 2.

The fertilizer was applied in two different ways, the broadcast treatment and the string treatment. To apply the fertiliser in strings a hole between every tree with a dimension of 0.2 x 0.2 x 0.2m was dug and in the broadcast treatment the fertilizer was spread evenly by hand.

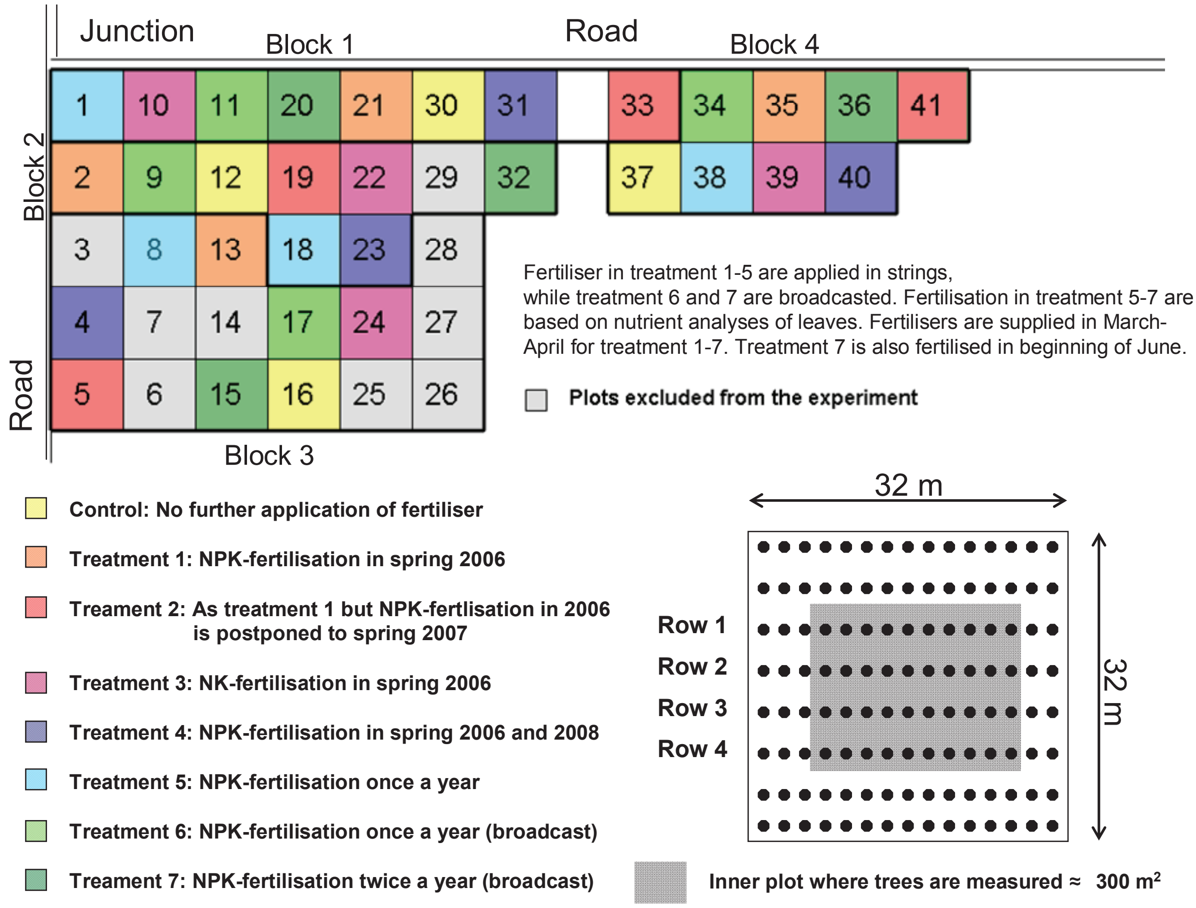


Figure 2; A survey map over the experiment in Baisha 2007 where there are eight different treatments repeated in four blocks, the total number is 32. Control C is an untreated plot and is labeled as 12, 16, 30 and 37. Treatment 1 (NPK-100) is labeled 2, 13, 2 and 35. Treatment 2 (NPK-0) is labeled 5, 19, 33 and 41. Treatment 3 (NK-90) is labeled 10, 22, 24 and 39. Treatment 4 (NPK-100-2) is labeled 4, 23, 31, and 40. Treatment 5 is labeled (NPK-150-S) is labeled 1, 8, 18 and 38. Treatment 6 (NPK-150-B) is labeled 9, 11, 17 and 34. Treatment 7 (NPK-300-B) is labeled 15, 20, 32 and 36 (Andersson 2007).

Note; Treatment 1-5 are applied in strings and 6-7 are broadcasted. The proportion in NPK is 16%, 12% and 12%, and 46-60 % for the NK fertilizer. The name of the treatments is a description of the amount of N used and the fertilization method (Andersson 2007).

2.3.1 Treatment description

There is a Control treatment (C) where no treatments have been made, which works as a reference treatment plot.

In the first treatment an NPK fertilizer was applied in spring 2006, containing 100 kg ha^{-1} N, 75 kg ha^{-1} P and 75 kg ha^{-1} K. The name of this plot was set to NPK-100 because of the amount of N used and combination of fertilizer used.

The second treatment looks just like the first one with a NPK fertilizer combination, and the same amount of fertilizer. The difference between these two is that the fertilizers on treatment 2 were applied in spring 2007. The name of this treatment is NPK-100-0.

The third treatment has a NK fertilizer combination with 185 kg ha^{-1} urea (46% N) and 125 kg ha^{-1} KCL (60% K_2O) applied. The name of this treatment is NK-90.

The fourth treatment contains 625 kg ha^{-1} NPK. Treatment four will be receiving an additional fertilization in spring 2008. So far the treatments NPK-100 and NPK-100 2 has received the same amount of fertilizers.

The fifth treatment has a fertilizer combination of NPK, and contains 150 kg ha^{-1} N, 115 kg ha^{-1} P and 115 kg ha^{-1} K, and is labeled NPK-150-S due to the amount of N used and the fertilizing method being used.

The sixth treatment has a fertilizer combination of NPK, and contains 150 kg ha^{-1} N, 115 kg ha^{-1} P and 115 kg ha^{-1} K. It is nearly identical to NPK-150-S, the only difference being that another fertilizer method is used, hence the name of the treatment NPK-150-B.

The seventh treatment has a fertilizer combination of NPK and contains 150 kg ha^{-1} N, 115 kg ha^{-1} P and 115 kg ha^{-1} K. This treatment will be fertilized twice a year with the same amount of fertilizer as NPK-150-B, hence the name of the treatment NPK-300-B.

2.4 Biomass measurements and leaf analysis

Biomass measurements and leaf analysis was done to investigate the effect of the fertilizers on the trees. The diameter from each tree was measured in centimeters at a height of 130 centimeters (diameter at breast height, DBH) with a caliper. Tree heights were measurement by a Haglöf Vertex III hypsometer and a transponder T3 in meters. To avoid errors the transponder was calibrated before measuring the first tree in each plot. The transponder was calibrated at a distance of ten meters from the T3, which was on a height of 1.3 meters (DBH). Six trees that had been measured earlier were measured from each plot, and two dominant trees were also selected and measures on the basis of biggest diameter. To calculate the volume the function used was:

$$V = 0.038447 * dbh^{2.058292} * h^{0.933308}$$

The function was originally developed by Paula Susila at Stora Enso Wood Supply. Volume functions for every treatment were then developed from a correlation between volume and diameter due to insufficient height data. The volume was presented in m^3.

2.4.1 Biomass measurements

For the biomass measurements treatment seven (NPK-300-B) and the control treatment were selected to be measured. The reason why these two treatments were selected was because it was assumed that NPK-300-B had the biggest growth amongst the treatments, due to more fertilizers applied. The control treatment was selected because NPK-300-B needed to be compared to an untreated area. The values from these readings were then calculated in a diameter/biomass function so that the whole area could be calculated. The diameter classes were selected by first dividing the diameter into four different sections (Tab 1) with the same amount of trees in each class.

Table 1: Selection scheme of the trees from the different plots

Treatment	Diameter classes(mm)	Plots
Control	70-95	30&30
	96-101	12&12
	102-106	16&37
	106-	16&37
NPK-300-B	70-73	32&36
	104-110	20&15
	110-119	20&15
	119-	32&36

Two trees were randomly selected from each diameter class (Tab 1) and manually harvested, biomass samples from the dead branches, alive upper branches (half of the live crown base), alive lower branches and leaves from the upper (half of the live crown base) and the lower part of the canopy were gathered using plastic covers, on which the trees had been harvested. All samples were weighed using a standard scale. It was important to make sure that the samples weren't disturbed from obstacles on the ground, when this could disrupt the measurements. The branches was divided into dead branches and alive branches .In order to make the transportation easier small samples cut off with a saw from the branches was collected. These samples were then weighed on a more sensitive scale. The values were then statistically calculated to get a value for each treatment and the amount biomass per hectare. The diameter of the tree including the bark thickness was measured along the stem starting at 100 centimeters, 130 centimeters (DBH), 200 centimeters, 300 centimeters and so on up to the end of the canopy. These measurements were taken with a caliper (Haglöf Vertex III) and a bark thickness measurer.

