Optimization of Plantation in Various Countries Using a Dynamic Model Approach

Nurhayati Sembiring, Humala Lodewijk Napitupulu, Meilita Tryana Sembiring, Aulia Ishak, and Rhyval Radot R
Department of Industrial Engineering
Faculty of Engineering
Universitas Sumatera Utara
Medan, Indonesia
nurhayatipandia68@usu.ac.id

Abstract
The forestry and plantation sectors are always experiencing developments every year. This development was carried out with the aim of obtaining sustainable productivity. Sustainable productivity will provide stable natural resources as raw material or food for the benefit of human life. One of the steps taken to obtain sustainable productivity is by replanting. Replanting activities need to be carried out to maintain the output from plantations and forestry to survive in order to meet high demand. Dynamic modelling is needed to provide an overview of the optimal form of replanting for the expected sustainability of productivity. This research will discuss the use of dynamic models in various parts of the country to model replanting activities in the forestry and plantation sectors. Each dynamic model used in this research still requires calibration to obtain high accuracy values. This will be an encouragement for researchers and management of the forestry and plantation sectors to obtain dynamic models with high accuracy values.

Keywords
Dynamic, model, plantation, forestry, optimization

1. Introduction
The forestry and plantation sectors have experienced very significant developments in recent years to meet industry demand as raw materials for the production process. Plantation and forestry are sectors that greatly affect global conditions both economically and their impact on the environment [1]. The productivity of the forestry and plantation sectors is influenced by a variety of dynamic variables. This condition of course makes it necessary to develop tools that can help management to optimize the management of the plantation and forestry sector by taking into account these dynamic variables. Currently, few studies have been conducted to analyze the optimization tools needed by management in the forestry and plantation sectors [2].

There are many variables that affect the productivity of the plantation and forestry sectors. These factors include the genetics of the plants themselves, climate and environment, and human intervention. These variables are dynamic and change over time. Therefore it is necessary to have a model that is used to predict changes in each variable in order to optimize the results of the two sectors [3].

This research was conducted to determine the use of a dynamic model approach to solving problems in the forestry and plantation sectors. The dynamic model approach is expected to optimize the productivity of the plantation and forestry sectors to achieve the output targets set by management.

2. Literature Review
2.1. Model
Models are tools used to understand, describe, and predict existing real systems. The development of types of models is currently experiencing a significant increase, including empirical and exponential models, semi-empirical models, and theoretical models. There are many other forms of models that can be used to analyze real systems [4].

2.2. Plantation and Forestry
Plantation and forestry are two sectors that greatly affect the economy as well as global environmental factors. Plantation and forestry supply raw materials derived from nature as input for industry to be processed into products

that are used by consumers. Every year, the development of plantation and forestry is always carried out to balance the population growth which has increased significantly [1].

2.3. Dynamic Model

Dynamic model is a model that uses time as an independent variable. Dynamic model describes the dynamics of a system with respect to the unit time function. This modeling is usually done repeatedly (iteration) so that the smallest error value is found [5].

There are various studies that have been conducted using a dynamic model approach to the plantation and forestry sectors. The dynamic model approach is used to predict the variables that affect the productivity of plantations and forestry so that they can be handled properly by the management. Table 1 shows a list of articles from various countries resulting from previous research that has been analyzed.

Table 1. Results of the dynamic model research for the plantation and forestry sectors

Paper By	***Method***	***Result***	***Research Sites***
Springer	MLP-NN (Multilayer Perceptron Neural Network)	The results showed that the increase in population was directly proportional to the increase in demand for food needs [6].	India
Elsevier	Creation of a new scheme to solve the problem of tree uncertainty by using strategic and tactical stochastic preamble for dynamic optimization model 0-1 mix in harvest time under time uncertainty	The results showed that tree planting under the tactical-tactical scenario had 42345 nodes which made it unrealistic to find optimal solutions [7].	Chile
Elsevier	Dynamic Computable General Equilibrium (CGE) Model	The results show that there will be an increase in people's welfare which is directly proportional to economic inequality [8].	Laos
Scientia Agricola	The research was conducted by analyzing previous research.	The method most commonly used in research using a dynamic modeling approach is the classical optimization method [2].	Russia
Elsevier	review of social capital (SC) and forest governance literature	This model describes the interaction between factors affecting natural resources and challenges in rural development based on a cooperative nature [9].	Spain

Table 1. Results of the dynamic model research for the plantation and forestry sectors (continued)

