Increase Malaysia Palm Oil Production efficiency

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LIST OF TABLE AND FIGURE

ABSTRACT

Malaysia is the second largest palm oil producer in the world. It has been suffering from low production efficiency for over 20 years. This paper tries to identify factors cause the low production efficiency by using system dynamics method. A model has been built to explain and further study slow improvement of production. The model also serves as a tool for explaining the problematic behaviours and understanding the feedbacks influence both oil palm area expansion and foreign labour workforce. Production efficiency is sensitive to high yield area fresh fruit branch yield rate, mature time and oil extraction rate. Production efficiency has weak relationship to labour. Policies to improve production efficiency has been suggested to improve the production efficiency within ten years.

Key words: palm oil, production efficiency, system dynamics, workforce.

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Finally, thanks to researchers from internet contribute their life on writing papers which really help me a lot on sharing knowledge with me.

INTRODUCTION

Malaysia's palm oil industry is the fourth largest contributor to the national economy [1].

The oil palm industry in Malaysia is export oriented industry. It is heavily depends on the world market. Most of the palm oil production has exported to foreign countries, only 10% of which is consumed by locals. As the world's palm oil demand is growing quickly, it is expected, both Indonesia and Malaysia will keep dominating the oil palm industry. The oil palm industry in Malaysia is very competitive and become one of the major economic sectors contributing to the total revenue of the country [2] .

In year 2009, there was a total of 22.40 million tons of oil palm products including palm oil, palm kernel oil, palm kernel cake, oleo-chemicals and finished products, equivalent to RM 49.59 billion of export revenue. [2] .

The palm oil industry can organize into four segments (Table 1.).

Segment	Related field
1	Seed nursery, Planting, Harvesting, Collecting and Milling
2	Refining, Bulking and Trading activities
3	Non-food downstream
4	Foodand health-based downstream

Table 1 Four Segment of Palm Oil Industry.

Malaysia has 4.7 million of oil palm plantation. Currently, the industries is dominated by large plantation companies, which is either private or government-link company. These large plantation companies hold 60% of total plantation land. Other than large companies, there are some plantation areas under the ownership of smallholders and independent smallholders, which account for 28% and 12% of the total area.

Palm oil industry has 2 core advantages over other substitutes:

- Strong demand

The demand for palm oil has increased sharply. It is driven by increasing global population. Average growth rate of global demand for oil and fats is 7% over the past ten years, over the same period palm oil has grown at 10% rate.

Oil palm can produces 4 to 5 ton of oil per ha. While other substitutes oil seeds such as Soybean, Sunflower and rapeseed can produce 5 to 10 times lower than oil palm (Table 2).

Oil crop	Oil production (million ton)	Harversted area (million ha)	Average oil yield (ton/ha/yr)	Oil Palm Yield/ Oil yield (Lower is better)
Oil Palm	42.7	11.20	3.80	1
Soybean	38.03	91.32	0.41	9.2
Sunflower	11.80	23.31	0.50	7.5
Rapeseed	19.31	29.49	0.65	5.8

Table 2: Comparison of Productivity of Oilseed Crops Source: FAO, 1996

Despite the advantage of palm oil industry, the industry is facing a serious of obstacles. These obstacles may threaten competitiveness of palm oil industry at global stage. The obstacles are:

- Scarcity of land bank

The potential land for oil palm plantation area is increasing dramatically. Malaysia can only rely on another 28% of potential oil palm plantation area. The global production market share of Malaysia has been decreasing gradually. In 2009 Indonesia overtook Malaysia in crude palm oil production.

- Labor intensive dependency

Oil palm industry in Malaysia is still heavily relied on foreign labor. Especially, in upstream sector, foreign labor plays an important role in harvesting, general upkeep and maintenance. Currently, there are a total of 369,000 foreign workers employed in plantations. Labor performance heavily influences production performance.

- Environment concerns

Anti-palm oil campaigns have become stronger. According to the research, oil palm plantation development has been descripted as “a poor substitute for natural forests” (Emily Fitzherbert, 2008). The claims from Anti-palm oil campaigns have generated a negative impact on perception of palm oil. The purpose of anti-palm oil campaigns is to slow down the acceleration of deforestation because of oil palm plantation expansion.

In September 21, 2010, Malaysia government has launched a programme, called Economic Transformation Programme. One of the programme related to oil palm development suggest that dependency of foreign worker will be reduced by 15% to 20% as a result of major gains in worker productivity, which is equivalent to reducing of 110,000 foreign workers.

The programme also target a 25% increase in national average FFB yield. Currently the average FFB yield is 21 ton per ha per year. By 2020, average FFB yield should achieve 26.2 ton per ha per year.

Oil extraction rate has not been improved over the past 10 year. Date to 2009, it averaged 20.5% in 2009. Economic Transformation Programme target a 23% oil extraction rate by 2020.

The focus for this paper is to model the slow improvement on production efficiency and test the policy options from Economic Transformation Programme. Then Suggesting a better policy which can aid achieve Economic Transformation Programme’s to achieve its goal.

LITERATURE REVIEW

Malaysia oil palm industry faces many challenges for years. One of those challenges is low palm oil yield rate. Palm oil yield rate is caused by low palm oil production rate and high land usage. Low yield decrease production rate, but increases land usage. Low yield rate decrease the average oil extraction rate. Increasing land usage raises number of worker and increase production cost. Mini tractor grabber is introduce to lower the production cost.

As a second, largest palm oil producer in the world, Malaysia is benefit from palm oil. Claire Carter, Willa Finley, James Fry,David Jackson and Lynn Willis (2007)[3], analyzed global crude palm oil supply and output, Claire Carter et al. compared the palm oil production, yield rate with other vegetable oil as well as oil price with other global major vegetable oils, they found that palm oil has advantages over other vegetable in production rate, sell price, production cost and yield rate. Yusof Basiron (2007)[4] also agreed with Claire et al. He found that oil palm is highly productive crop, which produces tenfold higher yield of oil than other. In other words, oil palm uses comparatively less land than other edible oil industry, and hence palm oil has no strong competitor, in term of price and production rate.

As the nature of oil palm, Claire et al. (2007) gave their conclusion on palm oil development that palm oil industry growth as long as there is willingness to plant more oil palm in environment sensitive areas and relatively lower price on demanding palm oil. Thus, palm oil production can increase, if environment and labor concern can be overcome. Abbai Belai et al.(2010) state that Malaysia currently has already turned 4.6 million hectare of agriculture land into oil palm area, which is account for 70% of total agricultural land[5]. Thus, land scarcity pressure is becoming higher.

How will oil palm expansion affect biodiversity? There are little research on how oil palm expansion affects biodiversity, especially in Malaysia. But Emily B. Fitzherbert, Matthew J. Struebig, Alexandra Morel, Finn Danielsen, Carsten A. Bru¨ hl, Paul F. Donald and Ben Phalan (2008)[6] compare the statistical data and the diversity of oil palm, they claimed that increasing the productivity of palm oil production from harvesting gain would only generate a conservation gain if it was linked to the protection of natural habitats. With high yield per unit area could reduce the area of land needed. In summary, Emily B et al. state that “oil palm is a particularly poor substitute for either primary or degraded forests, and whereas any conversion of natural forest is inevitably damaging to biodiversity, oil palm plantations support even fewer forest species than do most other agricultural options" . Therefore, oil palm is not an ideal replacement for natural forest.

If oil palm expansion is not a good alternative way to respond to the inevitable increasing demand of oil palm, increasing production in existing plantation could be one of the solution. Khoo Khee Ming and D Chandramohan (2002) [7] predicted the gap of between low and high yield (yield rate) will come down in the future as the lower yield palm are replanted by comparing best practice and national average yield rate. But Khoo et al.(2002) did not explain how low yield palm will be replanted. But It seems that replanting oil palm can increase the yield rate.

However, Claire et al. (2007) did raise two concerns on palm oil harvesting process. First palm oil industry is still a labor-intensive system. Second, It is practically difficult to mechanize. These two concerns were becoming more burdensome as labor shortage pressure push up wage rates. With high wage rate, it might increase the palm oil production cost and decrease palm oil competitiveness. These two behaviors have been addressed by Abbai Belai et al. (2008).

A labor-intensive oil palm system could be vulnerable to labor workforce. Khoo et al. referenced a survey from Malaysia Agricultural and stated that worker dependency in west and east Malaysia were 40% and 37% respectively. He also state that Malaysia policy were confusing. The frequent abrupt changes in policy caused the shortage of workers. At the same time, recruitment and employment costs have been pushed ahead, which adding the production cost. Khoo et al's view, indeed, is similar to Claire et al, which labor shortage increased production cost.

The Malaysian Palm Oil Cluster Final Report[5] which written by Abbai Belai, Daniel Boakye, John Vrakas, Hashim Wasswa(2011) shows that the recent growth of palm oil was result in increasing in edible oil globally. Malaysia has managed to increase its productivity through innovation. Abbai Belai et al. compiled a table and point out that Labor cost in Malaysia was higher than Indonesia which is the largest palm oil producer. Malaysia labor cost was 4.5 dollar per hours, while Indonesia was only 0.6. Thus, labor cost could be one of the major problems for oil palm.

To reduce production cost, mechanization in oil palm plantation is has been considered. Abbai Belai et al. (2008) found that in palm oil harvesting 75% of FFB collection is rely on manual labor and 25% is done mostly through mini tractor grabber.

The mini tractor grabber has 5 year life time, which is as long as foreign labor tenures ends time.

Jalani, B S et al.(2002)[8] concluded that mechanization and automation are to be adopted in all sectors from oil palm planting to processing because of current low productivity. The increased productivity and yield would help supply the growing demand of oil. Jalani et al. examined a few factors causing low productivity, such as marginal areas, inadequate agronomic inputs, ineffective and inadequate management, shortage of skilled labor and low replanting Rate.   These factors, indeed can group into 3 categories, which are land, labor workforce and management. Jalani et al. also raised the similar issues as other scholars. One different statement was low productivity could lower down average oil extraction rate[1].

How yield per unit area per year affects by production rate and land usage for oil palm and whether yield rate have strong effect on labour number. The thesis will answer clarified the issue and answer the doubt.

[1] We should make it clear that average oil extraction rate is different from oil extraction rate. Average oil extraction rate is an average of yield fresh fruit towards oil production in general. However, oil extraction rate is capability of a machine to extract oil palm. Therefore, oil extraction rate is machine dependence

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THE DYNAMIC PROBLEM

Production efficiency is a synonym of oil yield per hectare per year. We uses production efficiency to shorten the name and make it become more understandable.

There are 4 indicators which can show the changes foreign worker, FFB yield and oil extraction rate. These indicators are production efficiency, production rate, total oil palm area and worker in plantation.

Since 1987, production efficiency, production rate, total oil palm area and worker in plantation have been steady increasing.

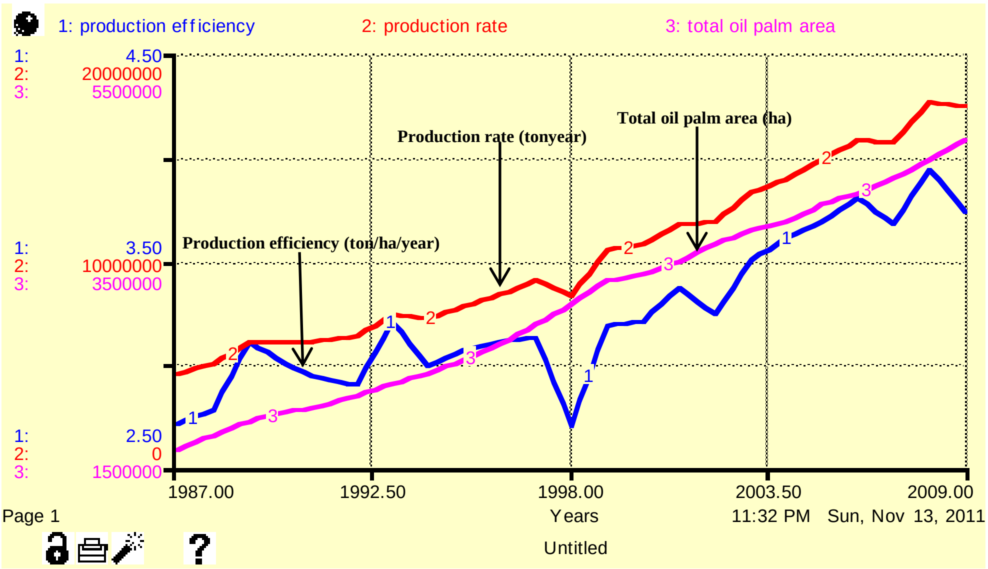

Figure 1: Production efficiency, oil palm area and production rate (Source: MPOB)

The production efficiency started from 2.71 then it had rose to 3.74 in year 2009. It had a 130% improvement. During the same period, production rate raised 400%, which had increased from 4 million ton to 17 million ton. Total oil palm area increased from 1.6 million has to 4.6 million has. The increment is 280%.

Although all of these indicators have been increasing for the past 10 years, however, the production efficiency was lagging behind in the increment percentage.

HYPOTHESIS

The system dynamics model describe in this section will give more dynamics insight for the production, workforce recruitment and how these sector mutually influence each other. The hypothesis will describe by using causal loop diagrams. The discussion of the model will highlights the main feedbacks that we believe are responsible for the system behaviour. Finally, the stock and flow structure of the model is explained and focus on the delays and interaction between the model sectors.

Hypothesis overview

In 2009, production efficiency is about 3.7 ton per ha per year. In theory, the production efficiency can reach 18.5 ton per ha per year (Dr. Yusof Basiron, 2006, MPOC). The production efficiency is a ratio of production rate and total oil palm area (Figure 1). Production efficiency is a measurement of utilization of land use.

There are 2 reasons we use production efficiency as an indicator. First, production efficiency shows the relationship between palm oil production and land usage. Second, production efficiency reflects the true nature of oil palm plantation. In the extremely condition, increasing of production rate may be caused by larger plantation area. Third, production efficiency decides the new plantation expansion speed.

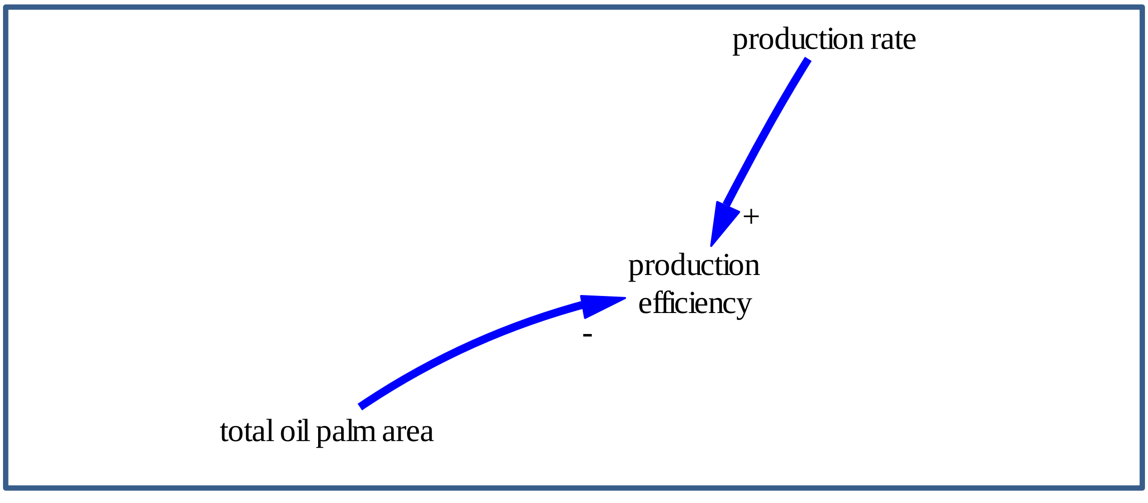

Figure 2: The factors influence production efficiency

CAUSAL LOOP DIAGRAM: CAPACITY SECTION

Capacity Section is about the plantation of oil palm area. There are three kinds of oil palm areas: Immature oil palm area, high yield mature oil palm area and deteriorated mature oil palm area.

PLANTATION CYCLE

New oil palm tree flows into immature oil palm area through a planting rate. After a few years, immature oil palm area becomes high yield mature area. High yield mature area can yield fresh fruit branch (FFB) used for oil extraction. When high yield mature area is becoming older, it will go in deteriorated mature area. Deteriorated mature area still can yield fresh fruit branch, but with a lower rate. When Deteriorated mature area become older estate owner may clear cut the old oil palm tree. After clear cut process, owner can replant new tree with a planting rate (R1, Figure 3). High planting rate leads to increasing of oil palm area. Oil palm area then feedbacks to planting rate.

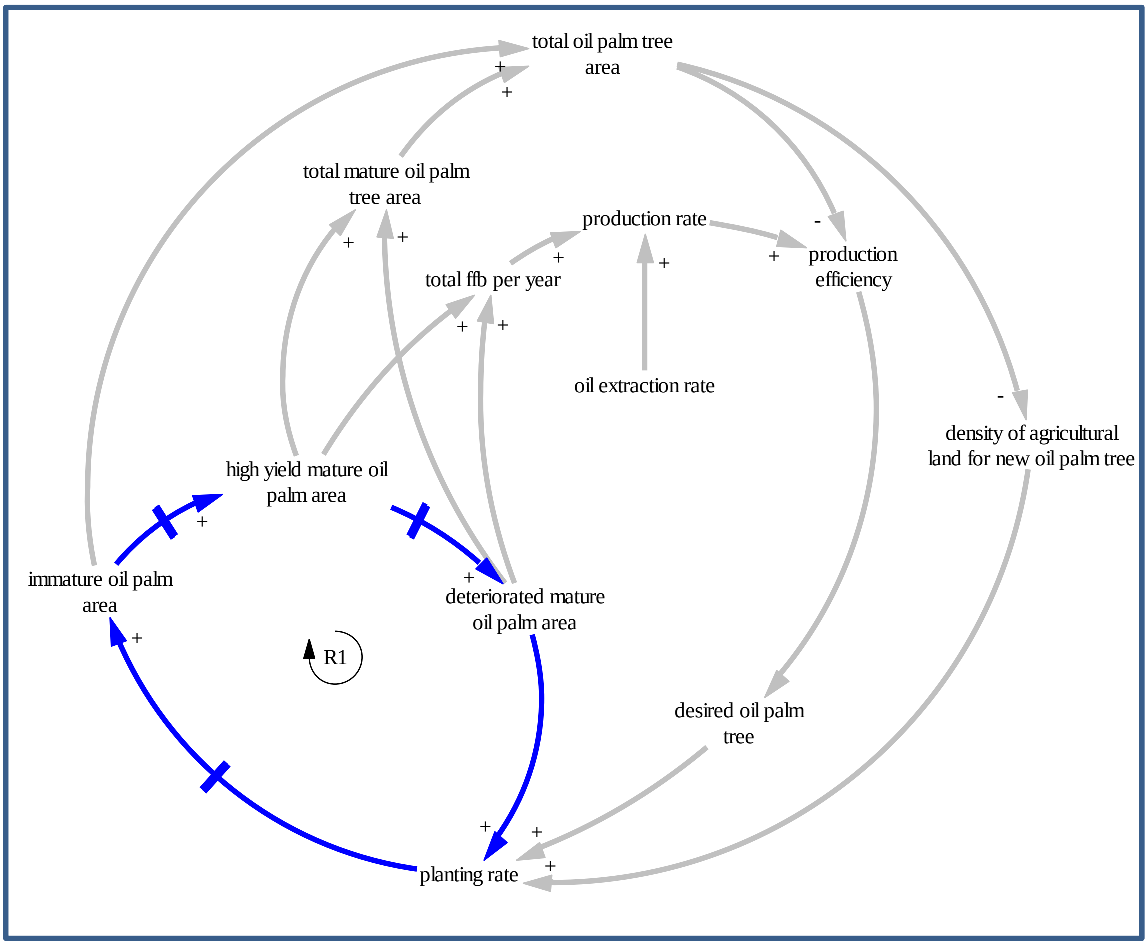

Figure 3: Plantation cycle

CONTRIBUTION OF DETERIORATED AND HIGH YIELD AREA TO PRODUCTION EFFICIENCY

Both high yield and deteriorated area can yield fresh fruit branch. From every year, harvested fresh fruit branch can be used for oil extraction. The extracted oil is the is production rate. Oil extraction rate (OER) is indicator of extraction efficiency. Production rate then influences the production efficiency. Production efficiency has negative impact on desired oil palm tree, because the production can be satisfied with less capacity if the production efficiency is very high (C1,C2, Figure 4).