Discs for density measurements were collected from three places of each tree, one at the stump height (S1), one at 5 meters (S2) and one at 10 meters (S3). All these samples were then weighed so that the fresh weight could be noted. To measure the density of the discs they needed to be saturated in water first for at least 2-3 days. To measure the density a balance vibracg with a capacity of 3000 grams and a sensitivity of 0, 1 gram was used. When the discs were saturated in water they were picked up and dried with a towel to remove any superfluous water that could affect the readings. The discs which were attached on a needle were then lowered into a bucket of water standing on a scale, and the weight of the discs was noted. The weight of the disc was considered to be the same as the volume of the discs. This result was called the green weight.

The discs where dried in an oven for 3-4 days at 105 º C. The dry weight of the discs could then be noted and divided by the green weight which showed the basic density (kg/m^3). The green density was calculated by dividing the fresh weight of the discs with the green volume (kg/m^3).

The log was divided into three pieces to make the weighing easier. It was weighed with a Salter model 235 scale, with an accuracy of 25 x 100 grams, and the measurement was done directly in the field.

2.4.2 Nutrients measurement

Leaf samples from two different trees were collected from each treatment and plot. The trees were randomly selected, but they needed to be alive and relatively healthy. The leaf samples were placed in paper bags and dried in an oven for two days at 85°C in the nursery in Shankou (southern China). The leaves were sent away to be analyzed in a laboratory in China. For a more detailed description of the analyzing process read Andersson's (2007) paper "Production in a fertilization experiment with *E. urophylla* in Guangxi, southern China" page 14. One measurement of the main nutrient compound on the whole area was made in Sweden. This analysis showed the overall nutrient concentration in the fertilizers.

2.4.3 Fire damage control

Due to a resent fire in the area a fire damage assessment was done. Depending on the severity of the damage of the tree and the canopy each tree was valued from a scale of 1-3, where 1 was unharmed and 3 were severe damage. If the bark had cracked open, and the inner trunk was visible the damage severity of 3 was used (Pic 2). This was also the case if the canopy clearly had been severely damaged by the fire. If no harm what so ever had been inflicted on the trunk or the canopy severity 1 were used.

Picture 2: Damage done to the bark due to exposure of extreme heat. The more grey/brown part is the actual stem, and the more brown parts are the wood beneath the stem. (Picture taken by Peter Genfors 2007)

3. Results

3.1 Stand data after 32 months

3.1.1 Density

The density of the discs collected showed a small difference between the control plot and treatment NPK-300-B (Tab 2: Tab 3). The basic density was slightly higher in the C treatment than in the NPK-300-B treatment (Tab 2). One value deviated in plot 36:S3, which had a remarkable lower value than the rest of the discs. Apart from this the values of the basic density showed a good resemblance with each other within the treatments. The biggest different within each plot was in plot 37 and 36, if the differences between S1 and S2 was compared. These plots had a difference of 43 respectively 67 kg/m^3 (Tab 2). The difference between the two treatments was too small to make an assumption that fertilizers decrease or increase density values. The results could however give a small indication that fertilizers might decrease basic density values.

Table 2: Mean basic density for the control treatment and the NPK-300-B treatment. S1 stands for samples taken from the base of the tree, S2 from five meters up and S3 from ten meters up.

Mean basic density value (kg/m^3)

Control

Plot	**12**	**16**	**30**	**37**	**Mean value**
S1	436	436	457	444	433
S2	446	444	417	429	**Standard deviation**
S3	441	413	431	401	16

NPK 300-B

Plot	**15**	**20**	**32**	**36**	**Mean value**
S1	427	407	409	405	415
S2	424	430	434	422	**Standard deviation**
S3	413	445	424	338	27

The values of the green density of the discs showed no significant difference between the treatments, apart from the values in plot 12/S2 and plot 36/S3 (Tab 3) that deviated from the rest. The biggest different in density within the plot was in plots 12 and 36 where the difference between S2 and S1 was 330 kg/m^{3}in plot 12, and between S1 and S3 342 kg/m^{3}in plot 36. Difference between the two treatments was too small to make an assumption that fertilizers decreased or increased density values. The results could however give a small indication that fertilizers might increase green density (Tab 3).

Table 3: Mean green values for the control treatment and the NPK-300-B treatment. S1 stands for samples taken from the base of the tree, S2 from five meters up and S3 from ten meters up.

Mean green density value (kg/m^3)

Control

Plot	**12**	**16**	**30**	**37**	**Mean value**
S1	1256	1241	1390	1252	1181
S2	926	1200	1186	1164	**Standard deviation**
S3	1181	1094	1169	1110	111

NPK 300-B

Plot	**15**	**20**	**32**	**36**	**Mean value**
S1	1294	1266	1234	1313	1194
S2	1185	1161	1177	1175	**Standard deviation**
S3	1205	1198	1150	971	88

3.1.2 Mean diameter growth after 32 months

There was no significant difference in diameter growth between the trees (Tab 4), apart from treatment NK-90 which compared to the reading taken by Andersson (2007) one year earlier only had a very small increment in diameter growth compared to the other treatments. NK-90 had even less increment in diameter growth compared with the control plot, which is rather conspicuous. The biggest mean diameter after 32 months was situated in both of the broadcasted treatments (NPK-150-B; NPK-300-B) and in treatment NPK-100. And the smallest diameter was situated in treatment NK-90. The biggest increment in growth compared to the results from Andersson (2007) was situated in NPK-100. The stem of mean basal area showed no significant deviation between the treatments.

Table 4: Mean diameter (cm) and the stem of mean basal area diameter values for the different treatments after 32 and 20 months of age. The values taken after 20 months of age are from Andersson (2007).

Treatments/ Age	Control	NPK 100	NPK 0	NK 90	NPK 100-2	NPK 150-S	NPK 150-B	NPK 300-B
20 months	7,45	7,2	7,05	7,15	7,28	7,39	7,93	7,98
32 months	9,80	10,52	9,64	7,49	9,91	10,25	10,52	10,74
Increment after one year (20 – 32)	2,35	3,32	2,59	0,34	2,63	2,86	2,59	2,76
Stem of mean basal area diameter	9,9	10,3	9,9	9,8	10,0	10,4	10,7	10,9

3.1.3 Mean height growth after 32 months

The broadcasted treatment NPK-150-B has got the largest mean value in height as was the case in Andersson´s (2007) results. The smallest mean value in height was found in treatment NK-90. The biggest increment in mean height compared to the results from Andersson (2007) was recorded in treatment NPK-100 and the smallest increment in mean height was recorded in NPK-150-B and the control treatment (Tab 5). The basal weighted area between the treatments showed no significant deviations in value, accept from in treatment NPK-0 which showed a much lower value.

Table 5: Mean height growth (m) for the different treatments after 32 and 20 months of age. Measurements taken after 20 months has been taken from Andersson (2007)

Treatments/ Age	Control	NPK 100	NPK 0	NK 90	NPK 100-2	NPK 150-S	NPK 150-B	NPK 300-B
20 months	11,3	10,7	10,8	10,8	10,8	11,0	12,2	11,4
32 months	15,9	16,4	15,9	15,7	16,2	16,4	16,9	16,5
Increment after one year (20 – 32)	4,7	5,8	5,1	4,8	5,3	5,4	4,7	5,1
Basal area weighted mean height	15,9	16,6	12,5	15,7	16,2	16,4	16,9	16,5

3.1.4 Volume growth over and under bark after 32 months

After 32 months of age the broadcasted treatments had the highest mean volume over and under bark and the smallest mean volume over and under bark was recorded in treatment NK-90 (Tab 6). The biggest increment in volume growth over bark after 32 months of age was recorded in treatment NPK-100, and the lowest increment in volume growth over bark was recorded in the control treatment. Among the fertilized treatments NK-90 had the lowest increment in volume growth over bark.