Paper By	***Method***	***Result***	***Research Sites***
Ahmad Dahlan University	Regression mathematical model	The proposed harvest schedule has better total cost than the current schedule and the expected quality targets are easier to achieve [10].	Indonesia
Springer	Auto-Regresive Distributed Lag (ARDL)	The results showed that crop and livestock production activities had a significant positive effect on carbon dioxide gas emissions [6].	China
Scientific Research Publishing	STELLA (Structural Thingking, experiential learning laboratory with animation)	The simulation results show that the dynamics of land cover are influenced by the price of palm oil and the number of human populations [11].	Malaysia
Atlantis Press	Using the DEA and Malmquist Index Model to study dynamic changes and spatial differences in forest efficiency in 21 of us in Sichuan province in the 2005-2014 time frame	The results show that the unsuccessful shows an increase in the graph. Forest efficiency values in the Chuan-dong, Chengdu, and Chuannan regions are relatively higher, the Chuanxibei area and the Panxi region have lower efficiency values [1].	China
Springer	Dynamic model of differences in plant age whose growth conditions were evaluated by the C3 method	By the time the plantation is 150 years old, the reserves of pine trees that have regenerated under the shade of a pine canopy will cover one-third of the total plantation reserves [12].	Russia
Springer	Revised Gash Model for simulating total canopy interception of Larch farms during growing season	This paper analyzed about the total values of rainfall, canopy interception, and suitable stem. [13].	China
Springer	Autoregressive (AR) and Moving Average (MA) or ARMA mathematical models	ARMA modelling can simulate changes in tree ring density growth [3].	China

Table 1. Results of the dynamic model research for the plantation and forestry sectors (continued)

Paper By	***Method***	***Result***	***Research Sites***
Springer	The method used is the dynamic distribution of seasonal C and N biomass.	The highest biomass content of C and N for grassland areas is in summer. Meanwhile, the Miscanthus field has the highest content during winter. [14].	Germany
Springer	Discrete model development for optimal evaluation of results	The chances of increasing the oil palm harvest will increase if the harvest cycle is shortened to 8.3 days which was originally 19.6 days [15].	Colombia
New Delhi Publishers	variant of the Gupta model	The model developed shows that stakeholders related to forestry in the study area are very concerned about forest sustainability because of the lack of alternative livelihood opportunities [16].	India
Institute of Chartered Foresters	SLeDG (Stand-level dynamic growth) Model	The association between height-age suggests a greater likelihood for Scottish pine (Pinus sylvestris) and Sitka spruce (Picea sitchensis) species in a comparison of the Bayesian model [17].	United Kingdom
Society of American Foresters	Development of a Slef-Thinning Model to predict the viability of stands and basalt areas based on the trajectory of planting.	The results showed the best growth and development analysis of Self-Thinning Model [18].	China
Society of American Foresters	The Cieszewski GADA model, the Chapman-Richards model ADA, the Chapman-Richards GADA model, the Schumacher ADA model, the Schumacher GADA model, and the McDill-Amateis GADA model.	The McDill-Amateis GADA model and the Chapman-Richards GADA model had the best results for the Intensively Managed Loblolly Pine (Pinus taeda) Farms in terms of statistical compatibility [19].	USA

3. Methods

This research was conducted by analyzing articles generated from previous research on dynamic models for the plantation and forestry sectors. Each article goes through an analysis phase to ensure that the discussion required for this study matches the content of the article [2].

The stages of working on this research can be seen in the flow chart in Figure 1.

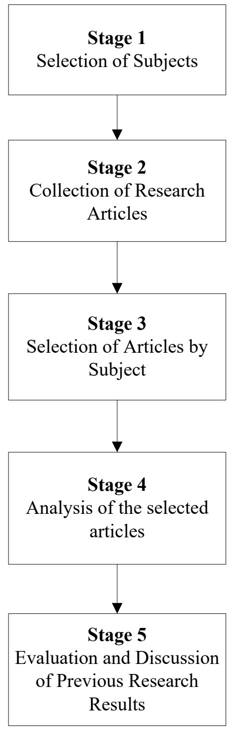

Figure 1. Stages of Research Methods

1. **Stage 1,** The initial stage of this research determines the theme to be discussed. This research will discuss the optimization of replanting using a dynamic approach model. The theme was chosen with the aim of seeing the development of dynamic models in optimizing replanting in various countries.
2. **Stage 2,** The second stage of this research is to collect papers. Papers collected come from various types of publishers. Papers that are the focus of research are those published in the last five years. Of course, the paper must have a topic that is in line with the objectives of this research.\
3. **Stage 3,** The third stage in this research method is to select the papers that have been selected. Papers that have been selected in the second stage based on a predetermined theme will be reselected. The re-selection was carried out to obtain a paper that was in accordance with the details of the subjects expected in this study. Thus, we can find papers in the last five years that match the subject of this research that come from various countries.
4. **Stage 4,** The fourth stage in this research is to analyze and evaluate the selected papers. Each paper selected from the third stage will be analyzed starting from the background, research objectives, methods, discussion, and conclusions. Each sub-chapter will be analyzed to know clearly the contents of the discussion of the selected paper.
5. **Stage 5,** The fifth stage or the final stage of this research method is to evaluate and discuss the results of the analysis carried out in the fourth stage. Evaluation is carried out to determine the advantages and disadvantages of the dynamic model used to optimize replanting activities. Evaluation and discussion is conducted to get an objective view of the selected papers that have been analyzed

