

ODD+D PROTOCOL FOR ABSOLUG VERSION 1.1.0

This OOD+ protocol is based on von Essen & Lambin (in review), Agent-based simulation of land use governance (ABSOLUG) in tropical commodity frontiers, *Journal of Artificial Societies and Social Simulation*

We developed ABSOLUG with the NetLogo multi-agent modeling software (Wilensky 1999) and described it using an adapted version of the ODD+ D (Overview, Design Concepts and Details, + Decisions) protocol (Grimm et al. 2006, 2010; Müller et al. 2013).

Overview

Purpose

The purpose of ABSOLUG is to advance our understanding of land use governance, identify macro-level patterns of interaction among governments, commodity producers, and NGOs in tropical deforestation frontiers, and to set a foundation for generating middle-range theories for multi-stakeholder governance approaches. The model represents a simplified, generic, tropical commodity production system, as opposed to a specific empirical case, and as such aims to generate interpretable macro-level patterns that are based on plausible, micro-level behavioral rules (Gilbert 2020). It is designed for scientists interested in land use governance of tropical commodity production systems, and for decision- and policymakers seeking to develop or enhance governance schemes in multi-stakeholder commodity systems.

Entities, state variables, and scale

The ABSOLUG model features a landscape consisting of cells (called patches) in which agents move and interact in discrete time steps (called ticks). It comprises four types of human agents (government, non-governmental organizations, smallholder producers, and largeholder producers), and a non-human entity (landscape). Definitions of largeholder and smallholder producers vary substantially with geographic context, for example a household in the Brazilian Amazon with 200ha under cultivation is considered a smallholder (Carrero et al. 2020) while cocoa-producing smallholder household in Ghana cultivates less than 5 ha of land on average (Bymolt et al. 2018). Generally, smallholders tend to rely on family members to work the land more frequently than largeholders, engage in polyculture, and cultivate less than 5 hectares (Bymolt et al. 2018; FAO 2015; Feintrenie et al. 2010). Largeholders employ laborers to work on their land, operate monocultures, and the area under cultivation ranges from 500 – 5000 ha (Carrero et al. 2020). The contributions to deforestation from small- and largeholders also vary substantially with commodities and geographic contexts, for example cocoa in West Africa is predominantly produced by smallholders while most of the soy in the Brazilian Amazon is produced by farms with an average size of 500ha (Carodenuto 2019; Cattelan & Dall’Agnol 2018). In our model, we categorize largeholders into three sub-groups (pioneers, mainstreamers, and laggards). Agents are homogenous within their respective type (e.g., smallholder or NGO) and sub-group (e.g., pioneer or laggard largeholder). The model operates along discrete time steps (ticks) where each tick represents three months, which is sufficiently granular to allow for actions within crop growing seasons yet broad enough to manage computing requirements.

The government-agent represents the political entity governing the landscape and is characterized by its propensity toward environment or business, its conservation goals, and subsidization and/or taxation of crop cultivation, eco-certification, and intensification. It monitors protected areas, penalizes the agricultural encroachment into protected areas, and responds to political pressure from NGOs and largeholders according to a user-defined cadence (*Government-action-cadence*). ABSOLUG users determine the goals of the government with respect to economic development and nature conservation, e.g., the government could prioritize the expansion of area under cultivation or aim to designate protected areas and promote environmentally friendly production methods.

The NGO-agent represents social and environmental NGOs that operate in the landscape and monitor the activities of the government and largeholder producers. They apply political pressure to the government if deforestation rates exceed a user-defined threshold, and campaign against largeholder producers who encroach protected areas or illegally acquire smallholder-owned land. Users can determine how often NGOs can campaign (*NGO-action-cadence*) and how well they can monitor deforestation and encroachment (*NGO-deforestation-monitoring*).