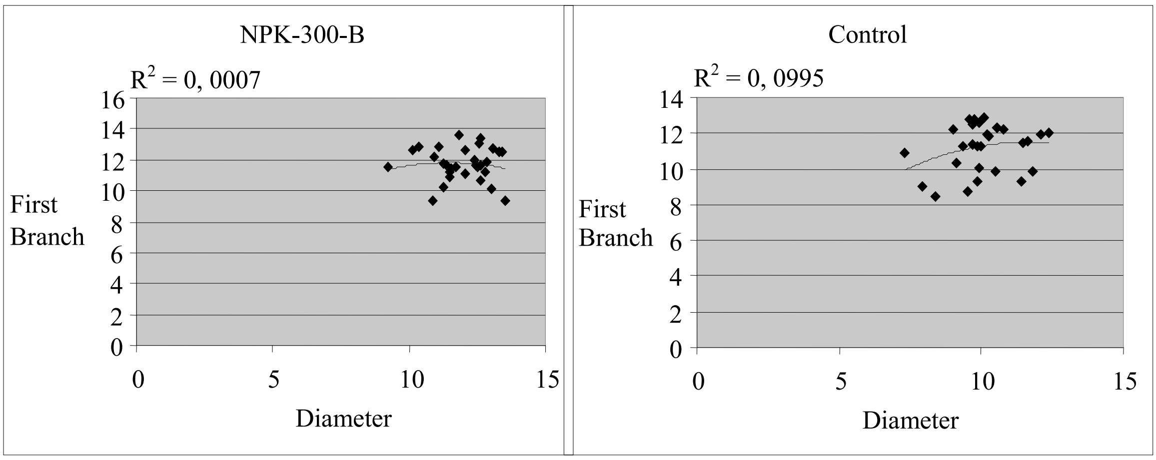
Table 6: Mean volume growth ($m^3 ha^{-1}$) over and under bark from the different treatments after 32 and 20months of age. Measurements taken after 20 months has been taken from Andersson (2007)

Treatment/ Age	Control	NPK 100	NPK 0	NK 90	NPK 100-2	NPK 150-S	NPK 150-B	NPK 300-B
20 months	33,6	30,8	30,2	30,5	31,9	30,8	39,2	39,0
32 months	66,7	74,4	66,6	64,8	71,8	73,2	81,3	82,4
Increment after one year (20 – 32)	33,1	43,6	36,4	34,3	39,9	42,4	42,1	43,4
UNDER BARK after 32 months	51,6	58,0	51,9	50,6	55,8	57,1	63,7	64,2

3.1.5 First branch and diameter relations

The R^2 values in NPK-300-B and the Control showed no correlation between the first branch and diameter (diag 1). This was also the case in all the other treatments.

Diagram 1: Statistical analysis of the relation between the first branch and diameter



3.1.6 Leaf analysis after 32 months

The nutrients concentration in the leaves had increased in almost every treatment compared with the readings after 20 months (Tab 8). The Mangan (Mn) concentration was doubled in some treatments; in some cases the Mn ratio was three times as high as the ratio after 20 months of age (Tab 8). The only nutrient that had a lower value after one year was the nutrient B, which had decreased in every treatment. The Copper (Cu) concentrations were a little bit odd in treatment NPK-100 where the value was twice as low as the years before. Also in treatment NPK-150-B the concentration of Cu was three times higher than the year before (Tab 8). The highest value of N was in NPK-100, the highest value of P was in NPK-150-B; NPK-150-S and the highest value of K were in NPK-300-B.

The lowest concentration of N, P and K amongst the fertilized treatments was found in NPK-100-2 (Tab 8). The control treatment had a lower N and P concentration than NPK-100-2 but a higher K concentration.NPK-300-B showed high levels of iron (Fe) concentration in the leaves, and compared to the readings done 20 months after planting the increase in Fe concentration had gone up approximately four times from previous year (Tab 8). Changes in P concentration have been insignificant over the past year (Tab 7).

In overall the only nutrient ratio that did not exceed the recommended value was the P/N. It had a lower value than the recommended ratio in all treatments. Compared Andersson´s (2007) values after 20 months most of the treatments had an increase in P/N ratio. The only treatment where it had a decrease was in the Control treatment and treatment NPK-100-2.

The values that had the most deviation from the recommended value were Ca/N and Mn/N. The values that had the least deviation were K/N. The Zn/N was the only ratio that was relatively constant. Fe/N had also quite the same values after one year besides in treatment NPK-300-B where the difference was quite conspicuous (Tab 8).

The only N related value that was close of the recommended ratio was most K/N and Cu/N ratios. Most of the other values were far from the recommended values. In general the nitrogen-ratio showed a deficit of P (Tab 7) and a surplus of the rest of the nutrients (Tab 8).

Table 7: Simplification of table 8. Difference in nutrition concentration over the last year (Left table). The two biggest variations in each column are shaded. Deviation from the recommended (percentage values) value in the nitro-ratio (Right table). The comparison has been made against Andersson´s (2007) values, taken after 20 months of age.

Treatment	N g/kg	P g/kg	K g/kg	**Treatments**	P/N 10%	K/N 35%
Control	2,09	0,07	1,31	**Control**	-4,77	3,13
NPK-100	3,66	0,25	1,82	**NPK-100**	-4,25	0,04
NPK-0	4,24	0,35	1,99	**NPK-0**	-3,97	1,14
NK-90	2,87	0,30	2,46	**NK-90**	-4,19	4,99
NPK-100-2	1,15	0,01	0,40	**NPK-100-2**	-4,68	-1,01
NPK-150-S	1,38	0,27	2,42	**NPK-150-S**	-3,50	4,02
NPK-150-B	2,43	0,31	2,5	**NPK-150-B**	-3,54	7,18
NPK-300-B	1,33	0,22	3,3	**NPK-300-B**	-3,28	19,70

Table 8: Leaf analysis from the different treatments. Absolute concentration in leaves, (upper table) and nutrients relation to nitrogen (lower table). Shaded areas show values taken when the trees are 20 months. The non-shaded are values taken when the trees are 32 months. Percentage in the lower table shows recommended nitrogen relations.

Treatment	N g/kg	P g/kg	K g/kg	Ca g/kg	Mg g/kg	Mn mg/kg	Cu mg/kg	Fe mg/kg	Zn mg/kg	B mg/kg
Control	16,87	0,88	6,43	3,88	2,20	160	8,89	92,07	18,35	31,63
	14,78	0,81	5,12	3,77	1,44	81	3,29	55,07	14,89	53,74
NPK-100	19,67	1,13	6,89	4,15	2,40	146	9,71	135,12	19,51	35,84
	16,01	0,88	5,07	3,59	1,32	45	21,77	135,78	14,92	60,31
NPK-0	18,27	1,10	6,60	4.60	2,48	172	7,20	82,58	15,87	31,06
	14,03	0,75	4,61	3,78	1,25	36	2,83	48,70	14,58	57,64
NK-90	18,66	1,08	7,46	3,55	2,11	166	6,85	77,38	15,10	28,05
	15,79	0,78	5,00	3,11	1,22	38	2,99	48,62	13,02	50,63
NPK-100-2	17,38	0,92	5,91	4,06	2,31	215	6,17	103,00	18,01	32,50
	16,23	0,91	5,51	2,8	1,47	129	2,48	65,61	12,03	51,00
NPK-150-S	18,45	1,20	7,20	4,23	2,72	120	6,61	82,75	15,18	34,03
	17,07	0,93	4,78	5,35	1,43	62	4,82	75,35	13,14	60,68
NPK-150-B	18,62	1,20	7,85	4,62	2,21	167	19,33	141,98	15,03	40,38
	16,19	0,89	5,35	3,84	1,43	78	6,78	91,14	14,57	74,40
NPK-300-B	17,51	1,18	9,58	3,56	2,74	149	9,21	246,73	17,86	69,94
	16,18	0,96	6,28	4,10	1,80	119	4,54	56,32	13,63	90,80

Recommended/ Treatments		P/N 10%	K/N 35%	Ca/N 2,5%	Mg/N 4%	Mn/N 0,05%	Cu/N 0,02%	Fe/N 0,2%	Zn/N 0,05%	B/N 0,05%
Control		5,23	38,13	23,02	13,01	0,95	0,05	0,55	0,11	0,19
		5,45	34,65	25,53	9,76	0,54	0,02	0,37	0,10	0,36
NPK-100		5,75	35,04	21,08	12,19	0,74	0,05	0,69	0,10	0,18
		5,20	31,68	22,39	8,23	0,28	0,14	0,85	0,09	0,38
NPK-0		6,03	36,14	25,15	13,58	0,94	0,04	0,45	0,09	0,17
		5,35	32,85	26,97	8,93	0,25	0,02	0,35	0,10	0,41
NK-90		5,81	39,99	19,01	11,30	0,89	0,03	0,41	0,08	0,15
		4,95	31,69	19,69	7,72	0,24	0,02	0,31	0,08	0,32
NPK-100-2		5,32	33,99	23,35	13,29	1,24	0,04	0,59	0,10	0,19
		5,60	33,95	17,27	9,03	0,80	0,02	0,40	0,07	0,31
NPK-150-S		6,50	39,02	22,94	14,72	0,65	0,04	0,45	0,08	0,18
		5,45	27,99	20,97	8,40	0,36	0,03	0,44	0,08	0,36
NPK-150-B		6,46	42,18	24,79	11,88	0,90	0,10	0,76	0,08	0,22
		5,52	33,07	23,71	8,85	0,48	0,04	0,56	0,09	0,46
NPK-300-B		6,72	54,7	20,34	15,63	0,85	0,05	1,41	0,10	0,40
		5,94	38,84	25,36	11,09	0,73	0,01	0,35	0,08	0,56

3.1.7 Biomass

After 32 months the highest values of biomass in leaves and branches was situated in the broadcasted treatments (Tab 9). The lowest reading of leave biomass was recorded in treatment NPK-100. The lowest levels of branch biomass were recorded in treatment NPK-0.

