A review: Hybrid model simulation in representing forestry conditions

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Abstract. The forestry and plantation system is an integration of several very complex and dynamic sub-systems. The integration is created due to the interaction of several factors that can affect the productivity of forestry and plantations. The method used in research is to analyze the prior literature that has been selected for discussion and evaluation. Every previous research result will be collected and studied, analyzed, determined, and finally evaluated to get the necessary conclusions. The results of the analysis and evaluation of the research show that the hybrid simulation model can represent various factors that affect the productivity of forestry and plantations. So it can be concluded that the hybrid simulation method helps the management of forestry and plantations in understanding the processes and interactions between sub-systems that occur within the forest and garden systems studied by observing the many influential variable inputs.

1. Introduction

The forestry and plantation system is an integration of several very complex and dynamic sub-systems. The integration is created due to the interaction of several factors that can affect the productivity of forestry and plantations. These factors can be in the form of an uncertain climate, land availability, soil conditions, and competition between vegetation [1]. Forestry management must be able to make predictions for each state that is affected by these factors. The results from forecasts are used to determine everything that needs to be done to increase forests and gardens [2]. We need to analyze as well as detailed research to predict the interactions of these factors. Research conducted directly in the field certainly requires a long time and an enormous cost. Therefore, researchers developed a method that can be used to study these interactions.

Making simulation models are the most efficient and practical step to study the interactions between climate, land availability, soil conditions, and competition between vegetation for forestry and plantation productivity. Model simulations can describe the interactions of each sub-system in detail for analysis and evaluation in predicting every condition that might occur. Making simulation models will save time and money for forestry and plantation management [3]. Model simulation is a form of simplification of a system and the interactions that occur in it. Model simulations can illustrate the characteristics of the system represented. Simulation models usually have a level of efficiency and also deviations from the simple forms that exist in the field [4]. In forestry and plantation management, the model simulation method is developing every time. The researcher develops to minimize the deviation between model simulations made against actual events in the field. Currently, researchers are developing a form of hybrid simulation to illustrate forest and plantation ecosystem models [5]. The objectives to be achieved in this research are to analyze the success rate of hybrid simulation methods in describing the actual conditions in the field. In research, the method used is the evaluation and analysis of research journals that have been done to find out any factors that can affect the productivity of forestry and plantations. The results of the analysis will be an evaluation material to determine the level of success of the hybrid simulation model method in predicting actual conditions.
2. Literature review

2.1 Agroforestry
Agroforestry has a focus on studying forestry, agriculture, as well as animal husbandry, as well as developing violence between increasing the productivity of plantations by preserving forests [6].

2.2 Forest and plantation process model
Forest and plantation process models are a mathematical picture of the biological systems of forests and plantations. Forest and plantation process models incorporate physiological and ecological factors as input into mathematical algorithms to create predictions that are closer to actual conditions [7].

2.3 Process model as a forest and plantation management tool
Forestry and plantation management is a control function of a broad and uncontrollable system. The process model as one of the tools in forestry and plantation management is used to conduct evaluations which that will help in to make decisions [8].

2.4 Hybrid simulation models
The hybrid simulation model is a combination of mechanical and empirical elements. Hybrid simulation models can for many states of input to be represented. Hybrid simulation models have the ability to unite the forms of biological realism and the general application of empirical growth models [9].

2.5 Simulation model in forest and plantation management
At present, many studies are analyzing the form of simulation models that are used as consideration in making important decisions regarding the condition of Forestry and Plantation to increase system productivity [10].

Table 1. Collection of research concerning forestry and plantation simulation models

