Swedish University of Agricultural Sciences
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Abstract

Chinas government has a multifunctional program for a more sustainable forestry since 2000. This six key forest programs goal is to develop a more sustainable forest sector but also take environment consideration. The state forest administration in China has decided to create 5.8 million hectare of fast growing and high yield forest. Eucalyptus has showed to have good properties for pulp and timber production and therefore Eucalyptus plantations are under development in costal areas in southern China. By adding extra nutrients, growth can be enhanced in Eucalyptus plantations. The purpose of this fertilization trial is to see the possible effects on growth in different fertilization treatments. This thesis is a part of a series of experiment conducted on the site the past years. The whole trial will be summarized the coming years. Treatment NPK 300-B had after 44 month the highest CAI of 47 m^3 ha^{-1}, $year^{-1}$. The lowest CAI had treatment NK-90 with 30 m^3 ha^{-1}, $year^{-1}$.Highest standing volume has treatment NPK- 300-B (131 m^3 ha^{-1}) followed by NPK-150-B (126 m^3 ha^{-1}). Four treatments are very close to each other and range between 110-119 m^3 ha^{-1}. The treatment with the lowest volume was NK-90 (96 m^3 ha^{-1}) followed by control treatment (101 m^3 ha^{-1}). Despite extra phosphorus the trial has not reach the target ratio for this nutrient and because of this the trail has potential for higher growth. No visual effect was visible on the root system between broadcast and string applied fertilizer.

Fires impact on wood quality has also been investigated in this study. The aim is also to evaluate the economic impact a fire can have in a stand. Fire damaged trees from three damage classes were dissected in three ways; as Chips, planks and discs to evaluate quality. The quality problems that were found were charcoal remains. These were located 3-4 m up in trees and seem to be randomly spread among the trees. Presence of gum were also found but it seems not to be a problem in the pulp process. The study indicates that it is hard to avoid charcoal in timber by judging only the surface and the size of the fire scars to estimate quality.

Best revenue has veneer in treatment NPK-150 B 58965 RMB/ ha^{-1} followed by NPK- 100 but in pulp and chipboard alternative best revenue were found in treatment NPK-100. Pulp had 40431 RMB/ ha^{-1} and chipboard had 5425 RMB/ ha^{-1}

Key Words: Eucalyptus, Fertilization, Fire, Roots, Wood quality

Sammanfattning

Kinas regering har haft flera skogsprogram under årens lopp. Det senaste nationella skogsprogrammet som Kinas regering gemomför är ett multifunktionellt program som heter *Six key forest program* där huvudmålet är att återbeskoga 76 miljoner hektar dålig jordbruksmark. I det nya skogsprogrammet finns ett mål att skapa 5.6 miljoner hektar av snabbväxande trädplantager. Eukalyptusen har visat sig att ha fina tillväxtmöjligheter och därför är plantager under utveckling i de kustnära områdena i södra Kina. Detta examens arbete är det tredje i en serie mätningar av ett mineralgödslingförsök. Försöket kommer att avslutas och sammanställas om något år. I försöket finns sju behandlingar i fyra block. Genom att tillföra näring så konstaterades det att tillväxtpotentialen av eukalyptus i Kina kan öka. Resultatet av den tredje mätningen, som redovisas i detta examens arbete, är att behandling NPK-300-B har den högsta löpande tillväxten på 47 m^3 ha^{-1} efter 44 månader. Lägst löpande tillväxt har behandling NP-90 med 30 m^3 ha^{-1}. Vid volymmätningen visade det sig att behandling NPK-300-B fortfarande har högst volym på 131 m^3 ha^{-1} följt av NPK-150-B på126 m^3 ha^{-1}. Fyra behandlingar ligger väldigt när varandra och har en volym på mellan 110-119 m^3 ha^{-1}. Lägst volym har behandling NK-90 på 96 m^3 ha^{-1} följt av kontrollbehandlingen 101 m^3 ha^{-1}. Trots extra näring så har försöket inte kommit upp i den önskade näringskvot som bör finnas i bladen. Därför finns det fortfarande potential för högre tillväxt i försöket. Rotsystemen undersöktes också för att utvärdera om det finns någon skillnad på rotsystemen beroende på hur mineralgödsel appliceras och det fanns ingen synlig skillnad mellan att gödsla i strängar och att sprida gödseln jämt på backen.

Brandens inverkan på vedkvaliteten och de ekonomiska konsekvenser som kan bli följden av sämre vedkvalitet har också undersökts i detta examensarbete. Brandskadade träd från tre olika skadeklasser var utvalda och söderdelades på tre sätt, flis, brädor och diskar. Det största kvalitetsproblem som hittades var kolrester 3-4 m upp i träden. Kåda gick att finna i brandljuden men ses inte som ett stort kvalitetsproblem i pappersmassaprocessen. Ett samband mellan storlek på brandljud och kolrester i träden gick ej att finna i denna undersökning. Försäljning av faner gav det bästa ekonomiska utfallet i den ekonomiska simuleringen. I samma simulering var behandling NPK-150 B med 58965 RMB/ ha^{-1} följt av behandling NPK- 100 på 57591 RMB/ ha^{-1} mest ekonomiskt. Efter detta hade pappersmassa- och spånskivealternativet med NPK-100 den bästa ekonomiska avkastningen på behandling. För pappersmassaalternativet var avkastningen 40431 RMB/ ha^{-1} och för spånskivealternativet 5425 RMB/ ha^{-1}

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1. Introduction

China has since it became the People’s Republic of China had different forest policies depending on the politic in the country. During the period 1950s-1970s the prevalent forest policies was sustainable yielding and silviculture with focus on timber production but in the 1980s the forest policies changed and shifted focus from the utilization of natural forest to high qualified plantations. The focus on timber production changed to diversified management and integrated utilization with the forest industry. In the early 1990s the forest policies focus change again towards multifunction programs were the influence of public participation started to play an important role in forestry and the environmental development (Xiaoping 1998). One enormous program which was developed during the 1990s was the six key forest program which objectives were to develop and create a more sustainable forest sector. Year 2000 the government launched the huge six key forest program, it changed the forestry management fundamentally.

The six key forest programs are a multifunction programs and aim to convert poor agricultural land into forest. The goal is to reforest 76 million hectares and it covers 97 % of the counties in China (Wang et.al. 2007). This program also includes protection of wild life, natural forest, prevention of soil erosion and prevention of desertification of grassland. The six key program also promote forestry development within the program as fast growing high yield plantation (FGHT) (Demurger et.al 2007).

1.1 Fast growing high yield plantation (FGHT)

To meet the increased demand of forest wood products and reduce Chinas dependency on imported wood products Chinas government decided to develop the domestic forestry (Findings 2004). Chinas goal is to build new pulp and paper mills to meet the increased demand of paper in the country. The State Forest Administration came up with a strategic development plan. Where the goal was to have 13.3 million hectare of fast growing high yield plantation (FGHT) and this plantation should be establish between 2001 and 2015. 5.8 million hectares was intended to be plantations used for pulp-wood. This FGHT program are concentrated in to four priority regions; (i) Northeast China - Inner Mongolia, (ii) The lower and middle reaches of the Yellow river, (iii) the lower and middle reaches of the Yangtze River and (iv) Chinas south coastal regions (C. Barr et al. 2004).