Smallholder-agents represent households that engage in shifting cultivation and commodity crop cultivation. Smallholders can move up to ten patches per tick and carry out one action per year (i.e., every four ticks) (parameter *Action cadence smallholder*), choosing among three actions: converting forest to crop land, intensify or certify owned crop land, or idle.

Largeholder-agents represent commodity crop producing companies or individual farmers with large landholdings and are categorized as pioneers (high intrinsic motivation to adopt sustainable cultivation practices, high reputational risk), mainstreamers (little intrinsic motivation to adopt sustainable cultivation practices, medium reputational risk), or laggards (no intrinsic motivation for sustainable cultivation, little reputational risk). The number of largeholders in each category is user-defined and largeholder agents remain in their respective category for the duration of the simulation. Largeholders can move across the landscape freely and carry out one action every 1.5 years (i.e., six ticks) (parameter *Action cadence largeholder*), choosing among four land use actions: converting forest to crop land, intensify or certify owned crop land, or idle. The action cadence reflects the balance between resource limitations for largeholders in developing new concessions and the rapid growth observed in some tropical commodities such as palm oil (265% increase in planted area between 1990 and 2010, Pirker et al. 2016) and soy in Brazil (almost tenfold increase in production volume between 1975 and 2015, Bicudo Da Silva et al. 2020).

The ABSOLUG landscape consists of 125 x 125 patches (15,625), each representing a 1-hectare unit of the landscape. A central attribute of patches is their land use type which can be either natural (forest, riparian zone, river), anthropogenic (marketplace, cropland, fallow), or hybrid (protected area, smallholder forest). The initial landscape is comprised of 13,980 forest patches (89.47% of total patches), 978 river and riparian patches (6.26%), and 665 anthropogenic patches (4.26%). Patches can transition from one land use to another through natural succession or human intervention. Other patch attributes include ownership and time of land use change and the default simulation duration is 40 years (160 ticks).

Process overview

The model represents three processes related to forest cover change: land use, governance, and business processes (Figure 1). Processes in agent-based models are the result of interactions among individual agents and are characterized by causal links and feedback loops (Gilbert 2020). Agent behavior is determined by conditional arguments (if-then arguments) and agents perform actions if the corresponding conditions are met, resulting in a model logic that is based on a network of conditional statements.

