Heart of Borneo

Investing in Nature for a Green Economy

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Technical Background Material

Kalimantan System Dynamics Model

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For
WWF Heart of Borneo Global Initiative

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1. Introduction

This document provides an overview of the System Dynamics, integrated modeling approach used to investigate the economic potential of green investment in Kalimantan. The methodology adopted here is the same as the one used in UNEP's Green Economy Report 2011.[1]

The modeling work presented in this report consists in the creation of several sectoral models, integrated into a regional model for Kalimantan. The analysis originating from the model focuses on the impacts of investing and implementing policy interventions in green- as opposed to Business as Usual (BAU) investments to determine the effect of these investments on stimulating the economy and preserve natural capital, lower carbon intensity, create jobs and improve equity.

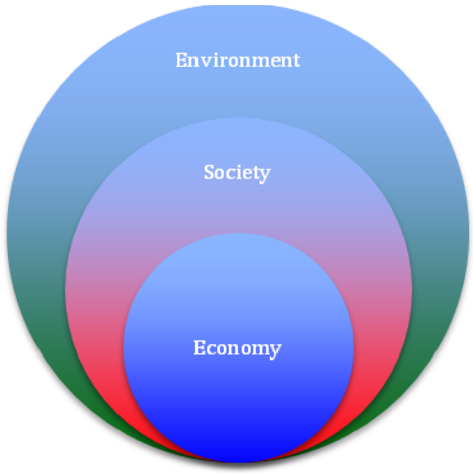
By generating systemic scenarios over time that address environmental, economic, and social issues in a single coherent framework, the model simulates the main short, medium and longer-term impacts of transitioning to a greener economy. The most important contribution of this model is its systemic structure that includes endogenous links within and across the economic, social, and environmental sectors through a variety of feedback loops[2]. Most existing models focus on one or two sectors, and make exogenous assumptions about other sectors that affect and are affected by the sector under consideration. Using endogenous formulations instead improves consistency over time and across sectors, because changes in the main drivers of the system analyzed are reflected throughout the model and analysis through feedback loops. While detailed sectoral analysis is very important, it is not adequate to demonstrate the whole set of relations and feedback loops that properly represent the functioning of the real world and that have to be taken into account in making the necessary transitions to greener economic and social structures.

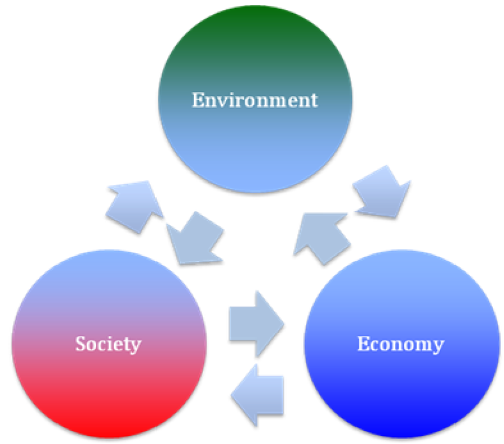
The model developed for this study, largely drawing upon the Threshold 21 (T21) family of models created by the Millennium Institute (see, among others, MI, 2005[3]; Bassi, 2010[4]), builds on assumptions (structural and numerical) from existing detailed sectoral economic and physical models into a comprehensive structure that generates scenarios of what is likely to happen throughout an integrated economic, social, and environmental system (see Figure 1).

Figure 1: Conceptual overview of T21.
The environment, society and the economy represent the highest level of aggregation in the model (See left).

[1] UNEP (2011) Modelling Global Green Investment Scenarios (http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_13_Modelling.pdf).
[2] Feedback is a process whereby an initial cause ripples through a chain of causation ultimately to re-affect itself (Roberts et al., 1983). Roberts, N., Andersen, D.F., Choate, J., Deal, R.M., Garet, M.S., Shaffer, W.A. (1983). Introduction to Computer Simulation. Addison-Wesley, p. 16, Reading, MA.
[3] Millennium Institute (2005). Threshold 21 (T21) Overview. Arlington, VA.
[4] Bassi, A.M. (2010). Reflections on the Validity of System Dynamics Integrated Simulation Models: the case of T21 and MCM. Currently submitted to *Sustainability*.

Although our environment encompasses society and the economy, for simplicity we represent them separately to highlight the interconnections existing across them (See right).





2. Technical specifications

There has been a long-standing perception among both the general public and policy makers that the goals of economic growth, environmental protection, national and energy security involve a complex set of trade-offs, one goal against another goal (Brown and Huntington, 2008[5]; CNA, 2007[6]; Howarth and Monahan, 1996[7]). This study aims at analyzing the dynamic complexity of the social, economic, and environmental characteristics of Kalimantan with the goal of evaluating whether green economy interventions can create synergies and help move toward various sustainability goals: preservation of natural capital, resilient economic growth and improved equity, job creation and low carbon development.

Finding that currently available national and regional planning models are either too detailed or narrowly focused, and perhaps too decision oriented and prescriptive, this study proposes an approach that a) extends and advances the policy analysis carried out with existing tools by accounting for the dynamic complexity embedded in the systems studied, and b) facilitates the investigation and understanding of the relations existing between energy and society, economy and the environment. This is crucial, since understanding the characteristics of real systems, feedback[8], delays[9] and non-linearity[10] is

[5] Brown, S. P. A., and Huntington, H. G. (2008). Energy Security and Climate Change Protection: Complementarity or Tradeoff? Energy Policy (2008) Vol. 36, No. 9.
[6] CNA Corporation (2007). National Security and the Threat of Climate Change, Alexandria, VA.
[7] Howarth, R. B. and Monahan, P.A. (1996). Economics, Ethics and Climate Policy: Framing the Debate. Global and Planetary Change, Vol. 11, No. 4, p. 187-199.
[8] "*Feedback is a process whereby an initial cause ripples through a chain of causation ultimately to re-affect itself*" (Roberts et al., 1983).
[9] Delays in this context are characterized as "*a phenomenon where the effect of one variable on another does not occur immediately*" (Forrester et al., 2002). These can in fact lead to instability, such as overshoot and oscillations, when coupled with balancing processes. Since delays influence the efficacy of policies in both the short and the longer term, their explicit representation generates many advantages. Among others, the direct

fundamental for the correct representation of structures, whose behavior is outside their normal operating range (Sterman, 2000[11]). The inclusion of cross-sectoral relationships - social, economic and environmental- allows for a wider analysis of the implication of policies by identifying potential side effects or longer-term bottlenecks for development. In other words, a policy can have very positive impacts for certain sectors and create issues for others. Also, successful policies in the longer term may have negative short-term impacts, for which mitigating actions may be designed and implemented.

The approach proposed uses System Dynamics as its foundation and incorporates various methodologies to build a structural model explicitly considering stocks and flows across society, the economy and the environment. Our integrated model for Kalimantan is used to: (1) provide an integrated analysis and evaluation of interventions choices; (2) generate projections of future developments (though acknowledging that long term accurate projection cannot easily be produced, even when simulating a large number of endogenous key variables (Sarewitz, 2000[12])); (3) increase the understanding of the relations underlying the system analyzed; (4) and bring consistency to sectoral models.

2.1 Introduction to the System Dynamics Kalimantan model

The Kalimantan model is structured to analyze medium-long term development issues. The model integrates in a single framework the economic, the social, and the environmental aspects of development planning. The level of aggregation used makes it well suited to look at resource allocation issues among different sectors. T21, upon which the Kalimantan model is based, is conceived to complement budgetary models and other short-medium term planning tools by providing a comprehensive and long-term perspective on development.

The model is useful at four levels in the planning process. First, the participatory process of model development provides insights on the coherence and consistency of objectives, hypotheses and data used for policymaking in different sectors. Second, the base run simulation of the model offers an outlook into key development issues. Third, alternative scenarios provide an understanding of how different strategic choices or external conditions can impact future development, and how policies synergistically interact. Fourth, the resulting development plan provides a clear basis for action in the various

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understanding that integrated complex systems are dominated by inertia in the short term, therefore the implementation of policies does not produce immediate significant impacts. As Jay Forrester states "*A system variable has a past path leading up to the current decision time. In the short term, the system has continuity and momentum that will keep it from deviating far from an extrapolation of the past*" (Forrester, 2008).
Forrester, J. W. (2002). Road Maps: A Guide to Learning System Dynamics. System Dynamics Group, Sloan School of Management, MIT, Cambridge, MA.
Forrester, J. W. (2008). System Dynamics – The Next Fifty Years. System Dynamics Review.