One of these six key programs is the fast-growing and FGHT. This program opened up for commercial forestry and industry in China. To develop the forest industry Chinas National development and planning commission (NDRC) issued a list of 42 priority pulp and paper projects for both domestic and foreigner investors and 13 of these projects are scheduled to be an integration of high grade paper with FGHT. Out of these 13 projects, three are planed to be large scale chemical pulp mills (C. Barr et al. 2005). The introduction of new technology and growing ability to produce more added value products in China has lead to that the government has closed over 4000 small scale pulp mills across China due to their problems with water pollution (With et.al 2006). About half of the small scale pulp mills were nonwood and used agriculture residues (Barr et.al 2005).

The central government supports the projects through different subsidies for example loans, discounted loans from state banks and extended repayment periods and fast track approval to companies who are on priority projects (Barr et al. 2005). Land lease for commercial forest companies in China has been allowed and this was a major change form the past.

Today is China is very dependent on raw-material import from the surrounding countries. The growth of GDP has in average been increasing with 10% since the free market reforms 1978 (Wikipedia 2008). The rapid growth with 1300 million people in China (Wikipedia 2008) creates a huge market and a need for raw- material and this has created an enormous pressure on the natural resources in the country. Year 2007 Russian logs were nearly 70% of Chinas total round wood import (FAO 2007). With the economic growth to day and increased prosperity it will be interesting to see if China will follow the cross- section curve (Figure1). If China develops the paper consumption as predicted the demand in the future will be huge. This means that China has good opportunities to develop pulp and paper production but also the consumption of other wood product will increase. China is still in the beginning of the GDP growth compared with other developing countries and of what the expected demand can be in the future.

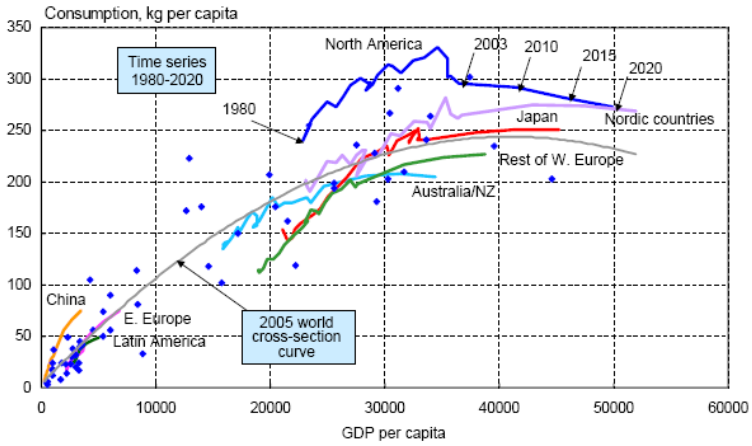

Figure 1. Paper consumption kg per capita source Jaakko Pöyry.

1.2 Pest, diseases and fires in plantations

Plantations in the world and in south East Asia are increasing and with this new problems emerge. Eucalyptus is in the most cases an exotic tree species. When new tree species are introduced in a new area there is usually no problem in the beginning, but after a while local pathogen and/or bacteria will adapt to the Eucalyptus or new diseases will come in from surrounding areas. The problems emerge mainly in stem shoots and leaves. To control pest and diseases in a plantation it is very important with a systematic diseases management (K, Old et, al., 2003).

The problem with fire in plantations is different in different parts of the world. Fires that occur commonly in the plantations in China are almost always caused by human impact. About 1% of the plantation burn every year and the main reason is people's careless handling with the fire. One common cause is when farmers burn the zone between the rise fields and the forest to get rid of grass and bushes in the spring. A second reason is funerals and tombs in the forest. After a funeral there is a tradition to burn a lot of status things in paper like clothes, mobile phones and fake money. The tradition is also to use fire crackers at funerals. In China the 4th or 5th of April is a very important national holyday and this has traditionally been the big tomb cleaning day every year. This date people burn paper money, paper cell phones, paper clothes, they remove grass, leaf and then they burn the slash on the site. The third reason is when people burn slashes/garbage behind the house and are not careful.

1.3 General site description over the trial

The trial is located in the province Guangxi in southern China and is situated outside Baisha 90 km from Beihai. GPS coordinates for the trial are WGS 84 Lat.21.652709, Long 109.669709. In January 2005 the experimental area was scarified with the ripping method. The ripping was 60 centimeter deep and was made with a big hook behind a bulldozer.

The climate is subtropical with an average temperature of 23° C, and average precipitation is 2100 mm (Andersson 2007). The soil is poor with a sandy top soil. Sub soil varies from loam to sandy clay (Andersson 2007).

Figure 2. Describes were the trial took place.

According to Risto Vuokko at StoraEnso Goangxi, a fire struck the trial in August 2007. This fire was a medium scale and resulted in many damaged trees.

An ocular fire damage assessment and classification of damage trees was made by Peter Genfors 2007. Each tree was valued from scale 1-3 where 1 is unharmed and 3 were severly damaged.

In 2008 the winter was extremely cold and the summer very rainy. Two typhoons stroke the trial and one of them was the biggest in many years. This has lead to that some trees are leaning and a couple of trees have been broken by the wind.

In November 2008 when the third revision was made of the fertilization trial, a new small creek was poring in the trial through plot 11, 12, 13, 17, 18 and 24 because of all rain. The plots are described in Figure 3.

In block 4, the trial contains tombs and old remains of tombs (Figure 3). The tomb has been established after the trial started, but there are examples on more tombs in other blocks. Tombs are mostly situated in between the rows. Block 4 has also the worst fire damage in the trial, with lot of scars from the fire still open one year after the fire.

1.4 Description of the thesis

This thesis has two major topics. First topic focuses on fertilizer impact on growth in Eucalyptus plantations in Southern China, while the second topic concerns impact of fire on wood quality, when the main purpose is to use the wood for pulp. The thesis will be divided in three chapters based on each topic. The first chapter covers the third year of monitoring nutrient status in leaves and yield in the fertilization trial in Baisha. Besides this, root distribution was also studied in the experiment.

The second chapter describes the wood quality after the fire. Trees were dissected into planks, discs and chips in the search for pollution.

The third chapter contains economic calculations for different fertilization treatments and what the economical impact of the fire can be in a stand.

2. Fertilization trial

2.1 Background to fertilization in Eucalyptus plantations in China

Due to agricultural activities during the last decades and with limited nutrient supply, the soil has degraded with the result of deficit of some nutrients. This is limiting the growth. The problem in southern China is that usually there is a deficit of the nutrient phosphorous in the soil. To achieve high yield it is necessary to use fertilization. One type of fertilization scheme that is used is a three years fertilization scheme. Year one a basal fertilizing along with the seedling is done year two and three additional fertilization is conduced (Shuxion. Qi et, al., 2007). StoraEnso is using a two year based fertilization scheme where the first fertilization is applied during the plantation. The Second fertilization is done the year after planting and the fertilization is applied in strings. (P. Andersson 2007). This fertilization experiment was initiated because of low productivity in eucalyptus in China compared with other countries as Brazil. StoraEnso saw a potential to reduce the rotation period by adding right nutrient.