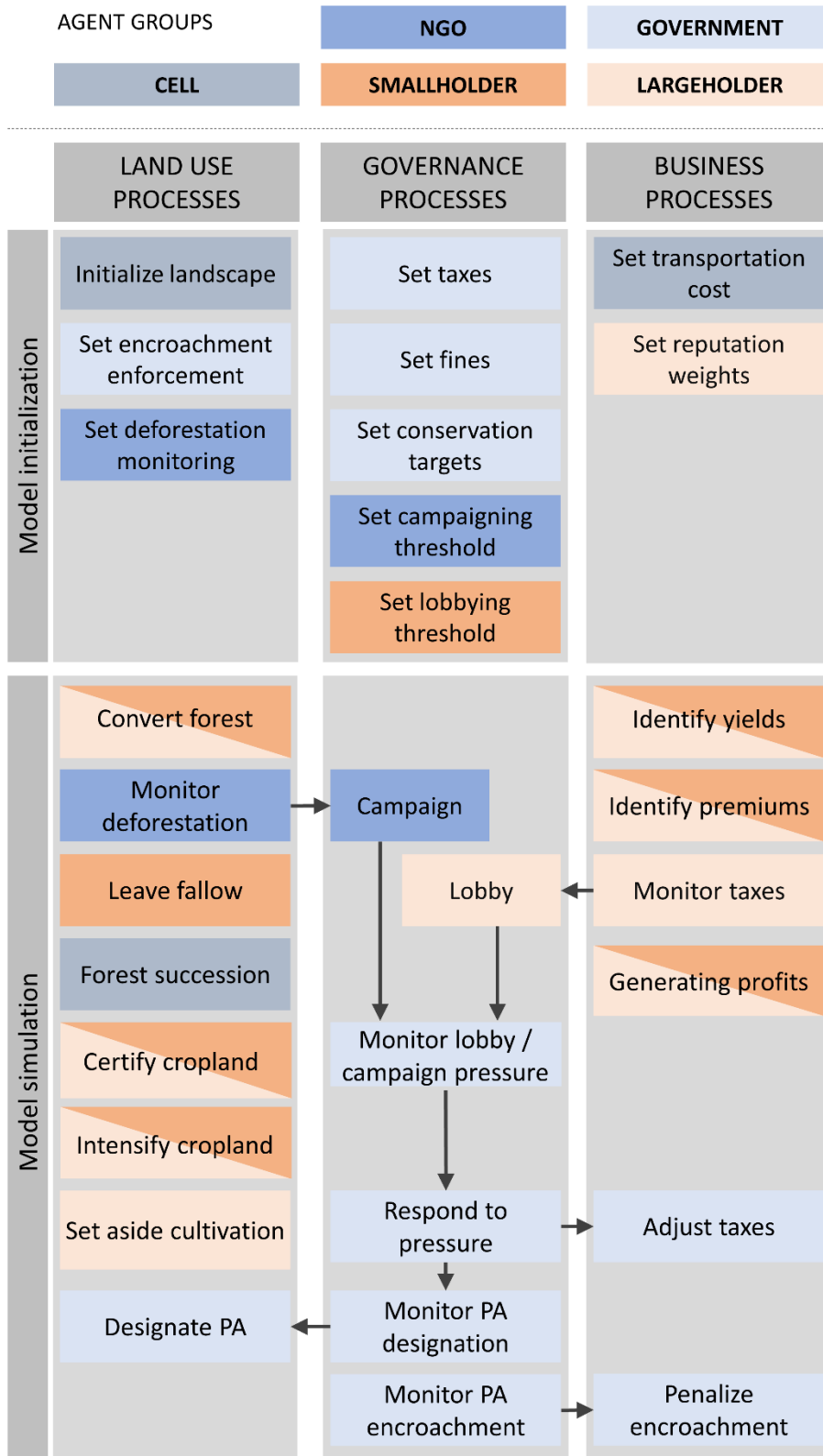


Figure 1: Process overview. Five agent groups engage in processes across three process columns (land use, governance, and business). Model initializations

determines the conditions at the start of the simulation. During the model simulation, processes occur repeatedly and may create feedback loops.

Business processes

Business processes revolve around crop cultivation driven by smallholders and largeholders (collectively called growers) seeking to maximize their profit. Profits are generated by engaging in crop cultivation and are defined as the difference between income and costs. Income is determined by yield, price, and price premiums, and costs by operational, transportation, and reputational costs. Initial, one-time costs, such as acquisition of land or costs of meeting eco-certification standards are rolled into the operational costs. Profits are calculated for each patch, using the net present value discounted to infinity with a discount rate of 5% (Heilmayr et al. 2020). Following Ricardo's law of rent, growers choose the most profitable action by sensing the landscape for the patch that generates the highest profit from cultivation, eco-certification, or intensification (Ricardo & Gonner 1891). If no patch is profitable, growers choose to idle. The profitability of a patch can vary among agent groups, depending on the group's reputational risk and inclination for sustainable practices.

Consistent with von Thünen's model of agricultural land use (von Thünen, 1826), the location of each patch in relation to the central marketplace determines the transportation costs associated with producing crops – the further away from the central marketplace, the higher the transportation cost. As the simulation progresses, transportation costs decrease to simulate improvements in infrastructure.

Smallholders engage in shifting cultivation and return to forest cells that they previously cultivated, creating an informal system of land ownership. When smallholders choose to certify or intensify a patch it is no longer part of the shifting cultivation cycle.

Process details: determining most profitable land use.