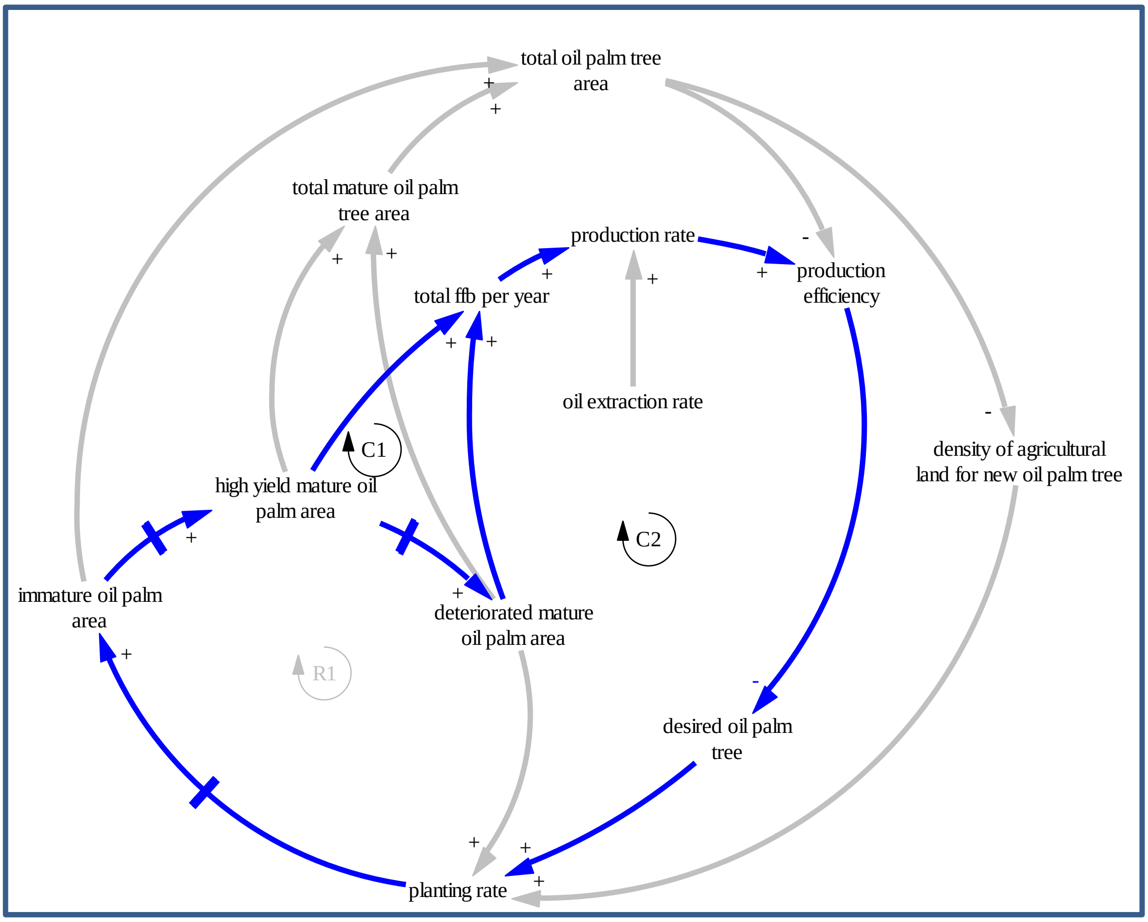

Figure 4 Contribution of deteriorated and high yield area to production efficiency

OIL PALM AREA RAISES PLANTING RATE

Total oil palm area is the sum of all oil palm area. Total oil palm area affects production efficiency reversely. Increasing of oil palm area is decreasing of production efficiency. In order to meet the demand of palm oil production, the desired oil palm tree will be increased. The increment then feedback to total oil palm area. (R2,R3,R4,R5, Figure 5).

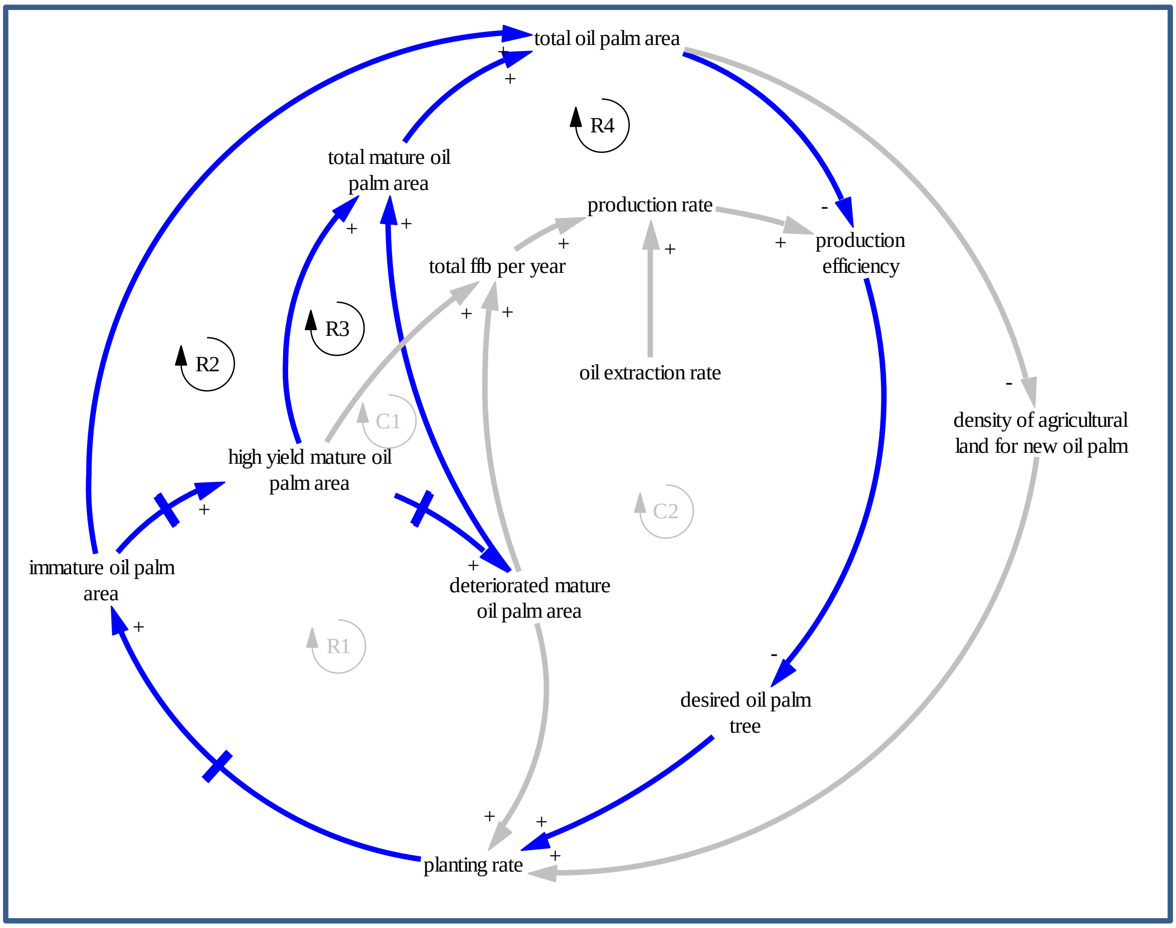

Figure 5: Oil palm area raises planting rate

PRODUCTION SECTION

Production of palm oil relies on machine. The palm oil processing is quite complicated, which included sterilization, threshing, digestion, pulp pressing, oil clarification, oil drying, oil packing. However, the process time is very short, which only takes a 48 hours to a few days. However, the model in the paper was used years as measuring unit. Therefore, the disturbance from the processing will not surface, because the measurement unit is very difference in scale and the bigger unit tends to pave the disturbance. Because of this reason, the palm oil processing has been simplified. The number of production is multiplication of fresh fruit branch and oil extraction rate.

Oil extraction rate (OER) was clearly defined .(Chang et al., oil palm Industry economic journal, volume 3, 2003[9]). In paper, Chang define the Oil extract rate as ratio of oil recovered and Fresh fruit branch (FFB) times 100. Mathematics formula is:

$$OER = \frac{\text{Oil Recovered}}{\text{FFB processed}} * 100$$

In the thesis, oil extraction rate is an average of machine performance. It measure how well the machine can extract palm oil. Oil extraction rate affects production rate positively (Figure 6).

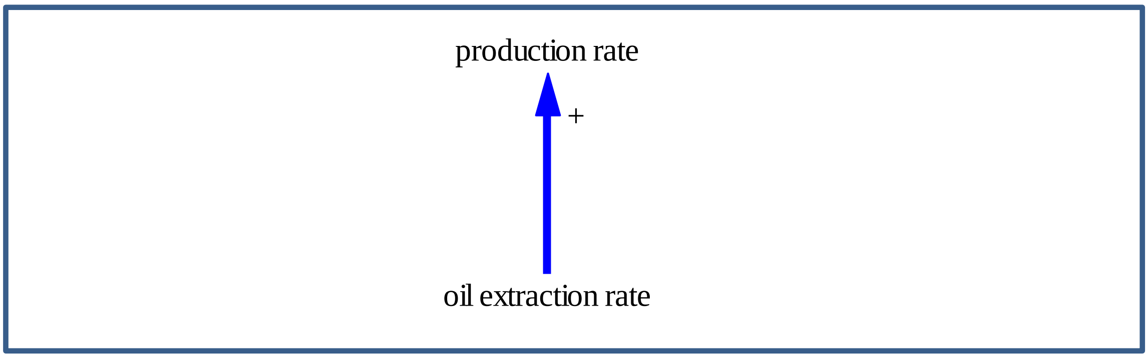

Figure 6: Oil Extraction rate and production rate

WORKER SECTION

Production of Palm oil depends on fresh fruit branch, which can be harvested through a mini tractor grabber or manual labour. Increasing of workforce through a hire a rate will increase the tatal ffb haversting rate because of labour can collect more fresh fruit. Increasing of fresh fruit will increase the production efficiency. The production efficiency then reduces the desired oil palm area because the demand of palm oil can be satisfied with smaller oil palm area. With smaller oil palm area, the demand of workforce will be reduced (C3,Figure 5).

High desired workforce demand will increase the interest of using machine to replace the worker. The workforce replacement will increase as the desired workforce. Desired workforce increases the number of actual mini tractor grabber, which can replace workforce partially (C4, R5, Figure 5).

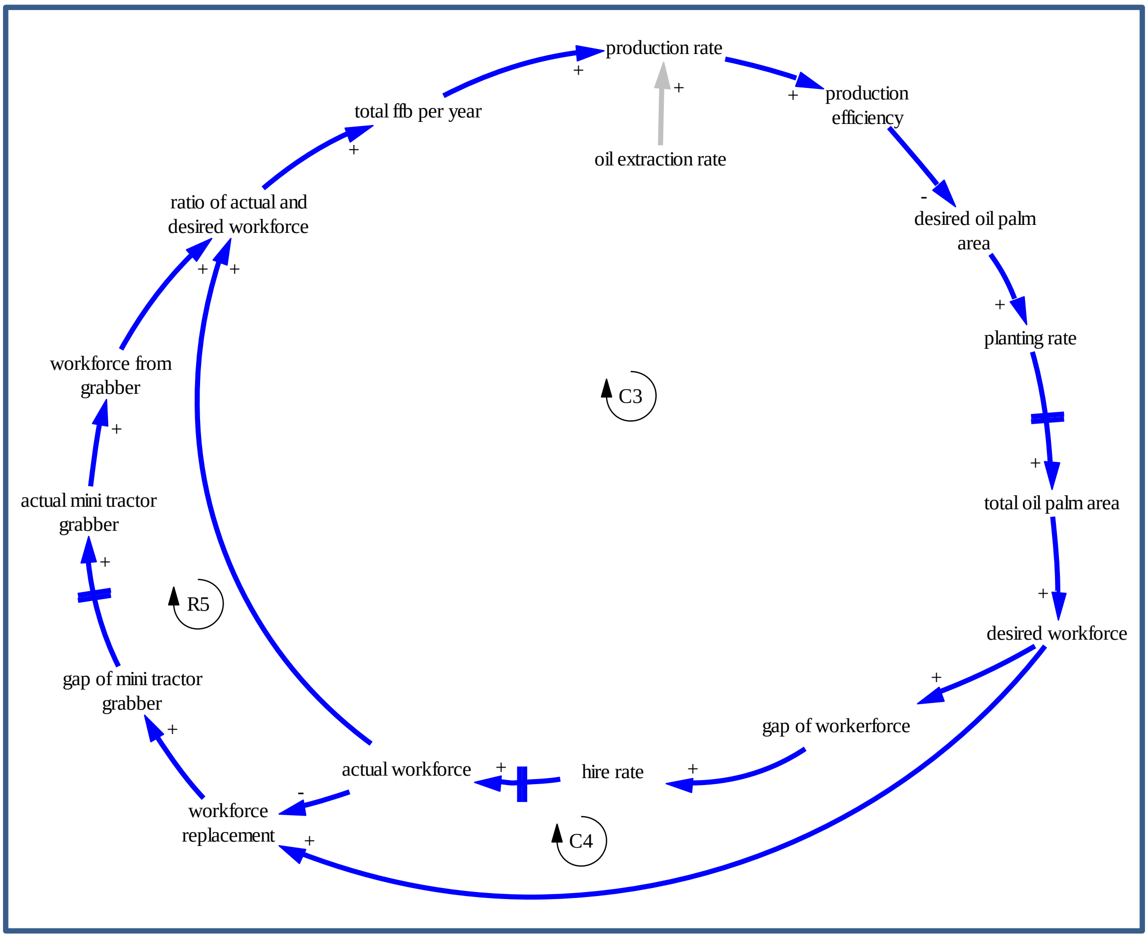

Figure 7: Workforce can be replaced by mini tractor grabber

MODEL STRUCTURE

This section is focus on elaborating the logic behind structures. Some of the important equations and model detail will be presented here.

The Model Boundary

The variables considered vital for understanding the oil palm system and the interplay between production efficiency and performance of the Palm Oil system.

Endogenous	Exogenous	Excluded
new planting rate desired replant rate production efficiency desired oil palm tree	clear cut delay mature time agriculture land bank FFB yield per high yield area per year FFB yield per deteriorated area per year land acquire delay average oil palm tree per workers domestic demand rate export demand rate grabber adjustment time grabber life time efficiency of grabber to worker efficiency of grabber to worker	system feedback to export demand international palm oil price influences to local market government implement new policies environment influences on oil palm growth rate and yield rate. oil palm trees density in one hectare area

Table 3: List of variables

In the model, we did not include the cost of production. We also assume that the demand of palm oil is mostly come from international. Malaysia domestic consumption is very small. Therefore, the influence from domestic consumption and feedback can be ignored.

Time Horizon

The oil palm tree production cycle is from 20 to 30 years. Depend on clear cut delay which could take 1 year to 10 year. In other words, the minimum production cycle is 20 years. We choose to run the model from 1987 to 2009 which is 22 years. The reason is the data before 1987 either incomplete or inconsistent among different authorities. Therefore, using these data is risky, unreliable and may lead to a wrong conclusion.

The Stock and Flow Structures

The stock and flow structure will be described by subdividing. The stock and flow structure will be described separately. Start with capacity modules, production modules and workforce modules. We will describe from a simplified structure, and then proceed further. The full stock and flow diagram is available in Appendix.

THE CAPACITY OIL PALM SECTION

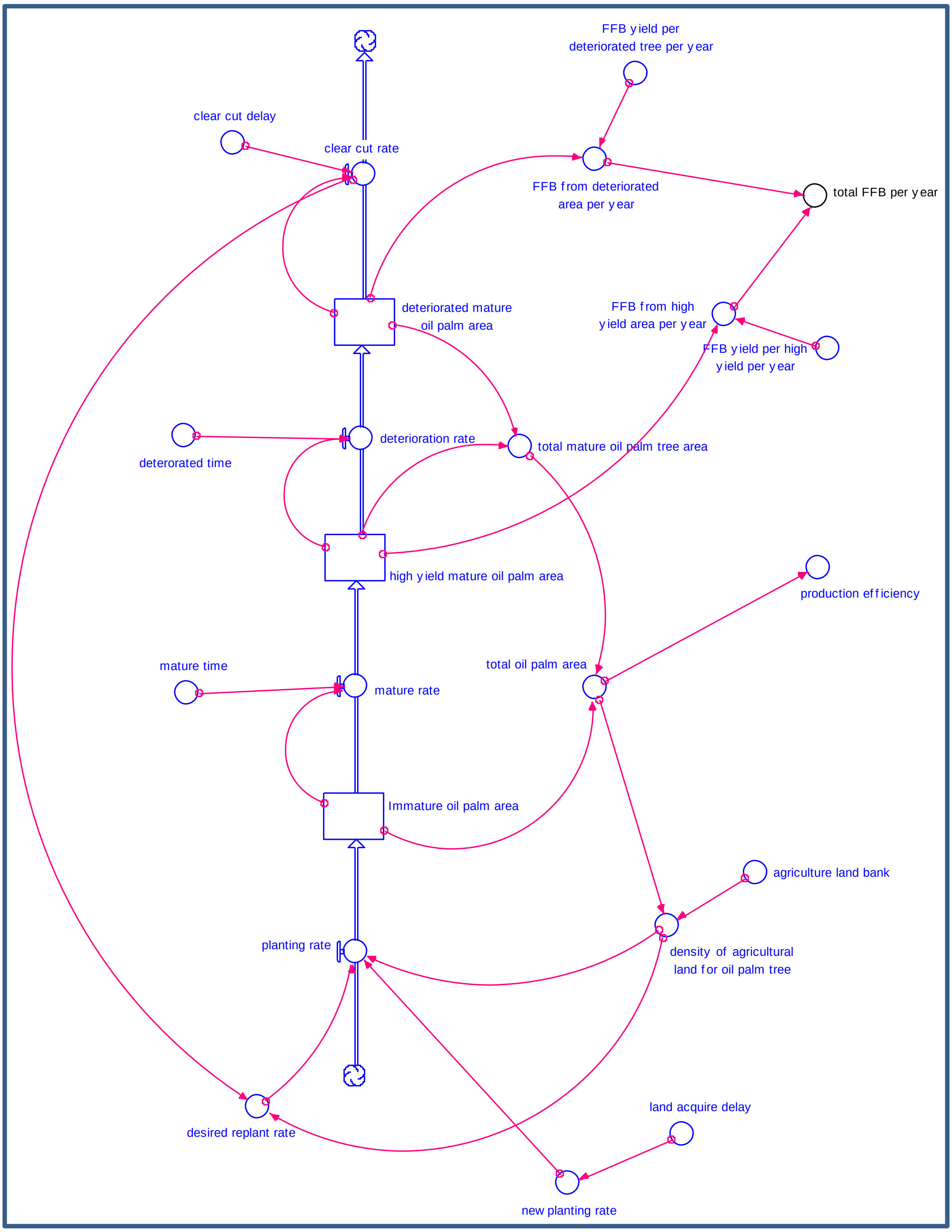

Figure 8: Stock and flow diagram for oil palm capacity

The capacity for palm oil only consists of 3 stocks: Immature oil palm area, high yield mature oil palm area and deteriorated oil palm area.

Each of the area represent the different age of oil palm tree grown in plantation. We assume that the system is in equilibrium state that inflows equal to outflows. With this assumption, we hypothesize that the plantation owner replants new oil palm to the same plantation after a clear cut process. The desired replant rate variable is the division of clear cut rate to density of agricultural land for oil palm tree. It will add to planting rate as well as new planting rate. New planting rate influences by the density of agriculture land. Density of agricultural land is represented in a percentage form, which has a meaning of availability for oil palm tree. If it drops into zero, there will be no more land for expansion.