2.2 Material and Methods

2.2.1 Description of the fertilization trial

This fertilization trial is a collaboration project between SLU and StoraEnso and has been running for four years and has been followed up every year. The goal of the experiment is to evaluate different fertilizations effect on production and economy.

The area was planted in March 2005 with a density of 1250 Eucalyptus plants per ha, where all seedlings was given the same amount of fertilizer in the start. The trial was established in March 2006. The Eucalyptus species used in this area is a hybrid between *E. uropylla* and *E. grandis*

There are eight different treatments in the trial which is divided into four blocks. Each treatment is replicated once in each block, this gives in total 32 plots. Size of the plot is 32 x 32 meter equal to ca 0.1 ha^{-1}.To avoid edge effects from neighboring plots measurements are only conducted at the inner plot of 300 m^2.

Fertilizers were applied in two different ways in the experiment. The fertilizer was applied in stings or broadcasted. Fertilizations in strings mean that a small hole (20x20x20 centimeter) was dug between every tree by hand. The fertilizers were placed into the hole and then covered with soil. Broadcasted fertilizers were applied evenly by hand over the whole plot surface.

The leaf analysis after 32 months showed a deficit of phosphate but a surplus of the rest of the nutrients. After analysis of the NPK-16-12-12 fertilize it showed that phosphate only contained 3.6 % of phosphate instead of 12 %. New fertilizers were used in spring 2008, NPK 16-6-16+0.3B and CalciumMonoPhosphate (CMP).

Plot 10 and 12 was excluded from the fertilization trial because of the damage from the fire and a typhoon, which caused tree mortality and there was not enough trees remained in these plots. Initially 1280 trees were measured at the first revision but tree mortality, mainly caused by drought, fire and typhoons reduced the number to1166 trees in 2008.

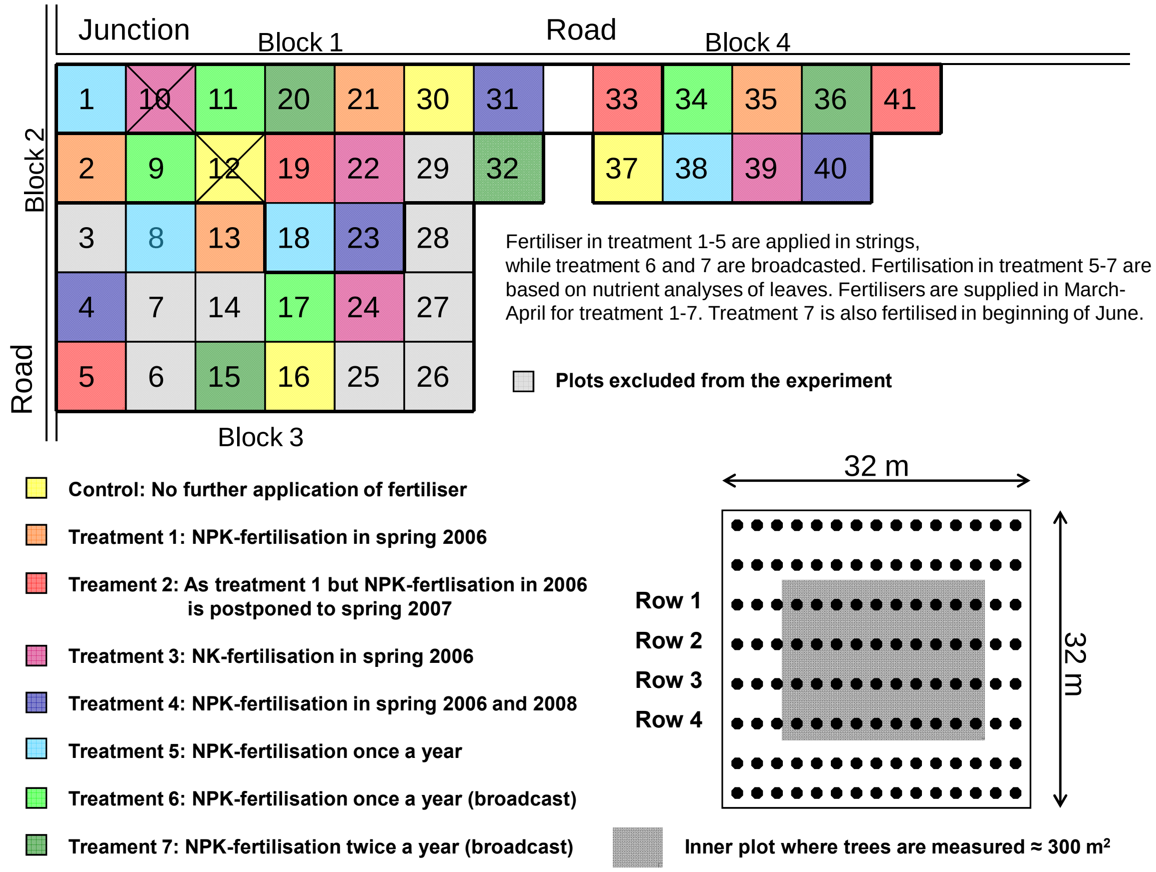

Figure 3. A map over Biasha trial 2008. The trial has eight treatments and repeated in four blocks. Total number from the start was 32 plots but 2008 plot 10 and 12 was excluded. Control C is untreated plot and is labeled 12, 16, 30 and 37. Treatment 1 (NPK- 100) labeled 2, 13, 21 and 35. Treatment 2 (NPK- 0) is labeled 5, 19, 33 and 41. Treatment 3 (NPK- 90) is labeled 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 (P. Andersson 2007).

2.2.2 Trial treatments

Control treatments with no fertilizer applied
Treatment 1: In spring 2006 was NPK fertilizer applied and it was 100 kg ha^{-1} N, 75 kg ha P and 75 kg ha K. In total 625 kg ha (NPK 16-12-12) Name of this treatment: NPK- 100 (Treatment 1 is the normal standard treatment at StoraEnso China.)

Treatment 2: The same amount NPK combination but the difference is that it was applied on in spring 2007. Name of this treatment: NPK-100-0. (Same standard treatment as treatment 1 but applied one year later than normally)

Treatment 3: Is applied with NK fertilizer and the combination was 185 kg ha^{-1} urea (46%) and 125 kg ha^{-1} KCL (60% k_2O). Name of this treatment: NK-90.

Treatment 4: Applied NPK 16-12-12 in string. The amount was 625 kg ha spring 2007 Name of this treatment: (NPK 100-2).

Treatment 5: Applied with NPK 16-12-12 in sting. The amount was 150 kg ha^{-1} N, 115 kg ha^{-1} P and 115 kg ha^{-1} K. Name of this treatment NPK-150-S. In year 2008, 120 kg ha^{-1} extra phosphate.

Treatment 6: Treated like treatment 5 but broadcasted fertilizer instead. Name of treatment: NPK-150-B. In year 2008, 120 kg ha^{-1} extra phosphate.