When their action cadence allows them to act, growers determine their action based on the net-present-value of each cultivation option, defined as:

$$NPV_{\text{cultivation}} = (y + r_{\text{gain}}) - (C_{\text{land}} + C_{\text{transportation}} + C_{\text{eco-certification}} + C_{\text{intensification}} + r_{\text{risk}}) / 5,$$

where y = yield, r_{gain} = reputational gain for the cultivator from engaging in eco-certification, r_{risk} = reputational risk for the cultivator from engaging in land conversion, and C = various costs.

Reputational gain and risk vary by largeholder type, with pioneer largeholders having the highest gains and risks, and laggard largeholders the lowest. Intensification is reputationally neutral and does not entail a reputational risk or gain. Land costs represent all costs related to ownership and cultivation of patches, as well as taxes. Transportation costs are determined by the distance of the patch to the central marketplace and the time of the simulation, defined as

$$C_{\text{transportation}} = \log_{10}(\text{distance-to-center}) / \log_{10}(\text{ticks}),$$

Where distance-to-center is the distance of the patch to the center of the model landscape.

Eco-certification and intensification costs are user-defined and can include represent government subsidies for sustainable cultivation. Growers scan each patch for each cultivation option and move to the patch with the highest net present value. If several patches have the same net present value, growers move to a random patch. Largeholders monitor changes in land-costs (i.e., taxes) and lobby the government to lower taxes once a user-defined threshold is crossed.

Governance processes

Governance processes represent lobbying and campaigning efforts by largeholders and NGOs and the government's responses. NGOs monitor deforestation rates and campaign directly against the government if rates exceed a threshold and indirectly against largeholders through demanding more stringent regulation of production. Largeholders monitor taxes on crop cultivation and lobby the government if a cost threshold is crossed or if no cultivation options are profitable. When responding to NGO campaigning, the government chooses between tax increases on crop cultivation or designation of protected areas. When responding to largeholder lobbying, the government decreases taxes on crop cultivation.

Process details: NGOs and largeholders applying political pressure

Largeholder lobbying is triggered by increases in cultivation cost or by a lack of profitable cultivation options. Largeholders monitor their cultivation costs every other tick (i.e., semiannually) and apply pressure to the government if the current cultivation costs exceed the initial cultivation costs by a user-defined percentage (parameter *Largeholder lobbying threshold*, Table 1). If there are no profitable cultivation options, largeholders apply a user-defined pressure value to the government each time they idle (parameter *Action cadence largeholder*).

NGOs monitor the landscape every other tick and apply pressure to the government if the annual deforestation rate exceeds a user-defined threshold (parameter *NGO campaigning threshold*, Table 1) or when a largeholder converts a patch of forest that is informally owned by a smallholder.

Process details: governments responding to pressure

Pressures on government accumulate over time and are accounted for in two pressure-contingents, one for lobbying pressure from largeholders and one for campaigning pressure from NGOs. By default, campaigning increases the NGO-pressure-contingent by one pressure-unit (see the Interactions section of the ODD+ protocol). Lobbying takes place when land taxes exceed the initial land taxes by a user-defined threshold that can vary for each largeholder type or when the economic conditions of the simulation force largeholders to idle. The amount of lobbying pressure applied to the largeholder-pressure-contingent depends on the lobbying thresholds and composition of the largeholders. The government checks its pressure contingents according to the user-defined Government-action-cadence and responds to pressure if the contingents reach a certain value which is determined by the governments inclination towards pro-environmental policies (parameter *Government favoring environment*) or inclination towards pro-cultivation policies (parameter *Government favoring business*). If the lobbying-pressure threshold is crossed, the government lowers taxes by a user-defined value (Richter et al. 2009). If the campaigning-pressure threshold is crossed, the government has two options, it either declares a protected area or increases taxes depending on its progress toward achieving its conservation

goal which is a user-defined percentage of the landscape to be protected by the end of the policy period. When it is on track to meeting its conservation goals, the government increases the current taxes by a user-defined percentage. The agent group, either NGOs or largeholders, achieving a government response resets its pressure contingent to its baseline while the agent group whose pressure was not responded to sets its pressure contingent to half of its current value. This mechanism reflects the recognition by agents that the government has limited capacity to respond to pressure while maintaining a raised pressure contingent from the losing side (Haslam & Godfrid 2020; Jänicke 1992). Interactions among the government and largeholders and/or smallholders are tracked.

