A HYBRID MODEL OF SYSTEM DYNAMICS AND GENETIC ALGORITHM TO INCREASE CRUDE PALM OIL PRODUCTION IN MALAYSIA

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Abstrak

Industri kelapa sawit di Malaysia sedang menghadapi perkembangan yang statik dalam pengeluaran minyak sawit mentah jika dibandingkan dengan Indonesia disebabkan tiga isu iaitu; (i) kekurangan kawasan tanaman; (ii) buruh yang terhad; dan (iii) peningkatan permintaan daripada industri biodiesel berasaskan minyak sawit. Dengan mengfokuskan isu tersebut, kajian terdahulu telah menggunakan pelbagai pendekatan. Walaubagaimanapun, penggunaan metod tanpa hibrid ini mempunyai beberapa kekurangan dan boleh ditambah baik dengan kaedah hibrid. Oleh itu, objektif kajian ini adalah untuk menentu pilihan polisi yang optimum bagi meningkatkan pengeluaran minyak sawit mentah di Malaysia. Dalam kajian ini, sebuah model hibrid sistem dinamik dan algoritma genetik telah dibangunkan untuk menentu polisi yang optimum bagi meningkatkan pengeluaran minyak sawit mentah di Malaysia. Lima pembolehubah polisi iaitu kadar penggunaan mesin, purata penanaman semula, mandat biodiesel di sektor pengangkutan, industri, dan 4 sektor yang relevan bagi mengenalpasti nilai polisi yang optimum. Lima pembolehubah polisi ini diuji dalam tiga scenario: tahun 2017, tahun 2020, dan berfasa sehingga tahun 2050. Daripada semua senario, optimisasi secara berfasa didapati paling berkesan dalam menghasilkan nilai pembolehubah polisi yang sesuai untuk mendapatkan pengeluaran minyak sawit mentah yang terbaik pada tahun 2050 setakat 20 larian populasi GA. Hybrid SD-GA melalui optimisasi secara berfasa mampu untuk mencadangkan polisi yang meyakinkan untuk dilaksana bagi mengelakkan kejutan yang tidak diingini kepada industri. Tambahan lagi, model hibrid ini juga berupaya untuk mengenalpasti pembolehubah polisi yang berkaitan dengan fungsi objektif pada sesuatu tempoh masa yang spesifik. Daripada perspektif pengurusan, kajian ini boleh membantu pihak pemegang taruh dalam industri minyak sawit ke arah pembuatan keputusan pelaburan yang lebih baik.

Kata kunci: Pengeluaran minyak sawit mentah, Sistem dinamik, Algoritma genetik, model hibrid SD-GA, polisi minyak sawit mentah

Abstract

Palm oil industry in Malaysia is facing a stagnant growth in terms of crude palm oil (CPO) production as compared to Indonesia due to three issues namely (i) the scarcity of plantation area, (ii) labour shortage, and (iii) the rising demand from palm-based biodiesel industry. Focusing on these issues, previous studies have been adopted various approaches. However, these non-hybridized methods have some shortcomings and can be improved by hybridization method. Hence, the objective of this research is to determine the optimal policy options to increase CPO production in Malaysia. In this research, a hybrid model of system dynamics (SD) and genetic algorithm (GA) was developed to determine the optimal policy in increasing the CPO production in Malaysia. Five policy variables namely mechanization adoption rate, average replanting, biodiesel mandates in transportation, industrial and 4 other relevant sectors were examined to determine optimal policy values. These five policy variables were tested in three scenarios: year 2017, year 2020, and in phases until 2050. From all the scenarios, the phase optimization emerged as the most effective in producing suitable policy variable values in order to obtain the best possible value of CPO production in year 2050 up to 20 GA population runs. The hybrid of SD-GA through phase optimization process is capable to recommend policies that are plausible to be implemented to avoid unwarranted shock to the industry. Furthermore, the hybrid model provides the ability of identifying the policy variables related to the objective function at any specific time line. From the managerial perspectives, this research helps the stakeholders in palm oil industry towards making a better future investment decision.

Keywords: Crude palm oil production, System dynamics, Genetic algorithm, SD-GA hybrid model, CPO policy

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List of Abbreviations

2SLS	Two Stage Least Squares
ABM	Agent-Based Modeling
AIDS	Acquired Immune Deficiency Syndrome
ARDL	Auto Regressive Distribution Lag
ARIMA	Auto Regressive Moving Average
CPO	Crude Palm Oil
DES	Discrete Event Simulation
DO	Dynamic Optimization
DSS	Decision Support System
EPP	Entry Point Project
ETP	Economic Transformation Program
GA	Genetic Algorithm
GHG	Green-House Gasses
GNI	Gross National Income
ISIS	Information Society Integrated System
MAPA	Malayan Agricultural Producers Association
MOO	Multiple Objective Optimization
MPOB	Malaysian Palm Oil Board
MSPO	Malaysian Sustainable Palm Oil
MyGAP	Malaysian Good Agricultural Practices
N2SLS	Nonlinear Two Stage Least Squares
NKEA	National Key Economic Area
OLS	Ordinary Least Squares
PPO	Processed Palm Oil
PRN	Partial Recurrent Network
RNN	Recurrent Neural Network
SCOR	Supply Chain Operational Reference
SD	System Dynamics
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution

VB	Visual Basics
VensimDLL	Vensim Direct Link Library

Publications

1. Shri-Dewi, A., Abidin, N. Z., Sapiri, H., & Zabid, M. F. M. (2015). Impact of various palm-based biodiesel blend mandates on Malaysian crude palm oil stock and price: a system dynamics approach. *Asian Social Sciences, 11* (25), 190-203.
2. Zabid, M. F. M., & Abidin, N. Z. (2015). Palm oil industry: a review of the literature on the modelling approaches and potential solution. In *AIP Conference Proceedings* (pp. 030004). AIP Publishing.
3. Zabid, M. F. M., Abidin, N. Z., & Shri-Dewi, A. (2017). Palm-based biodiesel blend mandate increase on the biodiesel industry growth in Malaysia: evidence from causal loop diagram. Manuscript submitted for publication.
4. Zabid, M. F. M., Abidin, N. Z., & Shri-Dewi, A. (2017). Towards improving oil palm fresh fruit bunches yield in Malaysia: a system dynamics approach. Accepted for publication in International Journal of Simulation and Process Modelling.
5. Zabid, M. F. M., Abidin, N. Z., Shri-Dewi, A. (2017). MYPOBDEX: an interactive decision support system for palm-based biodiesel investors. *International Journal of Economic Perspectives, 11* (1), 260-272.
6. Zabid, M. F. M., Abidin, N. Z., Shri-Dewi, A. (2017). Palm oil supply demand characteristics and behaviour: a system dynamics approach. Accepted for publication in Journal on Food, Agriculture and Society, Vol. 6 (2).

CHAPTER ONE
INTRODUCTION

Vegetable oils have been an important commodity in the world oils and fats market. In the recent decade, it has become the main substitutes of animal fats as the source of cooking oils and fats. Among the seven highly traded vegetable oil in the world market, palm oil has been significantly increased in terms of its production and consumption. This is hugely attributing to its economic viability in oil palm plantation and palm oil production vis-à-vis other vegetable oil. Currently, the world largest producer of palm oil is Indonesia followed by Malaysia, with the combination of these two countries the total production of palm oil contributes approximately eighty percent of the world palm oil production (MPOB, 2016; GAPKI, 2016).

1.1 Palm Oil Industry in Malaysia at a Glance

The important role of palm oil as one of the Malaysia's main economic contributor cannot be denied, as this industry has been studied from many perspectives. For instance in the general economic perspective (Shamsudin, Mohamed, & Arshad, 1988; Shamsudin, Arshad, Mohammad, & Rahman, 1995; Mohammad, Mohd Fauzi, & Ramli, 1999); palm-based biodiesel industry (Yahaya, Sabri, & Kennedy, 2006; Shri Dewi, Ali, & Alias, 2014; Azadeh, Arani, & Dashti, 2014); production planning (Tan & Fong, 1998; Nwawe, Akintola, Ikpi, & Rahji, 2008; Banitalebi, Aziz, Aziz, & Nasir, 2016); and environment (Diban, Aziz, Foo, Jia, Li, & Tan, 2016). Palm oil also is an important economic stimulus as there are many affiliates industries such as food, cosmetics and alternative fuel that also contribute to the economic growth in Malaysia. In 2016, a total of RM41.44 billion of export value was contributed by palm oil industry which accounts for 5.3 percent of total Malaysia's export value (MATRADE, 2017).

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REFERENCES

Abdulla, I., Arshad, F. M., Bala, B. K., Noh, K. M., & Tasrif, M. (2014). Impact of CPO export duties on Malaysian palm oil industry. *American Journal of Applied Sciences, 11* (8), 1301-1309.

Abdullah, R. (2012). An analysis of crude palm oil production in Malaysia. *Oil Palm Industry Economic Journal*, *12* (2).

Abdullah, R., & Wahid, M. B. (2011). World palm oil supply, demand, price and prospects: Focus on Malaysian and Indonesian palm oil industry. *Oil Palm Industry Industry Economic Journal*, *11*, 13-25.

Abdullah, R., Ismail, A., & Rahman, A. K. (2011). Labor requirements in the Malaysian oil palm industry in 2010. *Oil Palm Industry Economic Journal, 11* (2).

Acosta, L. A., Rounsevell, M. D., Bakker, M., Doorn, A. V., Gómez-Delgado, M., & Delgado, M. (2014). An agent-based assessment of land use and ecosystem changes in traditional agricultural landscape of Portugal. *Intelligent Information Management, 6*, 55-80.