New palm oil tree flows into immature oil palm area stock through a planting rate. The planting rate influences by availability of land. The immature oil palm area approximately takes 3 years, to become high yield mature. Only the mature oil palm area can yield fresh fruit branch (FFB). The fresh fruit branch from high yield mature area, is the multiplication of FFB yield per high yield area per year and the high yield area.

The high yield area oil palm can stay in the stock for 17 year. During this period, the oil palm area production is very high. Average fresh fruit branch yield per hectare per year is about 23. After high yield period, it slowly change into deteriorated mature oil palm area As high yield area, deteriorated mature oil palm area can also yield fresh fruit branch, but with a lower rate of 18 yield per hectare per year in average. Both high yield and deteriorated area are mature oil palm tree area.

The total oil palm area is the sum of immature and mature oil palm. The total oil palm area influences the production efficiency reversely.

As we assume that the capacity of oil palm sector is in equilibrium state. If there is no expansion of oil palm area, the immature, high yield and deteriorated area should balance them self in a ratio of 3:17:5, according to the delay of each stock.

THE PRODUCTION SECTION

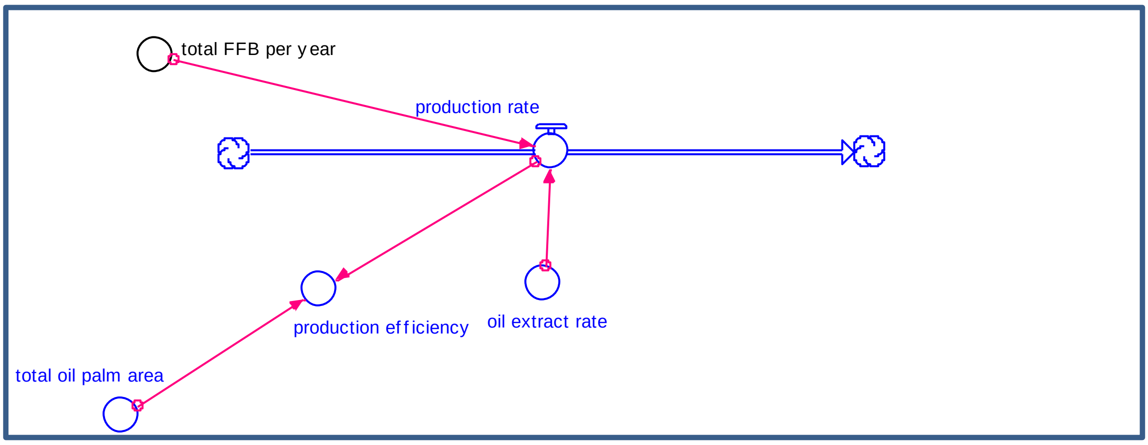

Figure 9: Production and production efficiency

The production efficiency is an indicator (Figure 7). It gauges the utilization of land usage. High production efficiency means the production is very effective. The reason we use production efficiency instead of production rate itself because the production is misleading. Increasing of production could be the result of oil palm area expansion. The formula of production efficiency is shown as follow:

$$Production\ efficiency = \frac{\text{Production rate}}{\text{Total oil palm area}}$$

The production section has no stock due to the reason we have stated in causal loop diagram production section.

THE WORKFORCE SECTION

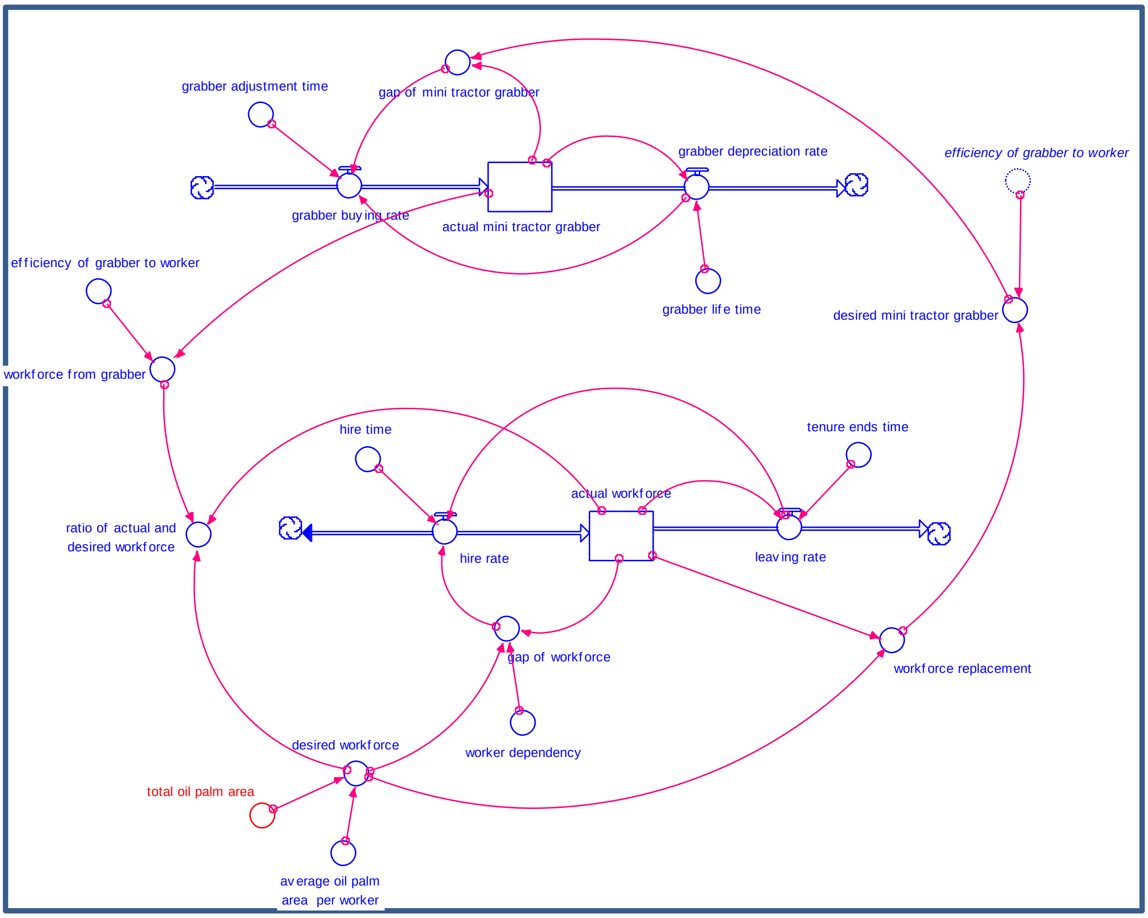

Figure 10: Workforce section

The workforce section consists of two productive elements, which are manual labour and machine. The upper stock, actual mini grabber is a machine which use for replacement of workforce when suffering from labour shortage. Because of the terrain limitation, the machine may not accessible to all terrain. This is the reason that manual labour workforce still dominating the oil palm area. The lower stock, actual workforce represents manual labour workforce (Figure 8).

We hypothesized workforce is decided by total oil palm area. This is reasonable, as the larger area need more workers to manage. Worker is the workforce that is needed to be allocated to harvest the fresh fruit branch. Using machine can indeed replace labour, but using machine cannot reduce fruit harvesting task need to be done.

The bottom left desired workforce is the total labour workforce needed. We assume that each single unit of labour workforce carry single unit of workforce. The single unit of work force can be described as average oil palm area per worker. Desired workforce has a reverse relationship to actual workforce. When there is a gap, labour will flow into or out of actual workforce through a hire rate. The labour can be reduced before tenure ends. In here, we assume that the hire time is 1 year. The tenure ends time is 5 years which is decided by the government. The labour exit the stock with the leaving rate will be replenished through hire rate, in order to stable the labour force. This can be done because government allow plantation owner to replenish the labour force, after the tenure ends. Worker dependency represents the dependency of labour workforce. Worker dependency is a decision which influences the hire rate.

When there is a scarcity of workforce, especially labour shortage, estate owner tends to search workforce replacement. The desired machine is called mini tractor grabber. The desired mini tractor grabber creates a gap of mini tractor grabber that eventually influences grabber buying rate. The adjustment time is 1 year. Through the buying rate, the system builds up the stock of mini tractor grabber. However, one should know that the grabber has a life time of 5 years. After 5 year, the owner may buy new grabbers again. The grabber can increase the productivity for almost 1.25 percentage compare with manual labour. The actual and desired workforce will always balance themselves so than the workforce can be fully utilized. Ratio of actual and desired workforce represents utilization of workforce.

ANALYSIS

The model is a tool that allows us to understand the real world structure. But the model cannot be as complex as the real world, otherwise the model will become too complicated to be comprehend. Therefore, building a simplified model which merely reflects the problem is the key. Through this, we may able to understand the problematic behavior and to study the structure causes the problem.

The model has to be tested and make sure that it will produce predicted behavior within a range of reasonable inputs. By testing the model, we may find out some ambiguous structures in the model which generate unreasonable result. We have to make sure that the model generates reasonable results. Then model will become stable. If the model is stable, we will have confident in it.

With a stable model, we can begin to use it to study as well as to understand our real structure effectively. The model running on a virtual environment can become a test ground for different alternative strategies, so that the impact of the strategies can be studied before implementation.

In this section, we will cover a few test designs to ensure the model is stable. The model will divide into two main sections: Direct structure test and structure orientated behavior test.

Direct structure test

The production section of the model is based on the descriptive data in Malaysia Palm Oil Board[2], wikipedia[3] website and Malaysia Felda holding[4] previously an government agency.

The production structure is based on Food and Agriculture Organization of the United Nations[5] which describe the process of oil processing in detail.

The workforce structure is based on the description on The Malaysia Palm Oil Cluster Final Report[6]

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2 http://www.mpob.gov.my/
3 http://en.wikipedia.org/wiki/Oil_palm
4 http://www.felda.net.my/feldav3/
5 PALM OIL PROCESSING, http://www.fao.org/DOCREP/005/Y4355E/y4355e04.htm
6 http://www.isc.hbs.edu/pdf/Student_Projects/Malaysia_Palm_Oil_2011.pdf

The detail has been described in literature review, causal loop section and stock and flow section, which the structure is a simplified version of real oil palm industry. The new planting rate is based the gap between oil production rate and export demand. Oil yield rate decides the number of new oil palm number than need to be planted.

Equilibrium shock test

The whole model was put into equilibrium state. By applying a sudden shock of 250 extra export demand after year 1995, the decided export rate raise until 500. At same moment the production efficiency fell slowly. From a value of 3.84, production efficiency dropped until a value of 3.82. Production efficiency slowly climbed back to equilibrium state approximately after 20 year.

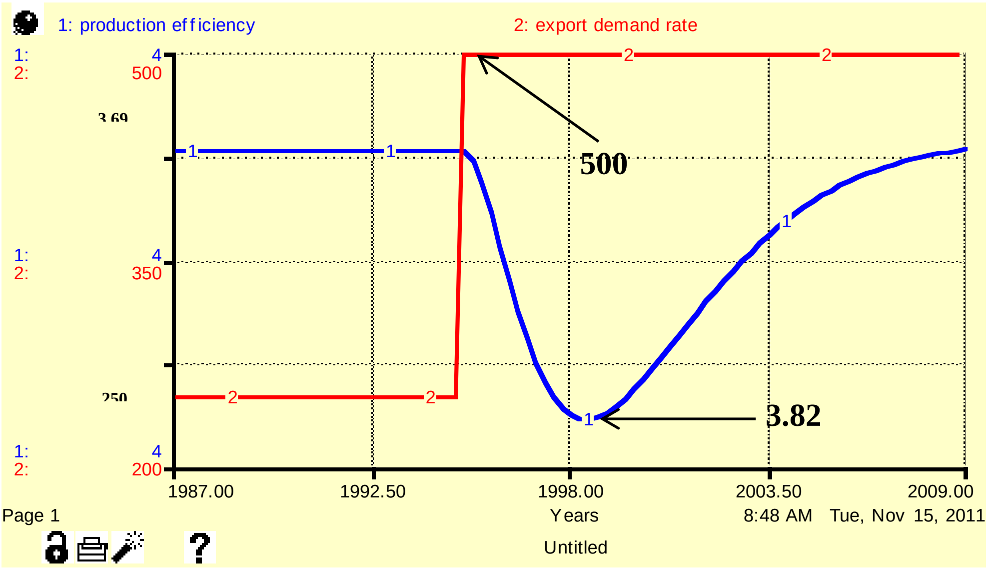

Figure 11: Production efficiency response to shock input

The falling of production efficiency is the system immediately responses to the sudden increase of export outflow. The decided export rate increases desired total consumption rate.

In order to fulfill the desire consumption rate, the system will increase new planting rate. The new planting rate increases immature oil palm area stock. The Immature oil palm area will take 3 years to become mature tree which can produce palm fruits that can be extracted for palm oil.

However, during the immature period, total oil palm tree stock has been increased. Thus, the production efficiency is lower because immature oil palm area cannot produce any palm fruit. The next section, we will test equilibrium shock reaction by cutting out individual loops. The loop cutting test will be presented in 2 sections: The capacity section and workforce section. In each section the loop cutting test has been conducted differently.

Capacity Section

CUTTING C1 LOOP

C1 loop is reinforcing loop which always strengthen the effect of the loop. By Cutting C1 loop, we break the link between new planting rate and immature oil palm area after the sudden shock. The production efficiency was raises because new planting rate.

If our hypothesis matches what we describe on C1 loop, cutting the C1 loop will reduce the production efficiency (Figure 10).

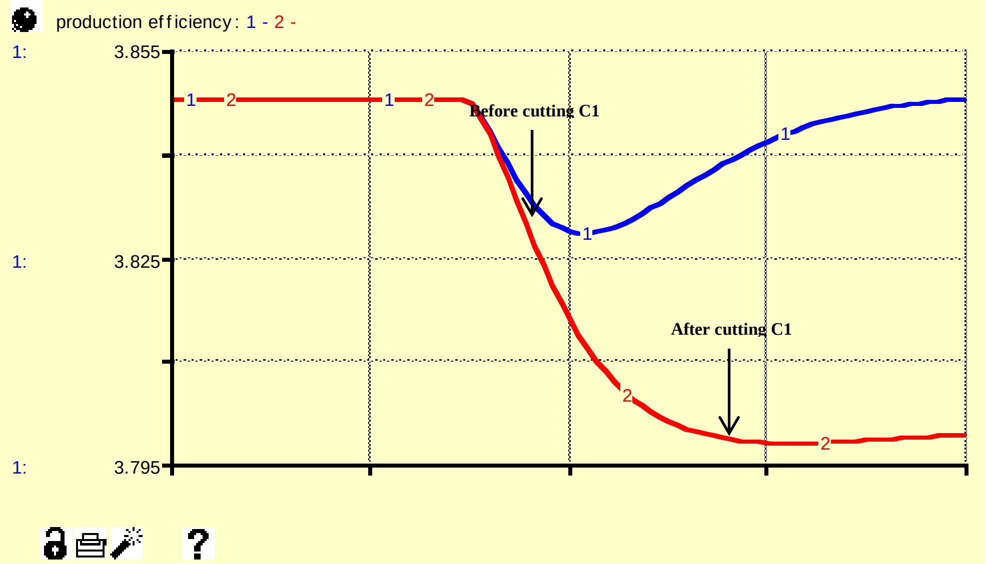

Figure 12: Cutting C1

CUTTING C2 LOOP

C2 are similar to C1 loop. It is reinforcing loop. By Cutting C1 loop, we should able to observer behavior similar to C1. It bounced back because of the C1 loop still running when C2 loop has been cut.

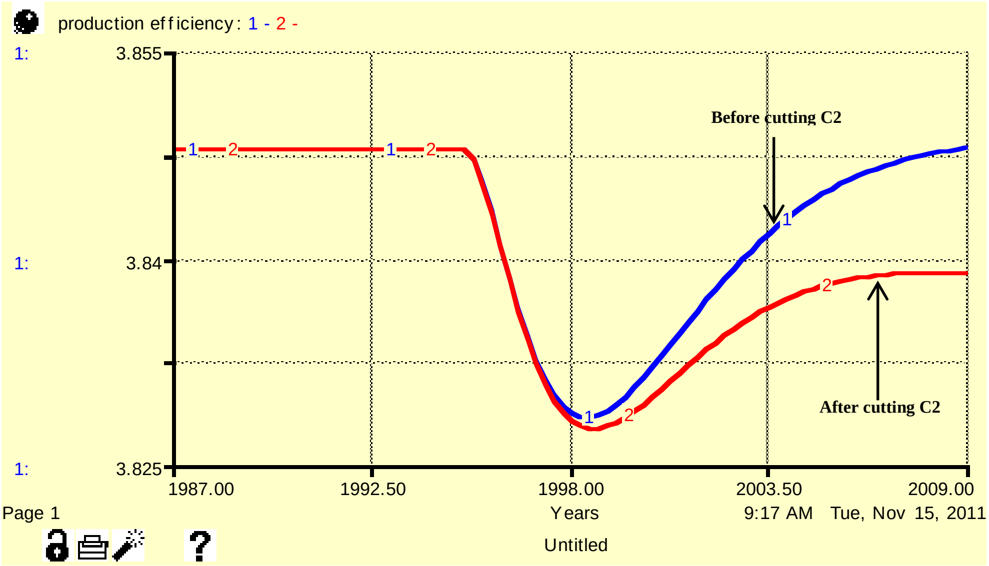

Figure 13: Cutting C2

CUTTING R2 LOOP

R2 is reinforcing loop. By cutting R2, the production efficiency should increase because it reduces the unproductive immature oil palm area from total oil palm area. The total oil palm area has a reverse relationship to productive efficiency.

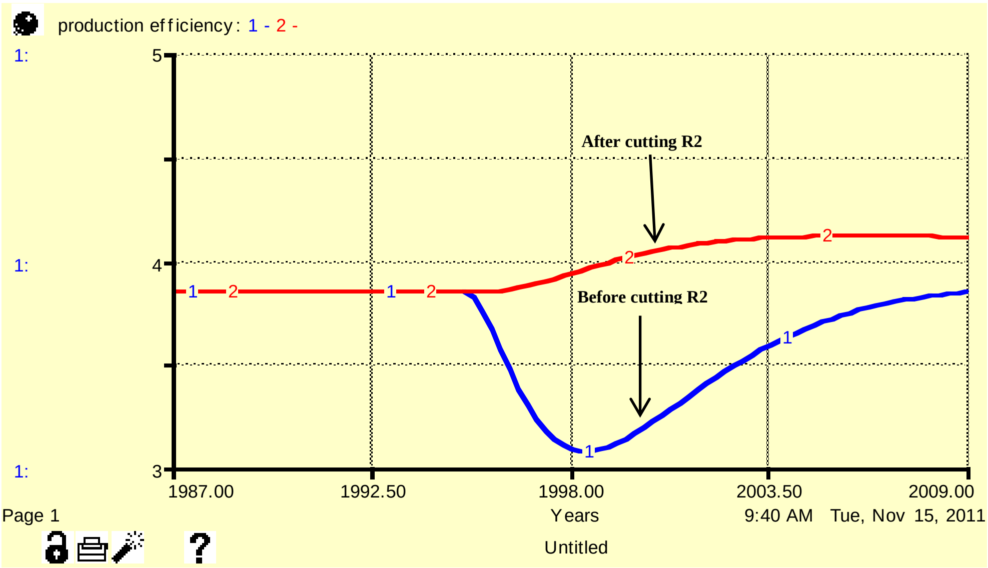

Figure 14: Cutting R2

CUTTING R3 LOOP

R3 is reinforcing loop. By cutting R3, the production efficiency should increase because it reduces the total oil palm area which has a reverse relationship to productive efficiency.