Table 9: Biomass from branches and leaves based on biomass functions (kg ha^{-1})

	Control	NPK 100	NPK 0	NK 90	NPK 100-2	NPK 150-S	NPK 150-B	NPK 300-B
Leaves	984	1167	1079	1094	1102	1172	1359	1293
Bransch	1 924	2 303	2 111	2 141	2 162	2 317	2 703	2 571

3.2 Economic calculation after 32 months

The best revenue was gained from treatment NPK-300-B and NPK-150-B (Tab 10). The lowest revenue was gained from treatment NK-90 and NPK-0; these two treatments were the only ones with lower net revenue than the control treatment.

Table 10: Revenue and cost from fertilization of the different treatments compared to the control treatment. Negative values show lower net revenue than the control treatment. The price for veneer is 600 RMB/m3 and 450 RMB/m3 for pulp. 1RMB = 0, 84 SEK (Source: SEB 2008-05-29)

Treatment	Control	NPK 100	NPK 0	NK 90	NPK 100-2	NPK 150-S	NPK 150-B	NPK 300-B
Amount of fertilization kg/ha	0	625	625	313	625	938	938	1875
Cost fertilization RMB/ha	0	875	875	58	875	1 313	1 313	2625
Cost fertilization method/ha	0	150	150	150	150	150	150	150
Total cost RMB/ha	0	1025	1025	208	1025	1 463	1 463	2775
Volume m^3	67	74	67	65	72	73	81	82
Net RMB for veneer/ha	40200	43615	38935	38672	42055	42458	47318	46665
Net RMB for pulp/ha	30015	32455	28945	28952	31285	31478	35123	34305
Benefits compared to C for veneer/ha	0	3415	– 1265	– 1528	1855	2258	7118	6465
Benefits compared to C for pulp/ha	0	2440	– 1070	– 1063	1270	1 463	5 108	4290

3.3 Dead and fire damaged trees

Every treatment but not every plot was affected by the fire. The damage done to the trunk was most severe in NK-90, NPK-100-2 and NPK-0 (Tab 11) if severity 3 were to be highlighted. The most affected treatment was NPK-100-2 where 71% of the trees were affected. The least affected area was treatment NPK-150-S.

Damage done to the canopy was most severe in treatment NK-90 and NPK-0 (Tab 11) if severity 3 where to be highlighted. The most affected treatment was NK-90 and NPK-0. The least affected was NPK-150-S where the canopies were completely unaffected (Appendix Tab 13).

Dead trees were found in every treatment (Tab 11). NPK-300-B and the control treatment had highest numbers of damaged trees. NPK-100-2 had the lowest numbers of dead trees.

Table 11: Average Fire damage done to the trees presented in % and observed dead trees in the plantation. Numbers 2 and 3 shows the magnitude of the damage done, 3 being severely damaged. **Dead trees are not presented in %.**

Treatment	Control	NPK 100	NPK 0	NK 90	NPK 100-2	NPK 150-S	NPK 150-B	NPK 300-B
Trunk (%)								
Unaffected	46	56	33	35	29	68	40	44
2	34	21	26	16	26	22	24	42
3	20	23	40	49	45	11	36	14
Canopy (%)								
Unaffected	92	87	60	60	68	100	74	86
2	7	12	31	31	30	0	25	9
3	1	1	8	8	2	0	1	5
Dead trees	11	8	5	3	2	10	3	11

4. Discussion fertilizing trial

Biomass
According to the results of the leave biomass fertilizers have a positive effect on the growth of the leaf biomass (Tab 9). This is probably a response of the fertilizing which increases the amount of nutrients that the tree can allocate to the leaves. This increase in biomass of the leaves should give the tree an increased level of photosynthesis, which increases the growth of the tree. The biggest biomass was found in the two broadcasted treatments (Tab 9) which indicates that fertilizers give higher biomass. A conclusion that biomass increases along with the amount of fertilizing can however not be assumed, due to a bigger biomass reading in NPK-150-B than in the more fertilized treatment NPK-300-B (Tab 9). Biomass gives a higher biomass to certain point, and after that other factors have a bigger importance.

The comparison between NPK-150-B and NPK-150-S becomes more interesting because the only thing that separates these two treatments is the distribution method. NPK-150-B has got the largest amount of biomass (Tab 9) which indicates that broadcasted fertilizers results in a higher biomass in the tree. The conclusion is that the tree can make use of the fertilizers more quickly, due to that a bigger area of the root system is being utilized. The result states that the amount of fertilizer and distribution is important in biomass growth.

The low R^2 value in Diagram 1 showed no relation between diameter and first branch height.

Diameter
When interpreting the readings of the diameter consideration has to be taken because of the fire damage done to the trees (Tab 11). Own observations have shown that the trunk

of the trees have cracked up (Pic 2), which gives a higher diameter reading. Because the plots have been scattered out in the affected area every treatment but not every plot has been affected by the fire. That is why all the readings have been treated in the same way as the year before. It is however wise to have in consideration that the trees have been affected by the fire and that the reading might not be entirely accurate.

According to the measurements done in November after 32 months of age the three biggest mean diameters were found in treatment NPK-300-B (10,75 centimeters), NPK-150-B (10,25 centimeters) and treatment NPK-100 (10,25 centimeters) (Tab 4). If the results from Andersson (2007) is compared with the readings done after 32 months of age treatment NPK-100 has got the highest increment in mean diameter. After having one of the smallest mean diameters after 20 months of age NPK-100 has got one of the biggest mean diameters after 32 months of age (Tab 4). This delay of increment may be a result of biomass allocating. The results showed a bigger biomass in the broadcasted treatments. This means that the priority of the tree lies in leave and branch biomass and not so much on trunk biomass. When the foliage is at satisfaction the allocation will be put to the trunk. The reduced increment in diameter recorded in treatment NPK-150-B and treatment NPK-300-B could also be explained by allocation of nutrients to the root growth. It would be interesting to do a root survey to see if the root biomass has increased in these areas. This is more a recommendation of future projects, but if an increment in root biomass could be proven the suggestion of root allocation could be strengthen. It may also be an affect of human errors in the measuring sequence.

NK-90 is the only treatment which has a lower increment than the control treatment. According to Andersson (2007) NK-90 had also a low value in diameter after 20 months of age but not the lowest. NK-90 had only an increment in mean diameter with 0, 34 cm. The low increment in mean diameter compared to the other treatment is logic, due to the lack of P in NK-90. It is harder to explain why the increment is so much lower than the control treatment. This might be a human error done during the diameter readings or an affect done by the fire (Tab 11).

Height

The results show that all the treatments have approximately the same height ranging from 15,7 (NK-90) meters and 16,9 meters (NPK-150-B) The interesting part is to compare the results taken by Andersson (2007) with the results taken after 32 months of age, and see how much they have grown over the past year. Treatments that have had a lower increment after 20 months of age has after one year "cached" up with the broadcasted treatments which had the highest mean height values after 20 months of age according to Andersson (2007).

Height increment can depend on different factors; the availability of nutrient, allocation of nutrients within the tree and competition. A tree may have an endless asset of nutrients but if it doesn't get sunlight it won't be able to survive. The way that trees cope with this problem is to grow taller than the surrounding vegetation. Because the trees have been planted in the same way (Fig 2), they have all got the same starting opportunities when it comes to sunlight and spacing. It might be that treatments with better fertilizing opportunities have had an advantage, and started to block the sun for the “less fortunate” trees. This triggers competition for sunlight and forces the “less fortunate” trees to increase in height. So the trees growing adjacent to treatment NPK-150-B have probably been blocked out after 20 months and been forced to increase their growth in height to survive. This only affects a few numbers of trees, and should therefore not have such a great impact on the rest of the treatment. The response to more nutrients and allocation within the tree is more likely to be the reason of the height increment in the treatments.

The increment over the past year in height could have been explained if the diameter increment would have been much bigger than the height increment. Allocation of nutrient would therefore have been concentrated on diameter growth instead of height growth. Since this is not the case there are two more things to consider in case of growth (Tab 4; Tab 5). It might be caused by increased root mass. This is however hard to prove because there is no data of the current root mass. It has been observed amongst White Spruce that the root mass increases after a while to compensate for the height and possible wind damages (Holgen and Sundström 2007). It can also be an increase in leave and branch biomass that have slowed the height growth down for the broadcasted treatments.

The results show both NPK-150-B and NPK-300-B have bigger leave and branch biomass then the other treatments (Tab 9). Dell and Xu (2003) states that applied fertilizers on poor soil may increase foliage. This shows that the decreased increment in height amongst the broadcasted treatments is because of increased leave and branch biomass. The trees have been concentrating on allocating their resources to the root mass and canopy.