Adnan, H. (2016, September 12). All systems go for B10 biodiesel; shoring up CPO prices, reducing stock seen. *The Star Online*. Retrieved from http://www.thestar.com.my/business/business-news/2016/09/12/all-systems-go-for-b10-biodiesel/

Akopov, A. S. (2012). Designing of integrated system dynamics models for an oil company. *International Journal of Computer Applications in Technology, 45* (4), 220-230.

Albi, E. G. (2009). *Metaheuristics: from design to implementation.* John Wiley & Sons.

Albin, S. (1997). Building a system dynamics model, part 1: Conceptualization. In *System Dynamics in Education Project, Report D-4597.* MIT.

Alborzi, M. (2008). Augmenting system dynamics with genetic algorithm and TOPSIS multivariate ranking module for multi-criteria optimization. *26th Intenational Conference of the System Dynamics Society.* Athens, Greece.

Amatzin, D. (2006). Labour constraints in the plantation industry. *Oil Palm Industry Economic Journal, 6* (2).

Arshad, F. M., & Hameed, A. A. (2012). Crude oil, palm oil stock and prices: How they link. *Review of Economics & Finance*.

Asari, F. F., Rahman, N. H., Razak, E. A., Ahmad, B. A., Harun, N. F., & Jusoff, K. (2011). A time series analysis of the relationship between total area planted, palm oil price and production of Malaysian palm oil. *World Applied Sciences Journal, 12,* 34-40.

Ayob, M. A., Abdullah, N., Aznor, S., & Latiff, Z. A. (2016). Push and pull factors of suburban local youth towards career in oil palm plantation. *International E-Journal of Advances in Social Sciences, 2* (4), 144-151.

Azadeh, A., Arani, H. V., & Dashti, H. (2014). A stochastic programming approach towards optimization of biofuel supply chain. *Energy, 76*, 513-525.

Balmann, A., Happe, K., Kellermann, K., & Kleingarn, A. (2002). Adjustment costs of agri-environment policy switchings: an agent-based analysis of the German region Hohenlohe. In M. Janssen, *Complexity and ecosystem management: the theory and practice of multi-agent systems* (pp. 127-157). Cheltenham, UK: Edward Elgar.

Banitalebi, A., Aziz, M. I., Aziz, Z. A., & Nasir, N. (2016). Modelling and Optimization for Palm Oil Plantation Management. *AIP Conference Proceedings 1750* (p. 030046). AIP Publishing.

Bank Indonesia. (2016). Inflation. Retrieved from http://www.bi.go.id

Baptista, M. L., Martinho, C. R., Lima, F., Santos, P. A., & Prendinger, H. (2014). Applying agent-based modeling to business simulations. *Developments in Business Simulation and Experiential Learning, 41*, 179-183.

Barnes, S., Golden, B., & Price, S. (2013). Applications of agent-based modeling and simulation to healthcare operations management. In *Handbook of healthcare operations management* (pp. 45-74). New York: Springer-Verlag.

Battiti, R., & Tecchioli, G. (1994). The reactive tabu search. *ORSA Journal on Computing, 6* (2), 126-140.

Bauer, S., & Kasnakoglu, H. (1990). Non-linear programming models for sector and policy analysis: Experiences with the Turkish agricultural sector model. *Economic Modeling, 7* (3), 275-290.

Beasley, D. (2000). Possible apllications of evolutionary computation. In T. Bäck, D. B. Fogel, & Z. M. (Eds.), *Evolutionary computation 1: basic algorithms and operators* (pp. 4-19). Bristol: Institute of Physic Publishing.

Bertsekas, D. P. (1999). *Nonlinear programming: 2nd edition.* Athena Scientific.

Beyer, H.-G., & Sendhoff, B. (2007). Robust optimization – A comprehensive survey. *Computer Methods in Applied Mechanics and Engineering, 196*, 3190–3218.

Bhowmik, B. (2010). Dynamic programming: Its principles, applications, strengths and limitations. *International Journal of Engineering Science and Technology, 2* (9), 4822-4826.

Bianchi, L., Dorigo, M., Gambardella, L. M., & Gutjahr, W. J. (2009). A survey on metaheuristics for stochastic combinatorial optimization. *Natural Computing: An International Journal, 8* (2), 239–287.

Blum, C., & Roli, A. (2003). Metaheuristics in ccombinatorial optimization: Overview and conceptual comparison. *ACM Computing Surveys, 35* (3), 268–308.

Bonabeau, E. (2001). Agent-based modeling: methods and techniques for simulating human systems. *Proceedings of National Academy of Sciences, 99,* (pp. 7280-7287).

Booker, L. B., Fogel, D. B., Whitley, D., Angeline, P., & Eiben, A. E. (2000). Binary strings. In T. Back, D. Fogel, & Z. Michalewicz, *Evolutionary computation 1: basics algorithms and operators* (pp. 256-307). Bristol: Institute of Physics Publishing.

Bouet, A., Estrades, C., & Laborde, D. (2012). Differential Export Taxes along the Oilseeds Value Chain: A Partial Equilibrium Analysis. *International Food Policy Research Institute (IFPRI) Discussion Paper 01236*. Retrieved from http://www.ifpri.org/blog/differential-export-taxes-along-oilseeds-value-chain

Bourg, D. M. (2006). Recipe13.7.programming a genetic algorithm for optimization. In D. M. Bourg, *Excel scientific and engineering cookbook* (pp. 385-400). Sebastopol, California: O'Reilly Media.

Branke, J., Kaußler, T., Smidt, C., & Schmeck, H. (2000). A multi-population approach to dynamic optimization problems. In *Evolutionary Design and Manufacture* (pp. 299-307). Springer, London.

Branke, J. (1999). *Evolutionary algorithms for dynamic optimization problems: a survey.* Karlsruhe, Germany: Institute AIFB, University of Karlsruhe.

Burke, E. K., & Kendall, G. (2005). *Search methodologies: introductory tutorials in optimization and decision support techniques.* New York: Springer.

Chen, Y. T., & Jeng, B. (2004). Policy Design by Fitting Desired Behavior Pattern for System Dynamics Models. *Proceedings of the 2004 International System Dynamics Conference.* Oxford, England.

Chen, Y.-T., Tu, Y.-M., & Jeng, B. (2011). A machine learning approach to policy optimization in system dynamics models. *System Research and Behavioural Science, 28,* 369-390. doi:10.1002/sres.1089

Cheng, S.-F., Lim, Y. P., & Liu, C.-C. (2009). An agent-based commodity trading simulation. *Proceedings of 8th International Conference in Autonomous Agents and Multiagent Systems,* (pp. 1377-1378). Budapest, Hungary.

Chidambar, A. (2016, December 5). Uptick in CPO prices to benefit Malaysian planters. *The Malaysian Reserve*. Retrieved from http://themalaysianreserve.com/new/story/uptick-cpo-prices-benefit-malaysian-planters

Chinneck, J. W. (2006). Heuristics for discrete search: genetic algorithms and simulated annealing. In J. W. Chinneck, *Practical optimization: a gentle introduction.* Ontario: Carleton University.

Choong, C. G., & McKay, A. (2014). Sustainability in the Malaysian palm oil industry. *Journal of Cleaner Production, 85*, 258-264.

Cobb, H. G. (1990). *An investigation into the use of hypermutation as an adaptive operator in genetic algorithms having continuous, time-dependent nonstationary environments (Technical Report AIC-90-001).* Washington, USA: Naval Research Laboratory.

Coyle, R. G. (1977). *Management system dynamics.* New York: John Wiley & Sons.

Coyle, R. G. (1985). The use of optimization methods for policy design in a system dynamics model. *System Dynamics Review, 1* (1), 81-91.

Cramb, R., & McCarthy, J. F. (2016). Introduction. In R. Cramb, & J. F. McCarthy, *The oil palm complex: smallholders, agribusiness and the state in Indonesia and Malaysia* (pp. 1-26). Singapore: NUS Press.

Dangerfield, B., & Roberts, C. (1999). Optimization as a statistical estimation tool: An example in estimating the AIDS treatment-free in dynamics model. *System Dynamics Review, 15* (3), 273-291.

Das, R., & Hanaoka, S. (2014). An agent-based model for resource allocation during relief distribution. *Journal of Humanitarian Logistics and Supply Chain Management, 4* (2), 265-285.

Das, S., Abraham, A., & Konar, A. (2009). *Metaheuristic clustering.* Chennai, India: Springer.

De Jong, K. (1975). *Analysis of behaviour of a class of genetic adaptive systems.* (Ph.D. thesis). University of Michigan.

Deep, K., & Thakur, M. (2007). A new mutation operator for real coded genetic algorithms. *Applied Mathematics and Computation, 193* (1), 211-230.

Department of Statistics Malaysia. (2016). *Consumer Price Index Malaysia*. Retrieved from http://www.dosm.gov.my

Diban, P., Aziz, M. K., Foo, D. C., Jia, X., Li, Z., & Tan, R. R. (2016). Optimal biomass plantation replanting policy using dynamic programming. *Journal of Cleaner Production, 126*, 409-418.

Doebelin, E. O. (1972). *System dynamics: modeling and response.* Merrill.

Duan, H. B., Xu, C. F., & Xing, Z. H. (2010). A hybrid artificial bee colony optimization and quantum evolutionary algorithm for continuous optimization problems. *International Journal of Neural Systems, 20* (1), 39-50.

Duggan, J. (2008). Using system dynamics and multi objective optimization to support policy analysis for complex systems. *Understanding Complex System*, 59-81.

Du, K. L., & Swamy, M. N. S. (2016). *Search and optimization by metaheuristics*. Springer

Economic Planning Unit. (2015). *Eleventh Malaysia plan: 2016 - 2020.* Putrajaya: Economic Planning Unit, Prime Minister's Department.