[10] Non-linear relationships cause feedback loops to vary in strength, depending on the state of the system (Meadows, 1980), and determine how structure defines behavior. For instance, with oil demand being influenced simultaneously by GDP, oil prices, energy efficiency, each embedded in a variety of feedback loops, non-linear behavior emerges from the model.

[11] Sterman, J. D. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World. Irwin/McGraw-Hill, Boston.

[12] Sarewitz, D. (2000). Science and Environmental Policy: An Excess of Objectivity. Columbia University, Center for Science, Policy, and Outcomes. Also in Earth Matters: The Earth Sciences, Philosophy, and the Claims of Community. Prentice Hall, p. 79-98, edited by Robert Frodemen (2000), New Jersey.

sectors, as well as for monitoring and evaluation of performance.

T21, starting from an initial framework, is generally fully customized to analyze selected issues within a specific context, as in the case of Kalimantan. The structure of both models includes monetary and physical indicators, to fully analyze the impacts of investments on natural resources, low carbon development, economic growth and job creation. Key characteristics of the model are highlighted below.

Boundaries: Variables that are considered an essential part of the development mechanisms, object of the research, are endogenously calculated. For example, GDP and its main determinants, population and its main determinants, and the demand and supply of natural resources are endogenously determined. Variables that have an important influence on the issues analyzed, but that are only weakly influenced by the issues analyzed or that cannot be endogenously estimated with confidence, are exogenously represented.

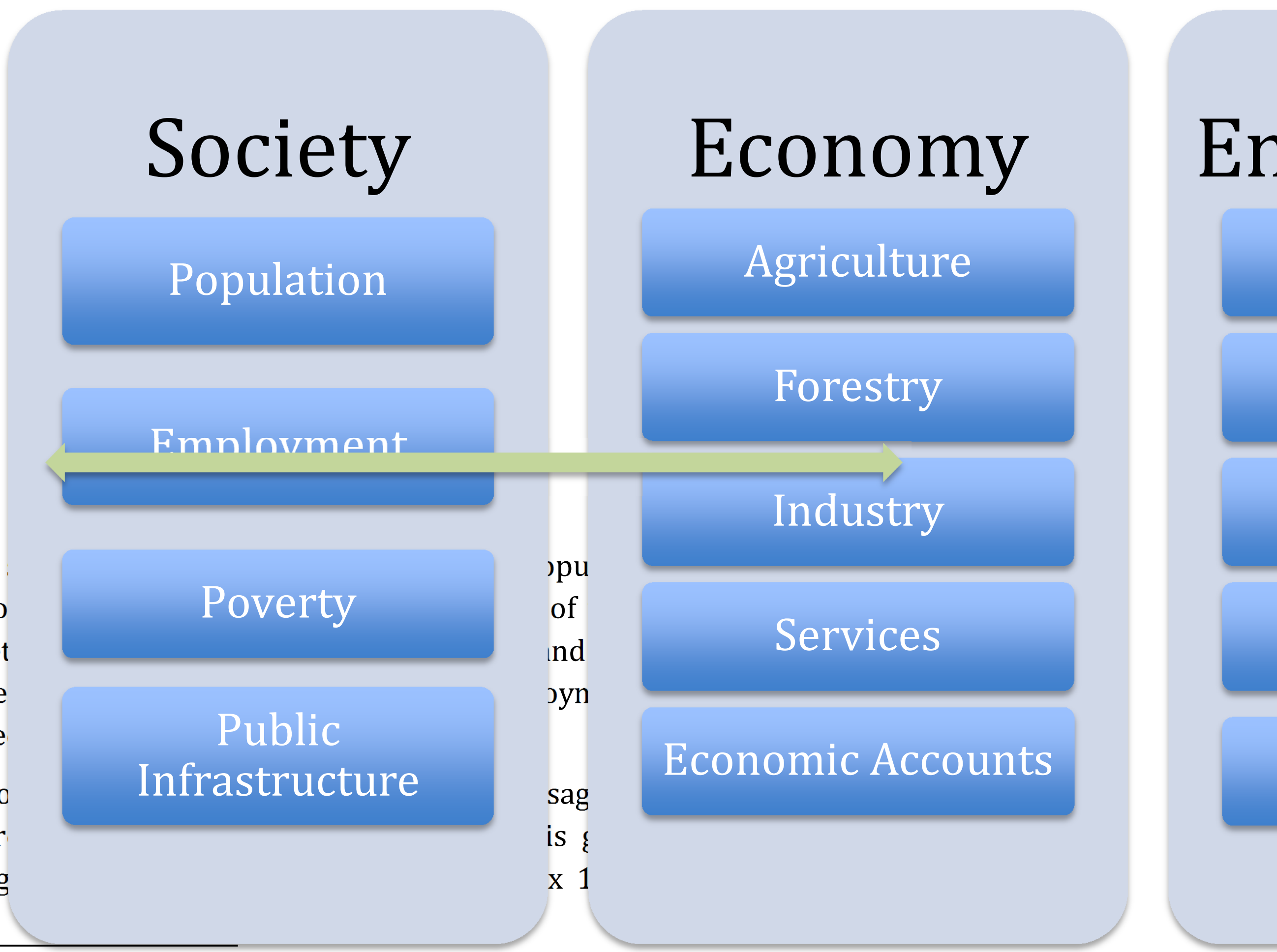
Granularity: The Kalimantan model is aggregated at the regional level, with now spatial disaggregation. On the other hand, the model can be coupled with a GIS framework to improve the geographical accuracy of the analysis in terms of both inputs and outputs. Thus, the framework is very applicable to different scales, ranging from communities to the world as shown by the many applications of T21[13]. Despite being an aggregated model, the main social, economic and environmental variables of the Kalimantan model are broken down in sub-components as required in order to analyze the focus issues. For example, population is divided into 82 age-cohorts and by gender, and the age-gender distinction is used in most social indicators; production is divided into industry, services and agriculture, this last further divided into crops, animal husbandry and forestry; land is divided into forest, agriculture, settlement and degraded. Finally, given its level of aggregation, the model is generally based on average values for variables such as unit costs and prices.

Time horizon: The Kalimantan model is built to analyze medium to long-term development issues. The time horizon for simulation starts back in 1990 and extends up to 2030. Beginning the simulation in 1990 ensures that, in most cases, the patterns of behavior characterizing the issues being investigated can be fully observed and replicated.

[13] For more information see Bassi and Baer (2009), Bassi and Yudken (2009), Bassi and Shilling (2010), Bassi et al. (2009a, 2009b, 2010).
Bassi, A.M., A. E. Baer (2009). Quantifying Cross-Sectoral Impacts of Investments in Climate Change Mitigation in Ecuador. Energy for Sustainable Development 13(2009)116-123.
Bassi, A.M., and J. S. Yudken (2009). Potential Challenges Faced by the U.S. Chemicals Industry Under a Carbon Policy. Sustainability 1(2009)592-611. Special issue on "Energy Policy and Sustainability".
Bassi, A.M., and J.D. Shilling (2010). Informing the US Energy Policy Debate with Threshold 21. Technological Forecasting & Social Change 77 (2010) 396–410
Bassi, A.M., J. Harrisson, R. Mistry (2009a). Using an Integrated Participatory Modeling Approach to Assess Water Management Options and Support Community Conversations on Maui. Sustainability 2009, 1(4), 1331-1348. Special issue on "Sustainable Water Management".
Bassi, A.M., Schoenberg, W., Powers, R. (2010). An integrated approach to energy prospects for North America and the Rest of the World. Energy Economics 32 (2010) 30–42.
Bassi, A.M., Yudken, J.S., Ruth, M. (2009b). Climate policy impacts on the competitiveness of energy-intensive manufacturing sectors. Energy Policy 37(2009)3052–3060

Modules, sectors and spheres: As a result of the variety of issues considered and sectors analyzed, the Kalimantan model is a relatively large size model accounting for over 40 different stock variables and several hundreds feedback loops. Given the size and the level of complexity of the model, its structure has been reorganized into smaller logical units, labeled as *modules*. A module is a structure, whose internal mechanisms can be understood in isolation from the rest of the model[14]. The 21 modules comprising the Kalimantan model are grouped into 14 *sectors*: 4 social, 5 economic and 5 environmental sectors, as are listed in Table 1. Sectors are groups of one or more modules of similar functional scope. For example, the water sector groups both the water demand and water supply modules. Finally, society, economy and environment are known as the three *spheres* of the model. All sectors in the Kalimantan model belong to one of the three spheres, depending on the type of issue they are designed to address. Modules are built to be in continuous interaction with other modules in the same sector, across sectors, and across spheres. Table 1 lists the spheres, sectors and modules of the Kalimantan model.