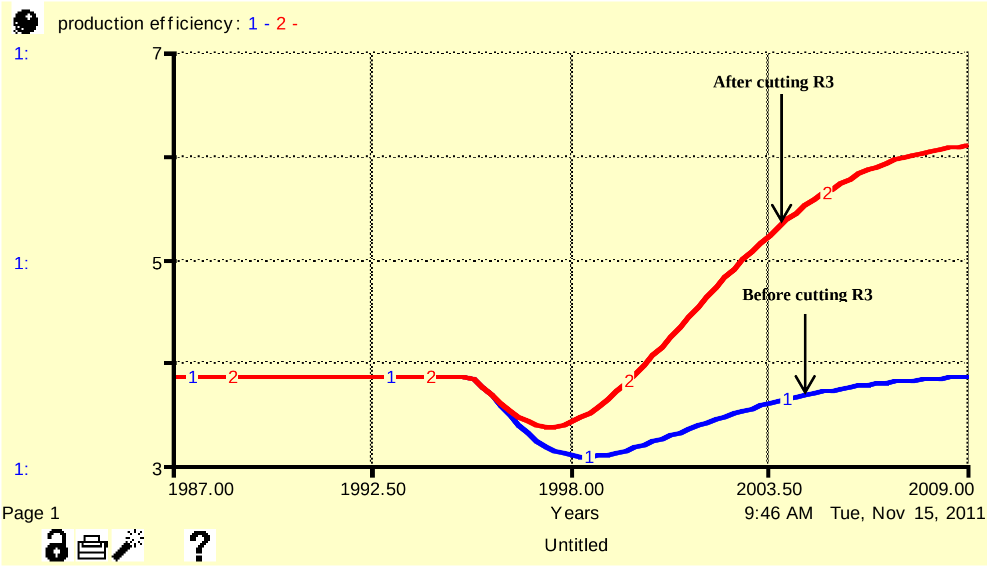

Figure 15: Cutting R3

CUTTING R4 LOOP

Similar to R3, cutting R4 should increase the production efficiency.

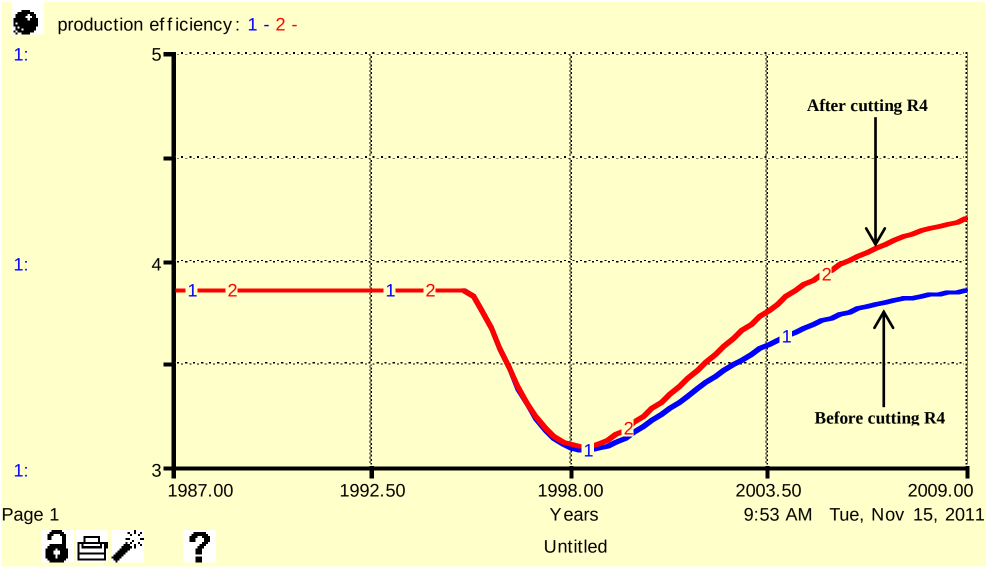

Figure 16: Cutting R4

Workforce Section

CUTTING C3 LOOP

Cutting C3 has no effect to production efficiency. The shock increases the desired workforce. However, cutting C3 loop, the actual workforce is not going to response to the shock. The workforce demand, switch to mini tractor grabber through workforce replacement. Therefore, mini tractor increases, while actual workforce remains unchanged. Workforce influences FFB harvesting directly, when workforce remain unchanged, production efficiency will not response to it.

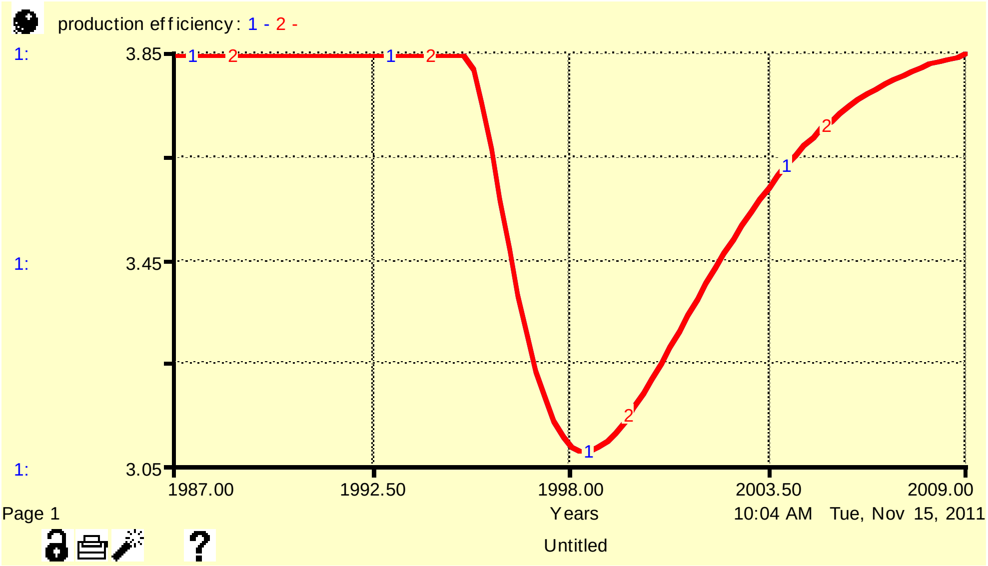

Figure 17: Cutting C3

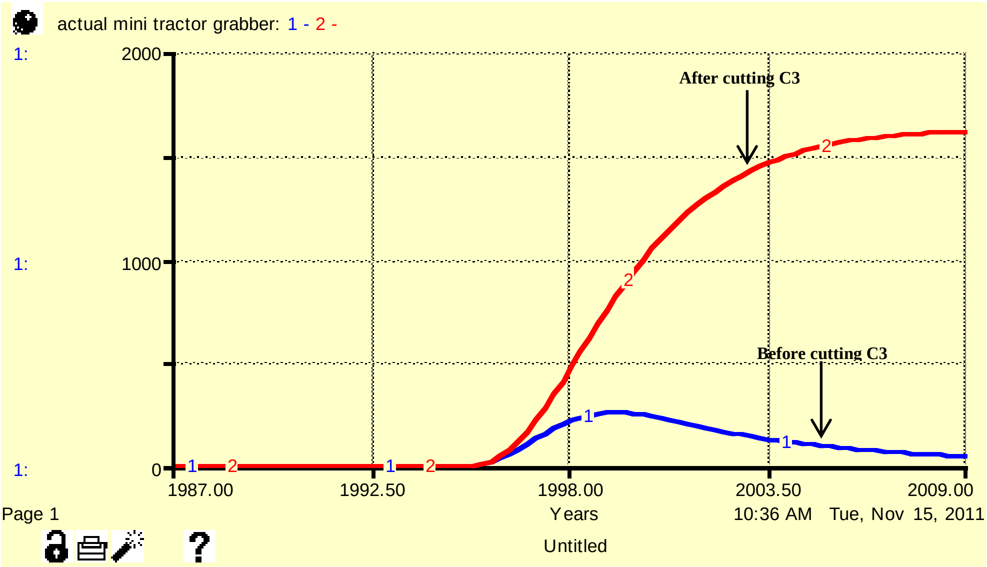

Figure 18: Cutting C3: Increasing of mini tractor grabber

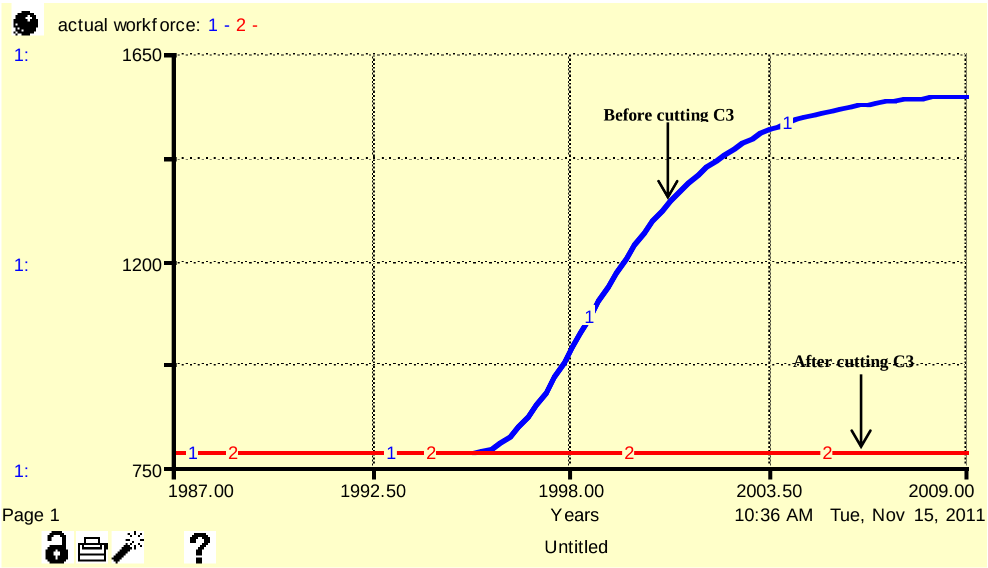

Figure 19: Cutting C3: Unchanging actual workforce

CUTTING C4 LOOP

C4 loop is very similar to C3 loop. Cutting C4 loop will leave the workforce demand to C3 loop. C4 is loop is almost identical to C3. Therefore, production efficiency remained unchanged.

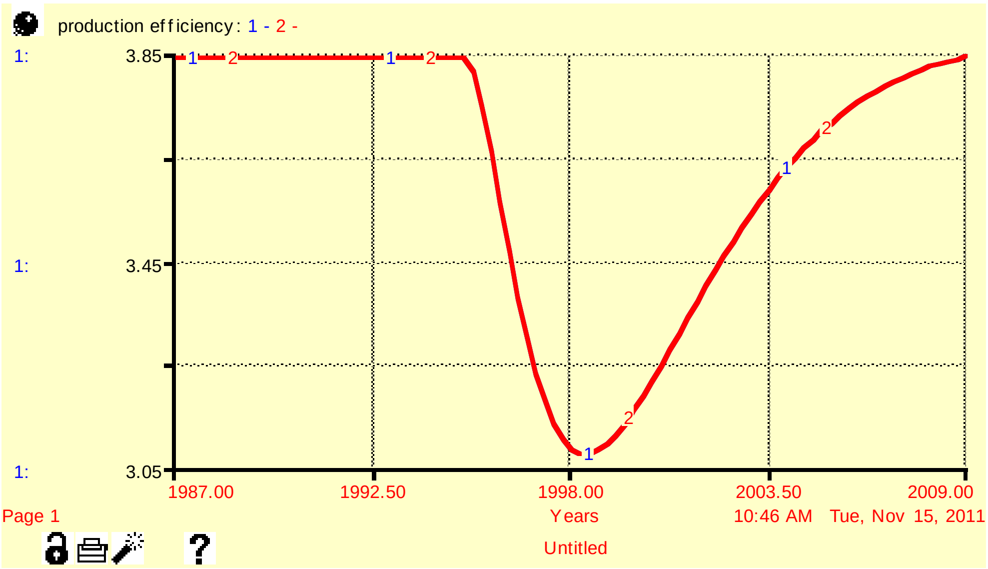

Figure 20: Cutting C4: Unchanging actual workforce

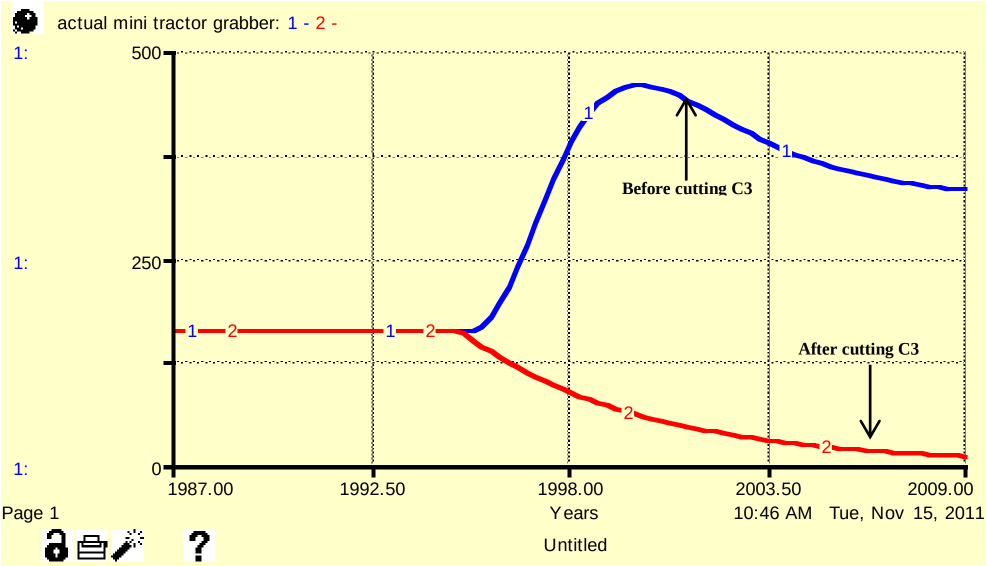

Figure 21: Cutting C4: Unchanging actual workforce

Sensitivity analysis

MATURE TIME

Mature time is the time that immature oil palm area becomes high yield mature area. Through cutting C1, C2, R3, R4 loops test, we believe that longer mature time will lead to poor performance of production efficiency (Figure 19). Longer mature time not only reduces the production efficiency, but it also increases the time for production efficiency restore back to its equilibrium state.

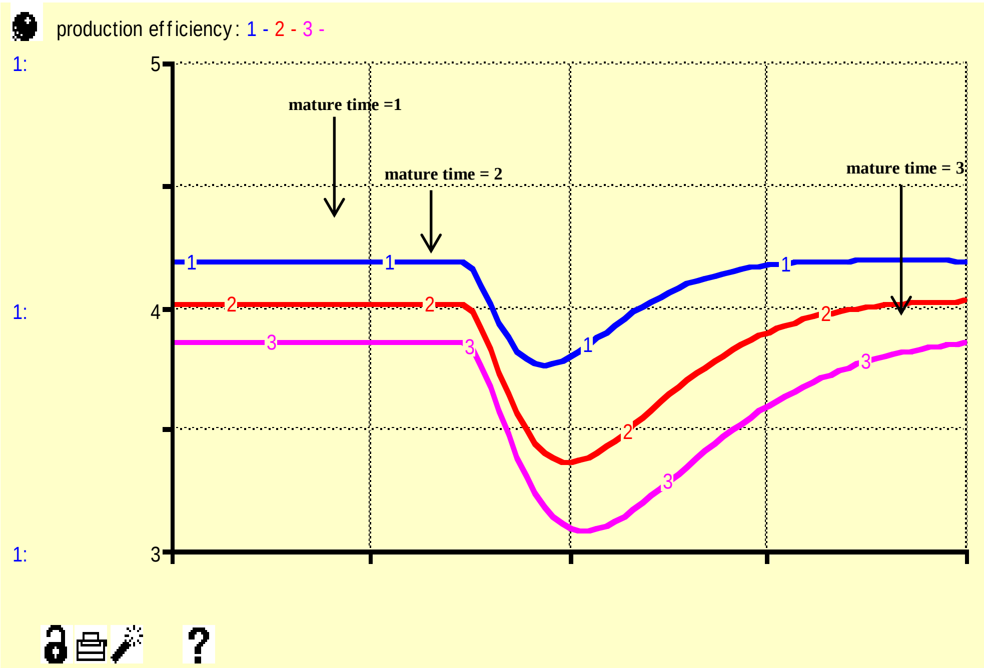

Figure 22: Long mature time poor performance

FFB YIELD PER HIGH YIELD AREA PER YEAR

FFB yield per high yield area per year is productivity indicator for oil palm tree. It can only be changed by using new breed of oil palm tree. From cutting C1 loop, we have realized that this variable may be responsible for the production efficiency. From the test, we have discovered this variable is very sensitive to production efficiency (Figure 20).

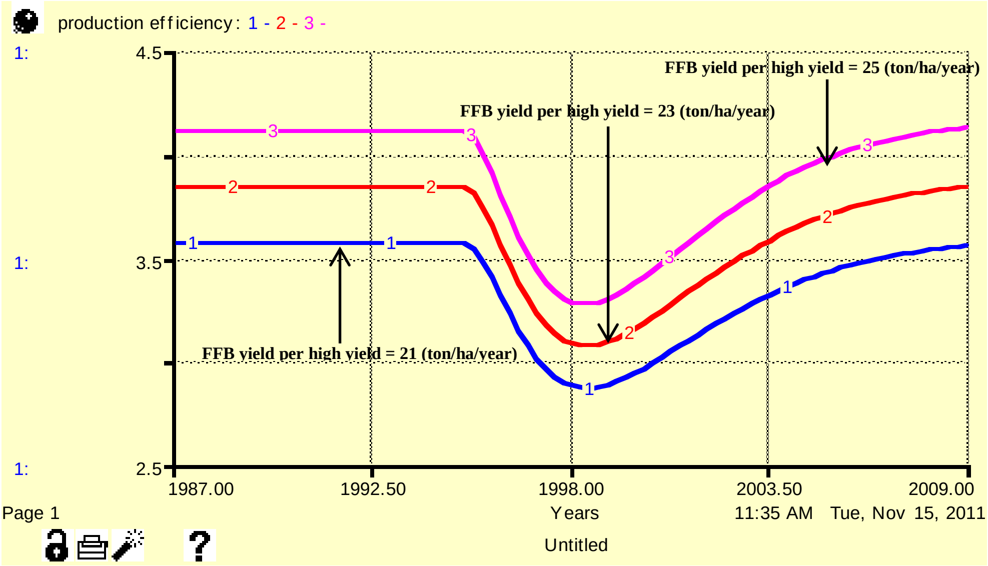

Figure 23: FFB yield in high yield area per year vs production efficiency

FFB YIELD PER DETERIORATED AREA PER YEAR

FFB yield per deteriorated area per year is similar to FFB yield per high yield area per year. We believe that this variable share the similar characteristics as FFB yield per high yield per year (Figure 21). This variable is not as sensitive as FFB yield per high yield area per year.

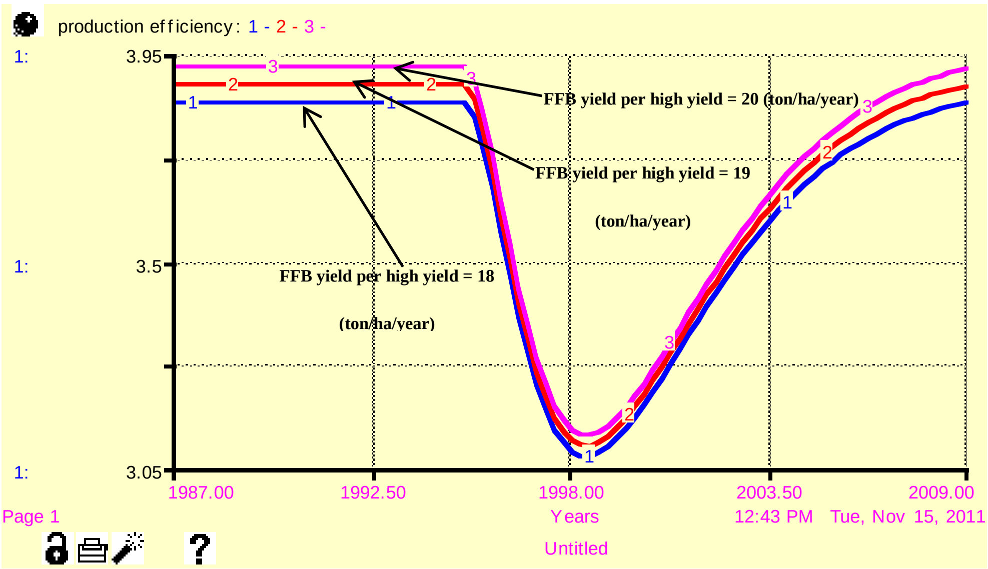

Figure 24: FFB yield in deteriorated area per year vs production efficiency

OIL EXTRACTION RATE

Oil extraction is a variable directly affects production efficiency. Oil extraction rate directly influences the production rate. And the production rate has a positive relationship with production efficiency. From the testing we determine production efficiency is sensitive to oil extraction.