Process details: conservation goal

The conservation goal is a percentage of the model landscape to be protected by the end of the simulation. It is modeled off the idea to formally protect a certain percentage of terrestrial and freshwater ecosystems by a target date, as seen in the Convention on Biological Diversity's Aichi Target 11 where signatories pledged to designate 17% of their terrestrial and inland waters as protected area by 2020 (SCBD 2011).

The trajectory towards achieving the conservation goal is a linear function defined as

$$\text{Conservation trajectory} = N_{\text{protected}} / T_{\text{policy}},$$

where $N_{\text{protected}}$ is the number of patches to be protected by the end of the simulation, and T_{policy} the duration of the policy in ticks.

At each tick, NGOs monitor progress towards the conservation goal and call on the government to act if the remaining natural area in the simulation world is smaller than the area determined by the conservation trajectory. If the campaigning-pressure threshold is crossed and the government is not on track to meeting its conservation goal, then it declares a large protected area (421 patches with 96 buffer patches) instead of raising land taxes.

If the government is set to be proactive towards achieving its conservation goal, it designates protected areas without NGO pressure. To reflect resource constraints faced by governments, proactive designation follows the same cadence as responses to pressure and is carried out only if neither pressure from NGOs nor largeholders exceeds their respective thresholds, i.e., the government only carries out an action once per year (i.e., every four ticks). A proactive government determines whether it is on track to meeting its conservation goal by comparing its conservation trajectory to the current area under protection. During the policy period (years 15 to 40), the government considers it is on track to meeting its conservation goal if the number of protected patches in the model world exceeds the number of protected patches as determined by the conservation trajectory. To reflect initial inertia and resource challenges, the government designates small protected areas (213 patches with 72 buffer patches) during years 25 to 32, and large protected areas (421 patches with 96 buffer patches) during years 32 – 40.

Land use processes

Land use processes pertain to regulation, alteration, and monitoring of forest cover, such as conversion, natural succession of forest, or designation of protected areas. The focus of this

model is on land use transitions associated with agriculture, thus excluding forestry operations (e.g., selective logging) and natural forest disturbances (e.g., drought, fires, storm events) that cause forest degradation. Smallholders convert a single patch per action while largeholders convert 45 patches in a concentric circle around their position. Eco-certification and intensification occur on already converted patches. Eco-certification can only occur on patches that have been converted prior to a user-defined cut-off value, resembling the use of cut-off dates in sustainability eco-certification schemes such as the Roundtable for Sustainable Palm Oil or the Round Table on Responsible Soy (RSPO 2018; RTRS 2017). Pioneer largeholders can engage in set-aside conversion where an area of 69 patches is affected of which two-thirds (45 patches) are converted to eco-certified crop land and one-third (24 patches) is set aside for conservation to replicate set-aside schemes such as Olam's Sustainable Palm Oil Policy in Mouila, Gabon (Booth 2012). Smallholders engaging in shifting cultivation and fallow their crop patches after 8 time-steps (2 years) (Hauser & Norgrove 2013; Mertz et al. 2009). Deforestation rate is calculated annually as

$$r = (1 / t_2 - t_1) * \ln (A_2 / A_1),$$

where A_1 and A_2 are forest cover at time t_1 and t_2 (Puyravaud 2003) and adjusted to model specifications.