Table 1: Spheres and Sectors of the Kalimantan Model



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[14] As it is emphasized later on in the text, although it is possible to understand the internal mechanism of a specific module in isolation from the rest of the model, the fully understanding of its functioning and relevance requires studying its role in the whole model's structure.

technology, but the specification varies from sector to sector and includes life expectancy, literacy, the availability of roads and use of river transport. Agriculture and forestry production is highly influenced by the availability and quality of natural resources. While capital and labor contribute to production, the forest and the quality of soil -together with water availability for agriculture and other factors- are key determinants of the performance of the sectors.

For this reason the model tracks the physical flow of key natural resources, endogenously calculating depletion and its impacts on production. As mentioned above, production in the three major economic sectors is influenced by social factors, such as life expectancy and education level, included in the calculation of total factor productivity (TFP) together with the impact of natural resources and infrastructure availability.

The Environment sphere tracks land allocation, water, waste and energy demand and supply. On top of this, the economic values of natural capital are estimated. The environment sphere also examines the impacts of environmental degradation (such as soil erosion, water degradation, forest depletion, and fossil fuel use and emissions) and climate variability (such as droughts and floods) both within environmental sectors and across other sectors, such as agricultural and forestry productivity. The model calculates also air emissions (CO_2, CH_4, N_2O, SO_X and greenhouse gas), considering both sources and sinks. Economic activities and demographic growth create increasing pressure on natural resources, while at the same time allowing for development of better and more efficient technologies.

Concerning the validation of the model, both structural and behavioral tests were carried out. On the structural validation, the Kalimantan model and its sectors were designed based on state of the art existing sectoral models and available statistics. The knowledge gained through the review of these models was then translated into the model, exogenous inputs were replaced with endogenous ones, and causal relations were explicitly represented in a disaggregated manner. The new structure of each sector was then verified and validated comparing the behavior of the model against historical data. More detailed analyses were then performed to identify and analyze the causal relations included in the model and the relevance of exogenous assumptions (or drivers), through the simulation of sensitivity analyses for selected variables. Further, extreme condition tests, feedback loop analysis as well as unit consistency tests were frequently performed on all modules. Further, boundaries as well as structural (i.e. causal relations and equations) and parameter consistency tests were normally checked with experts in the field analyzed. Overall, the structure of the model presents lower detailed but higher dynamic complexity (cross sectoral relationships and feedback loops) when compared with other existing models (e.g. MARKAL, in the energy sector). In other words, each sector developed for the study is relatively simple when taken in isolation, and the complexity comes out of the feedback loops built into the model across modules and sectors.

Text Box 1: The Cobb-Douglas production function in T21 for agriculture, industry and services macro sectors.

The classic form of the CD production function is expressed as following:

$$Y = A * K^\alpha * L^{(1-\alpha)}$$

Where A represents the total factor productivity (TFP), K represents the stock of capital, and L represents labor. The constant α represents the elasticity of output to capital: the ratio between the percentage change of output and the percentage change of an input. The elasticity of output to labor is set to 1-α, assuming that there are constant returns to scale (the production function is thus first order, homogeneous). In T21 and the Kalimantan model the standard CD production function is transformed into a more transparent algebraic form, and TFP is expanded to include several different elements.

The equation used to estimate industry production, as an example, is as shown below:

$$yi_t = yi_{t-1} * ric_t^{\alpha} * ril_t^{\beta} * fpi_t$$

Where yi_t is the current industry production, yi_{t-1} is the initial industry production, ric_t is the relative industry capital, ril_t is the relative industry labor and fpi_t is the industry factor productivity.
Moreover, α is the elasticity of capital and β is the elasticity of labor.
Industry factor productivity fpi_t is determined by health (relative life expectancy), education (relative adult literacy), relative length of the road network and relative river transport capacity. The total factor productivity of industry is calculated as the product of the effects of all input factors.

Agriculture yield, still determined by a transformed Cobb-Douglas production function, uses land on top of capital and labor and additional inputs for TFP. By multiplying the harvested area by crop yield per hectare, we determine the total crop yield. Total crop yield multiplied by crop value added gives agriculture (food processing) production, or the total value added. TFP is influenced by soil quality (a function of the type of fertilizer used), fertilizer use, precipitation (having both positive and negative impacts), and road length. Moreover, quality of labor is determined by literacy (average years of schooling) of the labor force and health conditions (life expectancy).

3. Key assumptions

Table 2: Numerical and structural assumptions used to calculate the value of natural capital, the main addition of the Kalimantan model relative to T21.

<table>
<tr><th>Variable</th><th>Unit</th><th>Value</th><th>Reference</th></tr>
<tr><td colspan="4">Natural stocks</td></tr>
<tr><td>Carbon price</td><td>USD/tCO_2</td><td>2 (and 15)</td><td>We analyze two scenarios, one with low carbon price and another one with a $15/$tCO_2$ charge. This is to illustrate the potential impact of carbon prices on the value of natural capital in Borneo. References include Venter et al. (2011) and McKinsey (2010).</td></tr>
<tr><td>Biodiversity value</td><td>USD/Ha</td><td>27</td><td>in the literature is as low as $4.6 hectares per year (Pearce and Pearce 2001) to $9,177 per hectare for pharmaceutically rich areas in Ecuador (Rauseer and Small 1998).</td></tr>
<tr><td>Forestland value (including primary and secondary forest, swamp forest, and mangrove forest)*</td><td>USD/Ha</td><td>$900 over the past ten years, projected to double up to 2030 in the BAU case; three times higher by 2030 in the GE case.</td><td>Estimated based on the weighted average potential profit from land use, including timber, palm oil and crop production. Palm oil and crop yield use local estimates, timber production uses global averages.</td></tr>
<tr><td>Agricultural and plantation soil value **</td><td>USD/Ha</td><td>$13.5 on average between 2011 and 2030; rising trend over time.</td><td>Estimated based on the projected differential in primary sector value-added per ha (including agriculture, palm oil and forestry) caused by soil quality in the BAU vs. GE scenarios.</td></tr>
<tr><td colspan="4">Ecosystem services</td></tr>
<tr><td>Precipitation and flood events</td><td colspan="3">Calibrated using historical data on precipitation and flood events. The key drivers of precipitation and flood/drought events are: a long-term precipitation trend including seasonal variations, an approximately 5-year random event for a large flood, and deforestation, influencing the frequency of floods.</td></tr>
<tr><td>Road and river transport</td><td colspan="3">Calibrated using precipitation and flood events historical data and communication with BHP Billiton on river use for productive operations. The main endogenous drivers affecting river use include: floods, also driving siltation, droughts, and water levels above and below levels of operations (driven by precipitation and siltation).</td></tr>
<tr><td>Agriculture production</td><td colspan="3">Calibrated using historical data, agriculture production is affected negatively by precipitation and water levels above and below optimal thresholds: high rainfall may lead to floods, which wash away topsoil, while droughts reduce seasonal yields.</td></tr>
<tr><td colspan="4">Ecosystem goods</td></tr>
<tr><td>NTFP</td><td>USD/Ha/ Year</td><td>32</td><td>Van Beukering et al. 2009. Other estimates of the value of NFTP in Southeast Asia range from 8 to 55 US$ per hectare (Caldecott 1988; Mai et al. 1999)</td></tr>
<tr><td>Tourism</td><td>USD/Ha/ Year</td><td>27</td><td>The value of tourism is calculated by using the references on biodiversity, making so that the total value of including tourism and NTFP production adds up to $60/ha per yea and is in line with the literature.</td></tr>
<tr><td colspan="4">Other relevant assumptions</td></tr>
<tr><td>Ecological agriculture cost</td><td>USD/Ha</td><td>100</td><td>Baker et al. (2007), UNEP (2011). We assume a cost difference between organic and chemical fertilizers of $680/ton or close to $100/ha.</td></tr>
<tr><td>CO_2 Carbon Storage (forest)</td><td>tCO_2/Ha</td><td>860</td><td>InVEST model: carbon module; Koh et al. (2011)</td></tr>
<tr><td>Palm Oil palm oil FFB yield</td><td>Ton/ha</td><td>22 (forested area)
20 (degraded area)</td><td>McKinsey (2010)</td></tr>
<tr><td>Palm Oil Average CPO extraction rate</td><td>Per cent</td><td>23%</td><td>McKinsey (2010)</td></tr>
<tr><td>Palm Oil Average KPO extraction rate</td><td>Per cent</td><td>5%</td><td>McKinsey (2010)</td></tr>
</table>

* Forestland value in this exercise is defined as the value of forest conversion. This value calculation is used with the assumption that the more conservation we have today, the higher value of land could be in the future. In other words, the value of forestland is the value of the potential use of this land going forward. Value added per ha (calculated using the value added per ton of forestry products) is assumed to be constant in real terms. Discounting is not applied when calculating these results. The model projects scenario results over time, providing annual (and more frequent) time steps for projections. Intervention costs, and the value of natural capital, among others, are assumed and/or calculated in real terms (constant monetary values, inflation adjusted).