Volume and nutrients

The treatment with the lowest volume after 32 months of age is NK-90. The biggest difference between NK-90 and the other treatments is the lack of P in the fertilizer compound. NK-90 is the only treatment besides the control treatment that lacks P. The explanation to why the NK-90´s increment in volume was so low is according to the results lack of P. A tree can only grow as much as the insufficient factor allows, which is supported by Young (1982). More fertilizers of the NK-90 compound can be distributed to the soil without any increase in growth. The soil will still have insufficient P, and therefore have a setback in growth. P is the macronutrient which is most critical for soils in southern China (oxisols and ultisols) and must be applied if a satisfied growth is to be achieved, which is also supported by Dell and Xu (2003).

The largest volumes after 32 months of age are in treatment NPK-150-B and NPK-300-B, which also had the largest volume one year earlier according to Andersson (2007). These two treatments differ from the rest mostly because the fertilizers have been applied with broadcasting compared to the string distribution (Fig 2). If the fertilizers are more evenly distributed the roots may be able to utilize the nutrients better. These two distribution techniques may cause the roots of the trees to grow differently. The majority of the root mass will probably be located near where the nutrients are, and therefore the trees in the broadcasted treatments will have a more even spread root system. This will give them an advantage compared to the other treatments, because the root system will have access to more nutrients. A more developed root system gives NPK-150-B and NPK-300-B the ability to utilize the fertilizers more efficiently.

Results from the nutrients analysis taken after 32 months of age show a big increase of nutrient concentration in almost every treatment (Tab 8) compared to Andersson´s (2007) results one year earlier. These deviations could be explained by the recent fire which was absent during Andersson´s (2007) readings, (Tab 11) or that nutrients could have been dormant in the ground and released after the measurements done after 20 months of age. It is hard to explain the big increase in nutrient concentration the past year, especially the increase in Mn concentration (Tab 8).

Fe/N-ratio has increased four times in treatment NPK-300-B compared to the results taken one year earlier by Andersson (2007) which is very suspicious. The decrease in B concentration could be a response to the increased Fe concentration in the leaves (Tab 8). Deficiencies of B have been recorded in Fe rich soils (Dell and Xu 2003), which could explain the decrease of B. High levels of Fe in the soil might inhibit the uptake of P which also is supported by Buck et al (1998). This might explain the low P concentration after 32 months. The lowered levels in growth recorded in the broadcasted treatments cannot be explained from the nutrients analysis.

The low values of P could point on a factor which could lower the potential growth rate of the trees (Tab 7; Tab 8). To use a different source of P could lead to a better uptake of the trees. The form in which the P nutrients are distributed could play a big role in how much of the nutrient actually stays within the plantation. The action taken to increase the amount of P in the trees might not be to increase the amount applied, but to change the form in which the P are distributed.

The main thought of having a nutrient composition of 16-12-12 (NPK) had a composition closer to 16-4-10 (NPK). This shows a much lesser P part than expected and could therefore explain the low P concentrations from the analysis. This deviation could perhaps be an effect of what form the P is distributed, and how much of the P has been leeching out. It could also be an effect of the fire (Pic 2; Tab 11). It could allso be an affect on the increased N values in the leaves (Tab 7).

The high values of the Ca/N-ratio is hard to explain because if this where true it would mean that the soil would be very calcium (Ca) rich. Ca rich soil inhibits the uptake of other nutrients such as Cu, Fe, Mn and Zinc (Zn) (Dell and Xu 2003). According to the leaf analysis (Tab 8) there are increased values of Mn, Cu, Fe and Zn concentrations in the leaves (Tab 8) compared to Andersson´s (2007) results taken after 20 months. This contradicts high levels of calcium in the soil. It could be normal levels of calcium present in the soil, and there are the N levels in the soils that are too low. This could explain the high levels of the nutrient ration in the leaves.
It would be recommended that the laboratory in China would undergo a calibration in order to exclude the possibilities for measuring errors, due to the strange concentrations in some of the nutrients.

Density
The results indicate that fertilization of a tree decreases the basic density of the tree, and increases the green density (Tab 2; Tab 3). Differences between the fertilized areas and unfertilized areas is however not obvious and a clear conclusion is hard to conclude. One factor of the low deviation could be that the area was fertilized not that long ago. Future results might have a bigger deviation between fertilized and un-fertilized areas (Fig 2). Density is a response on water flow inside the tree (Brian et al 2004). This may be why the basic density decreases in trees which are fertilized because of the increased water flow, due to an increased yield when fertilizers are added. This also means that when fertilizers are applied the tree will get less dense and therefore will suffer less shrinkage and expansion of the wood (Raven et al 1998).

Green density can be explained from water flow (Tab 3). Green density is a measurement done from taking the fresh weight of the discs divided with the green volume. And the reason why the green density is higher in fertilized trees is probably because it contains more water than the unfertilized trees. In some cases the NPK-300-B has a higher basic density if individual discs are observed. This is a little bit harder to explain and may just be an effect of individual trees having individual fluctuations in density.

5 Discussion and results for agroforestry

5.1 Agroforestry in southern China

Several interviewed people believe that agroforestry and *Eucalyptus spp.* can be a part of modern silviculture. Forest farmers in southern China are in present days combining *E. urophylla* with cassava, peanuts and chilli (interviews; Tab 12).

Table 12: Different possible combination with trees and crops obtained from interviews

Tree species	Rotation period (years)	Crop	Rotation period (years)	Spacing Between the tree rows (m)	Number of crop rows between the tree spacing	Revenue RMB/Ha	Other
E. urophylla	4-5	Cassava	1	3	1	7500	Very good food crop
E. urophylla	4-5	Peanuts	1	3	6	1275-1530	Nitro-fixing abilities
E. urophylla	4-5	Chili	1	3	-	12000	Water demanding

Possibilities with *Eucalyptus spp.* in agroforestry

Through literature and interviews a big interest of agroforestry in China has been observed. The big interest in agroforestry could be explained from the scarce arable land due to population density. The choice of agroforestry is a good way to utilize the area. But is it possible to use *Eucalyptus spp.* in agroforestry?

Normally *Eucalyptus spp.* is not a preferred agroforestry species because it lacks nitrogen fixing abilities and require large amount of water and nutrients. The best profit made from *Eucalyptus spp.* would therefore be acquired from monoculture (Sungsumarn 1993). Despite this it is worth taking larger interest in this fast growing species in agroforestry. Succeeding with *Eucalyptus spp*. in agroforestry is a question about adequate resources. There are farmers in India who uses *Eucalyptus spp.* in agroforestry (Xiaomei et al 2007). Trials using pineapple and E*ucalyptus spp.* in Heinan province southern China have also been observed (Interviews). The result was an increase in growth of the *Eucalyptus spp* and the farmers could get their investments back in a two to three years time (interview). So *Eucalyptus spp.* should definitely not be "banned" from agroforestry practice. Sungsumarn (1993) has a point when he writes of *Eucalyptus spp.* not being suitable agroforestry and would definitely be a problem amongst small farmers, where nutrients come in short quantities. Forest companies on the other hand do have resources such as manpower and fertilisers to reduce competition between trees and crops. Larger companies should therefore be able to coupe with the disadvantages that comes with having *Eucalyptus spp.* in agroforestry.

Intercropping *E. urophylla* with cassava (*Manihot spp.*), peanuts or chilli has been observed out in the field through own observations and interviews (Tab 12). Combining *E. urophylla* and chilli is quite bold but interesting. Mainly because it has got the best revenue according to the recent market (Tab 12). This combination has only been observed as a trial without any descent continuous data (interview). It is therefore not an attractive choice for the companies due to that chilli is a water demanding crop (interviews; Tab 12). To combine chilli with *E. urophylla* which also demands allot of water to grow would just decrease the growth rate of both species too much. Chilli is mostly a food crop which could work for farmers if the resources are available. A more suitable crop for companies would be a crop which companies could use for own purposes. Crops that contain a lot of energy that can be used as bio-energy, or crops that could benefit the tree.

A more preferable choice of intercropping would be peanuts (Tab 12). Peanuts are part of the *Leguminosae* family which is famous for their nitro-fixing abilities, which is also supported by Magness et al (1971). Peanuts intercropped with *E. urophylla.* (Tab 12) could provide with N to the soil. Nitro-fixing species intercropped with *E. urophylla* could reduce the use of chemical induced fertilisation of N. Thereby reduce productivity depression, environmental pollution (Kang and Ma 2003) and expenses for N development. According to local farmers a 20% increase in yield could be achieved by intercropping peanuts with *E. urophylla.* (interview). The reliability of this source is however hard to tell. So it would be interesting to do a follow-up of this combination to investigate the potentials.

Inoculation with nitrogen-fixing bacteria in *E. urophylla* seeds increases the growth of the seedlings (Kang and Ma 2003). So by introducing nitrogen-fixing species as peanuts the same effect might be achieved. Probably not with as much due to the short period that the peanuts are present, but the assumption that the growth of the E*ucalyptus spp.* could benefit from growing with nitrogen-fixing species could be more reliable.