4. Results

After passing through a fairly rigorous paper selection stage, it was found that eighteen papers from various publishers and various countries were published in the last five years. Figure 2 shows a diagram depicting papers obtained from various countries in the world.

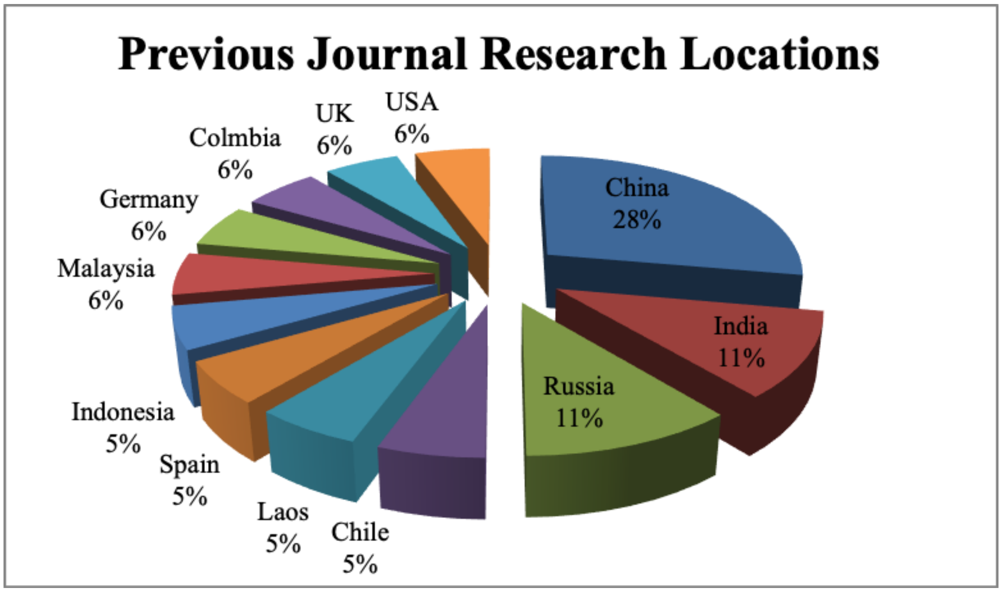

Figure 2. Previous Research Locations

From the data above, it can be seen that research on dynamic model approaches to optimize replanting activities is still dominated by Asian countries. China was the largest paper contributor in this study with a percentage of 28% of the eighteen papers that were selected. Five papers obtained from China discuss replanting activities that use dynamic models to get the best pattern based on factors that affect the growth of a plant. These factors include plant age, soil contour, gas emissions, environmental conditions, and the condition of the plant canopy. Research originating from China also compared three forms of dynamic models that were used to find the best model that could be used in the replanting method.

It is quite surprising that the percentage of Russia is quite high considering that Russia does not have a large enough forest area. Russia which is known as one of the ice countries has the second highest percentage in the papers selected in this study. Russia's position is followed by India which is also an Asian country with its southern region which is still classified as a tropical region. From each dynamic model used in the selected paper, it is still necessary to recalibrate it to get the accuracy value that is closest to the actual condition. Various previous models were analyzed and re-evaluated for improvement in order to obtain high accuracy values. Improvements are made starting with adding the number of related variables, decreasing the error value, reducing the deviation value, and making necessary model modifications according to the actual conditions in the field. This development has been carried out quite rapidly in the last five years. However, this research is mostly carried out by countries in the Asian continent.

The use of dynamic models for optimization of non-forestry plantation processing by management shows a significant development. Each dynamic model in the study undergoes development and calibration to increase the efficiency and effectiveness of its use. The use of dynamic models is very important to predict dynamic variables in the future. The results of this prediction will be used as material for analysis and evaluation for management to prepare themselves for future conditions [20].

Most of the dynamic models used are in the form of a regression mathematical model. In addition, the form of the model used is also a programming in computer software. Several articles also make use of the two forms of the model and compare to get the form of the model with the smallest error value [4].