** The impact of climate change on agriculture production is not strongly validated for Kalimantan, due to the lack of data. A multivariate analysis was carried out, using historical data on precipitation and yields for Indonesia, and other regional studies adopted for the modelling work included in UNEP's Green Economy Report on the impact of climate change on yields, to provide a baseline. When doing sensitivity analysis it was noticed that the impact of investments (e.g., fertilizers) and land use on yields is more relevant than the impact of soil quality (driven by natural events, such as floods). This is also due to the fact that some impacts of climate change may be more localized than others, or seasonal, and with a national (Kalimantan-wide) model that provides annual projections relevant local events are averaged across the provinces.

4. Data sources

Social sectors:

- Budan Pusat, Staticstik (BPS), Subyek Staticstik, Available at: http://www.bps.go.id/, Accessed 2011, for national and province statistics.
- World Bank (2011). World Development Indicators Database (WDI).
- Employment, education: World Bank (2011). World Development Indicators Database (WDI). Accessed 2011.
- Palm oil employment: L.P Koh, H.K. Gibbs, P.V.Potapov, M.C. Hansen, 2011, Indonesia's forest moratorium, Environmental and socioeconimc tradeoffs for the Kalimantan region.
- Palm oil wage: BKPM – JICA, 2005, Investment Opportunities Study For Each Province of East, West, Central and South Kalimantan, Executive summary For West Kalimantan.

Economic sectors:

- Budan Pusat, Staticstik (BPS), Subyek Staticstik, Available at: http://www.bps.go.id/, Accessed 2011, for national and province statistics.
- World Bank (2011). World Development Indicators Database (WDI).
- Eva Wollenberg, Ani Adiwinata Nawir, Asung Uluk and Herry Pramono, 2001, Income is Not Enough: The Effect of Economic Incentives on Forest Product Conservation, Center for International Forestry Research (CIFOR).

Land and agriculture sectors:

- Data and draft report of Andy Dean, Thomas Barano, Nirmal Bhagabati, Emily McKenzie, Anna Van Paddenburg, Amy Rosenthal Agus Salim, 2011, Case Study for Scenarios Primer: Borneo.
- L.P Koh, H.K. Gibbs, P.V.Potapov, M.C. Hansen, 2011, Indonesia's forest moratorium, Environmental and socioeconomic tradeoffs for the Kalimantan region.
- Production or harvest cycle:
    - WWF, 2010, Literature review: Methodologies for financial and economic assessment of forest ecosystem services and land uses that cause deforestation in Borneo, Heart of Borneo Network Initiative, Prepared by Iván Darío Valencia.
    - Maturana, J. 2005. Economic Costs and Benefits of Allocating Forest Land for Industrial Tree Plantation Development in Indonesia. Center for International Forestry Research (CIFOR), Bogor, Indonesia.
    - Baker, C.J., Saxton, K.E., Ritchie, W.R., Chamen, W.C.T., Reicosky, D.C., Ribeiro, M.F.S., Justice, S.E., and Hobbs, P.R. (2007). No-Tillage Seeding in Conservation Agriculture, 2nd Edition. Published jointly by FAO (Rome, Italy), and CABI (Wallingford, U.K.).

Forestry sector:

- NTFP value per ha:
    - Caldecott, J.O. & I.T.F. Programme (1988). Hunting and Wildlife Management in Sarawak.
    - Beukering, P.J.H. van, Grogan, K., Hansfort, S.L., Seager, D. (2009). “An Economic Valuation of Aceh's forests - The road towards sustainable development.” Instituut voor Milieuvraagstukken: Amsterdam.
    - Eva Wollenberg, Ani Adiwinata Nawir, Asung Uluk and Herry Pramono, 2001, Income is Not Enough: The Effect of Economic Incentives on Forest Product Conservation, Center for International Forestry Research (CIFOR).

- Ecotourism value:
    - Pearce DW, Pearce C (2001). “The value of forest ecosystems.” Convention on Biological Diversity. Available online at www.biodiv.org/doc/publications/cbd-ts-04.pdf.
    - Fisher, Brendan, David P Edwards, Xingli Giam, and David S Wilcove (2011). “The high costs of conserving Southeast Asia’s lowland rainforests,” Frontiers in Ecology and the Environment 9: 329–334. doi:10.1890/100079.
- Forestry production: Food and Agriculture Organization of the United Nations FAO (2008). Contribution of the Forestry Sector to National Economies 1990-2006. Rome.

Palm oil sector:

- McKinsey& Company, 2010, East Kalimantan low carbon growth plan: Use of degraded land for palm oil.
- Palm oil Price: USDA, 2010, Oilseeds: World markets and Trade.

Energy sector:

- US Department of Energy, Energy Information Administration EIA (2009). International Energy Statistics. Available at: http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm.
- CO2 reduction cost: International Energy Agency IEA (2009). World Energy Outlook 2009. Paris.
- Power generation cost and factors: International Energy Agency IEA (2008). World Energy Outlook 2008 Power Generation Cost Assumptions. Paris.

Water sector:

- World Bank (2011). World Development Indicators Database (WDI). Accessed 2011.
- Water level and impacts on river transport: Communication with BHP Billiton (forwarded by Anna Paddenburg, WWF).

Climate:

- Precipitation, temperature, floods, drought:
    - Warren, R. F.; Price, J. T.; Goswami, S. (2010). “Some Good Practices for Integration and Outreach and their Implementation in the Community Integrated Assessment System (CIAS) and its associated web portal CLIMASCOPE.” *American Geophysical Union*, Fall Meeting 2010, abstract #PA33A-1603.

- World Bank (2011) Climate Change Knowledge Portal For Development Practitioners and Policy Makers." Accessed online at http://sdwebx.worldbank.org/climateportal/ on August 31, 2011.

Natural capital:

- Biodiversity value per ha
    - Pearce DW, Pearce C (2001). "The value of forest ecosystems." Convention on Biological Diversity. Available online at www.biodiv.org/doc/publications/cbd-ts-04.pdf.
    - Fisher, Brendan, David P Edwards, Xingli Giam, and David S Wilcove (2011). "The high costs of conserving Southeast Asia's lowland rainforests," Frontiers in Ecology and the Environment 9: 329–334. doi:10.1890/100079.
    - Rausser, G.C. & Small, A.A. (1998). *Bioprospecting with patent races*. Columbia University, Columbia Business School.
- Carbon price:
    - Venter, O., E. Meijaard, H. Possingham, R. Dennis, D. Sheil, S. Wich, L. Hovani and K. Wilson. 2009. Carbon payments as a safeguard for threatened tropical mammals. Conservation Letters, 2(3), 123-129.
    - Source from: WWF, 2010, Literature review: Methodologies for financial and economic assessment of forest ecosystem services and land uses that cause deforestation in Borneo, Heart of Borneo Network Initiative, Prepared by Iván Darío Valencia.
- L.P Koh, H.K. Gibbs, P.V.Potapov, M.C. Hansen, 2011, Indonesia's forest moratorium, Environmental and socioeconomic tradeoffs for the Kalimantan region.
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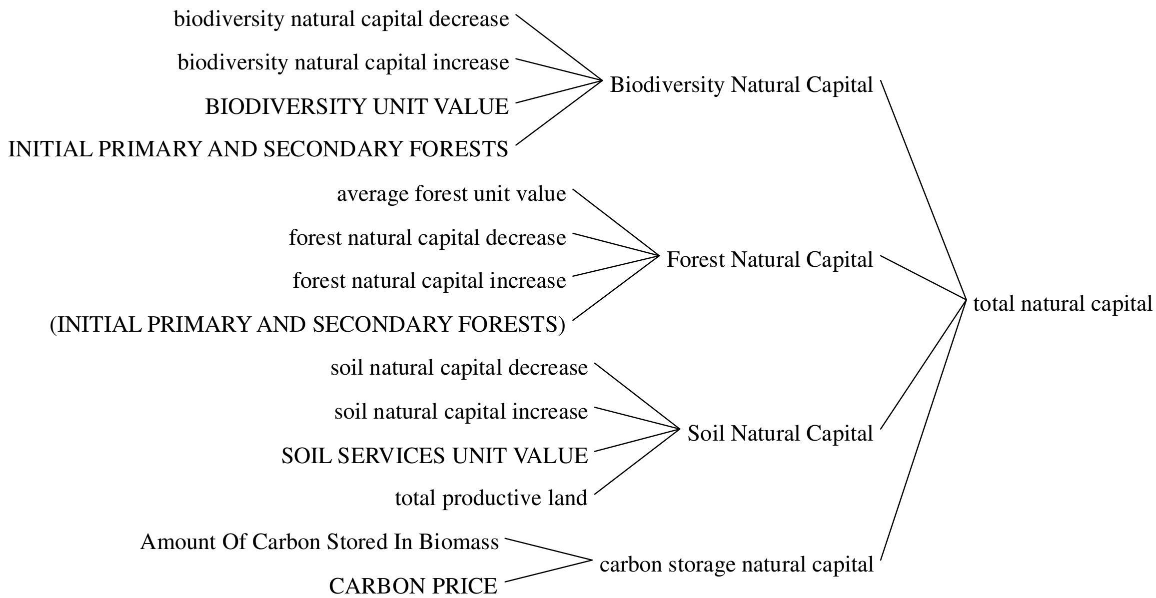
5. Main environmental equations, GDP and population

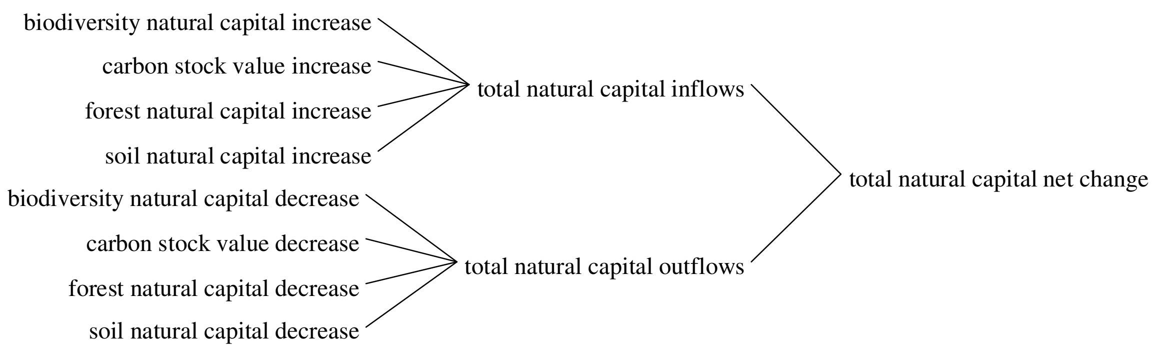
Total natural capital

Total natural capital = biodiversity natural capital + forest natural capital + soil natural capital + carbon storage natural capital
Units: Usd00



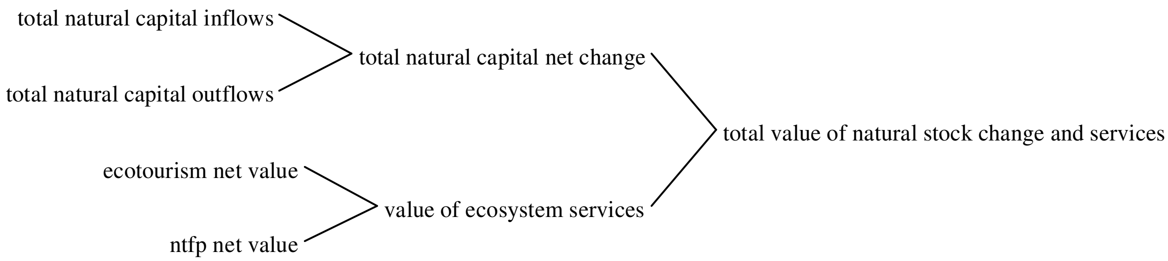
Total natural capital net increase

Total natural capital net change = total natural capital inflows-total natural capital outflows
Units: Usd00/Year



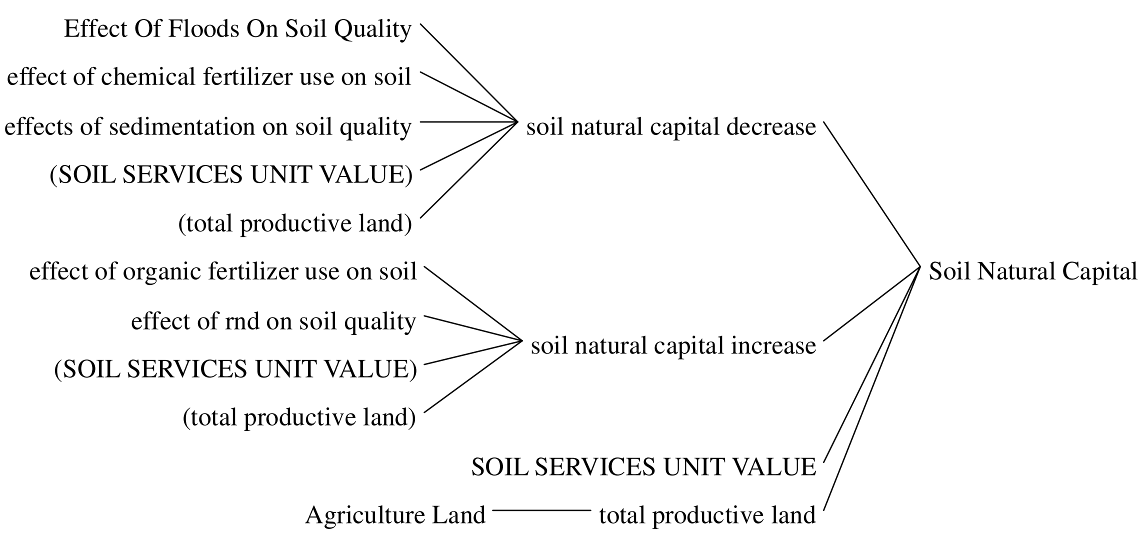
Total value of natural stock increase and services

Total value of natural stock increase and services = total natural capital net change + value of ecosystem services
Units: Usd00/Year



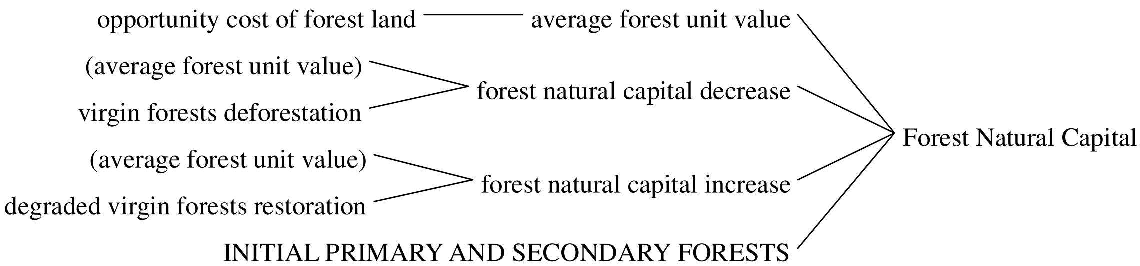
Soil natural capital

Soil Natural Capital = INTEG (soil natural capital increase - soil natural capital decrease, SOIL SERVICES UNIT VALUE * total productive land)
Units: Usd00