Eden, C. (1994). Cognitive mapping and problem structuring for system dynamics model building. *System Dynamics Review,* 257-276 .

Eksin, C. (2008). Genetic algorithm for multi-objective optimization in dynamics systems. *Proceedings of the 26th International System Dynamics Conference*, (p. 1).

Eshelman, L. J. (2000). Genetic algorithms. In T. Back, D. B. Fogel, & Z. Michalewicz, *Evolutionary computation 1: basic algorithms and operators* (pp. 64-74). Bristol: Institute of Physics Publishing.

Fazeeda, M., & Razman, M. T. (2012). Measuring palm oil mill capacity using modeling and simulation. *International Journal of Technology Management, 1*, 1-8.

Forrester, J. W. (1961). *Industrial dynamics.* Cambridge, Massachusetts: Productivity Press - MIT.

Forrester, J. W. (1980). *Conceptualization of a model to study market growth.* System Dynamics Group, Sloan School of Management, Massachusetts Institute of Technology.

Forrester, J., & Senge, P. (1980). Tests for building confidence in system dynamics model. *TIMS Studies in the Management Sciences, 14*, 209-228.

GAPKI. (2016). *Indonesia Palm Oil Statistics Data 2016*. Retrieved from Indonesian Palm Oil Association (GAPKI): https://gapki.id/ina-palm-oil-statistics-2016-full-year/

Geweke, J., Horowitz, J., & Pesaran, H. (2008). *Econometrics.* (S. N. Durlauf, & L. E. Blume, Eds.) doi:10.1057/9780230226203.0425

Ghaffarzadegan, N., Lyneis, J., & Richardson, G. P. (2011). How small system dynamics models can help the public policy process. *System Dynamics Review, 27* (1), 22-44.

Giraldo, D. P., Betancur, M. J., & Arango, S. (2008). Food security in development countries: A systemic perspective. *Proceedings of the 26th International Conference of the System Dynamics Society.* Athens, Greece.

Glover, F. (1989). Tabu search - Part 1. *ORSA Journal on Computing, 1* (2), 190–206. doi:10.1287/ijoc.1.3.190

Glover, F. (1990a). Tabu search - Part 2. *ORSA Journal on Computing, 2* (1), 4–32. doi:10.1287/ijoc.2.1.4

Glover, F. (1990b). Tabu search: A Tutorial. *INTERFACES, 20*, 74-94.

Glover, F., Taillard, E., & Werra, D. d. (1993). A user's guide to tabu search. *Annals of Operations Research, 41*, 3-28.

Goldberg, D. E. (1989). *Genetic algorithms in search, optimization and machine Learning.* United States of America: Addison-Wesley Publishing Company, Inc.

Graham, A. K., & Ariza, C. A. (2003). Dynamic, hard and strategic questions: Using optimization to answer a marketing resource allocation question. *System Dynamics Review, 19 (1)*, 27-46.

Granger, C. (2008). *Forecasting.* (S. N. Durlauf, & L. E. Blume, Eds.) doi:10.1057/9780230226203.0591

Greene, W. H. (2012). *Eonometric analysis seventh edition international edition.* (S. Yagan, Ed.) England: Pearson Education Limited.

Groesser, S. N., & Schaffernicht, M. (2012). Mental models of dynamic systems: taking stock and lookin ahead. *System Dynamics Review, 28* (1), 46-68.

Grossman, B. (2002). Policy optimization in dynamics models with genetic algorithm. *International System Dynamics Conference.* Palermo.

Hai, T. C. (2000). *Land use and the oil palm industry in Malaysia.* WWF Forest Information System Database. Retrieved from http://assets.panda.org/downloads/oplanduseabridged.pdf

Hamdar, B., & Hejase, H. (2012). Linear programming approach for credit need determination: Implications for extension program planning. *European Journal of Social Sciences, 32* (2), 216-224.

Hamzah, H. I., Ismail, A., Abdullah, R., Idris, K., Salleh, K. M., Ghani, E. A., . . . Hamzah, M. H. (2015). Impact of tax imposition on cost competitiveness of the Malaysian palm oil industry. *Oil Palm Industry Economic Journal, 15* (2), 11-20.

Hannah, L. A. (2015). Stochastic optimization. *International Encyclopaedia of the Social & Behavioral Sciences, 2*, 473-481.

Hasan, M. F., Reed, M. R., & Marchant, M. A. (2001). Effects of an export tax on competitiveness: The case of the Indonesian palm oil industry. *Journal Economic Development, 26* (2), 77-90.

Heckman, J. (2008). Econometric causality. *International Statistical Review, 76* (1), 1-27.

Heckman, J. (2010). Building bridges between the structural and program evaluation approach to evaluating policy. *Journal of Economic Literature, 48* (2), 356-398.

Hekimoglu, M., & Barlas, Y. (2010). Senstivity analysis of system dynamics models by behaviour pattern measures. *Proceedings of the 28th International Conference of the System Dynamics Society*. Seoul, Korea.

Henseler, M., Wirsig, A., Herrmann, S., Krimly, T., & Dabbert, S. (2009). Modeling the impact of global change on regional agricultural land use through an activity-based non-linear programming approach. *Agricultural Systems, 100* (1), 31-42.

Hussein, S. E., & El-Nasr, M. A. (2013). Resources allocation in higher education based on system dynamics and genetic algorithm. *International Journal of Computer Applications, 77*, 40-48.

INFORMS Computing Society. (2013). The nature of mathematical programming. Retrieved from http://glossary.computing.society.informs.org/index.php?page=nature.html

Ingber, L. (1993). Simulated annealing: Practice versus theory. *Mathematical and Computer Modelling, 18* (11), 29-57.

Ismail, A. (2013). The effect of labour shortage in the supply and demand of palm oil in Malaysia. *Oil Palm Industry Economic Journal, 13* (2), 15-26.

Ismail, A., Ahmad, S. M., & Sharudin, Z. (2015). Labour productivity in the Malaysian oil palm plantation sector. *Oil Palm Industry Economic Journal, 15* (2), 1-10.

Jahanpour, M. A., Afshar, A., & Alimohammadi, S. (2013). Optimum management of cyclic storage systems: A simulation-optimization approach. *Journal - American Water Works Association*, 671-683. doi:10.5942/jawwa.2013.105.0142

Jelani, A. R., Hitam, A., Jamak, J., Noor, M., Gono, Y., & Ariffin, O. (2008). Cantas - A tool for the efficient harvesting of oil palm fresh fruit bunches. *Journal of Oil Palm Research, 20*, 548-558.

Jensen, P. A. (2004). Models. Retrieved from http://www.me.utexas.edu/~jensen/ORMM/models/

Keloharju, R. (1977). Multi-objective decision models in system dynamics. *Dynamica, 3* (1), 3-13.

Keloharju, R., & Wolstenholme, E. F. (1988). The basic concept of system dynamics optimization. *Systems Practice, 1* (1), 65-86.

Khachaturyan, A., Semenovskaya, S., & Vainshtein, B. (1979). Statistical-thermodynamic approach to determination of structure amplitude phases. *Soviet Physics, Crystallography, 24* (5), 519–524.

Kirkpatrick, S., Gelatt, C. D., & Vecchi, M. P. (1983). Optimization by simulated annealing. *Science, 220 (4598)*, 671-680.

Koswanage, N. (2011, June 22). Growing labour shortage to hit Malaysia's palm oil output. Retrieved from http://www.reuters.com

Kuhn, H. W., & Tucker, A. W. (1951). Nonlinear programming. *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability* (pp. 481-492). Berkeley, California: University of California Press.

Kuo, C. H., Michel, A. N., & Gray, W. G. (1992). Design of optimal pump-and-treat strategies for contaminated groundwater remediation using the simulated annealing algorithm. *Advances in Water Resources, 15* (2), 95-105.

Lackner, M. R. (1962). Toward a general simulation capability. *Proceedings of the SJCC,* (pp. 1-14). San Francisco, California, 1-3 May 1962.

Lair, N. A., Chan, C. H., Chua, B. L., & Liew, W. Y. (2012). Application of simulation in process improvement of palm oil mill FFB production: A case study. *International Conference on Statistics in Science, Business, and Engineering (ICSSBE)* (pp. 1-5). Langkawi, Malaysia: IEEE. doi:10.1109/ICSSBE.2012.6396617

Lane, D. C. (2008). The emergence and use of diagramming in system dynamics: a critical account. *Systems Research and Behavioral Science, 25,* 3-23.

Larson, D. F. (1996). *Indonesia's palm oil subsector (Policy Research Working Paper No. 1654).* World Bank. Retrieved from http://documents.worldbank.org/curated/en/824561468751147284/Indonesias-palm-oil-subsector

Lestari, F., Ismail, K., Hamid, A. A., Supriyanto, E., Yanti, N., & Sutupo, W. (2014). Supply chain configuration using hybrid SCOR model and discrete event simulation. *Proceedings of the World Congress on Engineering 2014.* London, U. K.

Linard, K. T. (2000). Application of system dynamics to pavement maintenance optimisation. *1st International Conference on Systems Thinking in Management,* (pp. 347-352).

Lockwood, C., & Moore, T. (1993). Harvest scheduling with spatial constraints: A simulated annealing approach. *Canadian Journal of Forest Research, 23* (3), 468-478.

Lopez-Pujalte, C., Bote, V. P., & Anegon, F. D. (2002). A test of genetic algorithms in relevance feedback. *Information Processing and Management, 38,* 793-805.

Luenberg, D.G., & Yinyu, Y. (2008). *Linear and nonlinear programming (fourth edition).* New York: Springer.

Maani, K., & Cavana, R. Y. (2000). *System thinking and modeling: understanding change and complexity.* Pearson Education.