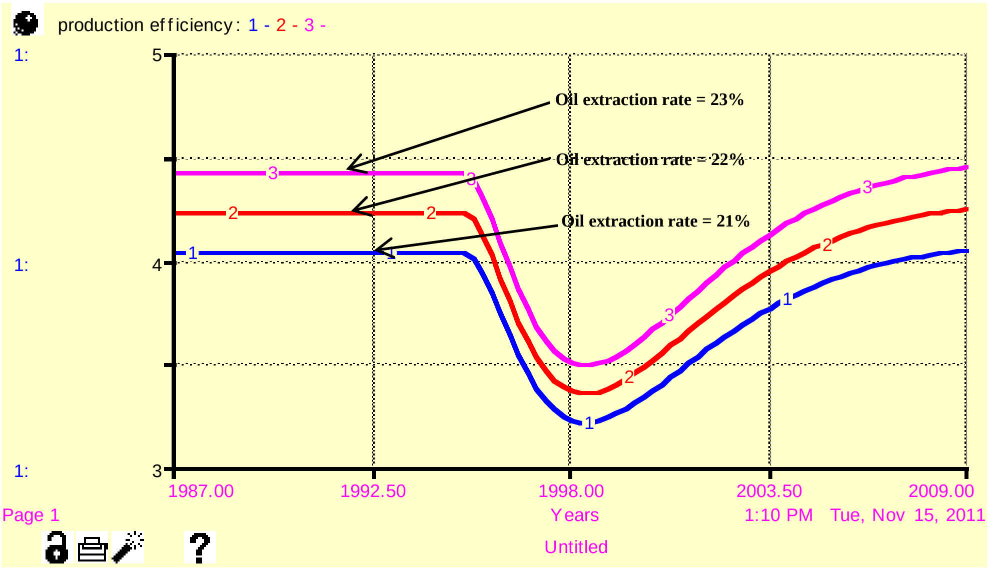

Figure 25: Oil extraction rate

Simulation settings

The simulator is ithink v9.14.

DT set to 0.25

Time measurement unit is year

Runge Kutta integration method was chosen to ensure accuracy result.

Simulation start from 1987 to 2009.

Recreation of reference mode

Recreation of reference mode is very essential. In this section we compared the reference mode with the historical data so that we can assess the gap between historical and simulation behavior. Theil;s statistics test was use to access the differences, even the bare eyes assessment had been conducted.

The stocks in the model were initialized with historical data. Some of the stocks which historical data was absent, we tried to create initialize it by using estimate data.

In this section, we recreate the reference mode with simulation setting. The model was initialized with historical setting. Some of the data which absent from historical data were replaced by estimated data. We would like to compare the behavior of historical behavior with the simulation behavior by examining variable of interest. Figure 26 was the simulation result. blue line is historical behavior and red line is simulation.

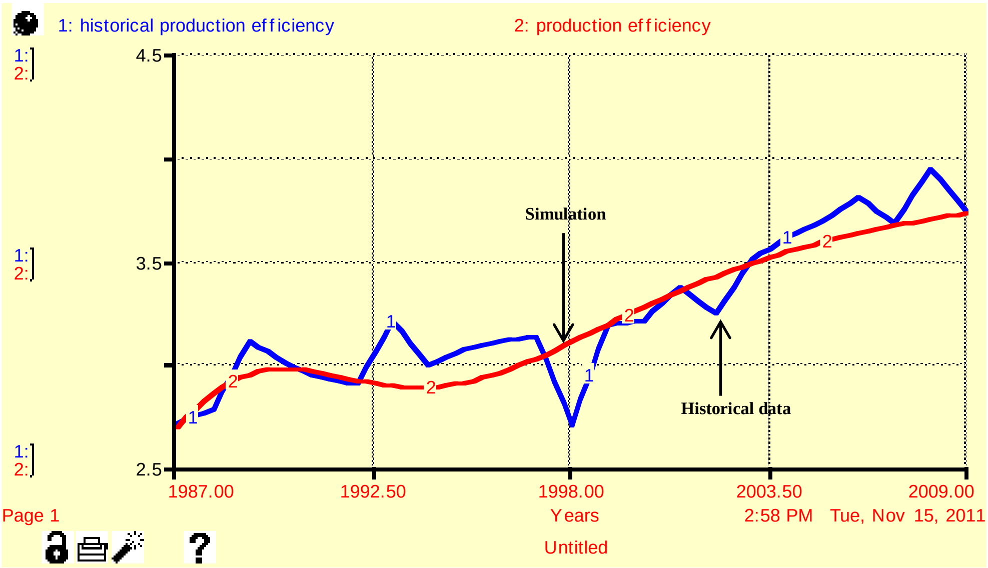

Figure 26: Recreation of reference mode

By directly observation without calculation, the simulation behavior matched the trend of historical behavior. Initial behavior tendency was similar to the historical Both starting point of simulation and ending point of simulation matched the historical data. Starting point matched the historical data because we initial the stocks with historical data. The ending point matched the ending history data just by chance. The noise of historical behavior was not be captured.

The historical and simulation behavior were found to match with each other. Simulated and actual trajectories can be explained by using Theil's Inequality Statistics (Theil, 1966). Trajectories can be explained in bias, unequal variation and unequal co-variation. The sum of bias, unequal variation and unequal co-variation should equal to 100%, if there are different between historical and simulation behavior. Historical and simulation behavior were found with 7% of bias, 4% of unequal variation. Hence, unequal co-variation is 89%. That means square error mainly arises from the point-by-point differences. However, the point-by-point differences are not imposes a treat on the validity of the model, as the purpose of the model is to understand the long term dynamics of the production efficiency in low term.

Historical production rate and simulation production rate

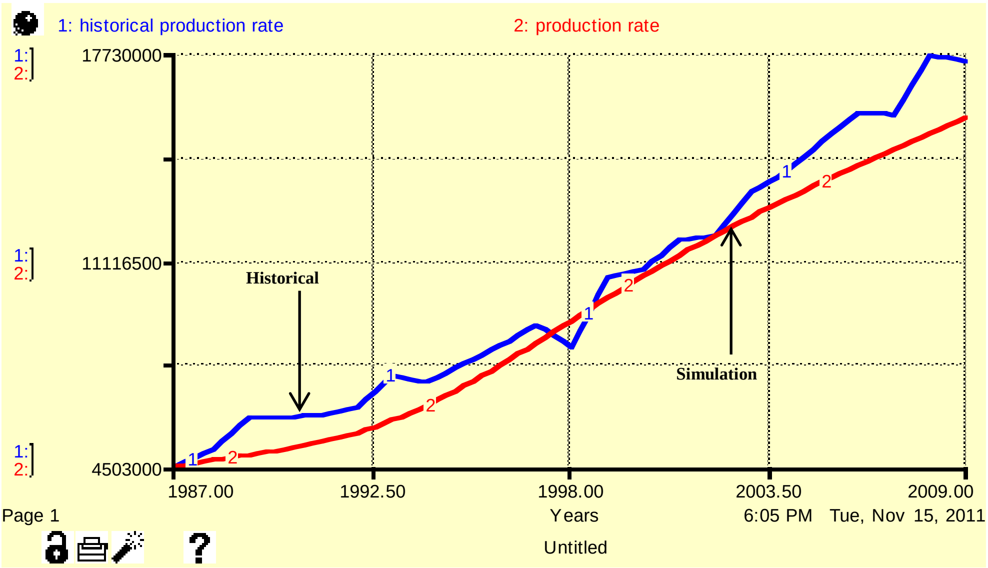

Figure 27: Historical and simulation production rate

The simulation behavior was constantly lower than historical behavior. However, the trend for simulation behavior is very similar to historical behavior. There is a sharp fall in 1998, but the simulation did not catch this changes. This sharp fall behavior was caused by Asia financial crisis in 1997. Malaysia oil palm industry is export driven industry, almost 90% of palm oil export to other countries. When the financial crisis hit Asia, the order from other countries decreased, as a result the production of palm oil fell.

Historical total oil palm area and simulation oil palm area

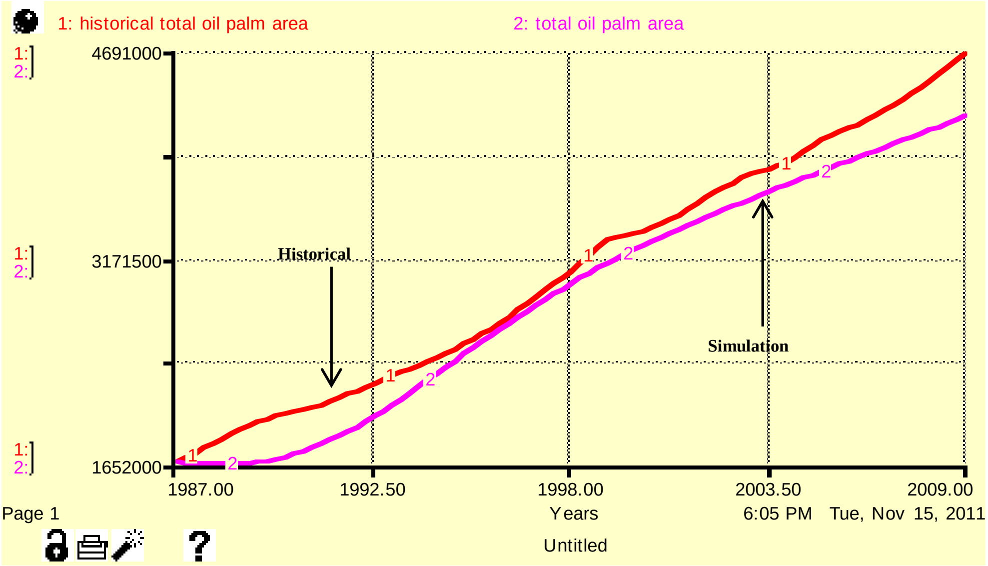

Figure 28: Historical and simulation total oil palm area

The trend in simulation behavior was similar to the historical trend. But there was an initial trend issues between 1987 to 1997 period. This can be explained as the demand of pail oil increased in an increasing rate during the period. The increasing of the demand encouraged expansion of oil palm plantation, which then led to an increasing of oil palm area. The model used in the simulation did not take care of this changes, due to demand of palm oil is driven by other countries and which was out of the model boundary.

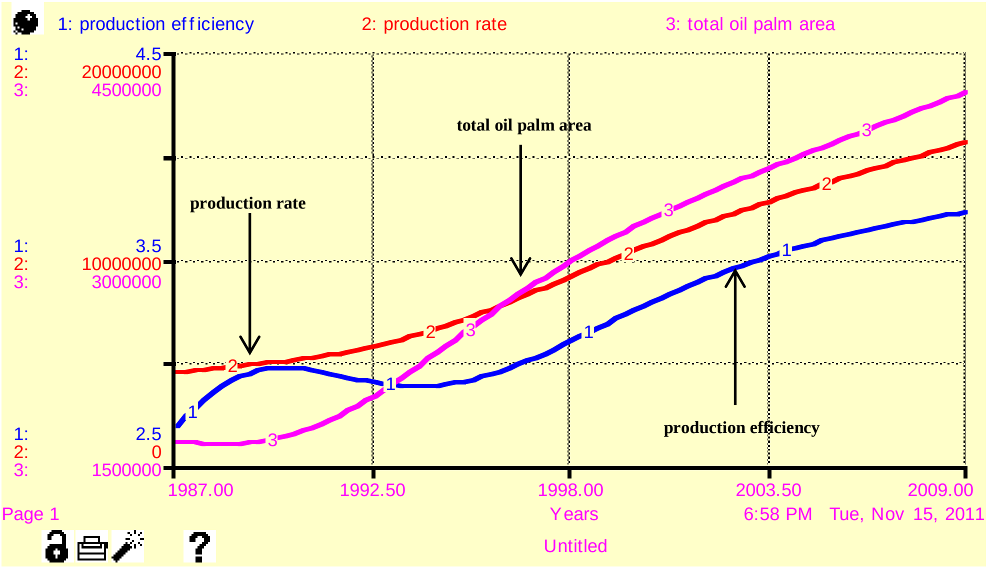

Figure 29: Reference mode reproduction

The simulation behaviors were not completely matched with the historical behaviours. However, most of the behavior trends were similar to the historical trends. For this, we believe that the model has already captured the dynamics problem from the real world. The two factors: production rate and total oil palm area react together which shape the production efficiency. The production efficiecny feedbacks to the system and create the dyanmics problem. From the reference mode (Figure 29), production rate and total oil palm area were react together, which generated fluctuation in production efficiency.

Reference mode: Sensitivity test

Previously shock test to the model shows that production efficiency is sensitive to mature time, FFB yield per high yield area per year, and oil extraction rate. To understand how these variables impact the reference mode. We will test these variables separately.

MATURE TIME

The increasing of 1 year of mature time, it will leads to a fall of production efficiency by 0.2. The behavior was expected as we conducted the shock test. The behaviors were similar to each other. Longer time of mature time decreased the production efficiency.

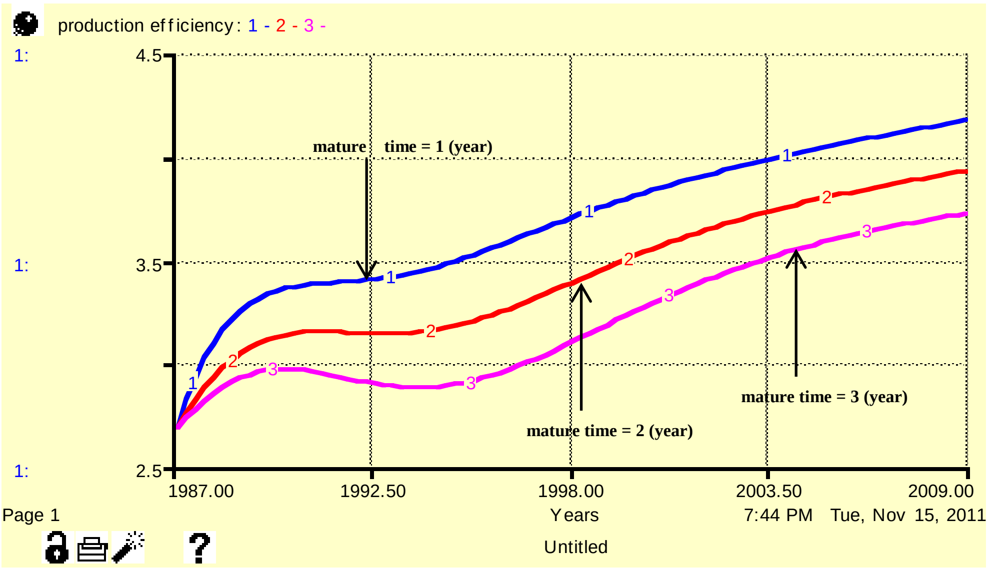

Figure 30: Mature time and reference mode

FFB YIELD PER HIGH YIELD AREA PER YEAR

The changes of 1 unit in FFB yield per high yield area per year, will only increase 0.1 of production efficiency.

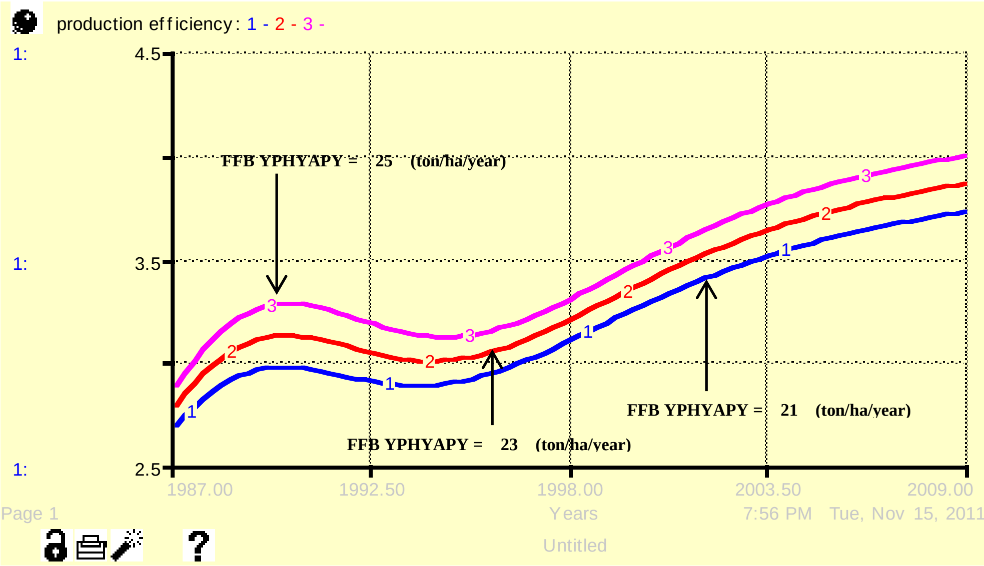

Figure 31: FFB yield per high yield area per year and reference mode

OIL EXTRACTION RATE

Oil extraction rate can influence the production efficiency very much. 1% of increment of oil extraction rate could increase 2 unit of prodution efficiency.

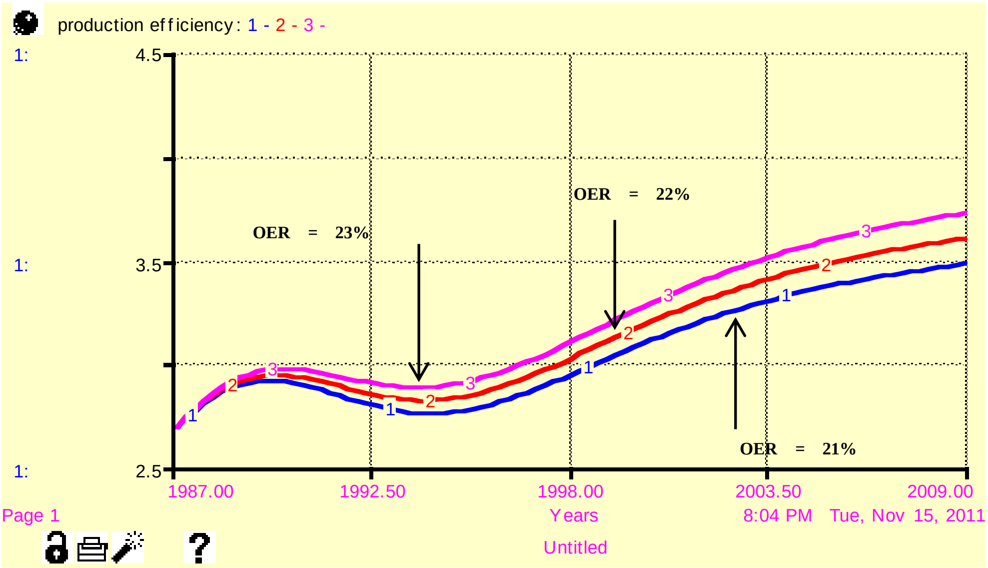

Figure 32: Oil extraction rate and reference mode

POLICY

After consideration two policies was proposed to improve the production efficiency. Mature time was sensitive the system. But changing the mature time with new breeding oil palm, in fact must take at less 26 years to complete a cycle. The policy for mature time was considered not effective and was out of our purpose of achieving significant result within 10 years.