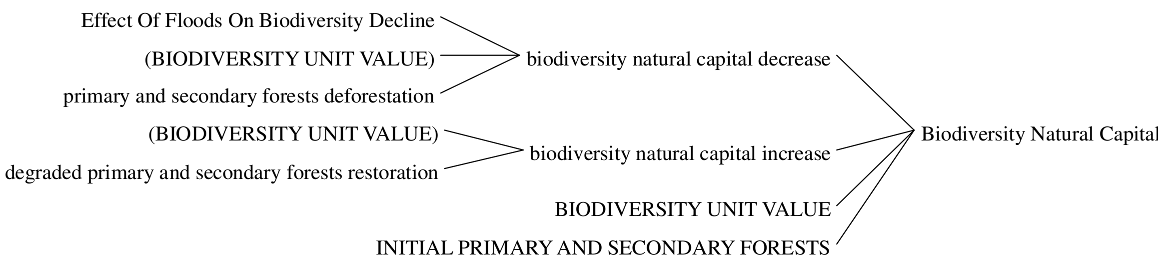
Forest natural capital

Forest Natural Capital = INTEG (forest natural capital increase-forest natural capital decrease, average forest unit value*INITIAL primary and secondary forests)
Units: Usd00



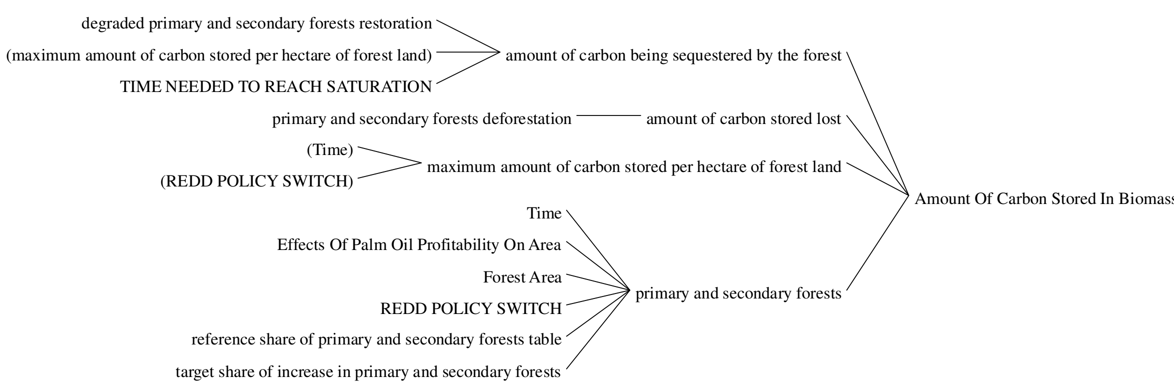
Biodiversity natural capital

Biodiversity Natural Capital = INTEG (biodiversity natural capital increase - biodiversity natural capital decrease, BIODIVERSITY UNIT VALUE*INITIAL primary and secondary forests)
Units: Usd00



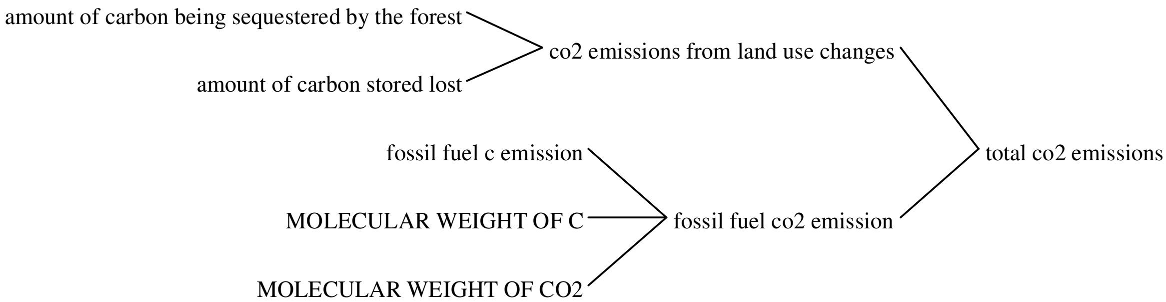
Carbon stored in biomass

Carbon Stored In Biomass = INTEG (amount of carbon being sequestered by the forest-amount of carbon stored lost, (primary and secondary forests)*MAXIMUM AMOUNT OF CARBON STORED PER HECTARE OF FOREST LAND)
Units: Ton CO_2



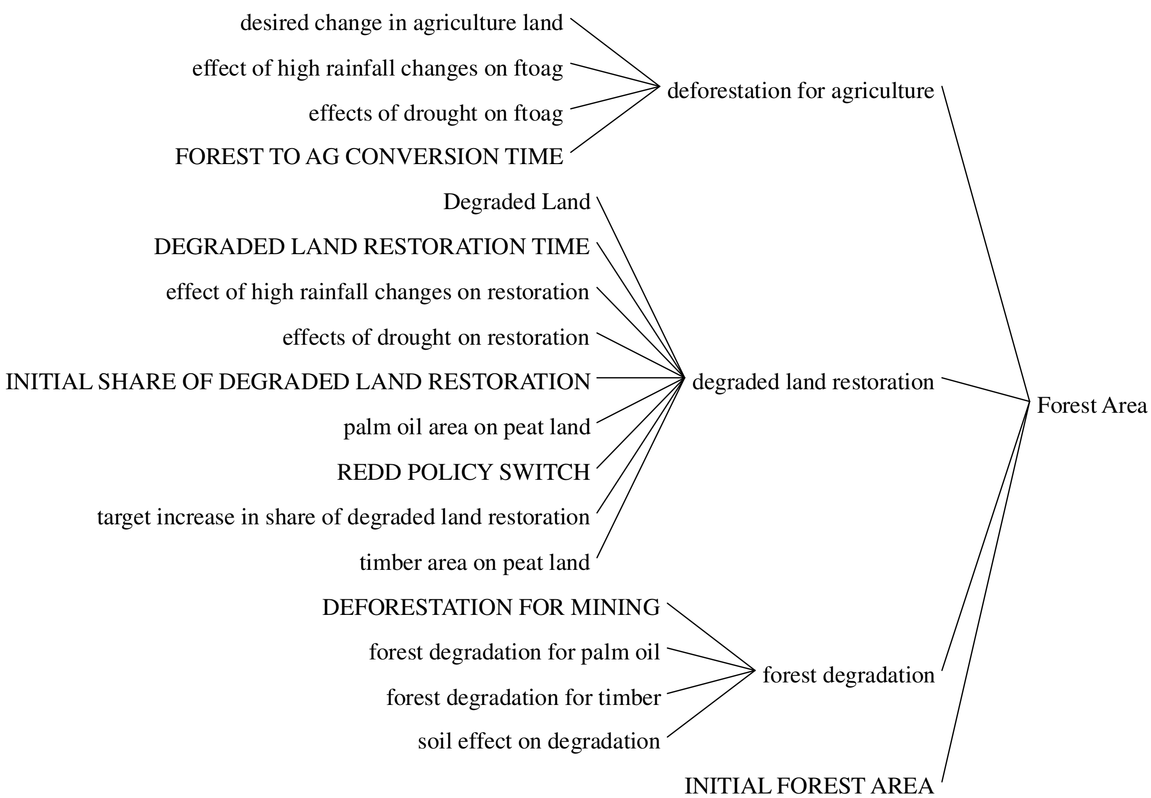
Total CO_2 emissions

Total CO_2 emissions = CO_2 emissions from land use changes + fossil fuel CO_2 emission
Units: Ton/Year



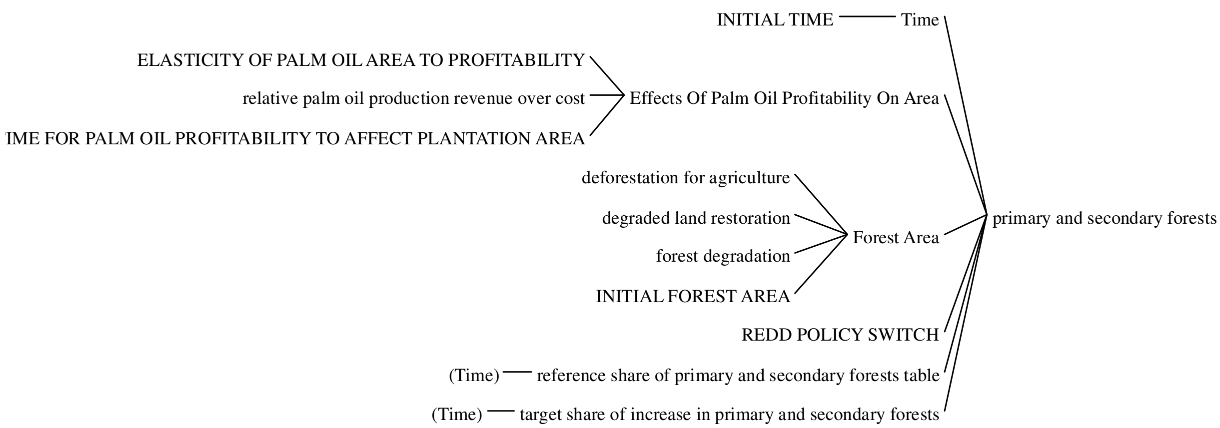
Forest area

Forest Area = INTEG (degraded land restoration - deforestation for agriculture - forest degradation, INITIAL FOREST AREA)
Units: Ha