Macal, C. M., & North, M. J. (2008). Agent-based modeling and simulation: ABMS examples. *Proceedings of the 2008 Winter Simulation Conference,* (pp. 101-112).

Macedo, J. (1989). A reference approach for policy optimization in system dynamics models. *System Dynamics Review*, *5* (2), 148-175.

Maidstone, R. (2012). Discrete event simulation, system dynamics and agent based simulation: Discussion and comparison. *System*, 1-6.

Majid, M. A., Aickelin, U., & Siebers, P. O. (2009). Comparing simulation output accuracy of discrete event and agent based models: A quantitative approach. *Proceedings of the 2009 Summer Computer Simulation Conference*, (pp. 177-184).

Marks, S. V., Larson, D. F., & Pomeroy, J. (1998). Economic effects of taxes on exports of palm oil products. *Bulletin of Indonesian Economic Studies*, *42* (3), 7-58.

MATRADE. (2017). Top 10 Major Export Products, 2016. Retrieved from http://www.matrade.gov.my/en/28-malaysian-exporters/trade-statistics/3447-top-10-major-export-products-2016

Mayer, D. G., Belward, J. A., & Burrage, K. (1998). Tabu search not an optimal choice for models of agricultural systems. *Agricultural Systems*, *58* (2), 243-251.

Mayer, D., Belward, J. A., Burrage, K., & Stuart, M. A. (1995). Optimization of a dairy farm model - Comparison of simulated annealing, simulated quenching and genetic algorithms. *Proceedings 1995 International Congress on Modelling and Simulation*, (pp. 33-38). Newcastle.

McCall, J. (2005). Genetic algorithms for modeling and optimisation. *Journal of Computational and Applied Mathematics*, *184*, 205-222.

Meadows, D. (1970). *Dynamics of commodity production cycles.* Cambridge: Wright-Allen.

Meadows, D. H. (1980). The unavoidable a priori. *Elements of the System Dynamics Method*, 23-57.

Michalewicz, Z. (1994). *Genetic algorithms + data structures = evolution programs.* New York: Springer - Verlag Berlin Heidelberg.

Miller, J. H. (1998). Active nonlinear test (ANT) of complex simulation models. *Management Science, 44 (6)*, 820-830.

Mitchell, M. (1996). *An introduction to genetic algorithms.* London: The MIT Press.

Mohammad, H. A., Mohd Fauzi, M. J., & Ramli, A. (1999). Interactions between Malaysian and Indonesian palm oil industries: Simulating the impact of liberalization of imports of CPO from Indonesia. *Journal of Oil Palm Research*, *11* (2), 46-56.

Mohammadi, S., Arshad, F. M., & Ibragimov, A. (2016). Future prospects and policy implications for biodiesel production in Malaysia: A system dynamics approach. *Institutions and Economies, 8* (4), 42-57.

Mohapatra, P. K., & Sharma, S. K. (1985). Synthetic design of policy decisions in system dynamic models: A modal control theoretical approach. *System Dynamics Review, 1* (1), 63-80.

Morecroft, J. D. (2007). *Strategic modeling and business dynamics: a feedback system approach.* John Wiley & Sons.

Mori, N., Kita, H., & Nishikawa, Y. (1996). Adaptation to a changing environment by means of the thermodynamical genetic algorithm. In H. M. Voigt, *Parallel poblem solving from nature, volume 1141 of LNCS* (pp. 513-522). Springer.

MPIC. (2006). *National biofuel policy.* Ministry of Plantation Industries and Commodities (MPIC).

MPOB. (2016). Economics and industry development division Malaysian palm oil board. Retrieved from http://bepi.mpob.gov.my/

MPOC. (2015). Malaysia Palm Oil Council. Retrieved from http://www.mpoc.org.my/default.aspx

Murty, K. G., Wan, Y.-w., Liu, J., Tseng, M. M., Leung, E., Lai, K.-K., & Chiu, H. W. (2005). Hong Kong international terminals gains elastic capacity using a data-intensive decision-support system. *Interfaces, 35* (1), 61-75.

Murugan, S., Choo, J. K., & Sihombing, H. (2013). Linear programming for palm oil industry. *International Journal of Humanities and Management Sciences, 1* (3), 184-187.

Nguyen, T. T., Bouvarel, I., Ponchant, P., & van der Werf, H. M. (2012). Using environmental constraints to formulate low impact poultry feeds. *Journal of Cleaner Production, 28,* 215-224.

Noor, N., Rahman, S. A., & Sulaiman, N. S. (2007). *Meal planning model for nursery.* (Unpublished technical report).

Nordin, A. B., & Simeh, M. A. (2009). Recent development of Malaysian palm oil stock level. *Oil Palm Industry Economic Journal, 9* (1).

Nwauwa, L. O. (2012). Palm oil marketing and distribution pattern in Imo state, Nigeria: An application of linear programming model. *Journal of Agricultural Research and Development, 2* (1), 37-43.

Nwauwa, L. O., Adenegan, K. O., Rahji, M. A., & Awoyemi, T. T. (2016a). Optimal transportation and spatial integration of regional palm oil markets in Nigeria. *International Journal of Operation Research and Information Systems, 7* (2), 62-83.

Nwauwa, L. O., Adenegan, K. O., Rahji, M. A., & Olaniyi, O. Z. (2016b). Primal-dual links to spatial equilibrium market model for palm oil in Nigeria. *International Journal of Operations Research and Information Systems, 7* (1), 58-73.

Nwawe, C. N., Akintola, J. O., Ikpi, A. E., & Rahji, M. A. (2008). Optimum plans for oil palm and food crop combinations in Edo and Delta states of Nigeria: Application of recursive linear programming. *Journal of Agriculture, Forestry and the Social Science, 6* (1).

Obado, J., Syaukat, Y., & Siregar, H. (2009). The impacts of export tax policy on the Indonesian crude palm oil industry. *Journal International Society for Southeast Asian Agricultural Sciences, 15* (2), 107-119.

Oil World. (2017). Global supply, demand and price outlook for vegetable oils as well as for palm oil. Retrieved from https://www.oilworld.biz/t/sample/sample_34.pdf

Oil World. (2017). *Oil World.* Retrieved from Oil World: https://www.oilworld.biz/t/sample/sample_34.pdf

Olaya, C. (2014). The scientist personality of system dynamics. *Proceedings of the 32nd International Conference of the System Dynamics Society*.

Olaya, C. (2015). Cows, agency, and the significance of operational thinking. *System Dynamics Review, 31* (4), 183-219.

Oppacher, F., & Wineberg, M. (1999). The shifting balance genetic algorithm: improving the GA in a dynamic environment. *Genetic and Evolutionary Computation Conference, Volume 1* (pp. 504-510). Morgan Kaufmann.

Ossimitz, G., & Mrotzek, M. (2008). The basics of system dynamics: discrete vs, continuous modelling of time. *Proceedings of the 26th International Conference of the System Dynamics Society.*

Özveren, C. M., & Sterman, J. D. (1989). Control theory heuristics for improving the behaviour of economic models. *System Dynamics Review, 5* (2), 130-147.

PEMANDU. (2010). Deepening Malaysia's palm oil advantage. In PEMANDU, *Economic Transformation Programme: A Roadmap for Malaysia* (pp. 280-314). Performance Management and Delivery Unit (PEMANDU), Malaysia Prime Minister Department.

PEMANDU. (2015). *National transformation programme (NTP) annual report 2015.* Performance Management and Delivery Unit (PEMANDU), Malaysia Prime Minister Department.

PEMANDU. (2016, October). *POTS KL 2016: NKEA palm oil initiatives - updates.* Retrieved from http://www.youtube.com

Pereira, A. J., & Saraiva, J. T. (2011). Generation expansion planning (GEP) - A long-term approach using system dynamics and genetic algorithms (GAs). *Energy, 36* (8), 5180-5199.

Pesaran, H., & Smith, R. P. (2012). *Counterfactual analysis in macroeconometrics: an empirical investigation into the effects of quantitative easing.* IZA Discussion Paper No. 6618.

Porter, B. (1969). *Synthesis of dynamical systems.* Newton, J. J.: Nelson.

Raghu, A. (2014, April 27). Labour crunch hurts Malaysian palm oil growers as Indonesians stay home. Retrieved from http://www.reuters.com

Rahman, A. K., Abdullah, R., & Shariff, F. M. (2012). The economic impact of the north-east monsoon and La Niña on oil palm production in Malaysia. *Oil Palm Industry Economic Journal, 12* (2).

Rahman, A. K., Abdullah, R., Balu, N., & Shariff, F. M. (2013). The impact of La Niña and El Niño events on crude palm oil prices: An econometric analysis. *Oil Palm Industry Economic Journal, 13* (2), 38-51.

Rahman, A. K., Abdullah, R., Simeh, M. A., Shariff, F. M., & Jaafar, H. (2011). Strenghtening the Malaysia palm oil-based biodiesel industry: Solving current issues and impact on CPO prices. *Oil Palm Industry Economic Journal, 11* (1).

Rahman, A. K., Balu, N., & Shariff, F. M. (2013). Impact of palm oil supply and demand on palm oil price behaviour. *Oil Palm Industry Economic Journal, 13* (1).

Rahman, R. A. (2014). *Evolutionary algorithms with average crossover and power heuristics for aquaculture diet formulation.* (Unpublished Ph.D. thesis). Universiti Utara Malaysia.

Ramli, A., Abas, R., & Ayatollah. (2007). Impact of palm oil-based biodiesel demand on palm oil price. *Oil Palm Industry Economic Journal, 7* (2), 19-27.

Randers, J. (1980). Elements of the system dynamics method. Portland: Productivity Press.

