Analysis of Productivity Improvement in the Palm Oil Plantation Revitalization of North Sumatera using Analytic Network Process

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Abstract—The idea of making North Sumatera as a barometer of national palm oil industry requires commodity efforts and agro-industry development of palm oil. One effort that can be done is by successful execution plantation revitalization. The plantation Revitalization is an effort to accelerate the development of smallholder plantations, through expansion and replanting by help of palm estate company as business partner and bank financing plantation revitalization fund. Business partner agreement is obliged and bound to make at least the same smallholder estate productivity with business partners, so that the refund rate to banks become larger and prosperous people as a plantation owner. Generally, low productivity of smallholder plantations under normal potential caused a lot of old and damaged plants with plant material at random. The purpose of revitalizing palm oil plantations is to increase their competitiveness through increased farm productivity. The research aims at identifying potential criteria in influencing estate productivity improvement priorities to be observed and followed up in order to improve the competitiveness of destinations and make North Sumatera barometer of national palm oil can be achieved. Research conducted with Analytical Network Process (ANP), to find the effect of dependency relationships between factors or criteria with the knowledge of the experts in order to produce an objective opinion and relevant depict the actual situation. The results showed that the priority factors that have the biggest impact as a determinant of farm productivity enhancement, namely plant health (0.184595), the insertion of seeds (0.130569), the type of fertilizer (0.116755), the number and dose of fertilizer (0.102303), the suitability of the tool and the work material (0.072098), the type of soil (0.056612), the frequency of fertilizer (0.057095), working procedures (0.048561), weed control (0.041679), pest control (0.037839), fertilization technology (0.036218), and the fertilization of seeds (0.028203). Plant population per acre and crop homogeneity becomes a major factor that needs to be observed and followed up that effort to improve productivity to enhance competitiveness of North Sumatera and became a national barometer can be achieved

Keywords— Revitalization, palm barometer, acceleration of plantation development, productivity, palm estate companies

I. INTRODUCTION

The potential of natural resources in the region of North Sumatera Indonesia is very large with a spacious plantation reaches 15.2% of the Indonesian palm oil plantations, CPO exports amounted to 7.9% of the total Indonesian palm oil exports, and the composition of unproductive young plants are estimated araound 17.2% of the total national palm oil plantations. To support the idea of making North Sumatera as a barometer of the national palm oil [13], it is needed to strengthen the availability of CPO agroindustry raw materials by maximizing the potential through the expansion and rejuvenation of plantation crops (plantation revitalization) to support the development of palm oil agroindustry in North Sumatera.

Plantation Revitalization is an effort to accelerate the development of smallholder plantation through the expansion, renovation and rehabilitation of the plantation crops which are supported by the banking and investment credit and also interest subsidy by the government involving palm estate companies as partners in the development and processing and marketing of production. Development efforts of plantation commodities face various problems such as low crop productivity under normal potential, due to a lot of old and damaged plants with random plant materials. On the other hand, one of the program goals is to improve competitiveness through increased productivity and development of plantation-based downstream industries.

Low productivity and quality of palm oil plantations (estates) is a common problem of Indonesian palm oil estates.

The amount of production highly depends on the type of soil, seed varieties, climate and technology applied. When compared to government palm oil estates and private palm oil estates then the soil conditions are relatively the same, but the results were much different in production. In optimal circumstances, the productivity of palm oil can reach 20-25 tonnes FFB / ha / year, or about 4-5 tonnes of CPO North Sumatera condition nowadays is still around 3.8 tonnes of CPO / ha / year, while its potential is about 7 tons of CPO / ha / year. The problem is due to the undeveloped downstream palm oil industry, large CPO exports, low level of technology, management, and quality of human resources [11]. Today, CPO export has been decreased to 50% with the use of CPO for downstream industries to 50% [8].