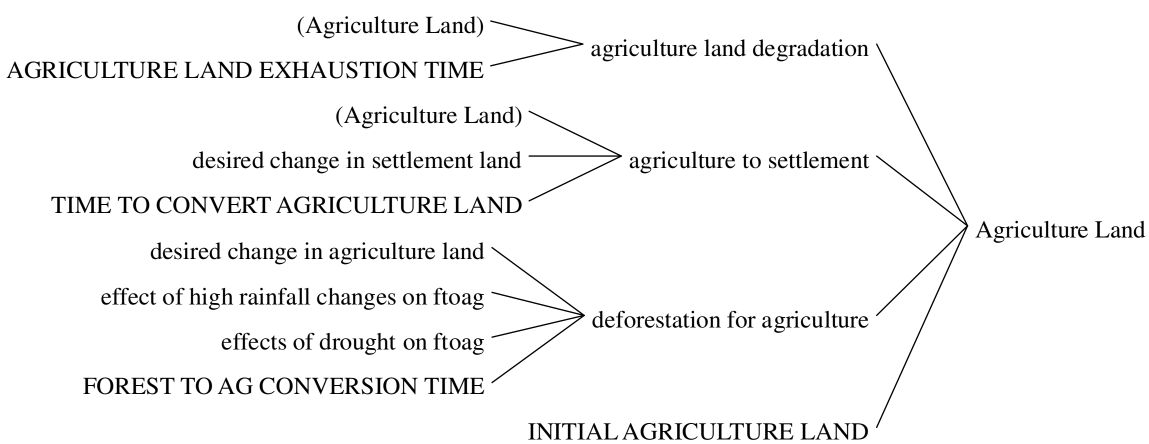
Primary and secondary forests

Primary and secondary forests = Forest Area * reference share of primary and secondary forests table * Effects Of Palm Oil Profitability On Area * IF THEN ELSE (Time>2010, 1+target share of increase in primary and secondary forests*REDD POLICY SWITCH, 1)
Units: Ha



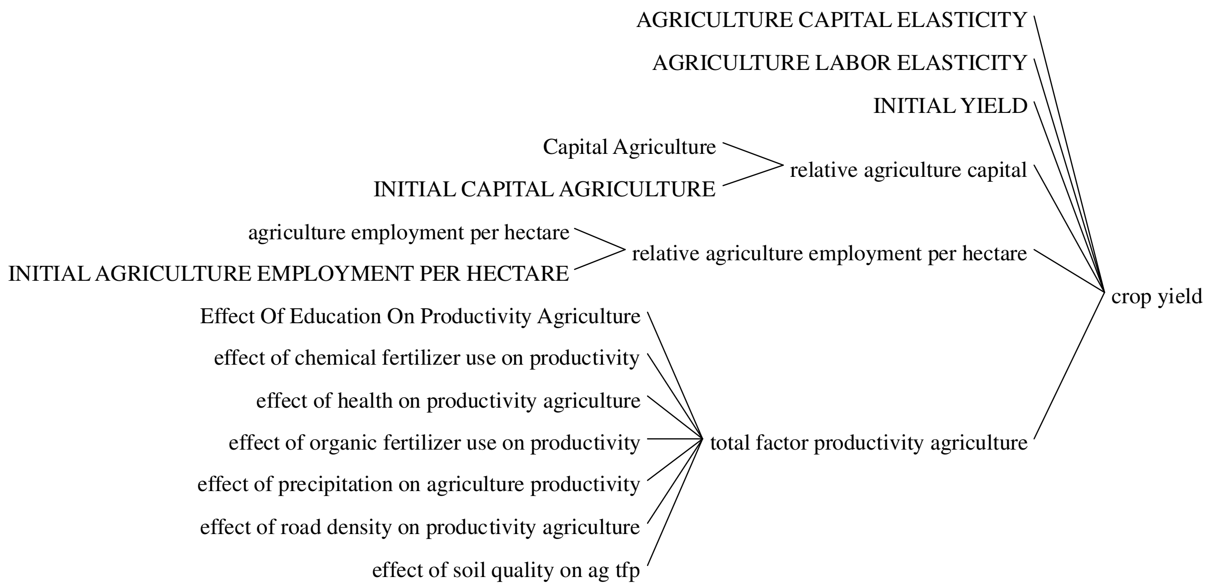
Agriculture land

Agriculture Land= INTEG (deforestation for agriculture-agriculture land degradation-agriculture to settlement, INITIAL AGRICULTURE LAND)
Units: Ha



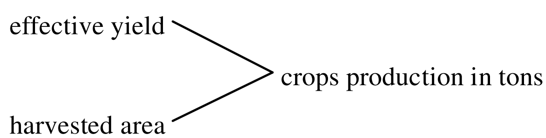
Crop yield

Crop yield = INITIAL YIELD * relative agriculture capital ^ AGRICULTURE CAPITAL ELASTICITY * total factor productivity agriculture * relative agriculture employment per hectare ^AGRICULTURE LABOR ELASTICITY
Units: Ton/Ha/Year



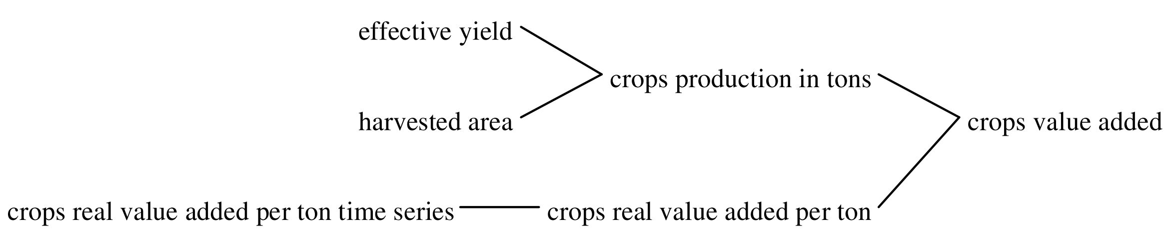
Crops production in tons

Crops production in tons = effective yield * harvested area
Units: Ton/Year



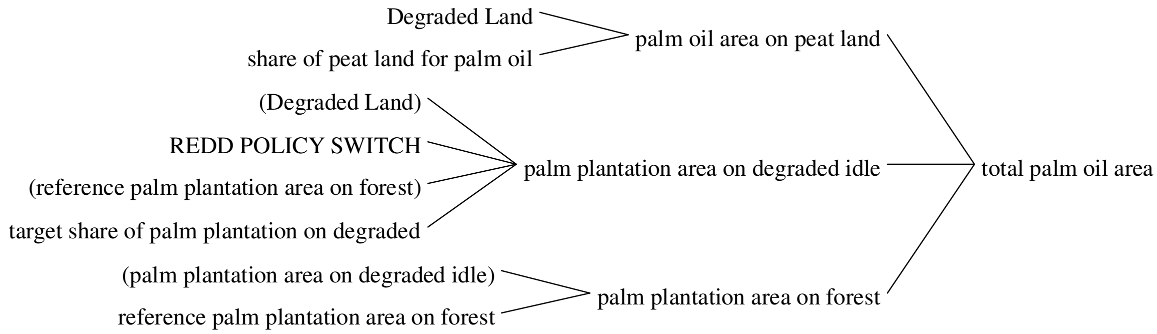
Crops value added

Crops value added = crops production in tons* crops real value added per ton
Units: Rp00/Year