Razali, S. N. (2011). *Menu planning system for Malaysian boarding school using self-adaptive hybrid genetic algorithms.* (Unpublished Ph.D. thesis). Universiti Utara Malaysia.

Reeves, C., & Rowe, J. (2003). *Genetic algorithm: principles and perspectives - a guide to GA theory*. Kluwer Academic Publisher.

Render, B., Stair, R. M., & Hanna, M. E. (2011). *Quantitative Analysis for Management, Global Edition.* Pearson Education Limited.

Richardson, G. P. (1999). *Feedback Thought in Social Science and Systems Theory.* Waltham, MA: Pegasus Communications.

Rifin, A. (2010). The effect of export tax on Indonesia's crude palm oil (CPO) export competitiveness. *ASEAN Economic Bulletin, 27* (2), 173-184.

Rifin, A. (2014). The effect of progressive export tax on Indonesian palm oil industry. *Oil Palm Industry Economic Journal, 14* (1), 1-8.

Roling, P. C., & Visser, H. G. (2008). Optimal airport surface traffic planning using mixed-integer linear programming. *International Journal of Aerospace Engineering, 1*, 1-11.

Sahman, M. A., Cunkas, M., Inal, S., Inal, F., Coskun, B., & Taskiran, U. (2009). Cost optimization of feed mixes by genetic algorithms. *Advances in Engineering Software, 40*, 965-974.

Satsangi, P. S., Mishra, D. S., Gaur, S. K., Singh, B. K., & Jain, D. K. (2003). System dynamics modeling, simulation and optimization of integrated urban systems: A soft computing approach. *Kybernetes, 32 (5/6)*, 808-817. doi:10.1108/03684920210443879

Saxena, P. (2011). *Animal diet formulation using nonlinear programming: an innovative approach.* Lambert Academic Publishing.

Schelling, T. C. (1971). Dynamics models of segregation. *Journal of Mathematical Sociology, 1* (2), 143-186.

Schreinemachers, P., Berger, T., Sirijinda, A., & Praneetvatakul, S. (2009). The diffusion of greenhouse agriculture in northen Thailand: Combining econometrics and agent-based modeling. *Canadian Journal of Agricultural Economics*, *57*, 513-536.

Schrijver, A. (1998). *Theory of linear and integer programming.* John Wiley & Sons.

Selvi, V., & Umarani, R. (2010). Comparative analysis of ant colony an particle swarm optimization techniques. *International Journal of Computer Applications, 5 (4)*, 1-6.

Senteri, Z. (1988). An econometric analysis of the United States' palm oil market. *Jurnal Ekonomi Malaysia, 18*, 85-105.

Shamsudin, M. N., Arshad, F. M., Mohammad, Z. A., & Rahman, A. (1995). Modeling the Malaysian Palm Oil Market: Some Theoretical and Empirical Issues.

Shamsudin, M. N., Mohamed, Z., & Arshad, F. M. (1988). Selected factors affecting palm oil prices. *Malaysian Journal of Agriculture Economics, 5*.

Sharief, S., Eldho, T., & Rastogi, A. (2008). Elitist GA based evolutionary algorithm for groundwater contaminant remediation using pump and treat method. *Proceedings of the 12th International Conference of International Association Methods and Advances in Geomechanics (IACMAG)*, (pp. 2505-2512). Goa, India.

Shri Dewi, A., Abidin, N. Z., Sapiri, H., & Zabid, M. F. (2015). Impact of various palm-based biodiesel blend bandates on Malaysian crude palm oil stock and price: A system dynamics approach. *Asian Social Sciences, 11* (25), 190-203.

Shri Dewi, A., Ali, A. M., & Alias, M. H. (2014). Impact of biodiesel blend mandate (B10) on the Malaysian palm oil industry. *Jurnal Ekonomi Malaysia, 48* (2), 29-40.

Shri Dewi, A., Arshad, F. M., Shamsudin, M. N., & Hameed, A. A. (2011a). An econometric analysis of the link between biodiesel demand and Malaysian palm oil market. *International Journal of Business and Management, 6* (2).

Shri Dewi, A., Arshad, F. M., Shamsudin, M. N., & Yusop, Z. (2009). The impact of biodiesel demand on the Malaysian palm oil market. *Prosiding Perkem IV*, (pp. 566-576). Kuantan, Pahang.

Shri Dewi, A., Arshad, F. M., Shamsudin, M. N., & Yusop, Z. (2010). The impact of biodiesel demand on the Malaysian palm oil market: A combination of econometric and system dynamics approach. *International Conference on Business and Economic Research (ICBER).* Kuching, Sarawak.

Shri Dewi, A., Arshad, F. M., Shamsudin, M. N., & Yusop, Z. (2011b). The relationship between petroleum prices, biodiesel demand and Malaysia palm oil prices: Evidence from simultaneous equations approach. *Banwa Journal*.

Shri Dewi, A., Arshad, F. M., Yusop, Z., Shamsudin, M. N., & Alias, M. H. (2011b). Impact of biodiesel demand on the Malaysian palm oil industry: A simultaneous equations approach. *IJMS, 18*, 73-90.

Siebers, P. O., Macal, C. M., Garnett, J., Buxton, D., & Pidd, M. (2010). Discrete-event simulation is dead, long live agent-based simulation! *Journal of Simulation, 4 (3)*, 204-210.

Silvia, V., Muhammad, S., Masbar, R., & Nasir, M. (2016). Optimization of smallholder palm oil in Nagan Raya and Aceh Tamiang Aceh province. *International Journal of Contemporary Applied Sciences, 3* (4), 1-17.

Skraba, A., Stanovov, V., Semenkin, E., & Kofjac, D. (2016). Hybridization of stochastic local search and genetic algorithm for human resource planning management. *Organizacija, 49*, 42-54. doi:10.1515/orga-2016-0005

Spears, W. M., & Jong, K. A. (1991). An analysis of multi-point crossover. In G. E. Rowlins, *Foundations of genetic algorithms* (pp. 301-315). San Francisco: Morgan-Koufmann.

Sterman, J. D. (1984). Appropriate summary statistics for evaluating the historical fit of system dynamics models. *Dynamica, 10*, 51-66.

Sterman, J. D. (2000). *Business dynamics: system thinking and modeling for a complex world.* Boston, MA: Irwin McGraw-Hill.

Suksaard, C., & Raweewan, M. (2013a). Optimization of supply and demand balance in a palm oil supply chain. *Thammasat International Journal of Science and Technology, 18* (2), 14-31.

Suksaard, C., & Raweewan, M. (2013b). Land allocation and transportation network planning for crude palm oil production in Thailand. *Proceedings of the 4th International Conference on Engineering, Project, and Production Management*, (pp. 795-805).

Susila, W. R. (2004). Impacts of CPO-export tax on several aspects of Indonesian CPO industry. *Oil Palm Industry Economic Journal*, *4* (2), 1-13.

Talib, B. A., & Darawi, Z. (2002). An economic analysis of the Malaysian palm oil market. *Oil Palm Industry Economic Journal*, *2* (1).

Talib, B. A., Mohd, F., Mohd, J., Mohd, N., & Rosli, Z. (2007). Impact assessment of liberalizing trade on Malaysian crude palm oil. *Oil Palm Industry Economic Journal, 7*, 9-17.

Tan, L. P., & Fong, C. O. (1988). Determination of the crop mix of a rubber and oil palm plantation - A programming approach. *European Journal of Operational Research, 34*, 362-371.

Taylor, B. W. (2007). *Introduction to management science.* New Jersey: Pearson Education.

Thamilselvan, R., & Balasubramanie, P. (2012). Integrating genetic algorithm, tabu search and simulated annealing for job shop scheduling problem. *International Journal of Computer Applications, 48* (5), 42-54.

The Guardian. (2015, December 12). Paris climate deal: nearly 200 nations sign in end of fossil fuel era. *The Guardian*. Retrieved from https://www.theguardian.com

The Star. (2015, April 15). Malaysia cuts May crude palm oil export taxes to zero. *The Star Online*. Retrieved from http://www.thestar.com.my

The Star. (2016a, February 12). Malaysia crude palm oil export tax May resume in March. *The Star Online*. Retrieved from http://www.thestar.com.my

The Star. (2016b, November 16). Implementation of B10, B7 biodiesel deferred. *The Star Online*. Retrieved from http://www.thestar.com.my

Tsutsui, S., Fujimoto, Y., & Ghosh, A. (1997). Forking genetic algorithms: GAs with search space division schemes. *Evolutionary Computation, 5* (1), 61-80.

Ursem, R. K. (1999). Multinational evolutionary algorithms. *Proceedings of the Congress of Evolutionary Computation*, (pp. 1633-1640).

USDA. (2015). *Malaysia global agriclutural information network (GAIN) annual biofuel report.* USDA Foreign Agricultural Services.

Utama, D. N., Djatna, T., Hambali, E., Marimin, & Kusdiana, D. (2012). Multi objectives fuzzy ant colony optimization design of supply path searching. *Journal of Computer Science and Information, 5* (2), 89-97.

Valizadeh, M., Syafiie, S., & Ahamad, I. S. (2014). Optimal planning of biodiesel supply chain using a linear programming model. *Proceedings of the 2014 IEEE* (pp. 1280-1284). IEEM.

Vavak, F., Jukes, K., & Fogarty, T. C. (1997). Adaptive combustion balancing in multiple burner boiler using a genetic algorithm with variable range of local search. *Seventh International Conference on Genetic Algorithms*, (pp. 719-726).

Wagner, D. B. (1995). Dynamic programming. *The Mathematica Journal, 5* (4), 42-51.