The efforts to improve the productivity of palm oil estates can be done by using superior cultivation techniques, the actions of technical culture and environmental factors [19]. The management of environment to grow, especially the availability of water is relatively more difficult than technical culture techniques such as the use of superior plant materials, plant spacing, fertilization, pest and disease control and Treatment plant, so that environmental factors are a major limiting factor in the production of palm oil [19].

The potential for the development of palm oil in North Sumatera is supported by the resources available, so the idea to make North Sumatera as a barometer of national palm oil is not impossible to happen. One way to make it work is to implement the revitalization of palm oil estates. This revitalization includes the expansion and the rejuvenation of the estate with the aim of optimizing the productivity of estates. The efforts to optimize the productivity of palm oil estates in North Sumatera at this time can not only be directed at the expansion of the land, but the productivity per hectare crop yield. This is due to limited potential land for palm oil. The problem is how the efforts can be done to improve the productivity of palm oil estates from which it should be produced with the great potential owned by North Sumatera, so that the production targets which are to support the needs of the CPO agroindustry and to strengthen it can be fulfilled in accordance with the greater market demand in the future.

II. PROBLEM STATEMENT

The problem occur from the effort of revitalizing North Sumatera as the first region of North Sumatera in Indonesia, which produces palm oil so famous as the granary of the national palm oil. Currently, North Sumatera is targeted to be a barometer of the national palm oil [7]. This is supported by the palm oil estate revitalization program that targets the improvement of the national palm oil productivity and qualified products in order to achieve the production targets in an effort to develop downstream industries and increase the added value. The problem faced in doing the revitalization palm oil estates is a FFB balance or continuity produced in estates to meet the abroad and domestic demands especially the needs of CPO agro-industry and downstream industry in North Sumatera.

III. RESEARCH OBJECTIVES

This study aims at identifying the potential criteria that influence the determinant factors in the improvement of estate productivities which are prioritized to be observed and followed up in order that the goal of increasing competitiveness and making North Sumatera as the barometer of national palm oil can be achieved.

IV. METHODOLOGY

A. Framework

Analytic Network Process (ANP) uses a network without having to set the level of the hierarchy as used in the Analytic Hierarchy Process (AHP). The main concept in the ANP is influence while the key concept in AHP is preference. ANP provides a general framework in treating decisions without making assumptions about the independence of the elements at a higher level than the elements at a lower level and on the independence of the elements in a level [21]. Network spread in all directions and allows the influence of a cluster to another cluster and the cluster itself and form a reciprocal cycle [21].

B. Procedures

The study was conducted in palm estate companies in North Sumatera province in 2011-2012. Primary data were obtained through direct observation in the field and interviews with experts in accordance with the research topic, the questionnaire tool. The collection of primary data through questionnaires or interviews were conducted using a purposive sampling technique, based on the the researcher assessment of the resource persons who meet the requirements as seen from the knowledge background or experience in order to achieve some results in line with the research objectives.

Field observations performed at several large estates, local and central government which are involved in plantation revitalization program. The collection of information from several experts conducted structurally by using the tools of questionnaire and unstructurally by conducting interviews. Resource persons came from the estate practitioners, researchers of Indonesian Oil Palm Research Institute (IOPRI), and special estate agencies of Horticulture Plantation Revitalization Department. The secondary data were obtained from literature, Central Bureau of Statistics, North Sumatera Plantation Office, Directorate General of Estates, Regional Development Planning Agency of North Sumatera, and North Sumatera GAPKI.