Intercropping *E. urophylla* with cassava (*Manihot spp.*) (Pic 2: Tab 12) has been observed on several occasions in southern China. Cassava makes a very good food source and therefore a reliable commodity, due to its high value on the market. Cassava has not got any direct abilities that could benefit the *Eucalyptus spp.* An introduction of mycorrhizae fungi could provide nutrients to the soil, and then be beneficial to the *Eucalyptus spp*.

Alley-cropping with cassava and *Eucalyptus spp.* has been made outside China, this showed a positive benefit/cost ratio (Wannawong et al 1991). This trial had similar spacing between the tree rows (4 X 4 m) as the *E. urophylla* plantation in southern China (Fig 2) which has a spacing of 2x4 m.

Picture 3: Intercropping with Eucalyptus (at the sides) and cassava (in the middle) in southern China. (Picture taken by Peter Genfors 2007)

It is however debatable if a food source commodity is suitable for companies, because this would mean another market to break in to. More resources and management would be needed. Prices on cassava can also fluctuate, which would mean a more instable investment on the crop. Competition of below ground aspects is also a reason to be unconvinced of the success of a combination with cassava and *Eucalyptus spp*. Interaction of the root systems could lead to a deficit in growth and damage inflicted to the *Eucalyptus spp.* roots when harvesting the cassava. How much the interaction between the root system is however unclear, it should be sufficient with a spacing 4 meters between the rows to sustain both root systems.

Cassava in combination with E*ucalyptus spp.* will also hinder soil loss and rainfall run off (Ghosh et al 1989), which would prove useful in areas where erosion is a big problem. Looking at the big picture, an investment in cassava could prove useful in a *Eucalyptus spp.* plantation despite the negative aspects.

Fertiliser compound such as the one used in NPK-150-B and NPK-300-B (Fig 2) could work in an agroforestry system due to the broadcasting tecnique and the larger amount of fertilisers distributed. Broadcasting is to be preferred in agroforestry, because the fertilisers would then be more even spread through the treatment. String distribution would only affect vegetation adjacent to the nutrients. String distribution is therefore not a good option in agroforestry practice. However any certain conclusions can not be made and this matter needs futher investigations to be conclusive.

Broadcasted treatments would increase the growth of shrubs and grass; which could work as a browsing ground for animals. Shading of the *Eucalyptus spp.* tree could then be utilized by the browsing animals. According to Silva Do Vale (2005) damage done to the trees trunk is minimal after 5-6 years. The damage done to the trees will depend on the type of animals grazing. It needs to be researched how agroforestry could be incorporated into *Eucalyptus spp.* based plantations in southern China and the consequences doing so. It would be interesting to see how an introduction of silvopastoral would work in a *Eucalyptus spp.* plantation.

Agroforestry among companies and the locals

Introduction of agroforestry in southern China is not a topic about introducing the system to the farmers, because the majorities already know what it is. It is more a term of perfecting and evolving the system to both parties' benefits. By conduction research and allowing locals to participate in the process may spread the knowledge. This can also work in favor for companies who are looking for cheap labor, but have a minor interest in crop production.

Locals could use the spare space to grow their crops on. In exchange for land the locals would have to plant and tend the trees. When the crops are harvested the land goes back to the company. This technique has been supported by Boonkird et al (1985). This would stop erosion problem which is caused by slash and burn practice and overexploitation of forestry products caused by local farmers, which according to Chavez (2004) is a problem. Van Noordwijk et al (2004) are recommending agroforestry to cope with the problem and get a more sustainable use of the land. This would work in favour for both the companies and the locals due to a more sustainable use of the land (Wannawong et al 1991), and therefore a more sustainable usage of the area.

Interviews indicate that local farmers still feel that the planted area is a place they can utilize as they always have. The forest is a place where they collect supplies and put cattle out for pasture. This might be a problem due to the fact that the locals don't have the knowledge when the animals might do harm to the trees. Instead of trying to drive them away and create tension between companies and locals it might be better to try and work together.

Allowing the locals to have browsing animals on the plantation in a controlled way, and use silvopastorism (Appendix) could increase the socioeconomic and environmental standards in the area. An introduction of silvopastorism into *Eucalyptus spp.* plantations could reduce soil erosion, weed control, increase fertilisers from the animals, reduce fire hazards, (Alvaro Ferreira De Mattos 2007; Mosquera-Losada et al 2006) and companies could gain good faith among the locals. The locals would have pasture for their cattle and a better understanding on how to act in a silvopastoral situation. Damage done to the tree and loss in yield is always an issue, but if the process is controlled the damage could be reduced to minimum.

What could the companies and the farmers gain on this;
Relations with the locals could strengthen. The observed locals or the interviewed farmers did however not give any signs on miss pleasing with having companies in the area (interviews). In areas where problems like this exist cooperation with the locals might solve a lot of problems.

Locals would have a bigger interest in the areas wellbeing, in terms of weeding and animal control. The area around the fertilizing trial the ground gets swiped for organic material such as leaves and branches (own observations). This is a problem due to loss of organic matter that could provide the soil with better stability and nutrients.

A cooperation of the area could provide the locals with a bigger farming ground. This would provide bigger harvests and more income for farmers, a better socioeconomically standard and a better relation between farmers and companies.

Agroforestry could help with local involvement, working opportunities and, differentiation of outcome. This would help to occupy unemployed locals, which would increase the socioeconomically standards in the area.

It would be interesting to see what agroforestry could do to the community in the long run in southern China if companies took an interest in the practice.

6. Conclusions

Fertilization trial
Broadcasted treatments have the highest growth after 32 months. An indication that the highest increment in growth located in NPK-100 was observed. The most suitable treatment is therefore hard to conclude; a survey of the root system should be done to sort the allocation question out. The recommended nutrient compound should be between

NPK-100 and NPK-150 with a broadcasted distribution system. NK-90 had a much lower increment in growth than the other treatments, which indicates that P is a critical nutrient for *Eucalyptus spp.* in southern China. The broadcasted treatments show a higher biomass growth than the other treatments. This is a result in both amount of nutrients applied and fertilizing technique. Density values indicate that fertilizers increase green density values and decrease basic density values, but the difference is too insignificant that any clear conclusions can be made. The best revenue in both veneer and pulp was recorded in treatment NPK-150-B and NPK-300-B. The highest fertilizing cost was recorded in NPK-300-B. It would be recommended that the laboratory in China would undergo a calibration in order to exclude the possibilities for measuring errors, due to the strange concentration ratios.

Agroforestry

Agroforestry can be cooperated into *E. urophylla* plantations using alley cropping as a agroforestry system with a spacing of at least 3-4 meters between the tree rows. Broadcasting would be preferred as fertilizing distribution. Preferably using cassava or peanuts as intercrop species, depending on the commodity interest of the user. The exact revenue made on this approach is hard to point out, but in rough numbers 7500 RMB/ha for cassava and 1275-1530 RMB for peanuts. Intercropping with chili is not as preferable due to high water demands from the crop. Browsing animals on the plantation is yet untested in southern China but has been conducted in Brazil. To evaluate the possibilities of having browsing animals in a *E. urophylla* plantation a trial should be done. Socioeconomically standards may be increased, but it is hard to make any conclusions from the site where the plantation is taking place. Recommendations and knowledge should therefore be collected by looking at other sites where trials involving socioeconomically issues have been made. It is however possible to increase the socioeconomically standards around the plantation in southern China with help of agroforestry practices.

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Appendix

7. Agroforestry

”Agroforestry is a land use that involves deliberate retention, introduction or mixture of trees or other woody perennials in crop/animal production fields to benefit from the resultant ecological and economic interactions”(Mcdicken and Vergara 1990)

7.1 Definitions of agroforestry

There are three major divisions in agroforestry, which then leads to several subdivisions and practices. There are in addition to these three major systems other smaller agroforestry systems such as trees combined with fishery and honey production.

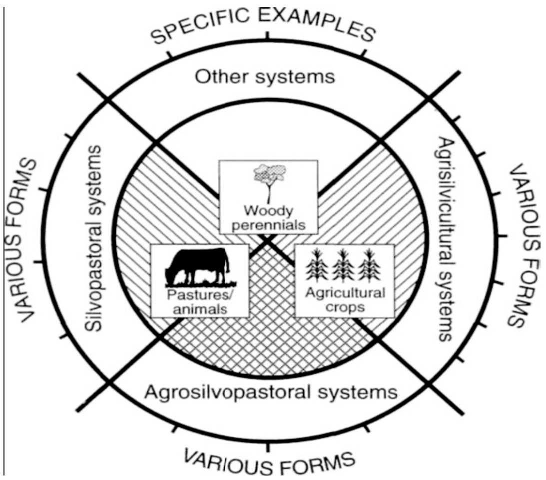


Figure 3:. Classification system within agroforestry (Nair 1993).