Treatment 7: Treated like treatment 6, but the amount of fertilizer is broadcasted twice a year instead. Name of this: treatment NPK-300-B. In year 2008, 240 kg ha^{-1} extra phosphate.(maximum growth)

2.2.3 Measurements of volume

To investigate the effect of fertilization in different treatments we measured biomass and analyzed the nutrient content in leaves. To measure volume we used a caliper for diameter and Haglöf Vertex III hypsometer for measuring tree heights. Diameter was measured at breast height, DBH (1.30 m above ground). All trees were cross callipered. To avoid errors the hypsometer was calibrated before measuring the first tree in every plot. Two trees with the largest DBH, were also selected to measure the dominant height.

Paula Susila, at StoraEnso Wood Supply, has developed a volume function for Eucalyptus. The volume is presented in m^3 and the function below only needs the tree height and DBH diameter.

$$V=0.038447*DBH^{2.058292}*H^{0.933308}$$

2.2.4 Analysis of nutrient content in leafs

Leaf samples from six different trees from plot 10 and 12 in block 1 were collected. These blocks were used because when the leaves are collected trees are cut down and it is better to use trees from plots excluded from the growth trial when doing this. The leaves were dried in an oven for 48 hours at a temperature of 85° C and then sent to laboratory in China for analysis. In Andersson´s Master Thesis (2007) you can find more details about this process.

2.2.5 Fertilizations impact on the root distribution

This survey was conducted to see if there are differences in the root distribution between the broadcasting and string methods, treatment 5 and 6. The type of fertilization method used for treatment 5 was the sting method and broadcasting was used in treatment 6. 10 trees were cut down and the stumps were dug up. Five stumps were dug up in plot 18 (treatment 5) and plot 9 (treatment 6). Both plots had leaning ground with dry soil in one end and moister soil in the other end of the plot. Of these five stumps on each plot, three stumps were selected on the dry soil and 2 stumps in the moister soil. The selected trees were just outside the measured inner plot but still within the same treatment (Figure 3). The root systems were examined ocularly.

The criteria for how the root system was judged came from (Shuxiong Q. et. al 2007). We looked at the following factors:

- Number of main stem and lateral roots.
- Roots should be evenly distributed around the tree.
- Root development: well grown around and down.

The stumps were dug up with a spade. The roots were followed in all lateral directions until a diameter of about 10 mm was reached. This was done to see if root distribution differs between string and broadcasted fertilization, or if the root followed the ripping line.

2.3 Results from the fertilization trial 2008

2.3.1 Results of the current annual increment (CAI) from the fertilization trial after 44 months

The broadcasted treatment NPK 300-B had after 44 months the highest current annual increment (CAI) of 47 m^3 ha^{-1}, $year^{-1}$. The lowest CAI had NK-90 treatment with 30 m^3 ha^{-1}, $year^{-1}$, where phosphorous has not been added at all.

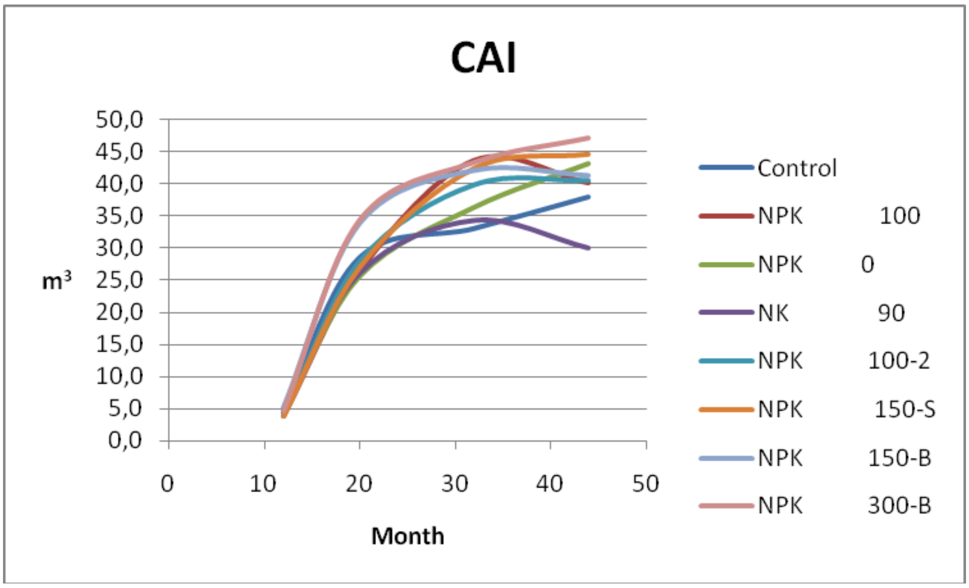

Figure 4. The current annual increment over bark in the different treatment after 12, 20, 32, 40 months. Data has been taken from P. Andersson (2007), P. Genfors (2008) and data from the establishment of the trail.

2.3.2 Results of the mean annual increment (MAI) from the fertilization trial after 44 months

Optimal rotation period in terms of production is when CAI becomes lower and cross the curve of mean annual increment (MAI). By comparing MAI and CAI, CAI is still considerably higher than MAI. In general CAI is ca 12 m3 higher than MAI if you compare Figure 3 and 4. CIA and MAI is closest for treatment NPK-90.

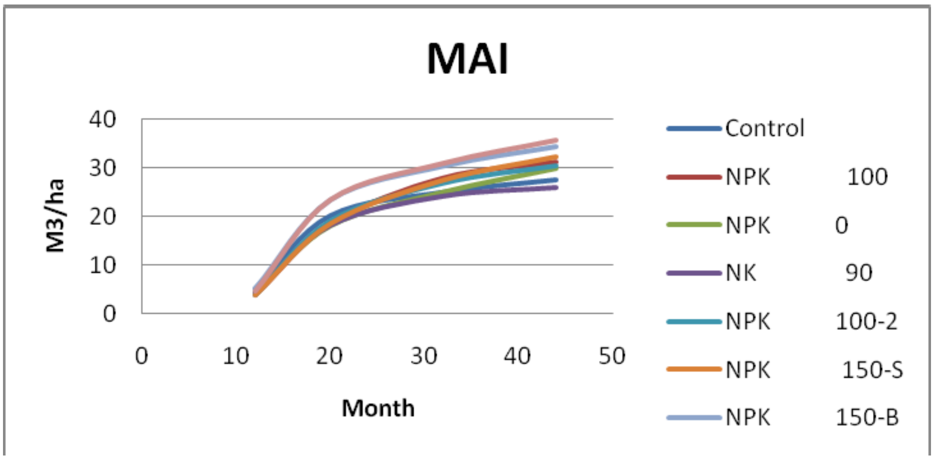

Figure 5. The Mean annual increment over bark in the different treatment after 12, 20, 32, 44 months. Data has been taken from P. Andersson (2007), P. Genfors (2008) and data from the establishment of trial.

2.3.3 Volume after 44 months

The highest standing volume has treatment NPK- 300-B (131 m^3 ha^{-1}) followed by NPK-150-B (126 m^3 ha^{-1}). Four treatments are very close to each other and range between 110-119 m^3 ha^{-1}. The treatment with the lowest volume was NK-90 (96 m^3 ha^{-1}) followed by control treatment (101 m^3 ha^{-1}).