The study examines the palm estate companies as a partner in the plantation development, processing and marketing of results by making the decision model of multi-criteria decision making (MCDM) that uses the criteria of productivity in the estate. It began with identifying and assessing the variables involved in improving the productivity of palm oil estates. After all were identified, distributing questionnaires of pairwise comparisons were conducted on expert judgments to determine their preferences. The scale used is the scale that starts from the same limited importance (Equally preferred) to the absolute importance (extremely preferred). Scale selection of 1 to 9 is based on psychological research that is based on the ability

of the human brain in expressing his order of preference. Expected given assessment is hoped to be based on expert assessment. Productivity improvement process flow diagram is presented in Figure 1.
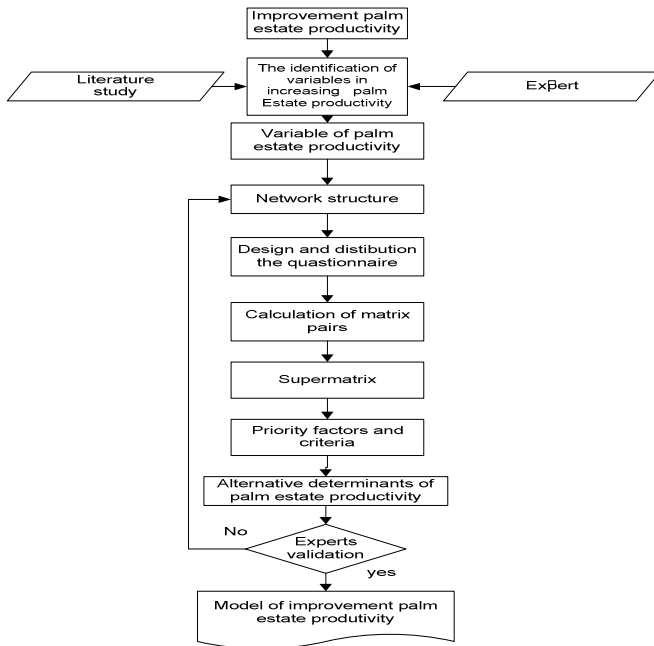

Fig. 1 Flow diagram of estate productivity improvement process

This decision model uses network analysis process required to reach the goals which have been set. Rationale estate productivity is important to evaluate, because the company will be implementing the revitalization of estate, with the rejuvenation and expansion of palm oil estate. Thus started from nurseries / seed selection, planting, maintenance, harvesting up to marketing of the products become the responsibility of the estate company. When there is an obligation by the palm estate company to be a guarantee of investment credit disbursed by banks will lead a palm estate company to be fully bound to make the palm oil estates managed to produce the results in accordance with the target productivity levels equal to that of the main estate and keep the quality of the estate in accordance with the technical standards so that assured certainty and sustainability efforts are guaranteed (according to the instructions of technical standards determined by the Minister of Agriculture cq. Directorate General of Estates).

V. RESULT AND DISCUSSION

Plantation Revitalization is an effort to accelerate the development of plantation through the expansion, rejuvenation and rehabilitation of plantations which is supported by the banking investment credit and interest subsidy by the government involving palm estate company in the business as a partner in improving the development of plantation, processing and product marketing [2]. This definition covers several important aspects, including the aspects of the development of smallholders, and aspects of the company as a plantation developing partner, processing and marketing results.

Factors that increase estate productivity refer to the environmental aspects, aspects of human resources and aspects of plant materials [12]; environmental factors, factors of plant material and agronomic measures factor [20]. Environmental factors (land) is an important factor because the palm oil plant will not grow economically if it is not planted on suitable land, so these factors are described with land suitability. Human resource factors are also important considerations based on plantation agriculture which is a business unit with a large-scale organization of labor intensive with detailed division of labor, modern technology, specialization, and system administration. These factors are described in the skill labor (specialization), supervision (system administration) and technology (working methods and the application of technology). Plant material factor is important because the selection of inappropriate plant material will bring a very big risk and will cause the company a loss of funds, time and effort if the seeds planted were not in accordance with the expected results. These factors are described in the quality of the seed. The technical culture factors most affect the growth and productivity, among others: seeding, fertilizing, plant population per acre and crop uniformity, and Treatment plant. Diagram of input output model of productivity improvement is illustrated in Figure 2 below:
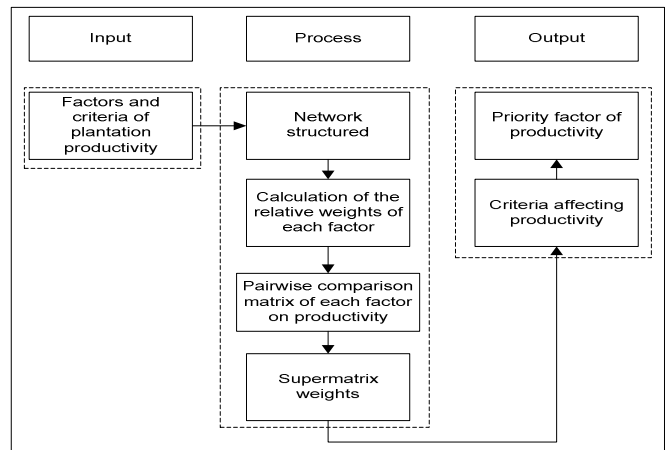