Wahid, M. B., & Simeh, M. A. (2010). Accelerated oil palm replanting: The way forward for a sustainable and competitive industry. *Oil Palm Industry Economic Journal, 10* (2), 29-38.

Wahid, M. B., Abdullah, R., & Shariff, F. M. (2010). Lesson learned from sustaining remunerative palm oil prices - The Malaysian experience. *Oil Palm Industry Economic Journal, 10* (1).

Wolstenholme, E. F. (1986). Algorithmic control modules for system dynamics models. *System Dynamics Review, 2* (1), 1-19.

Wolstenholme, E. F., & Al-Alusi, A. S. (1987). System dynamics and heuristics optimization in defence analysis. *System Dynamics Review, 3* (2), 102-115.

Worldbank. (2016). Commodity markets. Retrieved from http://www.worldbank.com

Xie, Y., & Peng, Q. (2012). Integration of value stream mapping and agent-based modeling for OR improvement. *Business Process Management Journal, 18* (4), 585-599.

Yahaya, J., Sabri, A., & W. Kennedy, S. (2006). Impacts of biodiesel development on the palm oil industry. *Malaysian Journal of Economic Studies, 43* (1 & 2).

Yasarcan, H. (2003). *Feedbacks, delays and non-linearities in decision structures.* (Ph.D. thesis). Industrial Engineering Department Istanbul Bogazici University.

Yean, G. P., & Zhidong, L. (2014). Econometric study on Malaysia's palm oil position in the world market to 2035. *Renewable and Sustainable Energy Reviews, 39*, 740-747.

Yu, S., & Wei, Y. M. (2012). Prediction of China's coal production-environmental pollution based on a hybrid genetic algorithm-system dynamics model. *Energy Policy, 42*, 521-529.

Yücel, G., & Barlas, Y. (2007). Pattern based system design/optimization. *Proceedings of the 25th International Conference of the System Dynamics Society.* Boston.

Yusoff, M. H., Abdullah, A. Z., Sultana, S., & Ahmad, M. (2013). Prospect and current status of B5 biodiesel implementation in Malaysia. *Energy Policy, 62*, 456-462.

Zante, d. F., Hertog, D. d., Berg, F. J., & Verhoeven, J. H. (2007). The Netherlands schedules track maintenance to improve track worker's safety. *Interfaces, 37* (2), 133-142.

APPENDIX

APPENDIX A: Palm Oil Supply Demand Sub-Model Equations

Average OER= 0.22
Units: Dmnl

Base CPO export demand growth= 3
Units: 1/Year

Base CPO import=
60000+RAMP(200000,0,3)+RAMP(80000,3,5)+RAMP(500,5,8)+RAMP(400000,8,11)+RAMP(5000,11,70)
Units: Tonne/Year

Base PPO export demand growth= 0.201
Units: 1/Year

Base PPO local demand growth= 0.155
Units: 1/Year

Biodiesel production= INTEG (Biodiesel production rate, 0)
Units: Tonne

CPO demand for biodiesel= Biodiesel production
Units: Tonne

CPO demand for PPO=Total PPO demand
Units: Tonne

CPO excess stock=Total CPO supply-Total CPO demand
Units: Tonne

CPO export demand= INTEG (CPO export demand change,400000)
Units: Tonne

CPO export demand change=
CPO export demand*Base CPO export demand growth*Factor affecting CPO export demand
Units: Tonne/Year

CPO export tax=
STEP(Lookup for CPO tax structure(CPO price),13)
Units: Dmnl

CPO import= INTEG (CPO import change, 46000)
Units: Tonne

CPO import change= Base CPO import*Effect of SB price on CPO import-CPO import
Units: Tonne/Year

CPO price= INTEG (CPO price change, 990)
Units: RM

CPO price change= Indicated CPO price/Time for CPO price adjustment
Units: RM/Year

CPO price influence on CPO export demand=
Lookup for effect of CPO price on CPO export demand (Relative CPO price on export demand)
Units: Dmnl

CPO production= INTEG (CPO production rate, 1e+007)
Units: Tonne

CPO production rate=
(Average OER*Total FFB yield-CPO production)/Time to adjust CPO production
Units: Tonne/Year

CPO supply demand ratio= Total CPO supply/Total CPO demand
Units: Dmnl

Effect of CPO export tax on demand=
1+STEP(-1+Lookup for effect of CPO export tax on CPO export(CPO export tax /Reference CPO export tax),13)
Units: Dmnl

Effect of CPO supply demand ratio on CPO price=
Lookup for effect of CPO SD on CPO price(Relative SD ratio)
Units: RM

Effect of SB price on CPO import=
(Soybean oil price/Reference soybean oil price)^Sensitivity of soybean oil price on CPO import
Units: Dmnl

Factor affecting CPO export demand=
CPO price influence on CPO export demand*Soybean oil price influence on CPO export demand*Effect of CPO export tax on demand
Units: Dmnl

Factor affecting PPO export demand=
PPO price influence on PPO export demand*Soybean oil price influence on PPO export
Units: Dmnl

Factor affecting PPO local demand=
PPO price influence on PPO local demand*SBO price influence on PPO local demand
Units: Dmnl

Historical soybean oil prices= Lookup for historical SBO prices (Time)
Units: USD/Tonne

Indicated CPO price= Effect of CPO supply demand ratio on CPO price

Units: RM

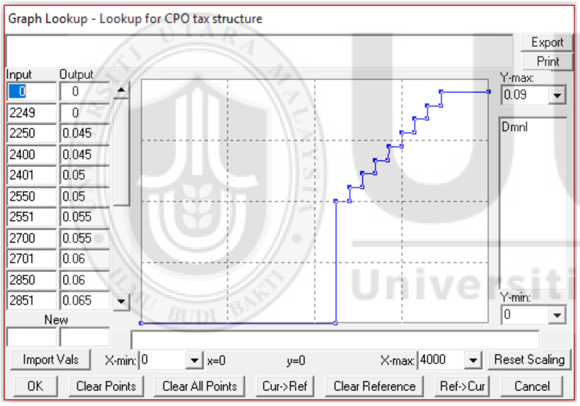
Initial CPO price references on CPO export demand= 3500
Units: RM

Initial PPO prices on PPO export demand= 3500
Units: RM

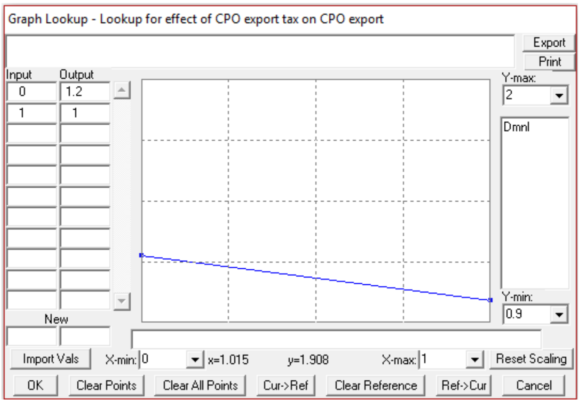
Initial reference CPO SD ratio= 1.5
Units: Dmnl

Initial reference PPO price on PPO local demand= 3500
Units: Dmnl

Lookup for CPO tax structure(
[(0,0)-(4000,0.09)],(0,0),(2249,0),(2250,0.045),(2400,0.045),(2401,0.05),(2550,0.05),(2551,0.055),(2700,0.055),(2701,0.06),(2850,0.06),(2851,0.065),(3000,0.065),(3001,0.07),(3150,0.07),(3151,0.075),(3300,0.075),(3301,0.08),(3450,0.08),(3451,0.085),(4000,0.085))
Units: Dmnl

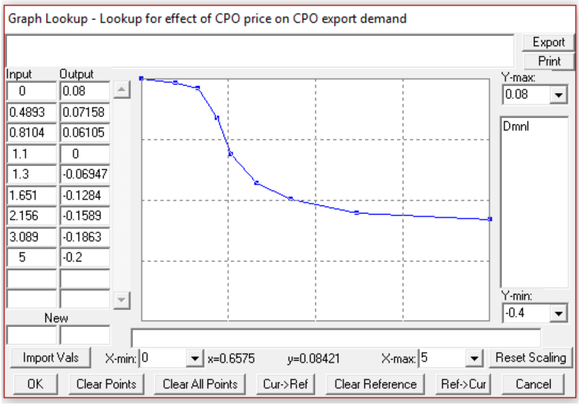


Lookup for effect of CPO export tax on CPO export(
[(0,0.9)-(1,2)],(0,1.05),(1,1))
Units: Dmnl

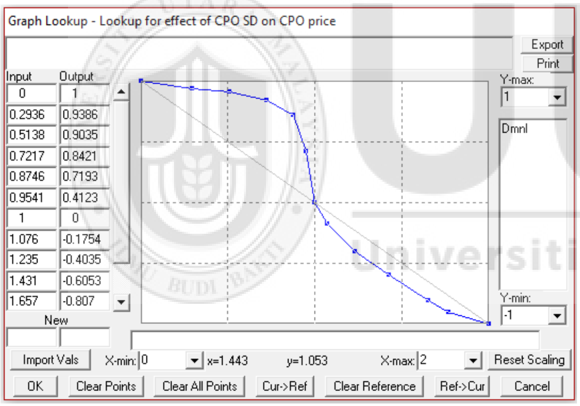


Lookup for effect of CPO price on CPO export demand(

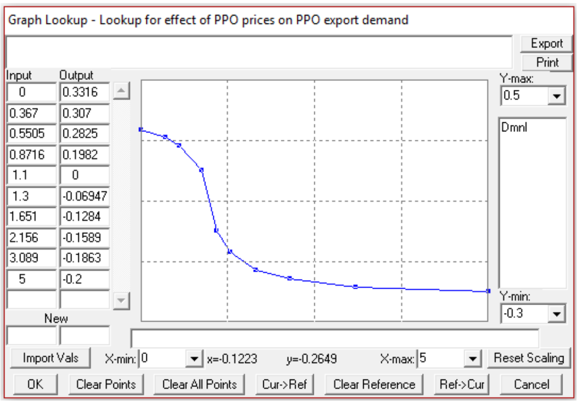
[(0,-0.4)-(5,0.08)],(0,0.08),(0.489297,0.0715789),(0.810398,0.0610526),(1.1,0),(1.29969,-0.0694737),(1.65138,-0.128421),(2.15596,-0.1589),(3.08869,-0.1863),(5,-0.2))
Units: Dmnl