We first elaborate and tested these policies. After that we conduct equilibrium test on both policies separately. Finally, we test both polices together in scenario testing section.

Policy Option 1

Allocating more workforce to high yield area. The policy directly increases the fresh fruit branch production. Fresh fruit branch directly increases production rate. This policy involves distribution of workforce.

Analysis of Policy option 1

The main idea of this policy was allocating more workforce to the high yield area, so that the efficiency in the high yield area can boast up greatly (Figure 33). This policy doesn’t change the number of workforce as it involved just only distribution of workforce.

This policy added two stocks which is actual workforce in deteriorated and actual work force in high yield. Workforce in deteriorated area will move to high yield area. However, workforce in high yield also moves back to deteriorated area. Usually workforce will stay at high yield area and deteriorated area for a 17:5 ratio. If the ratio increases, that means workforce will be concentrate to high yield area. Because of high yield area can yield higher rate of fresh fruit per year. Therefore, increasing harvesting activity in high yield area can boast up the production rate.

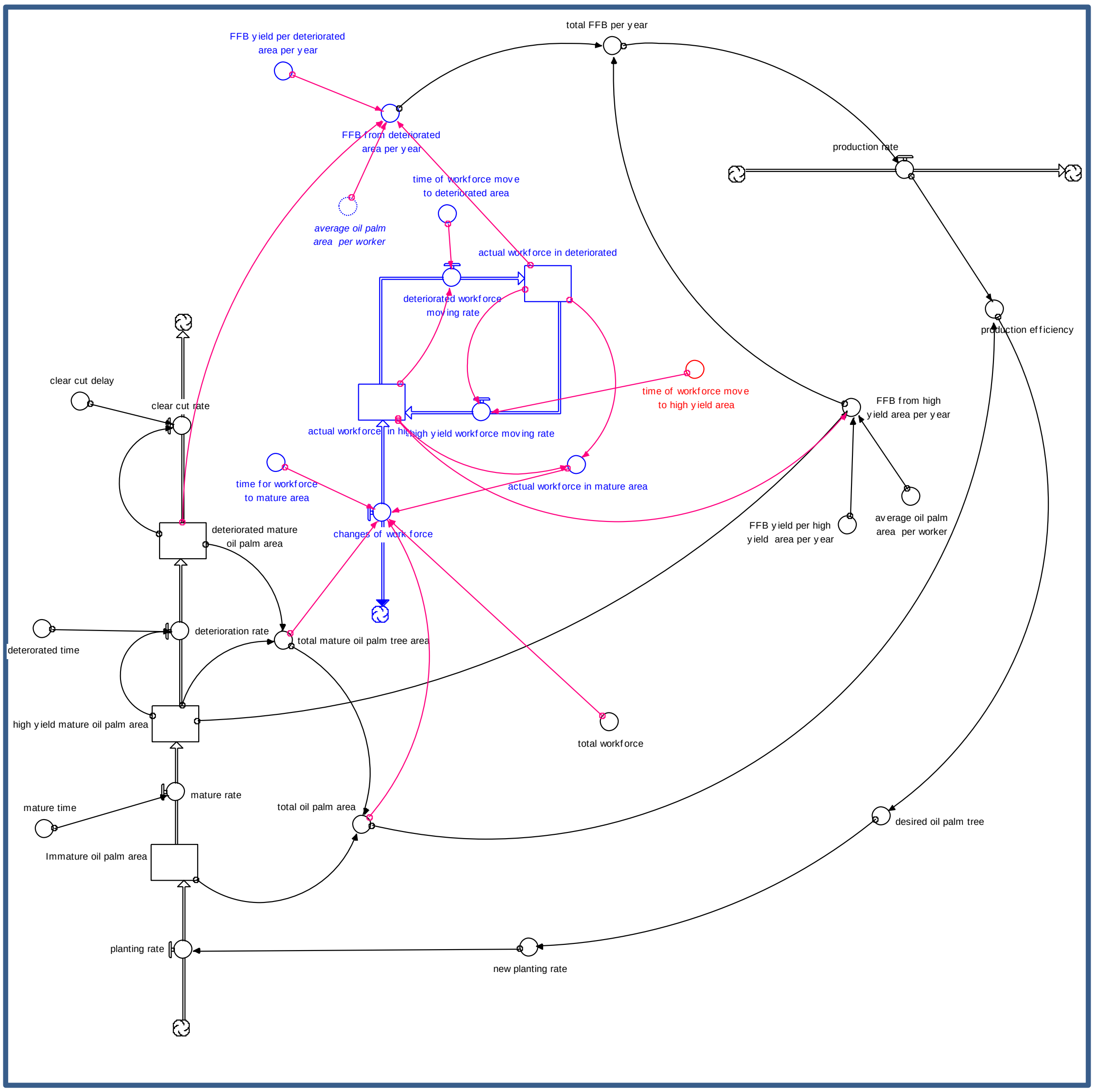

Figure 33: Policy option 1, reallocate workforce

Policy Option 1 testing

The policy was tested in two ways: 1) equilibrium test 2) scenario testing. In equilibrium tests, we compared the behavior of the model before and after adding new structure (Figure 34, 35, 36, 37).

From the testing, we know that after adding new structure was create a similar behavior to the original behavior.

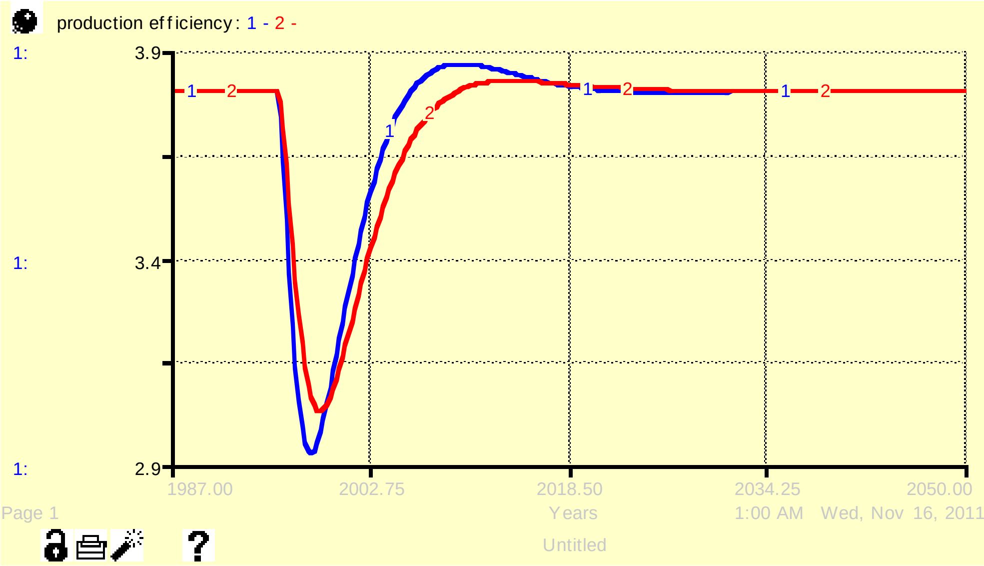

Figure 34: Production efficiency. (1) before (2) after the using new policy.

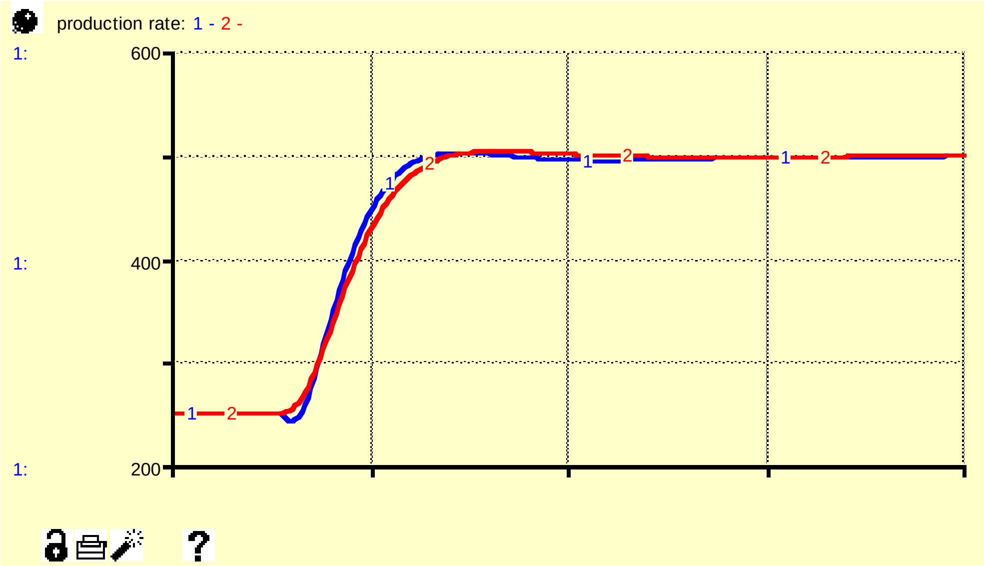

Figure 35: Production rate. (1) before (2) after the using new policy

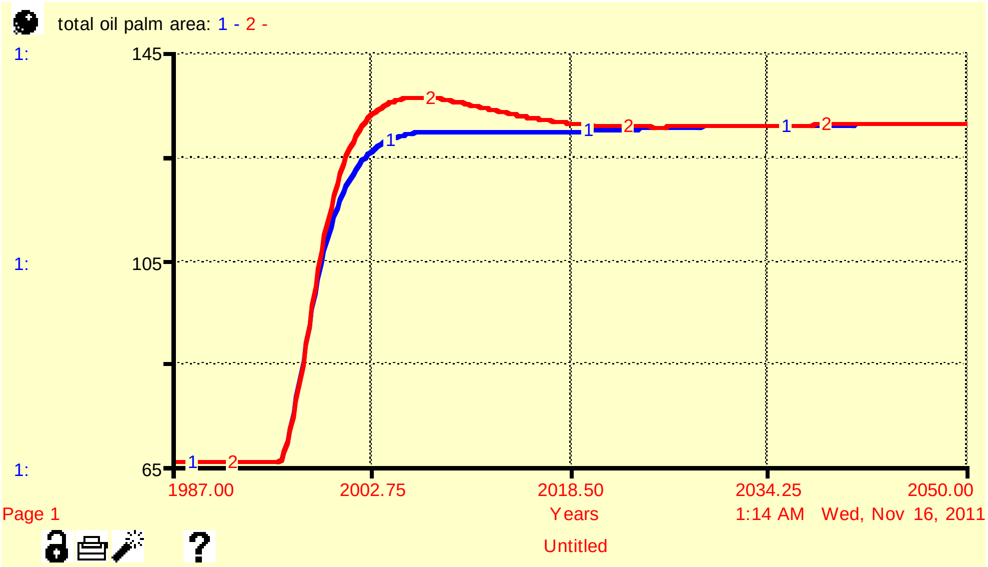

Figure 36: Average FFB yield. (1) before (2) after the using new policy

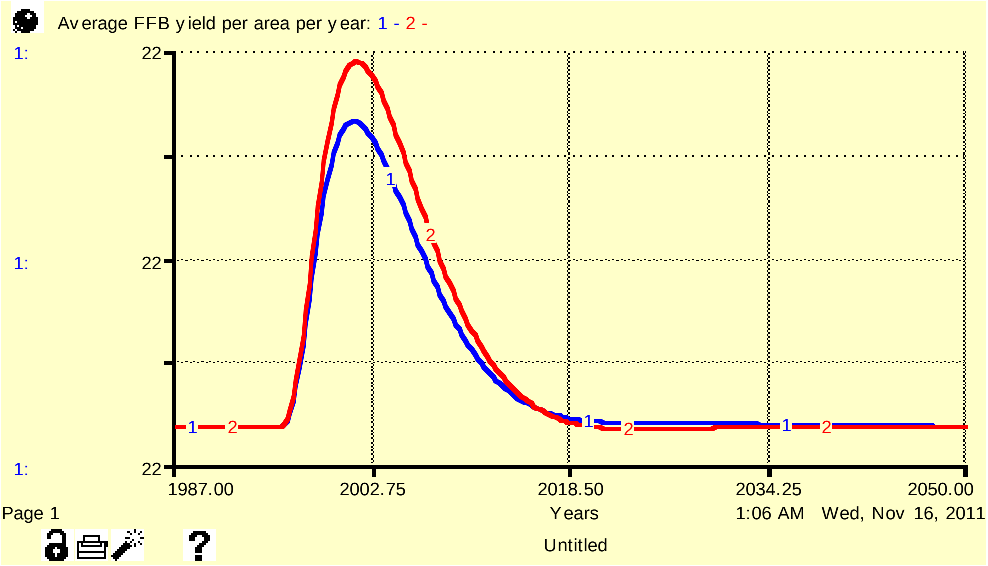

Figure 37: Average FFB yield. (1) before (2) after the using new policy

Policy Option 2

Improvement of oil extraction rate do not need any public funding. This can be done through private investment(Economic Transformation Programme, 295 [10]). Oil extraction improvement takes time. The advancement time is an adjustment time, In estimation, the investment of raising oil extraction rate from 0.2 to 0.23. Advancement time is the parameter which we would like to change

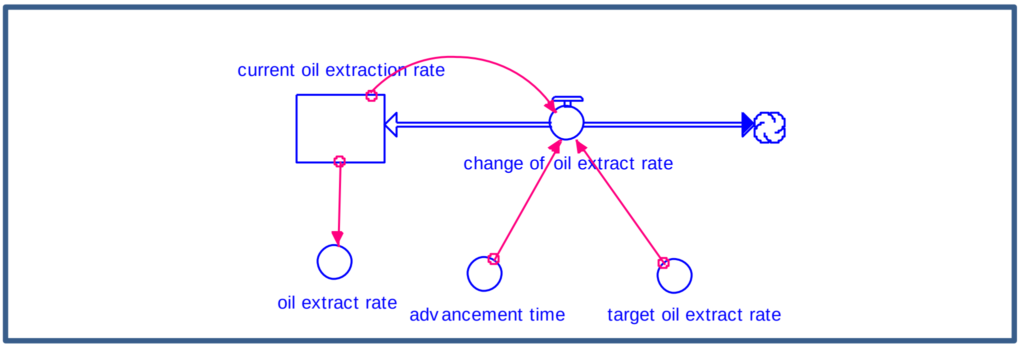

Figure 38: Oil extraction rate

Policy Option 2 testing

The policy was tested in two ways: 1) equilibrium test 2) scenario testing. In equilibrium tests, we compared the behavior of the model before and after adding new structure.

After adding the structure to the model, as expected the production efficiency improve as the simulation runs (Figure 39). The initial fall and spike was observed. Initial fall was due to sudden increment of oil palm extraction rate, which suddenly push high the production rate. The production rate feedback to the system caused decreasing of planting rate. Decreasing of planting rate decreased oil palm stock and therefore reduced FFB yield per year. Little FFB yield per year decreased the production rate. When the production fell the production efficiency fell as well. The spike was mainly caused by the export shock.

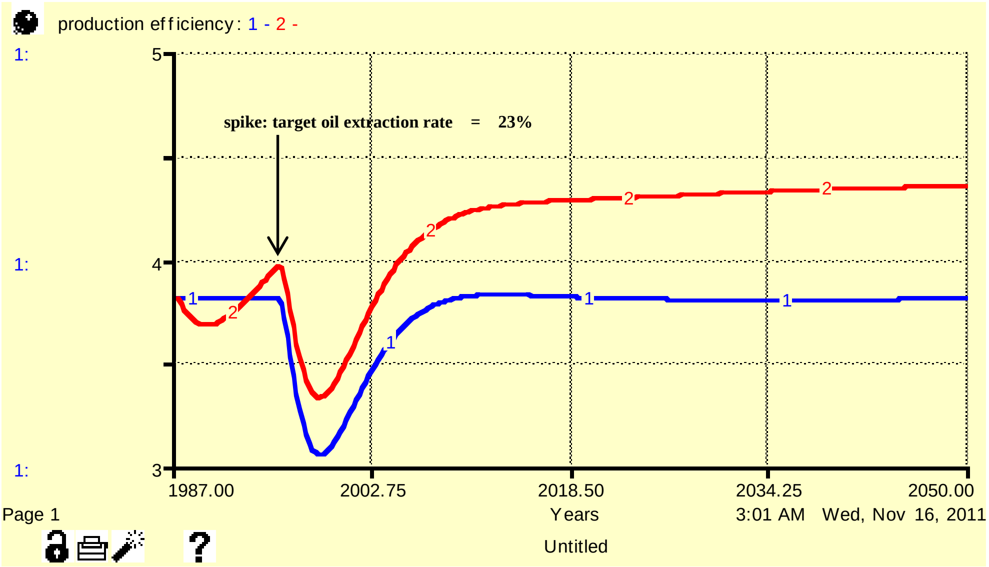

Figure 39: Production efficiency. (1) before (2) after the using new policy

Scenario testing for policies option 1 and 2

We first run without any policy. Then we run only policy 1. Next we run only policy 2. Lastly we run the policy 1 and policy 2 together.