Fig. 2 Diagram of input-output models improvement estate productivity

The network structure of estate productivity is based on the theories of palm oil production and the efforts that can be done to increase the production of palm oil, with the involvement of resource persons who have expertise to understand and indeed involved (practitioners) in plantation activity to get an accurate assessment and were able to describe the actual conditions of the factors and criteria whose weight will be identified and determined in the analysis of *Analytical Network Process*. Analysis using ANP estimates the reciprocal relationship or dependence (feedback) from each level from top to bottom or from bottom to top in the structure of the network, so there is no a hierarchy in which the assessment is only done from the top down and the bottom level does not affect the levels upon it.

The estate productivity network structure is depicted in Figure 3. Dependency relationships between clusters or factors and the relationship between the criteria in the cluster are indicated by arrows. Curved arrows above each cluster

show the interplay within the cluster or factor itself, while the arrows coming out of the cluster show the relationship between affect or influence each other inter different criteria cluster. Factors of land suitability interplay with factors of technology applications, fertilization and Treatment plant. While the seed quality factors, SPH and homogeneity (population per hectare and crop uniformity) and working methods are influenced by factors of land suitability.
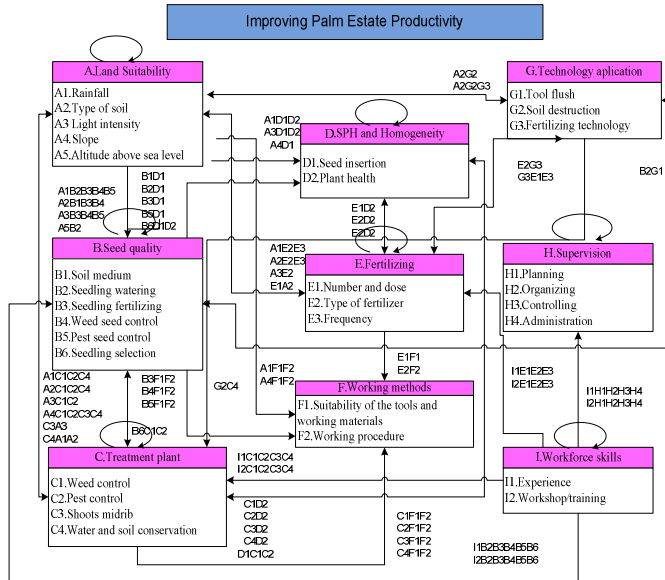

Fig. 3 The network structure of palm estate productivity

The final results of the ANP is limited supermatrix which is a multiplication of supermatriks with himself. This limited Supermatrix provides a constant weight value of several iterations multiplication supermatriks happened. Limited Supermatrix produces a constant weight value of each criterion based on the analysis of the feedback from each of the criteria to other criteria, either in the same cluster or factor or not.