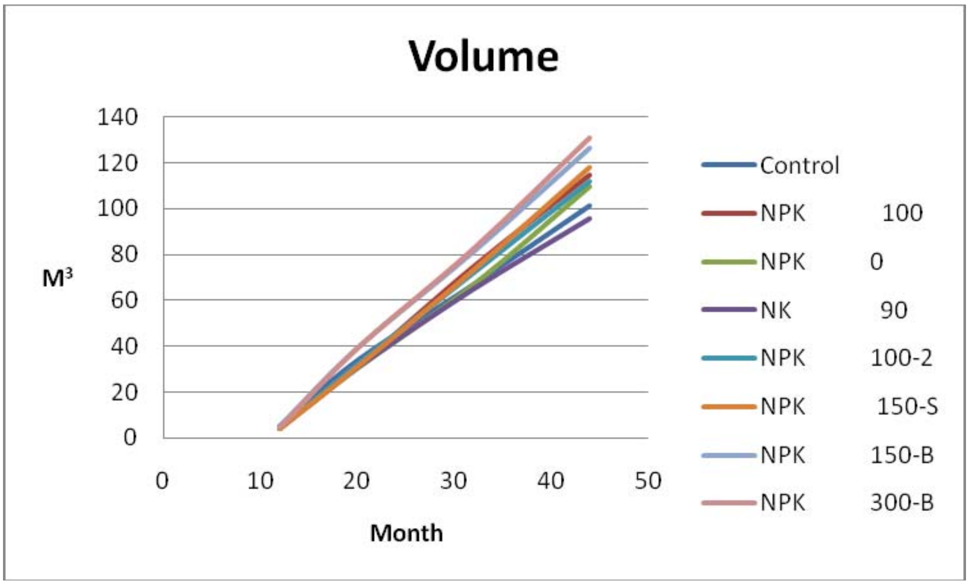

Figure 6. Standing volume in m3 ha-1. Data has been collected from different treatments after 12, 20, 32, 44 months. Data has been taken from P. Andersson (2007), P. Genfors (2008) and data from the establishment of trial.

2.3.4 Leaf analysis after 44 months

The analyzed leaves show after three years of fertilization that P/N ratio was still low. The copper ratio levels is now back to normal and the rest of recommended ratios are normal or above recommended target values.

The extra CMP fertilization in treatment NPK-150-B that was conducted 2008 did not reach the recommended P/N ratio of 10%, but the ratio has slightly been improved (6.46%). Comparing with the control treatment where the P/N ratio is decreasing slightly.

In general it is no big change since previous years. There still is a deficit of phosphorous and to minor extent potassium, but a surplus for the rest of the nutrients (Table 6).

Table 1. Left analyze from treatment the control and NPK-150-B. The upper table is the concentration of nutrients in the leaves and the lower table is the recommended ratio relation to nitrogen

Treatment	Months after planting	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	20	14,78	0,81	5,12	3,77	1,44	81	3,29	55,07	14,89	53,74
	32	16,87	0,88	6,43	3,88	2,2	160	8,89	92,07	18,35	31,63
	48	19,84	1,03	6,25	5,01	2,22	271	5,84	271,01	24,07	49,5
NPK-150-B	20	16,19	0,89	5,35	3,84	1,43	78	6,78	91,14	14,57	74,4
	32	18,62	1,2	7,85	4,62	2,21	167	19,33	141,98	15,03	40,38
	44	20,63	1,39	6,64	6,25	2,73	157	4,60	157,6	25,15	50,82

		Recommended ratio									
Treatment	Months after planting		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	20		5,45	34,65	25,53	9,76	0,54	0,02	0,37	0,1	0,36
	32		5,23	38,13	23,02	13,01	0,95	0,05	0,55	0,11	0,19
	44		5,18	31,514	25,25	11,19	1,76	0,03	0,67	0.12	0,25
NPK-150-B	20		5,52	33,07	23,71	8,85	0,48	0,04	0,56	0,09	0,46
	34		6,46	42,18	24,79	11,88	0,9	0,10	0,76	0,08	0,22
	44		6,72	32,19	30,30	13,23	0,76	0,02	0,46	0,12	0,25

2.3.5 Root distribution in the trial

The root systems started to distribute about 20 centimeters under the surface. Roots spread in average 1-1.2 meter in lateral direction. The diameter of each root system was about 2 meters. Every root system had at least one lateral root that had the same direction as the ripping line. The rest of the root distribution was more randomly spread. It was no obvious difference in root systems between the two treatments. All stumps had at least four well developed deep roots that spread deep down in the ground (Figure 8). In four root systems the main lateral roots grew straight in the beginning and in the last 30-40 centimeters turns right like it was twisting (Figure 7). All trees which had a root system in the ground water or under the water level for a longer time had dead roots probably due to lack of oxygen and also the wood were discolored in the base of the tree.

The root contact between trees was only within the planting line and no roots had contact with other root systems from the other tree lines.

Figure 7. Shows the twisting roots.

Figure 8. Shows the developed root system.

Figure 9. Discolored wood of the base of a tree.

Table 2. Root system table were the treatment, type of soil, and the number of lateral roots are counted. Distribution and root development are evaluated after comparison with the roots in the sample

	Soil	Stump	Number of main lateral roots	Distribution around the cutting stump (1-5)	Root development: around and down at the same time (1-5)
Treatment 6	Dry	1	7	5	5
		2	4	3	3
		3	4	2	2
	Soak	4	4	4	4
		5	3	2	3
Treatment 5	Dry	6	4	3	3
		7	6	4	4
		8	4	3	4
	Soak	9	3	2	2
		10	3	3	3

2.4 Analysis and discussion Fertilization trial

44 months since the start of the fertilization trial, lot of unexpected events has happened. This has lead to that the trial has suffered some damage and probably has not reached the potential maximum growth because of fire, typhoons and high levels of ground water.

The CAI measurements indicate that some of the treatment has peaked the increment rate and the increment rates are slowing down, but not for all treatments. Probably there will be a couple more years of high CAI figures before the CAI peak. The possible causes of why the CAI has slowed down in some of the treatments could be the fire 2007 that damaged many trees and the trees have to allocate the energy to heal the trunk instead of growing higher. The high levels of ground water in the stand and the typhoon damage had quite small impact in this year's measurement. Next year the effects maybe are more visible and is the probable cause if some of the treatments still show low figures in CAI.

It is a good sign that the CAI and MAI ratio has not crossed each others curves in every treatment. The treatment with the worst ratio is treatment NK 90 and the difference is only 4 m^3/ha^{-1} and the treatment with the highest ratio is treatment NPK 0 which had a ratio of 13, 2 m^3/ha^{-1}. This means as long as CAI is higher than MAI it is more beneficial to let the stand grow and when ratio crosses it is more beneficial to cut the stand.

The treatment with highest growth was NPK-300-B (130, 7 m^3/ha^{-1}) and the treatment with the lowest growth was NK-90 (95, 6 m^3/ha^{-1}). The difference in volume between the treatments was only 35, 1 m^3/ha^{-1} and this can be due to three different reasons. One is the deficit of phosphor and that this still limits the growth. Second reason could be that it is some other nutrient than phosphor that limits the growth. The third reason could be a climate factor that limits the growth. Example of what could limit the growth in this case could be lack of/ or too much water or not enough of sun hours.