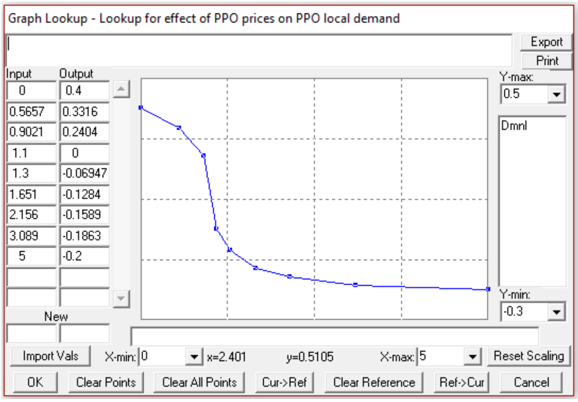
Lookup for effect of CPO SD on CPO price(
[(0,-1)-(2,1)],(0,1),(1,0),(2,-1)],(0,1),(0.293578,0.938596),(0.513761,0.903509),(0.721713,0.842105),(0.874618,0.719298),(0.954128,0.412281),(1,0),(1.07645,0.175439),(1.23547,-0.403509),(1.43119,-0.605263),(1.65749,-0.807018),(1.7737,-0.903509),(2,-1))
Units: Dmnl



Lookup for effect of PPO prices on PPO export demand(
[(0,-0.3)-(5,0.5)],(0,0.331579),(0.366972,0.307018),(0.550459,0.282456),(0.87156,0.198246),(1.1,0),(1.29969,-0.0694737),(1.65138,-0.128421),(2.15596,-0.1589),(3.08869, -0.1863),(5,-0.2))
Units: Dmnl



Lookup for effect of PPO prices on PPO local demand(
[(0,-0.3)-(5,0.5)],(0,0.4),(0.565749,0.331579),(0.902141,0.240351),(1.1,0)
,(1.29969,-0.0694737),(1.65138,-0.128421),(2.15596,-0.1589),(3.08869,-0.1863),(5,-0.2))
Units: Dmnl



PPO export demand= INTEG (PPO export demand change, 9e+006)
Units: Tonne

PPO export demand change=
Factor affecting PPO export demand*Base PPO export demand growth*PPO export demand
Units: Tonne/Year

PPO local demand= INTEG (PPO local demand change, 1.2e+006)
Units: Tonne

PPO local demand change=
Factor affecting PPO local demand*Base PPO local demand growth*PPO local demand
Units: Tonne/Year

PPO price= 1.03*CPO price
Units: RM

PPO price influence on PPO export demand=
Lookup for effect of PPO prices on PPO export demand (Relative PPO prices on export demand)
Units: Dmnl

PPO price influence on PPO local demand=
Lookup for effect of PPO prices on PPO local demand (Relative PPO prices on local demand)
Units: Dmnl

Reference CPO export tax= 0.045
Units: Dmnl

Reference CPO price on CPO export demand=

SMOOTH3I(CPO price,Time for CPO price references on CPO export demand,Initial CPO price references on CPO export demand)
Units: RM

Reference CPO SD ratio=
SMOOTH3I(CPO supply demand ratio, Time to perceived CPO SD ratio, Initial reference CPO SD ratio)
Units: Dmnl

Reference PPO price on PPO export demand=
SMOOTH3I(PPO price,Time for PPO price references on PPO export demand,Initial PPO prices on PPO export demand)
Units: RM

Reference PPO price on PPO local demand=
SMOOTH3I(PPO price,Time for PPO price references on PPO local demand,Initial reference PPO price on PPO local demand)
Units: RM

Reference soybean oil price= 980
Units: USD/Tonne

Relative CPO price on export demand=
CPO price/Reference CPO price on CPO export demand
Units: Dmnl

Relative PPO prices on export demand=
PPO price/Reference PPO price on PPO export demand
Units: Dmnl

Relative PPO prices on local demand=
PPO price/Reference PPO price on PPO local demand
Units: Dmnl

Relative SD ratio=
CPO supply demand ratio/Reference CPO SD ratio
Units: Dmnl

SBO price influence on PPO local demand=
(Soybean oil price/Reference soybean oil price)^Sensitivity of SBO prices on PPO local demand
Units: Dmnl

Sensitivity of SBO prices on PPO local demand= 0.479
Units: Dmnl

Sensitivity of soybean oil price on CPO import= 0.1
Units: Dmnl

Sensitivity of soybean oil price on PPO export demand= 0.004
Units: Dmnl

Sensitivity of soybean oil prices on CPO export demand= 0.9
Units: Dmnl
0.001

Soybean oil price= DELAY3(Historical soybean oil prices, 3)
Units: USD/Tonne

Soybean oil price influence on CPO export demand=
(Soybean oil price/Reference soybean oil price)^Sensitivity of soybean oil prices on CPO export demand
Units: Dmnl

Soybean oil price influence on PPO export=
(Soybean oil price/Reference soybean oil price)^Sensitivity of soybean oil price on PPO export demand
Units: Dmnl

Time for CPO price adjustment= 2
Units: Year

Time for CPO price references on CPO export demand= 5
Units: Year

Time for PPO price references on PPO export demand= 5
Units: Year

Time for PPO price references on PPO local demand= 5
Units: Year

Time to adjust CPO production= 1
Units: Year

Time to perceived CPO SD ratio= 5
Units: Year

Total CPO demand= CPO demand for PPO+CPO export demand + CPO demand for biodiesel
Units: Tonne

Total CPO supply= CPO production + CPO import
Units: Tonne

Total FFB yield=
Effect of labour on FFB yield*SMOOTH (Effect of adverse weather on FFB yield 4) *(Mature area yield + Ageing area yield)
Units: Tonne

Total PPO demand= PPO export demand + PPO local demand
Units: Tonne

APPENDIX B: Oil Palm Plantation Sub-Model Equations

Ageing area= INTEG (Ageing rate-Cutting rate, 1e+006)
Units: Hectare

Ageing area yield= Ageing area*Avg yield per ha for ageing area
Units: Tonne

Ageing period= 20
Units: Year

Ageing rate=
Fraction of ageing rate + (Initial mature area/Ageing period)*PULSE(0,20)
Units: Hectare/Year

Avg new planting= 150000
Units: Hectare

Avg replanting= 50000
Units: Hectare

Avg yield per ha for ageing area= 19
Units: Tonne/Hectare

Avg yield per ha for mature area= 25
Units: Tonne/Hectare

CPO price effect on replanting=
Lookup for CPO price effect on replanting (Relative CPO price on replanting)
Units: Dmnl

Cutting rate= MIN(Ageing area, Replanting)/Time for cutting
Units: Hectare/Year

Effect of adverse weather on FFB yield=
1+(-0.1*PULSE(0, 1))+(-0.1*PULSE(4, 1))+(-0.1*PULSE(8, 1))+(-0.1*PULSE(12, 1))+(-0.1*PULSE(16, 1))+(-0.1*PULSE(20, 1))+(-0.1*PULSE(24, 1))+(-0.1*PULSE(28, 1))+(-0.1*PULSE(32, 1))+(-0.1*PULSE(36, 1))+(-0.1*PULSE(40, 1))+(-0.1*PULSE(44, 1))+(-0.1*PULSE(48, 1))+(-0.1*PULSE(52, 1))+(-0.1*PULSE(56, 1))+(-0.1*PULSE(60, 1))+(-0.1*PULSE(64, 1))
Units: Dmnl

Effect of labour on FFB yield=
Lookup for effect of labour on FFB yield(Relative labour land ratio)
Units: Dmnl

Effect of land availability on expansion plan=
Lookup for effect of land availability on expansion plan(Ratio of potential land for oil palm plantation)
Units: Dmnl

FFB yield per ha= Total FFB yield/Total plantation area

Units: Tonne/Hectare

Fraction of ageing rate= DELAY FIXED(Maturity rate, Ageing period , 0)
Units: Hectare/Year

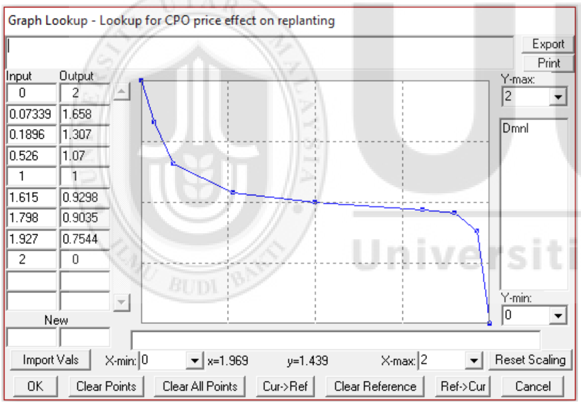
Fraction of maturity rate= DELAY FIXED(Planting rate, Maturity period , 0)
Units: Hectare/Year