Reciprocal relationships (feedback) and mutual influence among the criteria in one cluster or inter-cluster criteria to improve the productivity of palm oil estates by using ANP generate priority criteria. The priority criteria of increasing estate productivity is shown in Table 1 below. ANP results indicate that the population factor and uniformity of plants per hectare (Stand Per hectares and homogeneity), treatment plants, fertilizing, working methods, land suitability and application of technology become the determining factors in improving the productivity of palm oil estates. For more details, the results of the ANP for each criterion in the cluster and inter-cluster criteria that shows the interrelationships and mutual influences can be seen in Figure 4 below. Clusters and criteria described are the cluster and the criteria that have limited weights on supermatrix shown in Table 1, so that only clusters and criteria with the weights above zero are described to have connectedness and reciprocal interplay in improving the productivity of palm oil estates.

In the cluster of plant population per hectare and uniformity of plants, plant health and seed insertion interplay (no reciprocal links) to the cluster fertilizers, Treatment plant, and technology applications. But the land suitability

cluster only gives effect to the insertion of seeds and plant health. Interactions also occur among the criteria in the cluster population per acre and crop uniformity.

TABLE 1
PRIORITY CRITERIA FOR INCREASED PRODUCTIVITY

|	Criteria	Weight
A1	Rainfall	0,00522
A2	Type of soil	0,05703
A3	Light intensity	0
A4	Slope	0
A5	Altitude above sea	0
B1	Soil medium	0,01609
B2	Watering seedlings	0,0282
B3	Fertilizing seedlings	0,00247
B4	Pest control seedlings	0,00389
B5	Weed seed	0,00808
B6	Seed selection	0,01335
C1	Weed control	0,04167
C2	Pest control	0,03783
C3	Shoots midrib	0
C4	Water and soil conservation	0,02201
D1	Seed insertion	0,13056
D2	Plant health	0,18459
E1	Amount and dose of fertilizer	0,1023
E2	Fertilizer type	0,11675
E3	Fertilizer frequency	0,05709
F1	The suitability of the tool	0,07209
F2	Work procedure	0,04856
G1	Tool flush	0,00306
G2	Destruction of soil	0,01333
G3	Fertilizing technology	0,03595
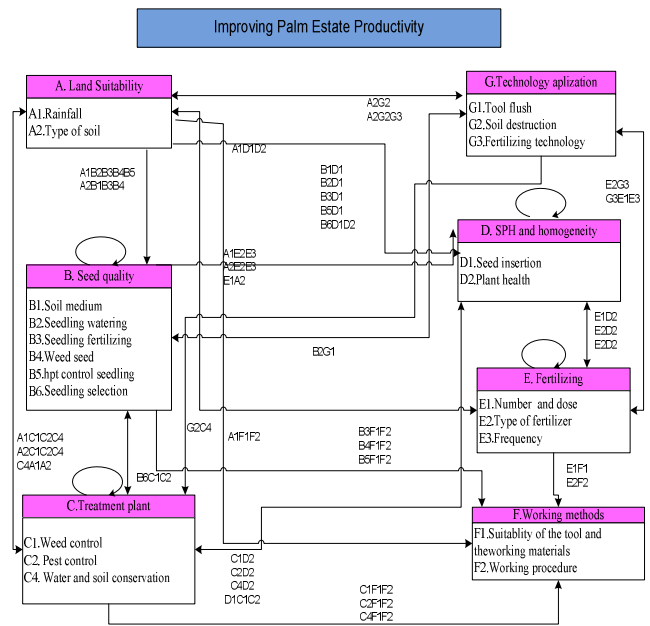
Fig. 4 Interplay productivity improvement of palm oil estate

1) Population factors per acre and crop uniformity (SPH and homogeneity).