5. Conclusion

Dynamic models for the plantation and forestry sectors are always developing from time to time. Recent research is always carried out to test existing models in order to increase the efficiency and effectiveness of the model. The purpose of developing the model is of course to get results that are closest to the real form that occurs in the field. The smaller the error value of the model, the greater the opportunity for management to make improvements and also to develop the plantation and forestry sectors.

6. Acknowledgments
This research's assistance has been received under contract number 156/UN5.2.3.1/PPM/ SPP-TALENTA USU/2020.

REFERENCES
[1] Chao Yu and Mei Li 2017 The Evaluation and Spatial Differentiation of Forestry Efficiency in Sichuan Province--Based on DEA-MI Model *Atlantis Press* **121** P 172 https://doi.org/10.2991/icammce-17.2017.36.

[2] Pedro Belavenutti, Carlos Romero, and Luis Diaz-Balteiro 2018 A critical survey of optimization methods in industrial forest plantations management *Scientia Agricola* **75** P 241 DOI: http://dx.doi.org/10.1590/1678-992X-2016-0479.

[3] Yi Liu and Minghui Guo 2019 Simulation of the growth ring density of Larix olgensis plantation wood with the ARMA model *Springer* **30** P 727 – 728 https://doi.org/10.1007/s11676-018-0637-2.

[4] Zebin Liu, Yanhui Wang, Ao Tian, Yu Liu, Ashley A. Webb, Yarui Wang, Haijun Zuo, Pengtao Yu, Wei Xiong, anda Lihong Xu 2018 Characteristics of canopy interception and its simulation with a revised Gash model for a larch plantation in the Liupan Mountains, China *Springer* **29** P 188 DOI 10.1007/s11676-017-0407-6.

[5] Abbas Ali Chandio, Waqar Akram, Fayyaz Ahmad, and Munir Ahmad 2020 Dynamic relationship among agriculture-energy-forestry and carbon dioxide (CO2) emissions: empirical evidence from China *Springer* **27** P 34079 https://doi.org/10.1007/s11356-020-09560-z.

[6] Ram Kumar Singh, Vinay Shankar Prasad Sinha, Pawan Kumar Joshi, and Manoj Kumar 2020 Modelling Agriculture, Forestry and Other Land Use (AFOLU) in response to climate change scenarios for the SAARC nations *Springer* **192** P 1 – 18 https://doi.org/10.1007/ s10661-020-8144-2.

[7] Antonio Alonso-Ayuso, Laureano F. Escudero, Monique Guignard, and Andres Weintraub 2019 On Dealing With Strategic and Tactical Decision Levels In Forestry Planning Under Uncertainty *Elsevier* **115** P 1 – 29 https://doi.org/10.1016/j.cor.2019.104836.

[8] Somvang Phimmavong and Rodney J. Keenan 2020 Forest plantation development, poverty, and inequality in Laos: A dynamic CGE microsimulation analysis *Elsevier* **111** P 1 – 10 https://doi.org/10.1016/j.forpol.2019.102055.

[9] Elena Górriz-Mifsud, Laura Secco, Elena Pisani 2016 Exploring the interlinkages between governance and social capital: A dynamic model for forestry *Elsevier* **65** P 25 – 36 https://doi.org/10.1016/j.forpol.2016.01.006.

[10] Siti Mahsanah Budijati and Bermawi Priyatna Iskandar 2018 Dynamic Programming to Solve Picking Schedule at The Tea Plantation *Ahmad Dahlan University* **7** P 285 – 290 DOI: http://dx.doi.org/10.14419/ijet.v7i4.30.22286.

[11] Nickson E. Otieno, Xeuping Dai, Daniele De Barba, Abbassi Bahman, Elise Smedbol, Marouan Rajeb, and Lise Jaton 2016 Palm Oil Production in Malaysia: An Analytical Systems Model for Balancing Economic Prosperity, Forest Conservation and Social Welfare *Scientific Research Publishing* **7** P 55 – 69 http://dx.doi.org/10.4236/as.2016.72006

[12] M. V. Rubtsov, Yu. B. Glazunov, and D. K. Nikolaev 2016 Regenerative and Age Dynamic of Spruce Population in Pine Plantations under Conditions Typical for Spruce Development *Springer* **9** P 884 – 893 https://doi.org/10.1134/S1995425516070088.

[13] Zebin Liu, Yanhui Wang, Ao Tian, Yu Liu, Ashley A. Webb, Yarui Wang, Haijun Zuo, Pengtao Yu, Wei Xiong, anda Lihong Xu 2018 Characteristics of canopy interception and its simulation with a revised Gash model for a larch plantation in the Liupan Mountains, China *Springer* **29** P 187 – 198 DOI 10.1007/s11676-017-0407-6.