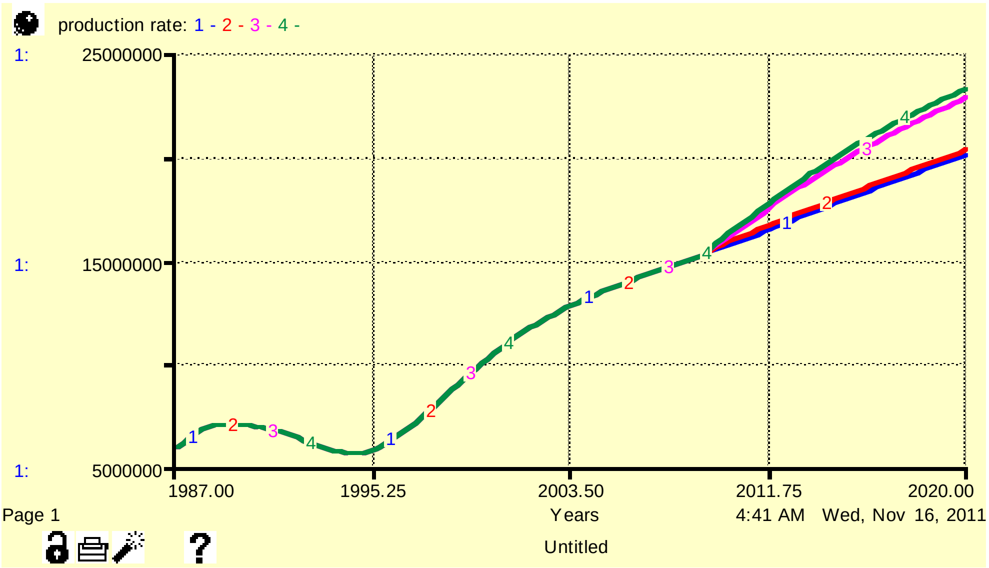

Figure 40: : Production rate. (1) without policy (2) with policy 1 (3) with policy 2 and (4) policy 1 and 2

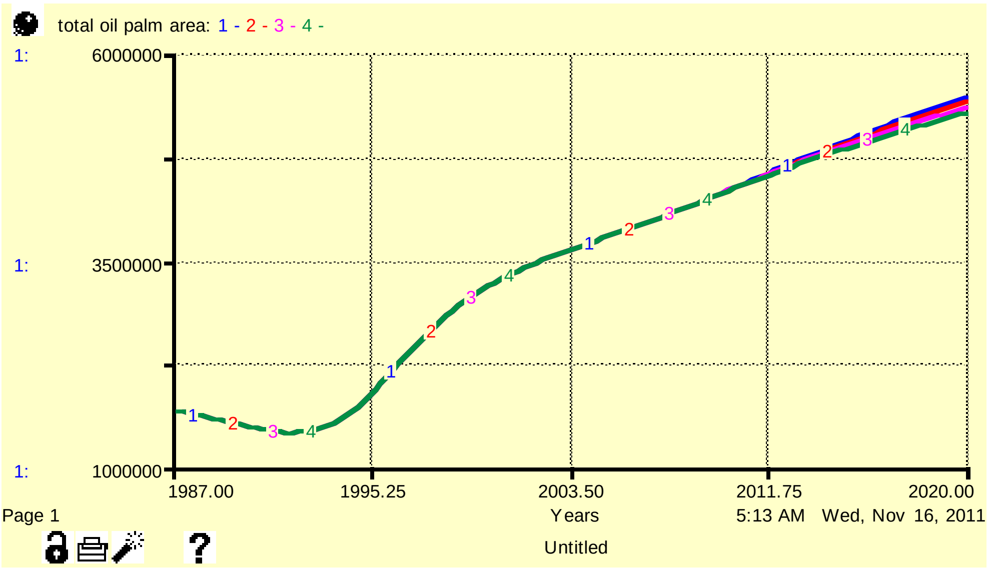

Figure 41: total oil palm area. (1) without policy (2) with policy 1 (3) with policy 2 and (4) policy 1 and 2

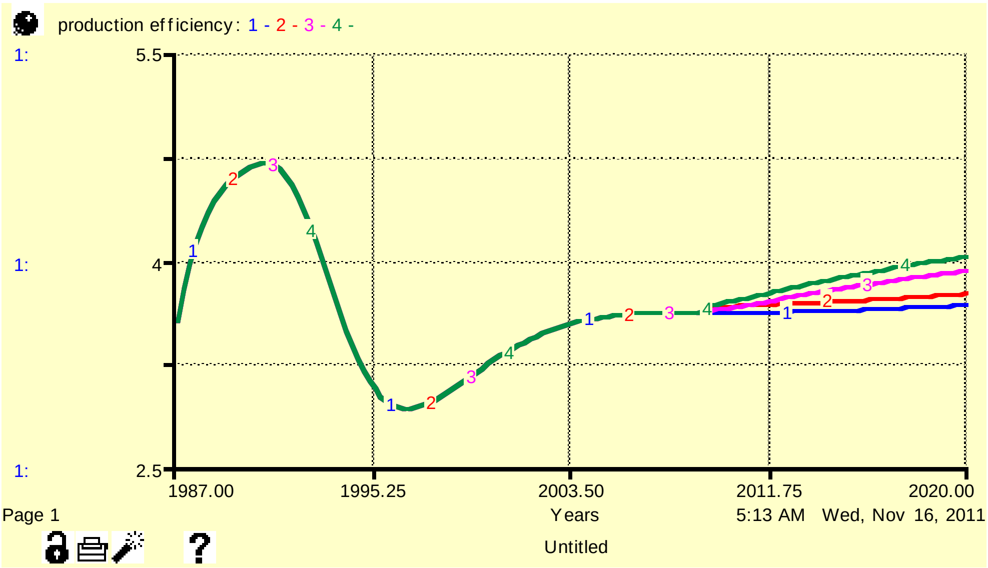

Figure 42: Production efficiency. (1) without policy (2) with policy 1 (3) with policy 2 and (4) policy 1 and 2

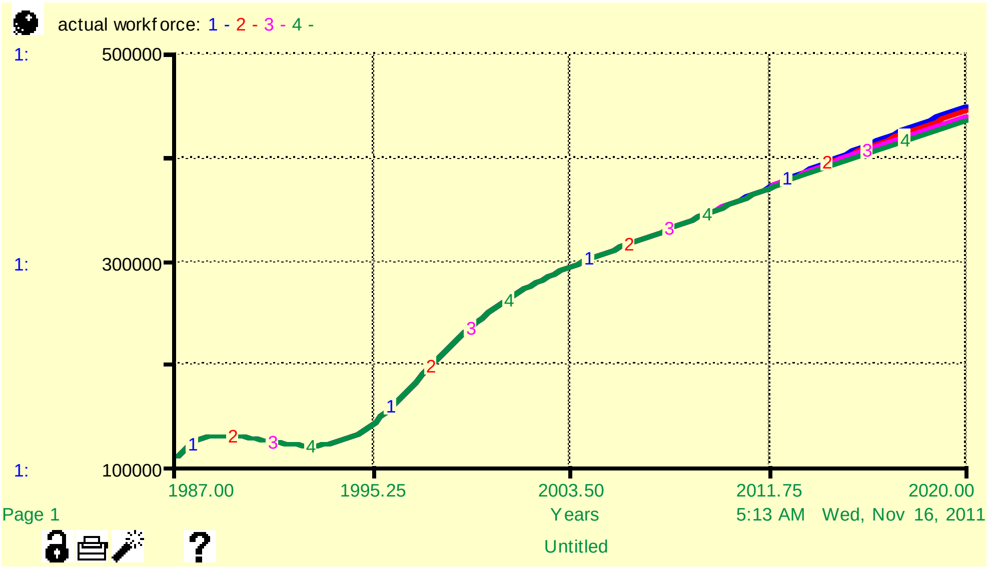

Figure 43: : Actual workforce. (1) without policy (2) with policy 1 (3) with policy 2 and (4) policy 1 and 2

Through observation (Figure 40, 41, 42, 43) from the difference policy, we were able to analyze and the behavior outcome.

Using Policy 1 separately we able the production indeed increase as expected. We found that increasing of oil extraction rate doesn't have help to reduce the number of labor workforce (Figure 43). Even the productivity has been increased, but the total oil palm area kept increasing. With the policies 1 and 2 combine, we can obtain a higher production rate as well as production efficiency.

CONCLUSION

From our research, through the modeling process, we have learned the leverage point of that responsible to the slow improvement of production efficiency. To resolve the problem we have developed 2 policies, to improve the production efficiency, through increasing fresh fruit branch yield in high yield area and oil extraction rate.

Fresh fruit branch yield in high yield area and extraction rate both play an important role on increasing production rate. The delays of oil palm tree clear cut time amazingly have weak relationship to production efficiency.

The workforce is not sensitive to the change of production efficiency. Mature rate, high yield FFB yield per high yield area per year and oil extraction rate are sensitive to production efficiency.

In term of supply and demand balance in oil palm system, actual workforce, which represents the number of worker was not to be blame of low production efficiency. As long as the plantation owner do not have willingness to switch from manual labor workforce to mechanical method, the manual labor still remain the same situation.

APPENDIX 1

Equations

actual_mini_tractor_grabber(t) = actual_mini_tractor_grabber(t - dt) + (grabber_buying_rate - grabber_depreciation_rate) * dt

INIT actual_mini_tractor_grabber = initial_mini_tractor_grabber

INFLOWS:

grabber_buying_rate = (grabber_depreciation_rate*grabber_adjustment_time + gap_of_mini_tractor_grabber)/grabber_adjustment_time

OUTFLOWS:

grabber_depreciation_rate = actual_mini_tractor_grabber/grabber_life_time

actual_workforce(t) = actual_workforce(t - dt) + (hire_rate - leaving_rate) * dt

INIT actual_workforce = initial_actual_estate_worker

INFLOWS:

hire_rate = ((gap_of_workforce)/hire_time) + leaving_rate

OUTFLOWS:

leaving_rate = actual_workforce/tenure_ends_time

decided_oil_extraction_rate(t) = decided_oil_extraction_rate(t - dt) + (change_of_oil_extract_rate) * dt

INIT decided_oil_extraction_rate = initial_oil_extraction_rate

INFLOWS:

change_of_oil_extract_rate = (target_oil_extract_rate-decided_oil_extraction_rate) /advancement_time

desired_domestic_consumption_rate(t) = desired_domestic_consumption_rate(t - dt) + (changing_of_domestic_consumption_rate) * dt

INIT desired_domestic_consumption_rate = domestic_demand_rate

INFLOWS:

changing_of_domestic_consumption_rate = MAX (0, ((domestic_demand_rate) - desired_domestic_consumption_rate)/adjustment_time_of__domestic_consumption_rate)

desired_export_rate(t) = desired_export_rate(t - dt) + (change_of_export_rate) * dt

INIT desired_export_rate = export_demand_rate

INFLOWS:

change_of_export_rate = (export_demand_rate - desired_export_rate)/adjustment_time_of_desired_export_rate

deteriorated_mature_oil_palm_area(t) = deteriorated_mature_oil_palm_area(t - dt) + (deterioration_rate - clear_cut_rate) * dt

INIT deteriorated_mature_oil_palm_area = initial_deteriorated_oil_palm_tree

INFLOWS:

deterioration_rate = high_yield_mature_oil_palm_area/deterorated_time

OUTFLOWS:

```
clear_cut_rate = deteriorated_mature_oil_palm_area/(clear_cut_delay )
domestic_stock(t) = domestic_stock(t - dt) + (production_rate - export_rate - domestic_consumption_rate) * dt
INIT domestic_stock = psychological_stock_level
INFLOWS:
production_rate = total_FFB_per_year*oil_extract_rate
OUTFLOWS:
export_rate = (desired_export_rate    - adjustment_of_psycholigical_and_domestic_stock_level -
perceived_palm_oil_production_gap)
domestic_consumption_rate = (desired_domestic_consumption_rate)
high_yield_mature_oil_palm_area(t) = high_yield_mature_oil_palm_area(t - dt) + (mature_rate - deterioration_rate)
* dt
INIT high_yield_mature_oil_palm_area = initial_high_yield_oil_palm_tree
INFLOWS:
mature_rate = Immature_oil_palm_area/(mature_time)
OUTFLOWS:
deterioration_rate = high_yield_mature_oil_palm_area/deterorated_time
Immature_oil_palm_area(t) = Immature_oil_palm_area(t - dt) + (planting_rate - mature_rate) * dt
INIT Immature_oil_palm_area = initial_immature_oil_palm_tree
INFLOWS:
planting_rate = MAX (0, (desired_replant_rate + new_planting_rate)) *
density_of_agricultural_land_for_oil_palm_tree
OUTFLOWS:
mature_rate = Immature_oil_palm_area/(mature_time)
initial_base_real_price(t) = initial_base_real_price(t - dt)
INIT initial_base_real_price = historical_domestic_real_price
initial_max_total_potential_land_for_oil_palm(t) = initial_max_total_potential_land_for_oil_palm(t - dt)
INIT initial_max_total_potential_land_for_oil_palm =
initial_deteriorated_oil_palm_tree+initial_high_yield_oil_palm_tree+initial_immature_oil_palm_tree
Noname_19(t) = Noname_19(t - dt)
INIT Noname_19 = IF (l=1) THEN
desired_workforce * worker_dependency
ELSE
historical_worker_in_plantation
perceived_production_rate(t) = perceived_production_rate(t - dt) + (changing_of_production_rate) * dt
INIT perceived_production_rate = production_rate
INFLOWS:
changing_of_production_rate = (production_rate - perceived_production_rate)/adjustment_time_of_production_rate
shock_test_immature_oil_palm_tree(t) = shock_test_immature_oil_palm_tree(t - dt) + (shock_test_new_plant_rate -
```

```
shock_test_new_plant_exit_rate) * dt
INIT shock_test_immature_oil_palm_tree = 0
INFLOWS:
shock_test_new_plant_rate = if (time>=shocktestyear) then
        if (is_cut_R2>0) then
                new_planting_rate * density_of_agricultural_land_for_oil_palm_tree
        ELSE
              0
ELSE
0
OUTFLOWS:
shock_test_new_plant_exit_rate = shock_test_immature_oil_palm_tree/mature_time
adjustment_of_psycholigical_and_domestic_stock_level = (psychological_stock_level -
domestic_stock)/correction_adjustment_time
adjustment_time_of_desired_export_rate = 1
adjustment_time_of_production_rate = 1
adjustment_time_of__domestic_consumption_rate = 1
advancement_time = 20
agriculture_land_bank = IF (i=0) then
        MAX (initial_max_total_potential_land_for_oil_palm,6600000 )
else
        Round (initial_max_total_potential_land_for_oil_palm * 100)/100
agriculture_land_increment = 100
annually_salary_for_estate_worker = 1000 * 12
Average_FFB_yield_per_area_per_year = (FFB_from_high_yield_area_per_year    +
FFB_from_deteriorated_area_per_year)

/ (
          (FFB_from_high_yield_area_per_year/FFB_yield_per_high_yield__area_per_year)
          +
        (FFB_from_deteriorated_area_per_year/FFB_yield_per_deteriorated_area_per_year)
)
average_FFB_yield_per_year =
(FFB_yield_per_deteriorated_area_per_year+FFB_yield_per_high_yield__area_per_year)/2
average_oil_palm_area_per_mini_tractor_grabber = 25
average_oil_palm_area__per_worker = 12
base_real_price = initial_base_real_price
clear_cut_delay = 5
```

```
correction_adjustment_time = 1
cost_of_production_per_unit_FFB = 5200
density_of_agricultural_land_for_oil_palm_tree = (1-
(total_oil_palm_area/(agriculture_land_bank+agriculture_land_increment)))
desired_mini_tractor_grabber = workforce_replacement*efficiency_of_grabber_to_worker
desired_oil_palm_tree = IF (production_efficiency =0) THEN
0
ELSE
        perceived_palm_oil_production_gap/production_efficiency
desired_replant_rate =     IF (density_of_agricultural_land_for_oil_palm_tree=0) THEN
        clear_cut_rate/1
    ELSE
        clear_cut_rate/density_of_agricultural_land_for_oil_palm_tree

desired_total_consumption_rate = desired_domestic_consumption_rate+desired_export_rate
desired_workforce = total_oil_palm_area/average_oil_palm_area__per_worker
deteriorated_palm_tree = FFB_yield_from_deteriorated/FFB_yield_per_deteriorated_area_per_year
deterorated_time = 17
domestic_demand_rate = IF (i = 0) THEN
 + (110000 * (TIME-STARTTIME) +   70000)

ELSE IF (j=1) THEN
              v1 + STEP (v1 * percent_of_domestic_shock/100,shocktestyear)
         ELSE
              v1
efficiency_of_grabber_to_worker =
average_oil_palm_area__per_worker/average_oil_palm_area_per_mini_tractor_grabber
export_demand_rate = IF (i = 0) THEN
  (540000* (TIME-STARTTIME) +   5500000 - 1000000 - 300000)

ELSE IF (j=1) THEN
              v2 + STEP (v2 * percent_of_export_shock/100,shocktestyear)
         ELSE
              v2
FFB_from_deteriorated_area_per_year =
deteriorated_mature_oil_palm_area*FFB_yield_per_deteriorated_area_per_year
FFB_from_high_yield_area_per_year =
high_yield_mature_oil_palm_area*FFB_yield_per_high_yield__area_per_year
```

```
FFB_yield_from_deteriorated = initial_total_FFB_yield - FFB_yield_from_high_yield
FFB_yield_from_high_yield =
initial_total_FFB_yield*(ratio_of_FFB_rate_in_High_yield_and_FFB_rate_indeteriorated/(1+ratio_of_FFB_rate_in_
High_yield_and_FFB_rate_indeteriorated))
FFB_yield_per_deteriorated_area_per_year = 17
FFB_yield_per_high_yield__area_per_year = 23
gap_of_mini_tractor_grabber = desired_mini_tractor_grabber - actual_mini_tractor_grabber
gap_of_workforce = if (time<shocktestyear) then
(	(desired_workforce ) - (actual_workforce / worker_dependency ))
else
(	(desired_workforce ) - (actual_workforce / worker_dependency ))
grabber_adjustment_time = 1
grabber_life_time = 5
high_yield_palm_tree = FFB_yield_from_high_yield/FFB_yield_per_high_yield__area_per_year
hire_time = 1
i = IF (Is_equilibrium_test =1 OR Is_shock_test = 1) THEN
1
ELSE
0
immature_tree = high_yield_palm_tree/deterorated_time*mature_time
initial_actual_estate_worker = Noname_19
initial_average_real_price = 764.28
initial_deteriorated_oil_palm_tree = IF (l=1) THEN
deteriorated_palm_tree
ELSE
historical_mature_palm_oil_tree * share_of_deteriorated
initial_high_yield_oil_palm_tree = IF (l=1) THEN
high_yield_palm_tree
ELSE
historical_mature_palm_oil_tree *share_of_high_yield
initial_immature_oil_palm_tree = IF (l=1) THEN
immature_tree
ELSE
historical_immature_oil_palm_tree
initial_mini_tractor_grabber = max (0,desired_mini_tractor_grabber)
initial_oil_extraction_rate = IF (i >= 1) THEN
	target_oil_extract_rate
```

```
ELSE
    0.15
initial_stock_switch = 0
initial_total_consumption_rate = domestic_demand_rate+export_demand_rate
initial_total_FFB_yield =       initial_total_consumption_rate / (target_oil_extract_rate)
is_cut_R2 = 0
Is_equilibrium_test = 0
Is_shock_test = 0
j = Is_shock_test
l = IF (i=1) THEN
1
ELSE
initial_stock_switch
land_acquire_delay = 2.5
mature_time = 3
minimum_supply_of_stock_in_year = 18/365
new_planting_rate = desired_oil_palm_tree/land_acquire_delay
Noname_9 = initial_total_FFB_yield * 0.2
oil_extract_rate = if (time >=2009) then
    decided_oil_extraction_rate
else
decided_oil_extraction_rate   - decided_oil_extraction_rate   + 0.2
palm_oil_production_cost = 50
perceived_palm_oil_production_gap = (desired_total_consumption_rate   - perceived_production_rate)
percent_of_domestic_shock = 100
percent_of_export_shock = 100
production_efficiency =       IF (total_oil_palm_area=0) THEN
        production_rate/total_oil_palm_area
    ELSE
        production_rate/total_oil_palm_area
production_efficiency_forecast = if (time >2009) then
historical_production_efficiency_2
else
historical_production_efficiency
production_rate_forecast = if (time >2009) then
historical_production_rate_2
else
historical_production_rate
```

```
psychological_stock_level = IF (i = 1) THEN
(perceived_production_rate)    * minimum_supply_of_stock_in_year
ELSE IF (STARTTIME = TIME) THEN
historical_domestic_stock
ELSE
(perceived_production_rate)    * minimum_supply_of_stock_in_year
ratio_of_actual_and_desired_workforce = if (time<shocktestyear) then
    IF (desired_workforce = 0) THEN
        0
     ELSE
        (actual_workforce + workforce_from_grabber) /desired_workforce
else
    IF (desired_workforce = 0) THEN
        0
     ELSE
        (actual_workforce + workforce_from_grabber) /desired_workforce
ratio_of_deteriorated_and_clear_cut = deterorated_time/clear_cut_delay
ratio_of_FFB_rate_in_High_yield_and_FFB_rate_indeteriorated =
ratio_of_deteriorated_and_clear_cut*ratio_of_FFB_yield_in_high_yield_and__FFB_yield_in_deteriorated
ratio_of_FFB_yield_in_high_yield_and__FFB_yield_in_deteriorated =
FFB_yield_per_high_yield__area_per_year/FFB_yield_per_deteriorated_area_per_year
refinary_cost = palm_oil_production_cost * total_FFB_per_year * oil_extract_rate
share_of_deteriorated = 1- share_of_high_yield
share_of_high_yield = deterorated_time/(clear_cut_delay + deterorated_time)
shocktestyear = 1995
target_oil_extract_rate = IF (i >= 1) THEN
    0.2
ELSE
    0.23
tenure_ends_time = 5
total_cost = (total_FFB_production_cost + refinary_cost-refinary_cost)
total_FFB_per_year =    (FFB_from_deteriorated_area_per_year+FFB_from_high_yield_area_per_year) *
ratio_of_actual_and_desired_workforce
total_FFB_production_cost = cost_of_production_per_unit_FFB*total_FFB_per_year
total_mature_oil_palm_tree_area = high_yield_mature_oil_palm_area + deteriorated_mature_oil_palm_area
total_oil_palm_area =
Immature_oil_palm_area    + total_mature_oil_palm_tree_area
total_oil_plam_area_and_forecast = if (time >2009) then
```

```
historical_total_oil_palm_area_2
else
historical_total_oil_palm_area
total_worker_cost = actual_workforce*annually_salary_for_estate_worker
v1 = 500
v2 = 500
worker_cost_and_total_cost = IF (total_worker_cost = 0) THEN
0
ELSE
total_cost/total_worker_cost
worker_dependency = 1
worker_forecast = if (time >2009) then
historical_worker_in_plantation_2
else
historical_worker_in_plantation
workforce_from_grabber = actual_mini_tractor_grabber /efficiency_of_grabber_to_worker
workforce_replacement = if (time<shocktestyear) then
    Max (0, (desired_workforce - actual_workforce)    )
else
    Max (0, (desired_workforce - actual_workforce)    )
historical_agriculture_land = GRAPH(TIME)
(1961, 4.2e+006), (1962, 4.3e+006), (1963, 4.3e+006), (1964, 4.4e+006), (1965, 4.4e+006), (1966, 4.5e+006), (1967,
4.5e+006), (1968, 4.6e+006), (1969, 4.6e+006), (1970, 4.7e+006), (1971, 4.7e+006), (1972, 4.8e+006), (1973,
4.8e+006), (1974, 4.9e+006), (1975, 4.9e+006), (1976, 5e+006), (1977, 5e+006), (1978, 5e+006), (1979, 5e+006),
(1980, 5.1e+006), (1981, 5.1e+006), (1982, 5.3e+006), (1983, 5.5e+006), (1984, 5.7e+006), (1985, 6e+006), (1986,
6.2e+006), (1987, 6.4e+006), (1988, 6.7e+006), (1989, 7e+006), (1990, 7.2e+006), (1991, 7.5e+006), (1992,
7.7e+006), (1993, 7.9e+006), (1994, 7.9e+006), (1995, 7.9e+006), (1996, 7.9e+006), (1997, 7.9e+006), (1998,
7.9e+006), (1999, 7.9e+006), (2000, 7.9e+006), (2001, 7.9e+006), (2002, 7.9e+006), (2003, 7.9e+006), (2004,
7.9e+006), (2005, 7.9e+006), (2006, 7.9e+006), (2007, 7.9e+006), (2008, 7.9e+006), (2009, 7.9e+006)
historical_domestic_consumption_rate = GRAPH(TIME)
(1980, 241951), (1981, 456616), (1982, 638867), (1983, 145000), (1984, 148879), (1985, 1e+006), (1986, 69812),
(1987, 118215), (1988, 542617), (1989, 1.2e+006), (1990, 414856), (1991, 984933), (1992, 463167), (1993,
1.9e+006), (1994, 565223), (1995, 1.4e+006), (1996, 1e+006), (1997, 1.7e+006), (1998, 568861), (1999, 1.6e+006),
(2000, 2e+006), (2001, 1.4e+006), (2002, 1.4e+006), (2003, 1.2e+006), (2004, 1.9e+006), (2005, 2.1e+006), (2006,
1.8e+006), (2007, 2e+006), (2008, 2.5e+006), (2009, 2.4e+006)
historical_domestic_Interest_rate_in_pecentage = GRAPH(TIME)
(1980, 8.50), (1981, 8.50), (1982, 8.50), (1983, 10.8), (1984, 12.2), (1985, 10.8), (1986, 10.0), (1987, 7.50), (1988,
7.50), (1989, 7.00), (1990, 6.99), (1991, 7.49), (1992, 8.68), (1993, 9.29), (1994, 8.22), (1995, 6.83), (1996, 8.03),
```