This is a major factor in improving the productivity of palm oil estates. This factor consists of plant health (0.184595) and the insertion of seeds (0.130569). This is supported by Purba [17] which states that the limiting factor to achieve high productivity of palm oil estates in North Sumatera is heterogeneity, due to high insertion plants. Prihutami also states the plant population per hectare becomes the determinants of the increase in palm oil

production while rainfall will have no effect on the increase in palm oil production due to the high diversity of the population because of the high heterogeneity planting year [14]. The weights of plant health and the insertion are big, becouse most activities conducted in palm oil plantations will affect the insertion and the health of these plants. The insertion of the plant is an activity that is being conducted at the time of planting seedlings to estates with the aim of getting a fixed amount of crop plants and the low variation of different planting years. In terms of number, seed insertion is done to get the number optimization of trees per hectare. Meanwhile, in terms of years of planting, it is to suppress heterogeneity, for easy set up and give the same treatment in fertilization, weed and pest control. This insertion is more affecting than the weed control pest and disease control. Principally, if the weed is clean, then it will reduce pests. So the plants will get light intensity which is relatively the same and this can improve plant health. Plant health includes the adequacy and balance of nutrients and plant resistance to pests and diseases.

Superior quality seeds will be useless if it is not done in the insertion activity fields. Seedling pest control, fertilizing and watering seeds are activities that will directly affect the insertion of the plant. This applies also to the health criteria that determines the homogeneous plant crops in fields. Plant populations per hectare and homogeneity of these plants become the main factors to consider if the efforts to increase the productivities are done.

2) Fertilizing Factor

Weighting criteria include fertilizer (0.116755), the amount / dose of fertilizer (0.102303) and frequency (0.057095). This factor has a high weight and determines the increase in farm productivity, which means fertilization is absolutely necessary if the production of palm oil per hectare of crop needs to be improved. Fertilization is necessary to restore the land's ability to provide nutrients for the growth and development of palm oil estate, by improving soil fertility and increasing plant resistance to disease and unfavorable climatic influences. This is supported by Purwantoro which states that estate productivity differences are due to maintenance of the garden that is not the same, one of them is in terms of the provision of agro inputs [18]. Purba states that the constraints in increasing the productivity of palm oil estates is imperfect fertilization [17]. Fertilizer type and amount of fertilizer give significant effects to an increase in farm productivity [26].

3) Working method factor

Working method factor consists of criteria of tools and working materials suitability (0.072098) and the working procedure criteria (0.048561). Risza stated that efforts directed at the determination and application of the most suitable working methods have a major impact on productivity [20]. Hence, working procedure needs to be applied. For pest control activities, the work procedures are more influencing than the suitability of the tool and the work material. It is in contrast to the activity or weed control criteria, because it affects the suitability of the tool and the work material rather than working procedures. Working methods affect the quality of seeds, fertilizers and Treatment plant, while all three of these factors greatly affect plant

health and seed insertion which are the main criteria in increasing productivity of palm oil estates.

4) Plant treatment factor

Plant treatment factor consists of soil and water conservation, pest and disease control, weed control and midrib stemming. Weed control (0.041679), pest control (0.037839) and the conservation of soil and water (0.022012) have a high weight and large enough impact to improve the productivity of estates. Control of weeds / pests and diseases is an attempt to protect / care for plants. Weed control is an attempt to increase the competitiveness of palm trees and undermine the competitiveness of weeds, to control plant life with the understanding concept of the life cycle of pests / diseases [12]. Understanding knowledge about weakest part of the life cycle of the chain is very useful in controlling plant pests and diseases effectively. Purba stated that the limiting factor of achieving crop productivities is the stemming delay and weed control [17], and Tarmisor states that the amount of pesticides used in pest and disease control is the factor that affects the productivity of estates [26].