[14] Christopher Poeplau, Kai Germer, and Kai-Uwe Schwarz 2019 Seasonal dynamics and depth distribution of belowground biomass carbon and nitrogen of extensive grassland and a Miscanthus plantation **440** P 119 – 113 https://doi.org/10.1007/s11104-019-04074-1.

[15] Mariana Escallón-Barrios, Daniel Castillo-Gomez, Jorge Leal, Carlos Montenegro2, and Andrés L. Medaglia 2020 Improving harvesting operations in an oil palm plantation *Springer* P 1 – 39 https://doi.org/10.1007/s10479-020-03686-6.

[16] Nilendu Chatterjee and Kausik Gupta 2018 A Dynamic Model of Forestry for the Dryland Areas of West Bengal *Economic Affairs* **66** P 557 – 567 DOI: 10.30954/0424-2513.2.2018.35.

[17] J. Lonsdale, F. Minunno, M. Mencuccini, and M. Perks 2015 Bayesian calibration and Bayesian model comparison of a stand level dynamic growth model for Sitka spruce and Scots pine *Institute of Chartered Foresters* **88** P 326 – 335 doi:10.1093/forestry/cpv003.

[18] Xiongqing Zhang, Quang V. Cao, Hanchen Wang, Aiguo Duan, and Jianguo Zhang 2020 Projecting Stand Survival and Basal Area Based on a Self-Thinning Model for Chinese Fir Plantations *Society of American Foresters* **66** P 361 – 370 doi: 10.1093/forsci/fxz086.

[19] Kynda R. Trim, Dean W. Coble, Yuhui Weng, Jeremy P. Stovall, and I-Kuai Hung 2020 A New Site Index Model for Intensively Managed Loblolly Pine (Pinus taeda) Plantations in the West Gulf Coastal Plain *Society of American Foresters* **66** P 2 – 13 doi:10.1093/forsci/fxz050.

[20] Antonio Alonso-Ayuso, Laureano F. Escudero, Monique Guignard, and Andres Weintraub 2019 On Dealing With Strategic and Tactical Decision Levels In Forestry Planning Under Uncertainty *Elsevier* **115** P 2 https://doi.org/10.1016/j.cor.2019.104836.

BIOGRAPHY

Ir. Nurhayati, MT, is a lecturer who teaches at the Department of Industrial Engineering, Faculty of Engineering, University of North Sumatra. She completed her undergraduate education at the University of North Sumatra in 1994. She also continued her education at the master's level at the Bandung Institute of Technology and completed it in 1999. She has some publication of scientific research. Some of the conferences she has attended recently are IOP Conference Series: Materials Science and Engineering.

Prof. Dr. Ir. Humala Lodewijk Napitupulu, DEA, is a professor who teaches at the Department of Industrial Engineering, Faculty of Engineering, University of North Sumatra. He completed his undergraduate education at the University of North Sumatra in 1979. He also continued his education at the master level at GSI Nancy France and completed in 1984 in the field of industrial engineering. He completed his doctoral degree at UFR GSI INPL Nancy France in 1989 with a major in industrial engineering. Currently he is conducting research on the level of reliability assessment of complex systems with simulation applications.

Dr. Meilita Tryana Sembiring, ST., MT, is the head of the Industrial Engineering Department, Faculty of Engineering, University of North Sumatra. She completed her undergraduate education at the University of North Sumatra in 1994. She also continued her education at the Bandung Institute of Technology master level and completed in 2004 in the field of industrial engineering. She completed her doctoral degree at the Bogor Agricultural Institute in 2015 with a field of agricultural industry technology.

Aulia Ishak, ST, MT, Ph.D, is one of the lecturers at the Department of Industrial Engineering, Faculty of Engineering, University of North Sumatra. He completed his undergraduate education at the University of North Sumatra in 1994. He also continued his education at the master level of the Surabaya Institute of Technology and completed it in 2002 in the field of industrial engineering. He completed his doctoral degree at the University Sains Malaysia in 2018 with a major in industrial engineering. Currently he is conducting research on the Design Of Compost Waste Bin Products Using Axiomatic Design Method, Quality Function Deployment (QFD), and Value Engineering Application.

Rhyval Radot R, is a final year student at the Department of Industrial Engineering, Faculty of Engineering, University of North Sumatra. Currently he is an active assistant in the Ergonomics and Work System Design Laboratory at the Department of Industrial Engineering, Faculty of Engineering, University of North Sumatra.