Agrisilviculture:	crops and trees.
Silvopastoral:	trees and pasture/animals
Agrosilvopastoral:	trees, crops and pasture/animals

7.1.1 Agrisilvicultural

This is a technique which combines agricultural crops with forest crops (Fig 3) (Browaldh 1995). A more primitive form of this technique is called swidden agriculture or slash and burn, which involves a continuous destruction of the forest by cutting and burning the forest lands (Chaudhry and Silim 1980). The locals who used this kind of system then used the area for agricultural crop planting, using the ashes as a type of fertilizer. This is however a pernicious technique and does more harm than good in the long term if not managed correctly. The present-day idea of agrisilviculture is to create a harmonic combination between crop farming and tree farming. This kind of system promotes the economic and the social development of the people living within or near the forest area. (Chaudhry and Silim 1980)

The tangya system

The characteristic of a tangya system is an area which is controlled by the government is allotted to a family, who is allowed to use the land for its own purposes. After a couple of years or after the crop harvest trees is planted on the area, after this the farmer is allowed to cultivate the land until the tree canopy closes (Macdicken and Vergara 1990).

The tangya system is a type of system where the user grows agricultural crops on a temporary basis in between regularly arranged rows of forest trees (Tejwani 1994) It's a type of shifting cultivation system where the idea is to temporarily cultivate a piece of land and then abandon the site and allow the site to regenerate. It is believed that the tangya system was first used in India as early as 1856 to establish teak plantations. The original idea was to let the locals have a piece of land for themselves for two years, and before abandoning the plot they had to plant it with teak stumps provided by the Forest Department. (MacDicken and Vergara 1990) In 1926 the tangya system was also introduced in Nigeria, the type crops used is unclear but the goal was just about the same, to enable forestry workers and their families to feed themselves (Gholz 1987).

Alley cropping

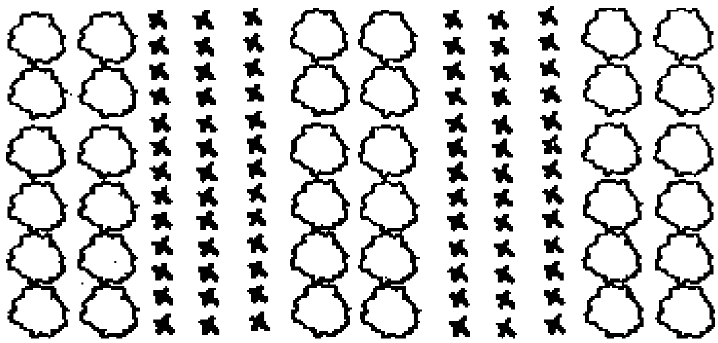


Figure 4: Alley cropping scheme with two rows of trees and three rows of crops (http://www.fao.org 2007-10-23)

Alley cropping is a form of fallow improvement, and has been practiced for a long time where farmers have used trees or shrubs as vegetative cover (Mcdicken and Vergara 1990). The idea with alley cropping is that crops are grown between planted hedgerows of woody shrubs or trees (Fig 4), and if managed correctly it may even reduce erosion, water loss (from evaporation) and improve soil conditions. When managing alley cropping it is important that the rows are wide enough so that the trees on the sides have enough space to grow on (www.omaf.gov.on.ca). If there is not enough spacing there is a good chance that the roots will interact with each other. The canopy of the tree will also block out the sun light in expense of the crops (Nair 1989). Alley cropping is best practiced on fertile soils.

Nitrogen-fixing species is to prefer when selecting tree species for an alley cropping, species such as *Leucaena spp.* which is the most popular one in alley cropping (www.worldagroforestrycentre.org), *Acacia spp.*, and Gliricidia (*Gliricidia sepium (*Jacq.)). These species could be intercropping with for example maize, mushrooms or rice. After time the canopy of the trees will grow denser and it is therefore important to alternate crops depending on their demand of sun light. For example when the trees are young and their canopy are less dense an intercropping with maize would be suitable, and after a while when the trees has grown taller a substitution would be preferred like mushrooms.

Alley cropping is a useful system with great benefits such as (http://www.fao.org):

- Higher crop yield combined with a longer cropping period
- Possibility for a more intensive cropping
- It regenerates the soil fertility more rapidly and effectively by the foliage
- External inputs such as fertilizers are reduced
- Allows a steady income from the crops while the tree are waiting to be harvested

Alley cropping should not be seen as a substitute for fertilizers. However the combination of alley cropping and fertilizers can result in a significantly higher crop yield than if the crops where to grow alone (Kang 1993).

7.1.2 Silvopastoral

Picture 4: A water buffalo grazing under a Eucalyptus stand in South of China (picture taken by Peter Genfors 2007)

The silvopastoral technique is a system that combines forest trees with grasses and bushes as an understory (Fig 4; Pic 4). The goal with this approach is to provide with fuel wood, timber and fodder for grazing animals (Buck et al 1998). It is very common in south eastern Asia especially in the highlands, east and central Africa and West Africa (Nair1989). If practiced correctly the silvopastoral system has many advantages, such as (Tejwani 1994); reduced herbaceous and short ligneous vegetation, reduced risk of fires mixing of leaf litter and decomposition a mineralization. Experiments with *Eucalyptus spp.* in a silvopastoral system left one conclusion. It requires a rainfall of at least 1000mm before *Eucalyptus spp* can encourage growth of grasses (Gholz 1987). Studies comparing grasses grown with and without *Eucalyptus spp.* showed an increased growth of grass under a *Eucalyptus spp.* stands (Gholz 1987).

It is mostly common to use nitrogen-fixing trees in a silvopastoral system (Mosquera-Losada et al 2006). Nitrogen-fixing species may provide soil with important nutrients, and will keep the system more sustainable. Most of the nitrogen-fixing species also has deep rooting system which allows them to collect nutrients from deep soil layers (Buck et al 1998), Due to their nitrogen-fixing abilities the leaves will become very nutrient-rich, and therefore a good fodder source for the animals (Elevitch and Wilkinson 1998-2003).

One of the most desired and appreciated silvopastoral species is *Acacia spp.,* because of its ability to provide food for grazing animals during dry seasons. This is possible because of that Acacia nearly always flowers during or before rains, which means that the eatable pods reaches maturity during the dry season. (Shroth et al 2004)

7.1.3 Agrosilvopastoral

The main objective with agrosilvopastoral is traditionally to combine woody components with crops and animal husbandry (Fig 4) (Rosso 1996). One of the techniques within agrosilvipastoral is the home garden system. It is extensively practiced in high rainfalls areas in India, Sri Lanka, Thailand, Malaysia, Indonesia, Papua New Guinea, and in south and Southeast Asia (Tejwani 1994). The home garden system is defined in Tejwani´s (1994)book agroforestry in India as a "*land use form on private lands surrounding individual houses with a definite fence, in which several tree species are cultivated together with annual and perennial crops, often with the inclusion of small livestock*".

Home gardens can provide the locals with fruits, firewood, fodder and medicines; it also provides a variety of products for the market all year round. One big advantage with the home garden system is that most people can participate, since most poor families in rural areas have a small garden around their houses. (Skutsch 1994)

7.2 Agroforestry's impact on soil nutrients, texture and soil water

7.2.1 Impact on the Soil

Soil erosion is a constant threat not only to the indigenous farmers but also to the forest companies active in the area. About 33% of the total territory in China is hit by erosion, and is a major problem in cultivated lands (http://english.people.com). It is therefore important to get the better of the situation before it's too late.

An introduction of agroforestry could decrease the erosion of the soil, especially if it is a fast growing species. A more effective use of the nutrients in the ground may be induced with an interaction of carefully selected species. For instance if tree species with long roots is combined with a crop species where the root are quite shallow, the tree species will use the nutrients and the moisture from deeper soil layers. These nutrients will transfer up into the canopy and then releasing the nutrients as litter to the soil surface. The crops will then be able to use the nutrients to increase their yield. The roots will also reduce nutrient loss by erosion and give the soil a better texture. (Young 1989; 1998)

The most promising agroforestry systems for erosion control are (Young 1998)

- Multistory tree gardens
- Perennial-crop combinations
- Contour hedgerows
- Trees on erosion-control structures
- Wind breaks and shelterbelts

7.2.2 Multistory tree garden

Woody and herbaceous crops are grown together in a spatially mixed, dense multistoried structure (Barker et al 1998). The systems are mostly dominated by perennial crops which lead to a high ratio of nutrients stored in the vegetation rather in the soil (Nair 1993). This enables a good nutrient cycle, and provides a relatively good protection against leaching and erosion. An important component of a tree garden system is fruit trees, because a tree garden system is mostly supposed to produce goods to the farmer; such as fuel-wood, forage-crops, spices, medicinal plants and other highly nutritious products (proteins, vitamins, and minerals) (Nair 1993).

7.2.3 Perennial-crop combinations

Perennial crops are mostly grown on sloping lands in the temperate zone, using tea, coffee, cacao, oil-palm, rubber and pine apple for example. They must however be well managed to be effective in a conservation purposes. It is possible to have a good erosion control under monocultures, but agroforestry with perennial crops offers a greater flexibility in management (Young 1998). The key to a good perennial-crop management is to maintain a good ground surface cover, which can be accomplished through leaf litter fall (Rubber plantations), mulching (Coffee and banana plantations) or spreading of crop cover (*Pueraria spp.*) (Young 1998).