Process details: largeholders converting, intensifying, or certifying land

After determining the net present value of all patches in the landscape, largeholder agents move to one of the patches with the highest value. When converting, patches are imprinted with information such as time of conversion, agent type, and the unique agent-ID of the converter. Largeholders can only certify or intensify patches they own, i.e., patches with a matching agent-ID, and only conventional crop patches can be eco-certified or intensified. Eco-certification is only possible on patches that have been converted prior to the cut-off date and users can define the production cost premium and sales price premium of eco-certified commodities. Largeholders move to the patch with the highest net present value and certify or intensify all patches with matching agent-IDs within a radius of 3.8 patches around their position.

Process details: smallholders converting, intensifying, or certifying land

After determining the net present value of patches in radius of 10 patches around their position, smallholder agents move to one of the patches with the highest net present value and convert, certify, or intensify the patch they are located on. When converting, smallholders imprint their unique agent-ID on the patch, creating an informal system of ownership where reforested patches are still associated with the smallholder agent who originally converted it. Smallholders engage in shifting cultivation and fallow their crop patches after 2 years (8 ticks). Fallow patches return to secondary forest after 5 years (20 ticks) and mature forest after 20 years to mimic natural forest succession in tropical ecosystems (Hauser & Norgrove 2013; Lourens et al. 2021; Mertz et al. 2009). To convert, smallholders return to their informally owned forest patches if possible and otherwise seek out non-owned patches.

Process details: protected area encroachment

Encroachment is the illegal conversion of patches in protected areas to cropland. It is punishable by a fine, whose amount varies with the protection-tier of the encroached patch. Patches can be protected in one of three tiers where Tier 1 protection has the highest encroachment fine and is typically applied to protected areas and river buffers. Tier 2 patches are buffer zones of protected areas and forest informally held by smallholders. Tier 3 protection can be applied to conventional forest patches. Land-use decisions by growers integrate the risk of being fined in their estimation of the cost of forest encroachment by multiplying the fine for encroachment by the perceived probability of enforcement. Whether a largeholder encroaches a protected area is determined by the cost of encroachment and by how much the largeholder values reputation (parameter Importance of reputation). Besides incurring a potential fine, encroachment into protected areas has negative reputational impact, as seen with Greenpeace's campaign against Nestlé for allegedly sourcing palm oil linked to deforestation (Greenpeace 2010). Pioneer largeholders incur the highest reputational damage and laggard largeholders the least. Encroachment of protected areas or riparian buffers (Tier 1) is considered most damaging to reputation and encroachment of conventional forest (Tier 3) the least. Reputational damage is expressed as a modifier on the cost side of the decision-making formula. To reflect the different levels of reputational damage associated with the conversion of forest patches with different degrees of formal protection, encroachment of Tier 1 patches is weighted with a factor of two, encroachment of Tier 2 patches with a factor of 1.5, and encroachment of Tier 3 patches with a factor of one.

Design concepts

Theoretical and empirical background

Our model simulates forest cover change in space and over time, building on four theoretical frameworks, the von Thünen model of land rent (spatial), Ricardo's law of rent (economic), the forest transition theory (temporal), and Abbot & Snidal's governance triangle (regulatory). In von Thünen's model, conversion of land is a result of actors seeking land rents. Rents are determined by proximity of the land to a central marketplace (Angelsen 2007; von Thünen 1826) and defined as the difference between income (yield, price) and cost (wages, capital, transport costs). Following Ricardo's law on rent, actors choose sites with higher rents over marginal sites with lower rents, given the same inputs of labor and capital (Ricardo & Gonner 1891). Growers seek to maximize land rents and individual agents hold no preferences for specific actions or locations (Sen 2017).

The governance triangle consists of private (growers), public (government), and civil society (NGOs) actors, all interacting in the regulatory standard-setting process (Abbott & Snidal 2009). Civil society organizations are pursuing to influence social and environmental practices of largeholder producers through a combination of public politics, i.e., advancing their agenda through public institutions, or through private politics, i.e., advancing their agenda by targeting private agents, often in the public domain (Baron & Diermeier 2007; Eberlein et al. 2014). The objectives of public actors, their regulatory power over the private sector, and their desire to regulate vary substantially across geographies. While some governments emphasize the conservation of natural ecosystems, others may prioritize economic development over the associated social and environmental externalities or may not have the resources and capacity to address them adequately (Abbott & Snidal 2009). Governments, in contrast to private and civil

society actors, have the option to directly regulate land use processes if their institutions are sufficiently strong (Abbott & Snidal 2009).