5) Seedling quality factor

The seedling quality factor is dominated by criteria of fertilizing seeds (0.028203), the use of soil media (0.016097), seed selection (0.013354), watering seedlings (0.008081), pest and disease control seedlings (0.003895) and weed control (0.002471). Purwantoro states that the constraints to increase the productivity of palm oil estates are that the seeds used must be original [18]. Purba stated that the key in improving productivity is superior plant materials and seed types [17]. To get quality seeds and high productivity per hectare of land, the activities of selecting seeds and watering the seedlings should be prioritized and done properly. Selection of seedlings describes the condition of seedlings which are ready to plant (seeds that have been selected). This seed selection is a the combination of how the work of watering, fertilizing, the control of weed and seedling pests, and how the use of soil media is done. This is a result reflecting of all activities in producing quality seedlings in the nursery. Watering the seeds is usually done in the lowlands, so water availability is not a problem. Seed selection activity is done continuously. Seedling pest control, fertilizing and watering seeds are activities that directly affect the insertion of the plant. The quality factor of these seeds can be organized and managed as needed.

6) Land suitability factor

Factor of land suitability is dominated by the criteria of soil type and rainfall. This factor weights relatively small because land suitability criteria such as rainfall, slope and altitude from sea level can not be adjusted as needed. Agustira and Amelia stated that the land suitability which is imposed leads to low productivity of palm oil estates [1]. In line with Purba who stated the suitability of land affects to the increase of crop productivity [17]. Soil type (0.056612) has the highest weight because it can be affected by soil conservation and types of fertilizers applied to crops. The type of soil meant is the soil physical properties which are usually distinguished between peat or mineral soil, and the hardpan or non hardpan soil. This is supported by Tarigan and Sipayung who stated the increase of plantatian

productivity can be done through biological and physical soil improvements [25]. Likewise, the rainfall (0.005429) can only be influenced or adjusted to the needs of soil and water conservation. Generally altitude affects rainfall. According to Siregar the rainfall is a climate suitability parameter to improve the productivity of palm oil estates [24] . But the criteria of light intensity, slope and land elevation from sea level are not adjustable and can not be customized as needed. In general, Goenadi stated the productivity of plants in the field is determined by the variety in its interaction with climate and soil fertility and pest nuisance [3].

7) Technology application factor

Technology application factor is described in the use of technology or tool flush of watering seedlings, soil destruction technology and fertilization technology. According to Yahya cultivation technology is required at all stages in an effort to improve crop productivity [27]. Tarigan and Sipayung suggested an increase of estate productivity is determined by technology and site-specific management plantation [25]. Increasing productivity by utilizing technology and innovation to increase production of CPO per hectare of land will result in more production from less land [4].

Each of the criteria for the application of the technology factor in increasing the productivity of estates has influences and affects a large enough with weight fertilization technology araound 0.036218, soil destruction technology (0.013442), and flush or technological tool watering seedlings (0.003078). Fertilization affects seed fertilizer technology, the amount and dose of fertilizer, and the frequency of fertilization. Technology application of land destruction affects and is affected by soil type, soil media seeding, and soil and water conservation in improving farm productivity. Meanwhile, watering technology application affects the seedling watering.

8) Supervision factor

This factor consists of criteria of planning, organizing, supervision and administration. Supervision is closely related to workforce skills, not only in supervision, planning, or organization but also in administration of labor skills which is derived from training or experience in the training and employment.

9) Workforce skill factor

This factor consists of the criteria of experience and education or training. To improve the productivity of estates, training for employment needs to be encouraged and the implementation should be controlled. This is because the estates are generally labor intensive, where labor is generally down high school education, only a few educated scholars with expertise. Accommodative factor of palm oil estates in the workforce who have no formal skills (high school and under) is related to the technological characteristics of palm oil estates with labor intensive to solid expertise / skills [25]. The low level of education at these locations will result in the low adoption and motivation of estate smallholders to manage the plantation [23]. Workforce skill factor and supervision have a weight close to zero, so it does not give any influence to the efforts to increase the productivity of palm oil estates.