Leaf analysis

Leaf samples from November 2008 showed a deficit of phosphorous and the extra amount of phosphate applied in 2008 was not sufficient and gave not the expected effect in growth. The pH form P. Andersson (2007) measurements had a pH of between 4.73- 4.95 and that showed the experimental area in the trial had a low pH At low pH phosphorous can be bound in the soil hard and not available for the trees to take up, even if it is applied as a conventional fertilizer. It is the opposite with a higher pH in the soil Malmer al.et (2003) and the optimum range is from 6 to 7.5. This is a factor that probably is one of the problems, which causes growth limitations in the trial experiment. It would be interesting to see how growth would be affected if the phosphorous limitation could be expelled and the effect limestone alone will have on growth on eucalyptus by an increased pH.

Roots

The result in this study was positive because it was no obvious visible difference of the root distribution between the two fertilization application methods. Two of ten root systems have almost the same root pattern and these roots came from different treatments. The diameter of the lateral root systems was in the most cases around two meters and this is probably something genetic for these Eucalyptus trees. One interesting result was that the roots did not spread more to the side were it had no competition from other trees and free space in the soil. This will leave a small strip on about two meters between the rows that are not used for any production so far. It may change in the future when the trees are getting higher. A weakness in the results is that the number of root systems is not enough to get a proper result. Roots from this experiment just indicate what could be found in future research. The most interesting result from this study was the presence of dead roots and location of these roots. Eucalyptus seems not to be able to stand in water or water sought soil and survive for a longer time. Which impact this will have in the future is not easy to say and this is a question which could bee interesting to look into.

3. Fire impact in the wood quality

3.1 Background

In this part of the study the goal is to see how fire impact wood quality and how suitable the fire damaged wood are for pulp production. StoraEnso wants to know what type of problem that can be expected in the wood after forest fires. For this study a Swedish standard from one of three independent wood grading organizations will be used. This organization supervise and monitor the agreements between forest owners and industry for how timber and pulp wood should be measured. The result from the independent wood grading organization is the base of what the industry will pay the forest owner. In formulary B-6010 version 05 from 2009-02-09 from VMF Qbera Sweden, it is stated that **metal, charcoal, stones, plastic** and **rubber** are not allowed in wood for timber and pulp purposes. These items will damage the machines or the pulp product and because of this they are not allowed in pulp wood.

3.2 Material and Methods

Due to the resent fire questions about fire impact on the wood quality appeared. These were the central questions.

- How much pollution can we expect in wood chips?
- Are there any difference in the chip size between a fire damaged and undamaged tree?
- How and what kind of pollution can be expected in a fire damage tree?
- What will a fire have for an impact on the stand economy?

3.2.1 The scan norm test

A chip fraction test was conducted to see if the fire had some impact in the chip fraction distribution. Two trees were selected from plot 10 and 12 and from fire damage category 1 and 3, just outside the inner plot. The selected trees, was classified by P. Genfors (2008). Class 1 is not visually affected by the fire. Class two was affected and class tree was severely affected by the fire. A 2 meter log was taken from each tree between 1 and 3 meter of hight. The log was cut in two half's to fit in the transport to the chip mill and the logs were marked F1 and F3 after the fire damage category. The chip mill was situated next to StoraEnsos nursery school in Zhankou. All the logs were debarked. The first logs that were chipped and assemble in a box, was F1. The log from damage class 3 (F3) was the last one to be chipped because of the risk for pollution. The chips were collected in two different paper boxes and send to Sweden. A Scan norm- CM 40:01 test was conducted at a control station outside Gävle of an independent wood measuring organization in Sweden called VMF Qbera.

Each sample of the test contained ten liter of chips from each box. A Scan Norm chip fraction test is conducted in this way. A measured weight and at least 10 liter of chips is poured on top of a machine which contain 6 different layers of riddle sizes.

The machine shakes for ten minutes and then the chips will have been sorted after size in the different riddle layers. Each layer contents are weighed and packed in plastic bags. From the weight data then the faction distribution can be counted. Chips from each fraction and the two damage categories were carefully examined on table with a white paper underneath the chips, to make it easier to see if there was some charcoal or other pollution remains among the chips.

Table 3. Riddle size for Scan norm CM 40:01. Source: A bjurvall Chip geomitry 2006. The chips will be sorted after size and the optimum size of a chip to Swedish pulp mills is F3A and F3B

Scan- CM 40:01 norm		
Class	**Typ of chips**	**Size of the riddle**
F1	Over sized chips	45 mm holes
F2	Over thick chips	8 mm slots
F3A	Larg accept chips	13 mm holes
F3B	Small accept chips	7 mm holes
F4	Pin Chips	3 mm holes
F5	Fine	

3.2.2 Visual discs study

To study the presence of pollution in the wood, discs was cut out with chain saw. The selected trees was measured and divided into three different damage classes, 1-3 by P. Genfors (2008). From this classification six trees in each plot 10 and 12 were selected, in total 12 trees. The six selected trees in each plot contained 2 trees from each class 1-3. In every tree five disc samples was collected at every meter from the base to the height of 4 meter. The thickness of the discs was four centimeters and in total 60 discs was collected. The discs were dried in a temperature of 105° C for four days. The discs were later examined in Sweden at the Swedish Agricultural University in Uppsala according to eleven criteria. Six of the criteria referred to disc edges and five to the disc surface. Discs with probable charcoal remains or other defects were brought to band saw for further dissection.

Table 4. The criteria of who the discs were evaluated and this was made in two steps. First step was the sides of the disc evaluated and in the second step was the surface of the disc evaluated

Discs						**Surface**				
Grime on dry branch	Grime on bark	Decay	Lyra	In closed bark	Dry branch	Cymetric	Visable damage	Grime	Dry branch	Others

*Lyra= open scare in trunk, Shaped damage.

3.2.3 Visual Plank Study

This study included samples from the same 12 trees, all logs were collected between a height of 2-3 and 3-4 meter. The total number of logs was 12. The logs were 96 centimeter long and the logs were brought to a local saw mill in Zhankou. The logs was then sawn in 1-1.5 centimeter thick planks from one side two another. The log stumps were 96 centimeter long and totally 54 planks were sawn. The planks were examined visually. The presences of charcoal, rot, open scars, bark inclosement, discolored wood, in closed wood, dry branches, insects and other damage were measured.

3.3 Results

3.3.1 Result Scan norm test

There was no visible difference between the sample F1 and F3 after the first examination after the chipping. The samples of wood chips showed no sign of pollution or any presence of charcoal after a close examination on light table. The dust after every fraction sample was examined with no trace of charcoal.

The fraction distribution between the two samples did not show any big differences.

Table 5. The chip distribution between the sample F I and FIII

Class I	In gram		Class III	In gram	
Total weight	4264		Total weight	4218	
F1	0	0%	F1	1,5	0%
F2	303	7%	F2	327	8%
F3A	2760	65%	F3A	2808	67%
F3B	938	22%	F3B	874	21%
F4	198	5%	F4	158	4%
F5	37	1%	F5	14	0%

3.3.2 Disc results

From the 12 trees, totally 60 discs were cut out. All of the 12 trees had charcoal grime on the first disc and four trees had remains on the second disc and tree marked CIB had charcoal grime on first, second and fifth disc. Seven trees had remains of charcoal. All charcoal remains were situated in the end of a burned off branches (Figure 12). 7 trees had all charcoal remains in burned off branches on the first discs that were collected from the base of the first log. Two trees had also charcoal remains on the second disc. The tree named 6IB had charcoals remains in the first, second fourth disc. This tree had also traces of charcoal grime on the bark on first, second and fifth disc. This tree had a disc which had an in closed charcoal branch (Figure 13). The most important result was that this tree had no sign from P. Genfors (2008) that it had any visual wounds or fire scars after the fire.