| Paper By         | Method                        | Result                                                                 | Volume and Year |
|------------------|-------------------------------|------------------------------------------------------------------------|-----------------|
| Elsevier         | Regression, CABALA, 3-PG, 3-PG +, and Forest-DNDC | Process-based models are not good at simulating young plants with plant age less than four years after planting, plants with high mortality values, and the interaction between plantation and silvicultural management. [8] Agent-Based Models (ABMs) can make representations that are relevant to species distribution, and it is recommended to combine them with models of species change ranges. [9] Through consideration of several factors that affect a system, researchers must be able to create a simulation model that includes each sub-system, the processes that are running, and interactions between sub-systems. [6] The 3-PG simulation model can be used for a wide geographical area coverage with a set of parameters for the rank oogenesis plant. The 3-PG model can also do weather prediction simulations. [10] | 220 (2009)          |
| Wiley            | Agent-Based Models (ABMs)     |                                                                        | 26 (2020)       |
| Institute of Chartered Foresters | CI-Based Modelling          |                                                                        | 79 (2006)       |
| Elsevier         | 3-PG                          |                                                                        | 406 (2017)      |
| Elsevier         | Climate-sensitive integrated stand growth model (CS-ISGM) | The CS-ISGM model can represent simulations of climate change in the future close to actual conditions on the ground. [11] | 376 (2016)      |
| Publisher      | Model/Method                                                                 | Description                                                                                                                                                                                                 | Year  |
|---------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| Elsevier      | SECRETS 3-PG                                                                 | The results show that plantation management must pay attention to the condition of soil carbon sequestration in the short cycle chain by using the SECRETS-3PG method. [12] | 221   |
| Elsevier      | Agricultural Production Systems Simulator Next Generation Eucalyptus (APSIM-Next Generation Eucalyptus) | The APSIM Eucalyptus Next Generation simulation model can calculate biomass from Eucalyptus plants and other parts of trees in edaphic conditions and silvicultural management processes. [2] | 469   |
| Elsevier      | 3-PG                                                                          | Using 3-PG simulations, a management strategy can be found as an alternative to increasing productivity by reducing the level of damage caused by storms. [13] | 26    |
| Elsevier      | Land-Use Change and Ecosystem Services (LUCES) and Agent-Based Model         | The LUCES simulation model can be utilized by the Indonesian government as a consideration for making decisions in achieving the INDC objectives as one of the supporting factors sustainable development. [14] | 23    |
| Elsevier      | Nonmetric Multidimensional Scaling (NMDS)                                   | The simulation results using the NMDS method show that Elytrigiarepens, which is one type of perennial grass, is an inhibiting factor for the growth of young hybrid poplar plants. [4] | 362   |
| Elsevier      | Process-Based Models                                                         | Process-Based Simulation can simulate the influence of weather factors and soil conditions on the growth of Eucalyptus with a fair evaluation and calibration process. [15] | 450   |
| Elsevier      | The bioclimatic model Jeffree and Jeffree                                    | The bioclimatic model Jeffree and Jeffree can carry out simulations that help experts assess the risk of planning management strategies for developing forestry productivity in South Africa. [16] | 187   |
| Elsevier      | Process-based model 3-PG                                                     | The 3-PG model carries out a very accurate analysis in describing the productivity potential of the Acacia hybrid plantation for each different climatic and soil conditions on mainland Vietnam. [5, 21] | 367   |
| Elsevier      | The simulation uses Stella software with the Euler method                    | The model used can represent the process of aboveground biomass production that is affected by Nitrogen fertilization. [17, 22] | 35    |
| Springer      | The SORTIE-ND model with Gap Light Index (GLI) software.                    | The SORTIE-ND model using the Gap Light Index (GLI) software can test the implementation of the possibilities that have been set against the objectives to be achieved. [18, 23] | 54    |
| Springer      | Moderate Resolution Imaging Spectroradiometer (MODIS)                        | Simulation models using a Moderate Resolution Imaging Spectroradiometer (MODIS) can show the effect of climate change that is uncertain to the addition of 47 (2017) |
After analysis and evaluation of 18 journals that have been selected with various types of keywords, it can be concluded that most research conducted from journals that have been reviewed is in 2016. The research location is dominated by three countries, including China, Brazil, and Canada. For further explanation, see the following figure.

**Figure 1.** Previous year of research journal

**Figure 2.** Prior journal research locations

### 3. Method

The method used in research is to analyze the prior literature that has been selected for discussion and evaluation. The steps taken are as follows:

**a. Stage 1.** Every report of previous research results is collected and studied.

**b. Stage 2.** Every report of previous research results that have been collected will be analyzed.

**c. Stage 3.** Every report of previous research results that have been analyzed and then selected for the methods used in the study.
d. **Stage 4.** Every report of previous research results is evaluated for their relevance to the stated research objectives.

![Diagram of Research Methods](image)

**Figure 3.** Research methods for past research analysis

4. **Research results**

Based from analysis and evaluation of the research show that the hybrid simulation model has can represent various factors that affect the productivity of forestry and plantations. Hybrid simulation models can receive many input formations to illustrate simulation models that are very close to the actual form. The hybrid simulation model has one weakness, which requires that the system representation process must experience a reduction in the number of calculation parameters used in the mathematical algorithm used. Among the various types of simulation methods available, hybrid simulation methods have the highest flexibility and also the small deviation value in applying a simulation model of a forestry and plantation system.

5. **Conclusion**

Forest and plantation management capabilities must be improved to encourage the productivity value of the existing system. The ability to predict conditions that will occur with a variety of variable interactions is essential to make decisions in planning to be done. The hybrid simulation model approach greatly facilitates forestry and plantation management in predicting every condition that might occur with various variables that can affect the system. So it can be concluded that the hybrid simulation method helps the management of forestry and plantations in understanding the processes and interactions between sub-systems that occur in the forest and garden systems under study by observing the many influential variable inputs.

**Acknowledgments**

This research received financial assistance from contract number 156 / UN5.2.3.1 / PPM / SPP-TALENTA USU/2020.

**References**

[1] Widianto, Wijayanto N and Suprayogo D 2003 Pengelolaan dan Pengembangan Agroforestri *World Agroforestry Centre (ICRAF)* Bogor, Indonesia.
[2] Smethursta P J, Valadaresb R V, Huthd N I, Almeidaa A C, Ellie E F and Nevesb J C L 2020 Generalized model for plantation production of Eucalyptus grandis and hybrids for genotype-site-management applications *Forest Ecology and Management* 469 1–14.