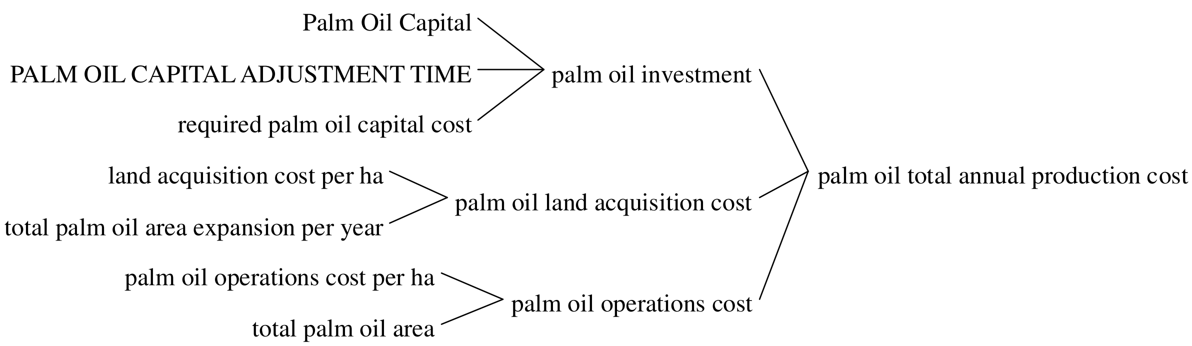
Total palm oil area

Total palm oil area = palm plantation area on forest + palm oil area on peat land + palm plantation area on degraded idle
Units: Ha



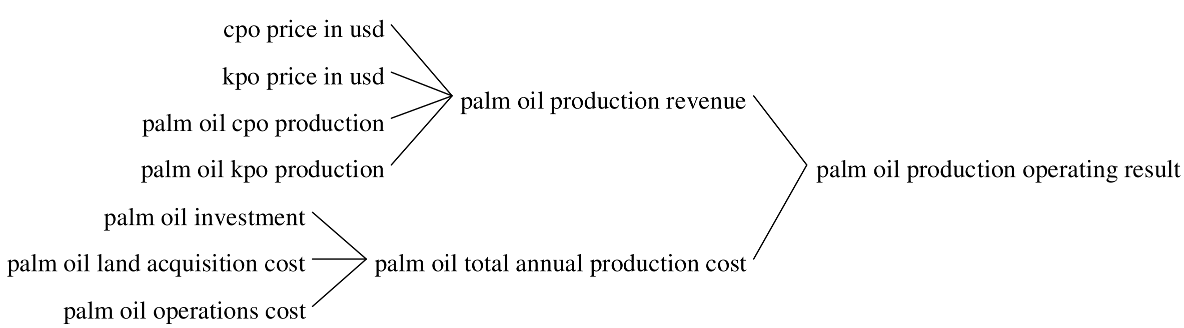
Palm oil total annual production cost

Palm oil total annual production cost = palm oil investment + palm oil land acquisition cost + palm oil operations cost
Units: USD10/Year



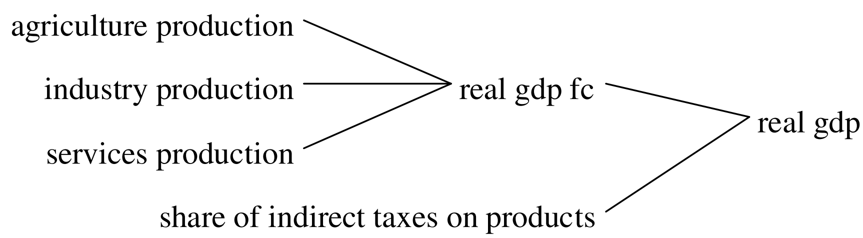
Palm oil production operating result

Palm oil production operating result = palm oil production revenue-palm oil total annual production cost
Units: USD10/Year



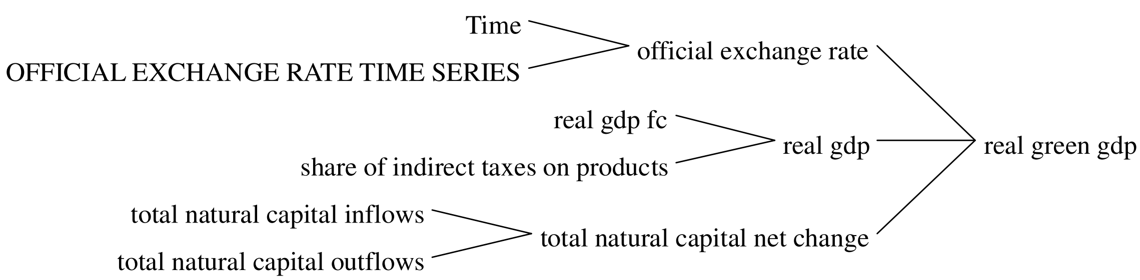
Real GDP

Real GDP = real GDP fc*(1+share of indirect taxes on products)
Units: Rp00/Year



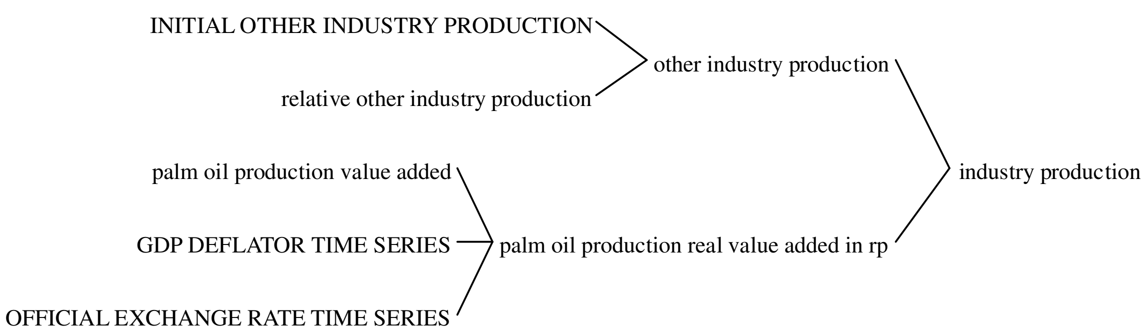
Real green GDP

Real green GDP = real GDP + (total natural capital net increase*official exchange rate)
Units: Rp00/Year



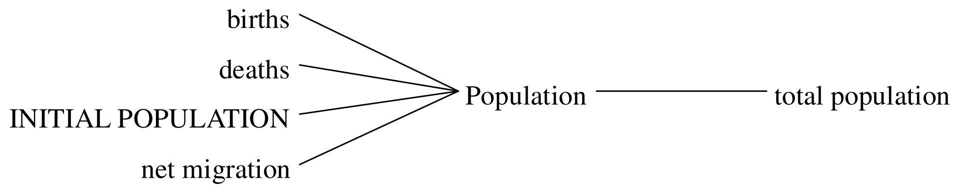
Industry production

Industry production = other industry production + palm oil production real value added in RP
Units: Rp00/Year



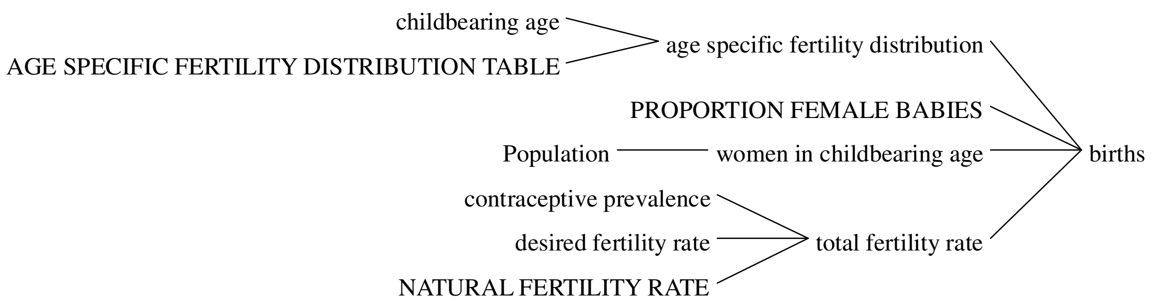
Total population

Total population = SUM(Population[sex!, age!])
Units: Person



Births

Births[FEMALE] = SUM(women in childbearing age[childbearing age!]*total fertility rate*age specific fertility distribution[childbearing age!])*PROPORTION FEMALE BABIES
Births[MALE] = SUM(women in childbearing age[childbearing age!]*total fertility rate*age specific fertility distribution[childbearing age!])*(1-PROPORTION FEMALE BABIES)
Units: Person/Year



Deaths

Deaths[sex,age] = Population[sex,age]*death rates[sex, age]
Units: Person/Year