If any problems occurred with unsymmetrical shaped discs it was in the two first discs. All the discs that were unsymmetrical were damage by fire. After the second disc in each tree they all had a round symmetric shape.

Tree named 6IIIA (Figure 11) is a tree with unexpected damage. The Figure 11 shows a fire damages in the cambium. This has lead to that the sapwood has converted to hardwood on two places on the disc. The tree has then in closed the damage and built extra wood fibers to lead water around the damage and also strengthen the trunk on this weak spots.

Figure 10 is a good sample of fire impact on a tree. The figure shows a thin black line which contains gum, in closed wood, decayed wood and were it is located.

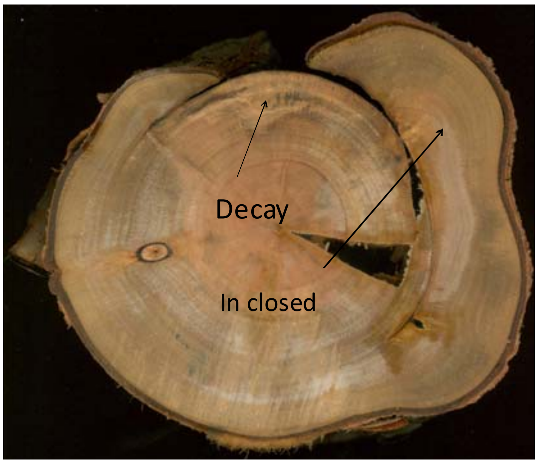

Figure 10. Disc with fire scare, decay and in closed wood.

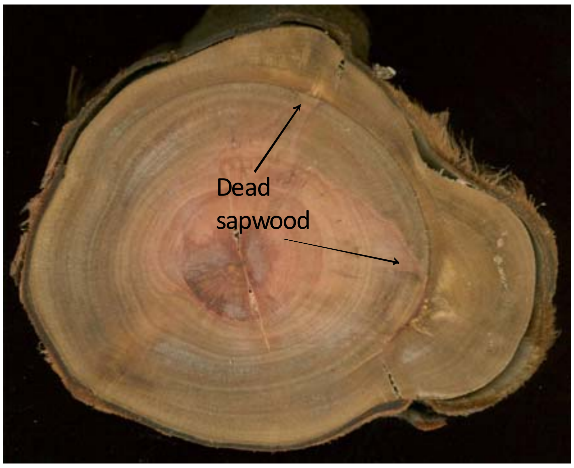

Figure 11. A disc with dead sapwood.

Figure 12. Shows a burned off branch with char-coal remains in the end.

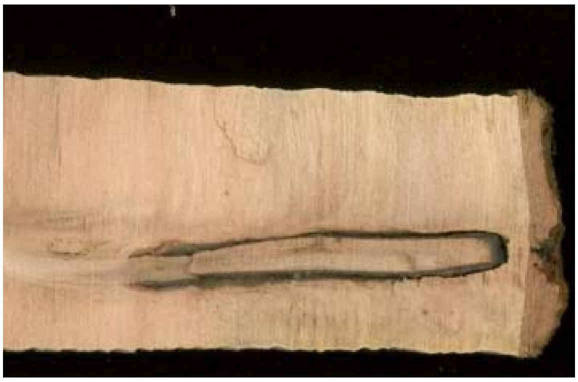

Figure 13. Shows a burned off branch which has been in closed.

3.3.3 Result of planks examined

After 54 samples was inspected, is was obvious that planks whit damaged zones in the stem had an average growth of about 3 centimeter when the tree tries to inclose the wounds, compared to undamaged zone were the growth is only 2 centimeter. In the fire scars, only gum was visual, there were no sign of charcoal or ash. Not all planks had fire scars but they still had damage in the cambium even if the bark was intact. This was seen as a small black line in the wood. The black line contained gum. Rot was found in some places in the wood. Where the rot were found, it was obvious that the bark had been damage by fire or had a open scar. The length of the rot damage differs, but it is not deeper than 1-2 centimeters in to the trunk. The presence of charcoal was found in two trees in damage class 2 and 3 at the height of 3 to 4 meters. The presence of charcoal was found in dead branches that had burned off and reached about 2 centimeters into the wood and this corresponds to what the growth have been under one year. In the samples there is no sign of insects' damage in the wood, not even in fire scar areas.

Table 6. Describes different trees and the measured parameters too get a picture of how the selected tree looked like in the samples

Tree and fire damage	Grime of charcoal	Decay	Lyra*	In closed bark	Dis coloured	In cosed wood	Dry branches	Trace of insects	Number of planks	Other damage
C1 Tree A	No	No	No	No	No	No	2,25	No	4	
C2 Tree A	Yes	No	No	No	No	No	1,5	No	4	
C3 Tree A	No	No	No	No	No	No	2,5	No	4	
C1 Tree B	No	No	No	No	No	No	2	No	3	
C2 Tree B	No	No	No	No	No	No	1,25	No	4	
C3 Tree B	No	No	No	No	No	No	1,5	No	4	
61 Tree A	No	No	No	No	No	No	0,5	No	4	
62 Tree A	No	5,41	No	1,4	No	8,5	1,8	No	6	
63 Tree A	Yes	4	3,1	1,5	No	16,8	1,5	No	8	
61 Tree B	No	No	No	No	No	No	1,8	No	5	
62 Tree B	No	No	No	No	No	No	0,6	No	5	
63 Tree B	No	22	No	No	No	11	2	No	2	

*Lyra= open scare in trunk, shaped damage.

3.4 Analysis and discussion

Scan norm test

The differences in chip geometry were smaller than expected and it was unexpected that there was no presence of charcoal polluted chips. A probable cause to the low presence of pollution can maybe be explained by manually removed bark and due to this the debarking was more properly done with no external pollution that could have been the case whit harvesters debarking. It could also be a coincidence that none of the trees used for the chip test had any burned off branches left in the trunk.

Disc and planks

The result after the examination indicated that the problem with charcoal is not located to the fire scars. In fact no trace of charcoal was found in the scars; only decayed wood was found in open fire scars. In the fire scars the only pollution that was found was gum. No sample had any discolored wood. Only very small yellow dots were found on some samples, but these seams not to have any affect on quality what so ever. In this investigation the problem with charcoal remains in wood seams to occur more or less randomly among the trees. It is not obvious that a tree with fire scars has charcoal remains inside the trunk. The problem can occur at all highs in a tree were there were dead branches. This will make it difficult to just cut of the first couple of meters and think that it is no problem to use this wood for chipboard and the rest for pulp. In this study charcoal was found in two trees at a height of over 3-4 meters in trees that were classified in different damage classes. This indicate that the problem with inclosed charcoal can be bigger that expected. To get more proper data some further and bigger study needs to be conducted.