Initial CPO price references on replanting=
5000
Units: Tonne

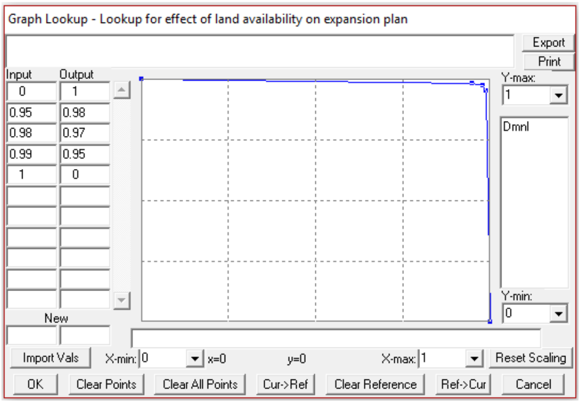
Initial mature area= 2e+006
Units: Hectare

Initial premature area= 300000
Units: Hectare

Lookup for CPO price effect on replanting (
[(0,0)-(2,2)],(0,2),(0.0733945,1.65789),(0.189602,1.30702),(0.525994,1.07018),(1,1),(1.61468,0.929825),(1.79817,0.903509),(1.92661,0.754386),(2,0))
Units: Dmnl



Lookup for effect of land availability on expansion plan(
[(0,0)-(1,1)],(0,1),(0.95,0.98),(0.98,0.97),(0.99,0.95),(1,0))
Units: Dmnl



Mature area= INTEG (Maturity rate-Ageing rate, Initial mature area)
Units: Hectare

Mature area yield= Mature area*Avg yield per ha for mature area
Units: Tonne

Maturity period=3
Units: Year

Maturity rate=
Fraction of maturity rate+(Initial premature area/Maturity period)*PULSE(0,3)
Units: Hectare/Year

Max land available= 6e+006
Units: Hectare

Motivation to replant= CPO price effect on replanting
Units: Dmnl

New planting=
MIN(Effect of land availability on expansion plan*Avg new planting, Vacant land)
Units: Hectare

Planting rate= (New planting + Replanting)/Time for planting
Units: Hectare/Year

Premature area= INTEG (Planting rate-Maturity rate,Initial premature area)
Units: Hectare

Ratio of potential land for oil palm plantation= Total plantation area/Max land available
Units: Dmnl

Reference CPO price on replanting=
SMOOTH3I(CPO price, Time for CPO price references on replanting, Initial CPO price references on replanting)
Units: RM

Relative CPO price on replanting= CPO price/Reference CPO price on replanting
Units: Dmnl

Replanting= MIN(Motivation to replant*Replanting rate, Ageing area)
Units: Hectare

Replanting rate=
50000+STEP(Avg replanting-50000,Year of replanting change-2000)
Units: Hectare

Time for CPO price references on replanting= 5
Units: Year

Time for cutting= 1
Units: Year

Time for planting= 1
Units: Year

Total FFB yield=
Effect of labour on FFB yield*SMOOTH(Effect of adverse weather on FFB yield, 4)*(Mature area yield + Ageing area yield)
Units: Tonne

Total plantation area= Premature area + Mature area + Ageing area
Units: Hectare

Total productive area= Mature area + Ageing area
Units: Hectare

Vacant land= MAX(Max land available-Total plantation area,0)
Units: Hectare

Year of replanting change= 2017
Units: Year

APPENDIX C: Palm-Based Biodiesel Sub-Model Equations

Biodiesel demand in industrial sector=
Total diesel use in industrial sector*Biodiesel mandate for industrial sector *STEP(1,16)
Units: Tonne

Biodiesel demand in other sector=
Total diesel use in other sector*Biodiesel mandate for other sector
Units: Tonne

Biodiesel demand in transport sector=
Biodiesel mandate for transport sector*Total diesel use on road
Units: Tonne

Biodiesel export= 100000
Units: Tonne

Biodiesel mandate for industrial sector=
STEP(0.07,16)+ STEP(Current biodiesel mandate for industrial sector-0.07, Year of biodiesel mandate for industrial sector implementation-2000)
Units: Dmnl

Biodiesel mandate for other sector=
STEP(Current biodiesel mandate for other sector, Year of biodiesel mandate for other sector implementation-2000)
Units: Dmnl

Biodiesel mandate for transport sector=
STEP(0.05,11)+STEP(0.07-0.05,14)+STEP(0.1-0.07,16)+STEP(Current biodiesel mandate for transport sector-0.1, Year of biodiesel mandate for transport sector implementation-2000)
Units: Dmnl

Biodiesel production= INTEG (Biodiesel production rate, 0)
Units: Tonne

Biodiesel production rate=
(Total biodiesel demand-Biodiesel production)/Time to adjust biodiesel production
Units: Tonne/Year

Current biodiesel mandate for industrial sector= 0.07
Units: Dmnl

Current biodiesel mandate for other sector= 0
Units: Dmnl

Current biodiesel mandate for transport sector= 0.39
Units: Dmnl

Time to adjust biodiesel production= 1
Units: Year

Total biodiesel demand=
STEP(1, 0)+Biodiesel demand in transport sector + Biodiesel demand in industrial sector + Biodiesel export + Biodiesel demand in other sector
Units: Tonne

TOTAL diesel consumption in all sector=
Total diesel use on road + Total diesel use in agriculture sector + Total diesel use in construction and mining sector + Total diesel use in industrial sector + Total diesel use in shipping and rail sector
Units: Tonne

Total diesel use in agriculture sector= 26803*Time+550316
Units: Tonne

Total diesel use in construction and mining sector= 10309*Time + 211659
Units: Tonne

Total diesel use in industrial sector= 8247.2*Time + 169327
Units: Tonne

Total diesel use in other sector=
Total diesel use in agriculture sector + Total diesel use in construction and mining sector + Total diesel use in shipping and rail sector
Units: Tonne

Total diesel use in shipping and rail sector= 26803*Time + 550316
Units: Tonne

Total diesel use on road= 134016*Time + 3e+006
Units: Tonne

Year of biodiesel mandate for industrial sector implementation= 2020
Units: Year

Year of biodiesel mandate for other sector implementation= 2020
Units: Year

Year of biodiesel mandate for transport sector implementation= 2020
Units: Year

APPENDIX D: Labour Sub-Model Equations

Actual labour land ratio= Labour stock/Total plantation area
Units: Labour/Hectare

Attractiveness of Indonesia palm oil industry=
1 + (0.3*Relative Indonesia palm oil growth+0.7*Relative wage rate)
Units: Dmnl

Contract duration= 5
Units: Year

Desired labour=
Total plantation area*Optimal labour land ratio
Units: Labour

Effect of labour on FFB yield=
Lookup for effect of labour on FFB yield (Relative labour land ratio)
Units: Dmnl

Effect of mechanization on labour=
0.2 + STEP(Mechanization adoption rate-0.2,Year of mechanization use change-2000)
Units: Dmnl

Factor affecting labour off rate= Attractiveness of Indonesia palm oil industry
Units: Dmnl

Fraction of labour taking= 0.25
Units: 1/Year

Gap of labour= Desired labour-Labour stock
Units: Labour

Indonesia palm oil industry growth= 3.4
Units: Dmnl

Indonesia wage= INTEG (Indonesia wage change, 300)
Units: RM

Indonesia wage change= Indonesia wage*Indonesia wage rate growth
Units: RM/Year

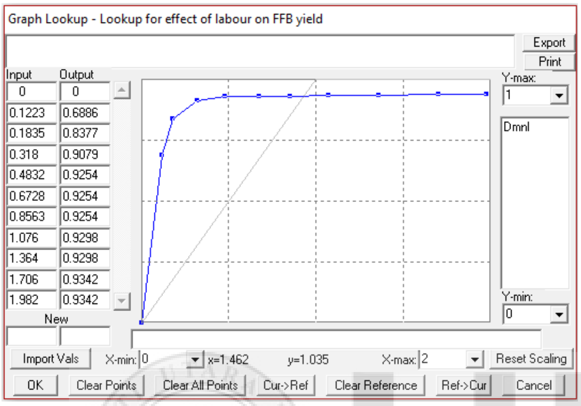
Indonesia wage rate growth= 0.04
Units: 1/Year

Labour off rate=
Factor affecting labour off rate*Labour stock/Contract duration*Year of contract duration change
Units: Labour/Year

Labour stock= INTEG (Labour taking rate-Labour off rate, 250000)
Units: Labour

Labour taking rate= Fraction of labour taking*Gap of labour
Units: Labour/Year

Lookup for effect of labour on FFB yield (
[(0,0)-(2,1),(0,0),(1,1),(2,1)],(0,0),(0.122324,0.688596),(0.183486,0.837719),(0.318043,0.907895),(0.48318,0.925439),(0.672783,0.925439),(0.856269,0.925439),(1.07645,0.929825),(1.36391,0.929825),(1.70642,0.934211),(1.98165,0.934211))
Units: Dmnl



Malaysia palm oil industry growth= 0.8
Units: Dmnl

Malaysia wage= INTEG (Malaysia wage change, 600)
Units: RM

Malaysia wage change= Malaysia wage*Malaysia wage rate growth
Units: RM/Year

Malaysia wage rate growth= 0.028
Units: 1/Year

Mechanization adoption rate= 0.2
Units: Dmnl

Optimal labour land ratio= 0.167
Units: Labour/Hectare

Relative Indonesia palm oil growth=
Indonesia palm oil industry growth/Malaysia palm oil industry growth
Units: Dmnl

Relative labour land ratio=
Actual labour land ratio/(Optimal labour land ratio/(1+Effect of mechanization on labour))
Units: Dmnl

Relative wage rate= Indonesia wage/Malaysia wage
Units: Dmnl

Total plantation area= Premature area + Mature area + Ageing area
Units: Hectare

Year of contract duration change= 1
Units: Dmnl

Year of mechanization use change=2017
Units: Year