Results of ANP towards the criteria and factors in increasing the productivity of palm oil estates are based on reciprocal relationships and dependencies depicted in Figure 5. The aim at improving the productivity of palm oil estates will be successful if the criteria for plant health and seed insertion are conducted continouslty and become a top priority for a success in productivity increase. Plant health can only be generated from the treatment to produce quality seeds, fertilizers and proper Treatment plant. While the factors of working methods, the suitability criteria of tool and working materials, and working procedures become the factors for supporting the implementation of fertilization, crop care and breeding activity (to get quality seeds). Factors of quality seeds, fertilizers, Treatment plant, and other factors supporting the increase of productivity (work methods, application of technology, labor skills, and supervision) become the factors that can be controlled or regulated and can be adjusted to the needs..
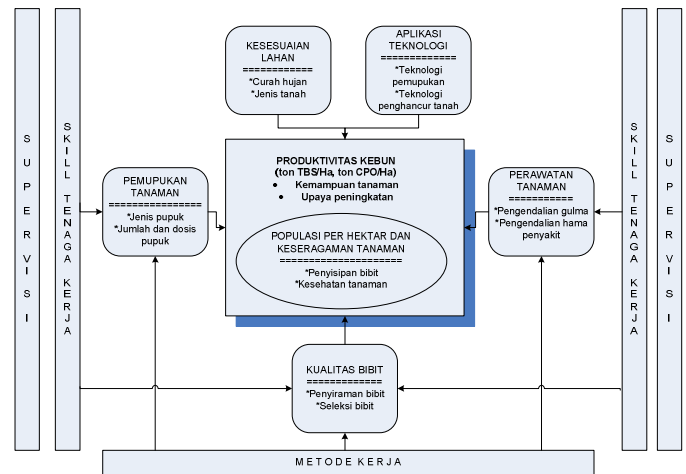

Fig. 5 Correlations among the factors in increasing the productivity of palm oil estate

The results of this study are verified to get a match between the input and output of the model whether or not it is running correctly. If there are some errors, then the model should be improved. The model of increasing productivity of palm oil estates and palm oil mills are built using Analytic Network Process, which is Super Decision ANP tools version 2.0.8. ANP method using Super Decision already has its own verification by calculating the inconsistency of the expert answers to the questionnaires which are presented in a pairwise comparison matrix. ANP processing results for each expert are processed to obtain the geometric mean of the experts. The results of the geometric mean is inserted into the input on the pairwise comparison matrix in ANP for a combination of all experts. ANP processing results in the form of a limited supermatrix are the weights for each criterion and cluster. From this supermatrix, priority of each criterion and inconsistency resulted from all reciprocal relationship among clusters and the criteria can be generated. There is ANP inconsistency result below 0.1 which indicates that the model has an acceptable consistency.

Furthermore, the model is validated to obtain valid models using the technique of face validity [22]. Questions

are submitted to the experts who have the capability in palm oil estates. These experts are from the plantation practitioners, RPN researchers, the Head of estate revitalization (Departement of Estate in North Sumatera). The technical implementation process is by presenting the model used in the research, experts then are given questionnaires to assess the model.

VI. CONCLUSION

Priority criteria that have the greatest impact in the increase of productivity of the estate are crop health (0.184595), insertion of seeds (0.130569), the type of fertilizer (0.116755), the amount and dose of fertilizer (0.102303), the suitability of the tool and the working materials (0.072098), the type of soil (0.056612), the frequency of fertilizer (0.057095), work procedures (0.048561), weed control (0.041679), pest control (0.037839), fertilization technology (0 , 036 218), and the fertilization of seeds (0.028203).

The priority order of factors increasing the productivity of palm oil estates is a population of plants per hectare and uniformity of plants, fertilizing, work methods, Treatment plant, seed quality, land suitability and application of technology.

Plant populations per hectare and homogeneity of plants with a total weight of 31.5% become the major factors that need to be observed and followed so that the efforts to increase the productivity of palm oil estates to enhance the competitiveness of North Sumatera and become a national barometer can be achieved.

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