(1997, 9.18), (1998, 9.53), (1999, 10.6), (2000, 6.79), (2001, 6.79), (2002, 6.40), (2003, 6.40), (2004, 6.00), (2005, 6.25), (2006, 6.75), (2007, 6.75), (2008, 6.50), (2009, 5.55), (2010, 6.30), (2011, 6.30), (2012, 6.30), (2013, 6.30), (2014, 6.30), (2015, 6.30), (2016, 6.30), (2017, 6.30), (2018, 6.30), (2019, 6.30), (2020, 6.30), (2021, 6.30), (2022, 6.30), (2023, 6.30), (2024, 6.30), (2025, 6.30), (2026, 6.30), (2027, 6.30), (2028, 6.30), (2029, 6.30), (2030, 6.30), (2031, 6.30), (2032, 6.30), (2033, 6.30), (2034, 6.30), (2035, 6.30), (2036, 6.30), (2037, 6.30), (2038, 6.30), (2039, 6.30), (2040, 6.30), (2041, 6.30), (2042, 6.30), (2043, 6.30), (2044, 6.30), (2045, 6.30), (2046, 6.30), (2047, 6.30), (2048, 6.30), (2049, 6.30), (2050, 6.30)

historical_domestic_price = GRAPH(TIME)

(1980, 919), (1981, 964), (1982, 829), (1983, 991), (1984, 1408), (1985, 1046), (1986, 579), (1987, 773), (1988, 1029), (1989, 822), (1990, 701), (1991, 837), (1992, 917), (1993, 890), (1994, 1284), (1995, 1473), (1996, 1192), (1997, 1358), (1998, 2378), (1999, 1450), (2000, 997), (2001, 895), (2002, 1364), (2003, 1544), (2004, 1610), (2005, 1394), (2006, 1511), (2007, 2531), (2008, 2778), (2009, 2245)

historical_domestic_real_price = GRAPH(TIME)

(1980, 919), (1981, 879), (1982, 714), (1983, 823), (1984, 1125), (1985, 815), (1986, 449), (1987, 596), (1988, 791), (1989, 616), (1990, 509), (1991, 583), (1992, 610), (1993, 572), (1994, 795), (1995, 882), (1996, 690), (1997, 766), (1998, 1273), (1999, 756), (2000, 511), (2001, 453), (2002, 678), (2003, 759), (2004, 781), (2005, 656), (2006, 686), (2007, 1127), (2008, 1173), (2009, 942)

historical_domestic_stock = GRAPH(TIME)

(1985, 342622), (1986, 342622), (1987, 278947), (1988, 575160), (1989, 765261), (1990, 424365), (1991, 456384), (1992, 341795), (1993, 777941), (1994, 430024), (1995, 496497), (1996, 435414), (1997, 549549), (1998, 373733), (1999, 717573), (2000, 905162), (2001, 734364), (2002, 589035), (2003, 594080), (2004, 890781), (2005, 892838), (2006, 878551), (2007, 926979), (2008, 1.2e+006), (2009, 1.2e+006)

historical_harvasted_area = GRAPH(TIME)

(1975, 258204), (1976, 292093), (1977, 325210), (1978, 366293), (1979, 403898), (1980, 433146), (1981, 466280), (1982, 505888), (1983, 545242), (1984, 592607), (1985, 626191), (1986, 671397), (1987, 1.2e+006), (1988, 1.4e+006), (1989, 1.5e+006), (1990, 1.6e+006), (1991, 1.6e+006), (1992, 1.7e+006), (1993, 1.8e+006), (1994, 1.9e+006), (1995, 2e+006), (1996, 2.1e+006), (1997, 2.3e+006), (1998, 2.3e+006), (1999, 2.6e+006), (2000, 2.6e+006), (2001, 2.7e+006), (2002, 2.8e+006), (2003, 2.9e+006), (2004, 3.1e+006), (2005, 3.2e+006), (2006, 3.3e+006), (2007, 3.8e+006), (2008, 3.9e+006), (2009, 3.9e+006)

historical_harvested_FFB = GRAPH(TIME)

(1975, 4.9e+006), (1976, 5e+006), (1977, 5.7e+006), (1978, 5.9e+006), (1979, 7.1e+006), (1980, 7.6e+006), (1981, 8.3e+006), (1982, 1e+007), (1983, 8.7e+006), (1984, 1.1e+007), (1985, 1.2e+007), (1986, 1.3e+007), (1987, 2.2e+007), (1988, 2.5e+007), (1989, 2.9e+007), (1990, 2.9e+007), (1991, 2.9e+007), (1992, 3e+007), (1993, 3.7e+007), (1994, 3.5e+007), (1995, 3.8e+007), (1996, 4e+007), (1997, 4.3e+007), (1998, 3.7e+007), (1999, 5e+007), (2000, 4.8e+007), (2001, 5.1e+007), (2002, 5.1e+007), (2003, 5.5e+007), (2004, 5.7e+007), (2005, 6.1e+007), (2006, 6.4e+007), (2007, 7.9e+007), (2008, 8.8e+007), (2009, 9e+007)

historical_immature_oil_palm_tree = GRAPH(TIME)

(1975, 256125), (1976, 260591), (1977, 260328), (1978, 249892), (1979, 268564), (1980, 245918), (1981, 259720), (1982, 294178), (1983, 242161), (1984, 257815), (1985, 281389), (1986, 238732), (1987, 299728), (1988, 275017), (1989, 274463), (1990, 283410), (1991, 267761), (1992, 307392), (1993, 285409), (1994, 267919), (1995, 297022), (1996, 339139), (1997, 379906), (1998, 481170), (1999, 456692), (2000, 434873), (2001, 493745), (2002, 481936), (2003, 498907), (2004, 424367), (2005, 419934), (2006, 461961), (2007, 540524), (2008, 572033), (2009, 615458)

historical_mature_palm_oil_tree = GRAPH(TIME)

(1975, 385666), (1976, 454009), (1977, 521486), (1978, 603087), (1979, 670299), (1980, 777388), (1981, 848143), (1982, 888619), (1983, 1e+006), (1984, 1.1e+006), (1985, 1.2e+006), (1986, 1.4e+006), (1987, 1.4e+006), (1988, 1.5e+006), (1989, 1.7e+006), (1990, 1.7e+006), (1991, 1.8e+006), (1992, 1.9e+006), (1993, 2e+006), (1994, 2.1e+006), (1995, 2.2e+006), (1996, 2.4e+006), (1997, 2.5e+006), (1998, 2.6e+006), (1999, 2.9e+006), (2000, 2.9e+006), (2001, 3e+006), (2002, 3.2e+006), (2003, 3.3e+006), (2004, 3.5e+006), (2005, 3.6e+006), (2006, 3.7e+006), (2007, 3.8e+006), (2008, 3.9e+006), (2009, 4.1e+006)

historical_palm_oil_export_rate = GRAPH(TIME)

(1975, 1.2e+006), (1976, 1.3e+006), (1977, 1.4e+006), (1978, 1.5e+006), (1979, 1.9e+006), (1980, 2.3e+006), (1981, 2.5e+006), (1982, 2.9e+006), (1983, 2.6e+006), (1984, 3.2e+006), (1985, 3.4e+006), (1986, 4.6e+006), (1987, 4.2e+006), (1988, 4.3e+006), (1989, 5.2e+006), (1990, 5.7e+006), (1991, 5.6e+006), (1992, 5.6e+006), (1993, 6.1e+006), (1994, 6.8e+006), (1995, 6.5e+006), (1996, 7.2e+006), (1997, 7.5e+006), (1998, 7.5e+006), (1999, 8.9e+006), (2000, 9.1e+006), (2001, 1.1e+007), (2002, 1.1e+007), (2003, 1.2e+007), (2004, 1.3e+007), (2005, 1.3e+007), (2006, 1.4e+007), (2007, 1.4e+007), (2008, 1.5e+007), (2009, 1.6e+007)

historical_production_efficiency = GRAPH(TIME)

(1975, 1.96), (1976, 1.95), (1977, 2.06), (1978, 2.09), (1979, 2.33), (1980, 2.51), (1981, 2.55), (1982, 2.97), (1983, 2.41), (1984, 2.79), (1985, 2.79), (1986, 2.84), (1987, 2.71), (1988, 2.78), (1989, 3.11), (1990, 3.00), (1991, 2.93), (1992, 2.90), (1993, 3.21), (1994, 2.99), (1995, 3.07), (1996, 3.11), (1997, 3.13), (1998, 2.70), (1999, 3.19), (2000, 3.21), (2001, 3.37), (2002, 3.24), (2003, 3.51), (2004, 3.61), (2005, 3.69), (2006, 3.81), (2007, 3.68), (2008, 3.95), (2009, 3.74)

historical_production_efficiency_2 = GRAPH(TIME)

(2009, 3.74), (2010, 4.10), (2011, 4.30), (2013, 4.40), (2014, 4.47), (2015, 4.53), (2016, 4.58), (2018, 4.58), (2019, 4.60), (2020, 4.58)

historical_production_of_palm_oil_per_hectare = GRAPH(TIME)

(1975, 4.87), (1976, 4.77), (1977, 4.96), (1978, 4.87), (1979, 5.42), (1980, 5.94), (1981, 6.05), (1982, 6.94), (1983, 5.53), (1984, 6.27), (1985, 6.60), (1986, 6.77), (1987, 3.67), (1988, 3.64), (1989, 4.05), (1990, 3.90), (1991, 3.75), (1992, 3.75), (1993, 4.09), (1994, 3.75), (1995, 3.90), (1996, 3.97), (1997, 4.00), (1998, 3.57), (1999, 4.11), (2000, 4.14), (2001, 4.43), (2002, 4.21), (2003, 4.58), (2004, 4.53), (2005, 4.66), (2006, 4.88), (2007, 4.20), (2008, 4.53), (2009, 4.53)

historical_production_rate = GRAPH(TIME)

(1975, 1.3e+006), (1976, 1.4e+006), (1977, 1.6e+006), (1978, 1.8e+006), (1979, 2.2e+006), (1980, 2.6e+006), (1981, 2.8e+006), (1982, 3.5e+006), (1983, 3e+006), (1984, 3.7e+006), (1985, 4.1e+006), (1986, 4.5e+006), (1987, 4.5e+006), (1988, 5e+006), (1989, 6.1e+006), (1990, 6.1e+006), (1991, 6.1e+006), (1992, 6.4e+006), (1993, 7.4e+006), (1994, 7.2e+006), (1995, 7.8e+006), (1996, 8.4e+006), (1997, 9.1e+006), (1998, 8.3e+006), (1999, 1.1e+007), (2000, 1.1e+007), (2001, 1.2e+007), (2002, 1.2e+007), (2003, 1.3e+007), (2004, 1.4e+007), (2005, 1.5e+007), (2006, 1.6e+007), (2007, 1.6e+007), (2008, 1.8e+007), (2009, 1.8e+007)

historical_production_rate_2 = GRAPH(TIME)

(2009, 1.8e+007), (2010, 2e+007), (2011, 2e+007), (2013, 2.2e+007), (2014, 2.2e+007), (2015, 2.3e+007), (2016, 2.4e+007), (2018, 2.5e+007), (2019, 2.6e+007), (2020, 2.6e+007)

historical_total_oil_palm_area = GRAPH(TIME)

(1975, 641791), (1976, 714600), (1977, 781814), (1978, 852979), (1979, 938863), (1980, 1e+006), (1981, 1.1e+006), (1982, 1.2e+006), (1983, 1.3e+006), (1984, 1.3e+006), (1985, 1.5e+006), (1986, 1.6e+006), (1987, 1.7e+006), (1988, 1.8e+006), (1989, 1.9e+006), (1990, 2e+006), (1991, 2.1e+006), (1992, 2.2e+006), (1993, 2.3e+006), (1994, 2.4e+006), (1995, 2.5e+006), (1996, 2.7e+006), (1997, 2.9e+006), (1998, 3.1e+006), (1999, 3.3e+006), (2000, 3.4e+006), (2001, 3.5e+006), (2002, 3.7e+006), (2003, 3.8e+006), (2004, 3.9e+006), (2005, 4.1e+006), (2006, 4.2e+006), (2007, 4.3e+006), (2008, 4.5e+006), (2009, 4.7e+006)

historical_total_oil_palm_area_2 = GRAPH(TIME)

(2009, 4.7e+006), (2010, 5.1e+006), (2011, 5.3e+006), (2012, 5.6e+006), (2013, 5.7e+006), (2014, 5.9e+006), (2016, 6.1e+006), (2017, 6.3e+006), (2018, 6.3e+006), (2019, 6.4e+006), (2020, 6.5e+006)

historical_worker_in_plantation = GRAPH(TIME)

(1975, 75975), (1976, 77459), (1977, 80947), (1978, 86634), (1979, 94990), (1980, 100963), (1981, 102373), (1982, 98106), (1983, 95237), (1984, 101493), (1985, 106539), (1986, 102976), (1987, 108470), (1988, 114681), (1989, 126498), (1990, 131842), (1991, 137140), (1992, 146369), (1993, 155295), (1994, 164808), (1995, 175427), (1996, 190183), (1997, 208646), (1998, 225100), (1999, 246088), (2000, 252549), (2001, 265182), (2002, 285444), (2003, 314658), (2004, 331648), (2005, 329709), (2006, 347755), (2007, 350000), (2008, 350000), (2009, 369000)

historical_worker_in_plantation_2 = GRAPH(TIME)

(2009, 369000), (2010, 382500), (2011, 395000), (2013, 410000), (2014, 430000), (2015, 442500), (2016, 467500), (2018, 472500), (2019, 487500), (2020, 500000)

Appendix 2. Full Stock and flow diagram

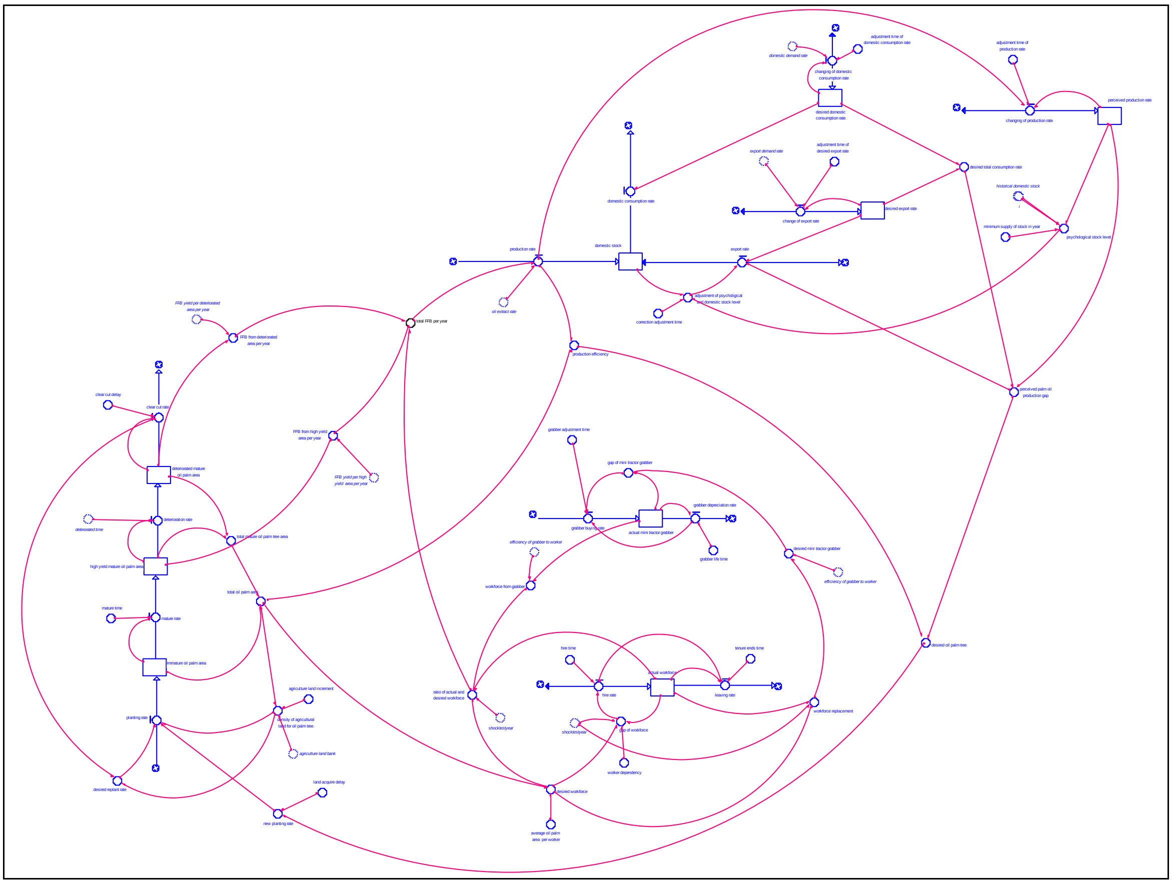

Figure 44: Full stock and flow diagram for oil palm

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