The main functions of a perennial-crop combination are (Young 1998):

- Reduction of evaporation from shaded trees and through mulch cover
- Reduction of erosion by root systems and mulch cover
- Nitrogen-fixation
- Increased water input
- Short term and medium term nutrient cycling through litter decomposition and soil organic matter

7.2.4 Contour hedgerows

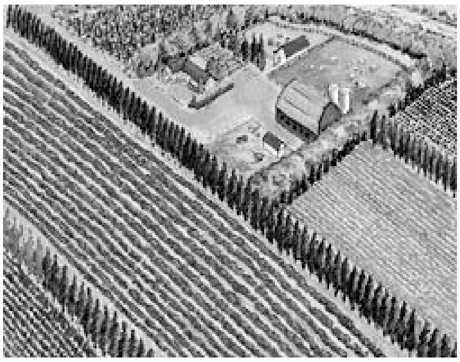
This system is defined as a variation of hedgerow intercropping, and is practiced on slopes with the primary objective of soil and water conservation (Young 1998). The structure of a hedgerow system are that the hedgerows generally are planted in a 4-8 m spacing, the distance between the plants are usually 25-50 centimeters depending on if the hedgerows are single or double (Young 1998). There have been several studies of runoff and erosion under contour hedgerows systems, for instance in Kenya (Kiepe 1995), Indonesia (Hawkins 1990) and Peru (Alegre and Rao 1995). In Southeast Asia contour hedgerows with leguminous trees on slopes has been used with success, and it has been shown an increase in yield levels when grown between hedgerows of leguminous trees (http://www.worldagroforestrycentre.org). This could effectively reduce erosion, even after a very short time span (18 months).

7.2.5 Trees on erosion-control structures

Trees are planted on terrace risers, banks, ditches and grass strips, they do not conserve the soil but they stabilize the structure and makes the land on which they grow on more productive (Young 1998).

7.2.6 Windbreaks and shelterbelts

This technology is worldwide used for shade and shelter (Pic 5). Its main functions are to reduce wind speed, and with that reduce wind erosion and wind damage to the crops (Young 1998). If the user have any desires to utilize a silvopastoral system windbreaks and shelterbelt may be proven useful as shelter for the livestock (Young 1998).



Picture 5: A windbreak\agroforestry system (Joshia 2000)

The choice of tree species is a crucial factor if a successful windbreak is to be established. If species not suitable for the purpose or the area are selected yield reduction may be unavoidable. Windbreaks of *Eucalyptus tereticornis* (SM.) in India showed a great reduction to yield production in the area (Young 1998). However if the windbreak is well managed an increase in crop yield can be achieved, for example in Niger where *Azadirachta indica* (A. Juss.) was used which increased the yield of millet by 20-50% (Young 1998).

When the selection of tree species for windbreaks performed the most important thing is to find combinations of species which properties is a resistance against high wind speed, being able to produce goods which the locals can utilize such as timber, fruits and fodder and don´t possess an adverse effect against adjacent crops and pastures (Young 1998). Species that are mostly used in windbreaks are *Casuarina eguisetfolia* (L.), *Casuarina glauca* (Sieber.), *Prosopis juliflora* (SW.), *Acacia spp.* and as mentioned before *Azadirachta indica* (Young 1998).

Almost any tree species can be used in windbreaks. However, fast growing trees should be used and deep rooted trees planted along the edges. For the windbreak to function all-year round, it is necessary that at least some of the selected species are evergreen (Beetz, 2002).

7.2.7 Reclamation forestry

Reclamation agroforestry is a way to use agroforestry in a soil restoring purpose. It has successfully been used in India where they restored fertility on degraded soils (Young 1998). The ways of restoring the soil fertility is first to establish a full forest cover with some nitrogen-fixing species. It is suggested to let the litter reach the ground surface, which means keeping it safe from any kind of grazing (Young 1989). This will provide the soil with organic matter, and give the soil a more erosion resistant texture (Nair 1993). This approach will also reduce the additional fertilizer cost, which most poor farmers can't afford (Young 2002) The use of E*ucalyptus spp.* has also been shown to reduce salinization in the soil, due to *Eucalyptus spp.* ability to lower the water table in the ground, and hence forth make the soil more fertile and productive (Nair 1993). This is possible because *Eucalyptus spp.* has a high water demand.

Successful trials of reclamation forestry have been made on several occasions, for example in India (Singh et al 1993), Indonesia (Soerianegara and Mansuri 1994), and Vietnam (Le Vanh Lanh 1994), where they managed to reestablish former degraded lands by planting different types of trees.

Trees which are suitable for reclamation forestry are trees with fast growing abilities, preferably nitrogen-fixing and be able to grow on adverse sites, such as saline, toxic or sandy soils (Young 2002). *Casuarina equisetifolia* (L.)*, Tephrosia candida* (Roxb.) and *Acacia spp.* (Young 1998)

7.2.8 Soil water management

There are two systems that are established as good means to increase water availability in the soil. Windbreaks reduce runoff by reduction in evaporation and contour hedgerows have an increased effect to the infiltration hence a reduction of runoff (Young 1998). The effect of trees on evaporation has shown to be of great significant for instance evaporation can be five times higher in the clearing than under a canopy cover in the tropics (Young 1998). This is an effect of the shading done by the canopy of the trees, because radiation is the domination factor in evaporation (Ong and Huxley 1996).

A carefully planned species selection may increase the efficiency of water uptake, and reduce the competition of water between crops and trees. In a study done by Kizito et al (2007) a combination of two native shrub species (*Guiera senegalensis* (J.F Gemel.) and *Piliostigma reticulatum* (DC.)) and annual food crops showed that the shrubs preferred water from the lower profile, which was less than 1.10 m. On this depth the shrubs did not compete with the foods crops for water. However in drier areas (800 mm year^{-1}) a tree-crop combination may prove to be a problem. In a *Eucalyptus camaldulensis* (Dehnh.) windbreak stand in northern Nigeria soil water was reduced by 25% up to 12 m from the trees. The consequence was that adjacent species of millet suffered from crop failure (Young 1998). With a rainfall of 900-1000 mm year^{-1} soil water depletion was not reported, in fact near Lusaka in Zambia where hedgerows of White popinac (*Leucaena leucocephala* (Lamk.)) and *Flemingia congesta* (Willd.) the adjacent maize did not suffer any crop failure, and the soil water was higher under the hedgerows than in the alleys (Young 1998). Multistory and silvopastoral agroforestry systems have been seen to improve the soil structure and moisture retention (Saha et al 2004).

Control over the fire damage in the plantation

Table 13: Number of trees affected by the fire in each plot. The numbers 1, 2 and 3 shows the severity of the damage, where 1 is unaffected.

Control	Bark			Leaves			NPK-100	Bark			Leaves		
	1	2	3	1	2	3		1	2	3	1	2	3
12	27	10	3	40	0	0	2	40	0	0	40	0	0
16	36	0	0	36	0	0	13	34	1	0	35	0	0
30	2	20	13	26	9	0	21	2	18	19	38	1	0
37	4	21	13	36	1	1	35	8	14	16	19	17	2
Average	14	10,6	6,4	27,8	2,4	0,8	Average	21	8,25	8,75	33	4,5	0,5
NPK-0							NK-90						
5	36	0	0	36	0	0	10	8	6	26	15	16	9
19	6	14	20	35	4	1	22	3	5	31	28	9	2
33	5	14	21	21	16	3	24	38	0	0	38	0	0
41	2	14	23	33	6	0	39	5	15	20	13	25	2
Average	12,25	10,5	16	31,25	6,5	1	Average	13,5	6,5	19,25	23,5	12,5	3,25
NPK-100-2							NPK-150-S						
4	39	0	0	39	0	0	1	19	21	0	40	0	0
23	1	23	16	38	2	0	8	40	0	0	40	0	0
31	3	11	26	10	27	3	18	35	0	0	35	0	0
40	2	8	29	21	18	0	38	8	12	15	35	0	0
Average	11,25	10,5	17,75	27	11,75	0,75	Average	25,5	8,25	3,75	37,5	0	0
NPK-150-B							NPK-300-B						
9	18	14	7	20	19	0	15	28	7	0	31	2	2
11	2	11	27	37	2	1	20	12	22	5	37	2	0
17	39	0	0	39	0	0	32	10	15	14	24	10	5
34	4	12	23	21	18	0	36	14	19	3	36	0	0
Average	15,75	9,25	14,25	29,25	9,75	0,25	Average	16	15,75	5,5	32	3,5	1,75

Interviews

Forest farmers
Sixianhe
Liaojun

Academician
Dr. Xu Jiang Chu

Other interviews were also made using the questioner; unfortunately their names and titles were lost in the process. Both were male researchers working with agroforestry. Contact person for these people was Hu Jiang, Stora Enso.