[3] Marsden C, Nouvellon Y, Laclau J-P, Corbeels M, McMurtrie R E, LuizStape J, Epron D and Maire G 2013 Modifying the G'DAY process-based model to simulate the spatial variability of Eucalyptus plantation growth on deep tropical soils *Forest Ecology and Management* 301 112–128.

[4] Henkel-Johnson D, Macdonald S E, Bork E W and Thomas B R 2016 *Influence of weed composition, abundance, and spatial proximity on growth in young hybrid poplar plantations* *Forest Ecology and Management* 362 55–68.

[5] Hung T T, Almeida A C, Eyles A and Mohammeda C 2016 Predicting productivity of Acacia hybrid plantations for a range of climates and soils in Vietnam *Forest Ecology and Management* 367 91–111.

[6] Richardson B, Watt M S, Mason E G and Kriticos D J 2006 Advances in modelling and decision support systems for vegetation management in young forest plantations *Forestry* 79 30–42.

[7] Johnsen K, Samuelson L, Teskey R, McNulty S and Fox T 2001 Process Models as Tools in Forestry Research and Management *Forest Science* 47 (1) 1–7.

[8] Miehle P, Battaglia M, Sands P J, Forrester D I, Feikema P M, Livesly S J, Morris J D and Arndt S K 2009 A comparison of four process-based models and a statistical regression model to predict growth of Eucalyptus globulus plantations *Ecological Modelling* 220 734–746.

[9] Dullinger I, Gattringer A, Wessely J, Moser D, Plutzar C, Willner W, Egger C, Gaube V, Haberl H, Mayer A, Bohner A, Gilli C, Pascher K, Essl F and Dullinger S 2020 A socio-ecological model for predicting impacts of land-use and climate change on regional plant diversity in the Austrian Alps *Global Change Biology* 26 2336–2352.

[10] Xie Y, Wang H AND Lei X 2017 Application of the 3-PG model to predict growth of Larixolgensis plantations in northeastern China *Forest Ecology and Management* 406 208–218.

[11] Lei X, Yu L and Hong L 2016 Climate-Sensitive Integrated Stand Growth Model (CS-ISGM) Of Changbai Larch (LarixOlgensis) *Plantations Forest Ecology and Management* 376 265–275.

[12] Sampson D A, Waring R H, Maier C A, Gough C M, Ducey M J and Johnsen K H 2006 Fertilization Effects On Forest Carbon Storage And Exchange, And Net Primary Production: A New Hybrid Process Model For Stand Management *Forest Ecology and Management* 221 91–109.

[13] Subramanian N, Nilssona U, Mossberg M and Bergh J 2019 Impacts of climate change, weather extremes and alternative strategies in managed forests *Ecoscience* 26 53–70.

[14] Suwarno A, Noordwijk M v, Weikard H-P and Suyamto D 2018 Indonesia’s Forest Conversion Moratorium Assessed With An Agent-Based Model Of Land-Use Change And Ecosystem Services (LUCES) *Mitig Adapt Strateg Glob Change* 23 211–229.

[15] Ellia E F, Sentelhasa P C, Freitas C H d, Carneirob R L and Alvaresc C A 2019 Intercomparison of structural features and performance of Eucalyptus simulation models and their ensemble for yield estimations *Forest Ecology and Management* 450 1–13.

[16] Staden v v, Erasmus B F N, Roux J, Wingfield M J and Jaarsveld A S v 2004 Modelling the spatial distribution of two important South African plantation forestry pathogens *Forest Ecology and Management* 187 61–73.

[17] Garten C T, Jr.a, Wullschleger S D and Classen A T 2011 Review and model-based analysis of factors influencing soil carbon sequestration under hybrid poplar *Biomass & Bioenergy* 35 214–226.

[18] Paquette A, Messier C, Pe’rinet P and Alain 2008 Cogliastro Simulating Light Availability under Different Hybrid Poplar Clones in a Mixed Intensive Plantation System *Forest Science* 54 (5) 481–489.
[19] Kang H, Seely B, Wang G, Cai Y, Innes J, Zheng D, Chen P and Wang T 2017 Simulating the impact of climate change on the growth of Chinese fir plantations in Fujian province, China New Zealand Journal of Forestry Science 47 (20) 1–12.
[20] Byrne K E and Mitchell S J 2012 Testing of WindFIRM/ForestGALES_BC: A hybrid-mechanistic model for predicting windthrow in partially harvested stands Forestry 86 185–199.
[21] Nizar M, Munir E, Munawar E and Irvan 2018 IOP Conf. Ser: Journal of Physics 1116(5) 052045
[22] Nizar M, Munir E, Irvan and Waller V 2018 IOP Conf. Ser: Earth and Environ. Sci. 216(1) 012043
[23] Octiva CS, Irvan, Sarah M, Trisakti B and Daimon H 2018 Rasayan J. Chem, 11(2) 791-797
[24] Yanqoritha N, Turmuzi M, Irvan, Fatimah, and Derlini 2018 Oriental Journal of Chemistry 34 (3) 1653-1657.
[25] Bani O, Taslim, Irvan and Iriany 2015 Journal of Engineering Science and Technology Special Issue 5 29-39