4. Economic calculations

The calculations are based on result from the fertilizations trials and the prices are provided by StoraEnso Guanxi.

The bottom row in the calculations is comparing the alternative use as Chipboard to pulp wood. Chipboard is so far the only use of the wood if it is not possible to use the wood in a pulp mill.

Table 7. Describes the economical outcome 2008. All prices are in Chinese currency (RMB).At Forex currency exchange 1SEK= 1.29 RMB (2009-03-18). Qinlian Particle Board pays at mill gate (2008-11-18) a price of 160 RMB/ ton. 1 ton fresh Eucalyptus = 0.9 m^3. All result are calculated in NPV are calculated with a rate of 7.8%. The cost for spreading the fertilizer is sat to 150 RMB/ha^{-1}. The cost for fertilizers and the amount of fertilizers can be seen in appendix table and table. This prices is what the calculation I based on: Venner 600 RMB/m^3, Pulp 450 RMB/m^3 and Chipboard 160 RMB/ton. NPK- 300-B is fertilized two times a year. Road construction and road maintenance are not included because there are already existing roads. The land leas charge and the harvesting cost are not including in the calculations

	Year	Control	NPK-100	NPK-100-0	NK-90	NPK-100-2	NPK-150-S	NPK-150-B	NPK-300-B
Cost of plantation establish	2005	7730	7730	7730	7730	7730	7730	7730	7730
Cost fertilization RMB/ ha	2006		1175		1840	1175	1688	1688	3375
Cost fertilization RMB/ ha	2007			2088			3058	2495	4988
Cost fertilization RMB/ ha	2008					2233	2540	2540	2690
Total cost in NPV and RMB/ha		9684	11049	11934	11822	13282	17482	16875	21672
Volume in m^3 2008		101	114	109	96	112	118	126	131
Net RMB for veneer/ha^{-1}		50916	57591	53706	45538	53738	53438	58965	56748
Net RMB for pulp/ha^{-1}		35766	40431	37296	31198	36983	35708	40005	37143
Net RMB for chipboard		4860	5425	3820	1944	2803	-461	1326	-2852
Benfits compared to C for veneer/ha			6675	2790	-5378	2822	2521	8048	5831
Benfits compared to C for pulp/ha			4665	1530	-4568	1217	-59	4238	1376
Benfits compered to C for chipboard			564	-1041	-2916	-2057	-5322	-3534	-7712
Benfits compered to chipboard for pulp		-30906	-35006	-33476	-29254	-34180	-36169	-38678	-39994

Table 8. Describes the economic outcom 2007. All prices are in Chinese currency (RMB).At Forex currency exchange 1SEK= 1.29 RMB (2009-03-18). Qinlian Particle Board pays at mill gate (2008-11-18) a price of 160 RMB/ ton. 1 ton fresh Eucalyptus = 0.9 m3. All results are calculated in NPV with a rate of 7.8%. The cost for spreading the fertilizer is sat to 150 RMB/ha-1. The cost for fertilizers and the amount of fertilizers can be seen in appendix table and table. This prices is what the calculation I based on: Venner 600 RMB/m3, Pulp 450 RMB/m3 and Chipboard 160 RMB/ton. NPK- 300-B is fertilized two times a year. The volume figures 2007 are from P. Genfors (2008)

	Year	**Control**	**NPK-100**	**NPK-100-0**	**NK-90**	**NPK-100-2**	**NPK-150-S**	**NPK-150-B**	**NPK-300-B**
Cost of plantation establish	2005	7730	7730	7730	7730	7730	7730	7730	7730
Cost fertilization RMB/ ha	2006		1175		1840	1175	1688	1688	3375
Cost fertilization RMB/ ha	2007			2088			3058	2495	4988
Cost fertilization RMB/ ha	2008					0	0	0	0
Total cost in NPV and RMB/ha		8983	10250	11070	10967	10250	13861	13298	17609
Volume in m^3 2007		67	74	67	65	72	73	81	82
Net RMB for veneer/ha		31037	34390	28890	27913	32830	30059	35482	31831
Net RMB for pulp/ha		21032	23230	18900	18193	22060	19079	23287	19471
Net RMB for chipboard		622	464	-1480	-1635	90	-3320	-1591	-5743
Benfits compared to C for veneer/ha			3353	-2148	-3124	1793	-978	4445	794
Benfits compared to C for pulp/ha			2198	-2133	-2839	1028	-1953	2255	-1561
Benfit compered to C for chipboard			-158	-2102	-2257	-532	-3942	-2213	-6365
Benfit compered to chipboard for pulp		-20410	-22766	-20380	-19829	-21971	-22399	-24878	-25214

Highest revenue year 2008 came from treatment NPK-150-B followed by NPK-100 when veneer prices were compared. When pulp wood prices are compared treatment NPK-100 followed by NPK-150-B had the best revenue. Finally chipboard prices had the lowest net revenue treatment NPK-100 followed by the control treatment was highest net income.

By comparing the benefit between chipboard and pulp wood 2008 the loss will be between -30906 to 39994 RMB/ ha^{-1} and treatment if they have to sell it for chipboard instead. 2007 the loss will be between -20410 and 25214 RMB/ ha^{-1} depending on treatment. This is if the wood from eucalyptus has to be sold to chipboard production instead of pulp wood because of quality faults caused by the fire in the stand.

4.1 Discussion economy

By comparing different treatments it is obvious that the differences are small. One interesting treatment is NPK-100 which has an average volume growth, but still the economic result is good. Compared with the treatments with higher growth and high costs for fertilization the results from NPK-100 are interesting to observe.

5. Conclusions

5.1 Fertilization trial

Treatment NPK-150-S has 2008 the highest CAI of 44.6 m^3/ha^{-1} compared with NPK-150-B result of 41.3 m^3/ha^{-1}. There are small differences in CAI between treatments and the fertilizations methods between year 2008 and 2007. Treatment NK-90 has 8 m^3/ha^{-1} lower CAI than the control treatment. Fertilizers effect and impact in the trial seems to level out.

No obvious difference in the root distribution was seen between the two different fertilization methods. But it was obvious that ground water has a big impact on the root system. Eucalyptus seems not be able to withstand water or water sought soil and survive for a longer time.

5.2 Fire impact on wood quality

Fire impact in a eucalyptus stand seems to be very difficult to estimate. From this survey we can not say which tree has the worst quality problems by only looking on the surface of the scars. The presence of gum can be found in fire damaged tree but is not a big problem in the pulp process. In this study charcoal were found in trees which did not have any sign of wounds or fire scars. This creates an uncertainty of what the wood quality are in these trees and it seems to be very hard to avoid this timber which contains charcoal in the harvesting process.

5.3 Economy

Best revenue for veneer has been calculated in treatment NPK-150B followed by NPK-100. For pulp and chipboard prices the best revenue was in treatment NPK-100. Based on economic calculation in this study it is the recommendation that a fire damaged areas should be cut as soon as possible and replanted.

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Picture1
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Interviews:
Genfors Weine, Senior vice president Plantation at StoraEnso
Huang Helen Office Assistant at StoraEnso in Hepu
Risto Voukko, Director of Research and Development at StoraEnso in Hepu.
Stig Svensson Chef of production of Nymölla pulp mill in Sweden

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