The forest transition theory describes empirical observations of forest cover change and identifies a contingent chronological sequence observed for a few countries (Angelsen 2007; Rudel et al. 2005). Starting with low rates of deforestation in a high forest cover landscape, deforestation rates increase until forest cover reaches a minimum after which a transition to forest expansion occurs, followed by an eventual stabilization (Angelsen 2007; Mather 1992; Rudel et al. 2005).

Individual decision-making

Decision-making occurs at the level of the individual agent and agents apply their decision-making logic consistently. Changes in input variables might affect decision-making, for example higher encroachment fines decrease the likelihood of agents encroaching protected areas. Crop-cultivating agents pursue the objective of maximizing profit based on the net present value of land rent. Cultural norms and values are reflected in different valuations of reputation by pioneer, mainstreamer, and laggard largeholders.

Individual sensing and prediction

Agents non-erroneously sense the values of variables relevant to their decision-making in a radius of ten patches around their current location (smallholders) or in the entire landscape (largeholders, NGOs, and the government). Cost for cognition or information gathering is not explicitly included and growers predict future revenue streams to determine the net present value of their actions. Relevant information to calculate revenue streams are available to agents and include yield, price, operational costs, premiums, potential fines, reputational impact, and transport costs.

Interactions

Direct interactions among NGOs, government, and growers include lobbying (largeholders to government), campaigning (NGOs to government and largeholder agents), and policy interventions such as taxation, subsidies, and fines (government to growers). Interactions depend on changes in state variables such as deforestation rate, taxes, and protected areas, and on detection of encroachment by growers, and are coded as if-then conditions. For example, the triggering of largeholder lobbying and NGO campaigning are coded as follows:

If ticks are even AND if $\text{land-taxes} > (\text{initial-land-taxes} * \text{pioneer-lobbying-threshold})$
Then increase largeholder-pressure-contingent by $(\# \text{-of-pioneers} / \text{total-}\# \text{-of-largeholders})$

If ticks are even AND if $(\text{Annual-deforestation} * \text{NGO-deforestation-monitoring}) > \text{NGO-reporting threshold}$

Then increase NGO-pressure-contingent by 1

Growers directly interact with the landscape by changing land use (e.g., from forest to cultivated land). The government interacts with the landscape by changing its protection status. Smallholders and largeholders can move across the landscape, while the government and NGOs are stationary. Growers compete indirectly for the best patches for crop cultivation.

Stochasticity

The initial placement of agents within the central marketplace is random. The delay before agents carry out their first action is a random value between zero and nine months (zero to three ticks) for smallholders and one to two years (four to eight ticks) for largeholders. This delay-difference allows smallholders to establish ownership over land patches without pressure from largeholders and mimics the low deforestation rates observed in the pre-frontier deforestation phase (Rodrigues et al. 2009). If presented with multiple equally profitable patches, agents randomly select one of these patches.

Observation

Outputs and variables that are monitored for analysis include deforestation rate, encroachment of protected areas, area of conventional, eco-certified, and intensified cultivated land, area of set-aside protected areas, area of forest, transactions among agents, operational costs (including taxes), idling of producers (measured as stagnation), and the political pressure applied to the government. All outputs are emerging from the actions of individual agents.

Details

Implementation details and initialization

The model has been implemented in NetLogo version 6.2.0 (<https://ccl.northwestern.edu/netlogo/>). The initial state of the landscape resembles a central marketplace surrounded by a homogenous, flat landscape with undisturbed forest, consistent yields, and two rivers (Figure 2). The model captures key processes of the system through simplification and stylization (Gilbert 2020).

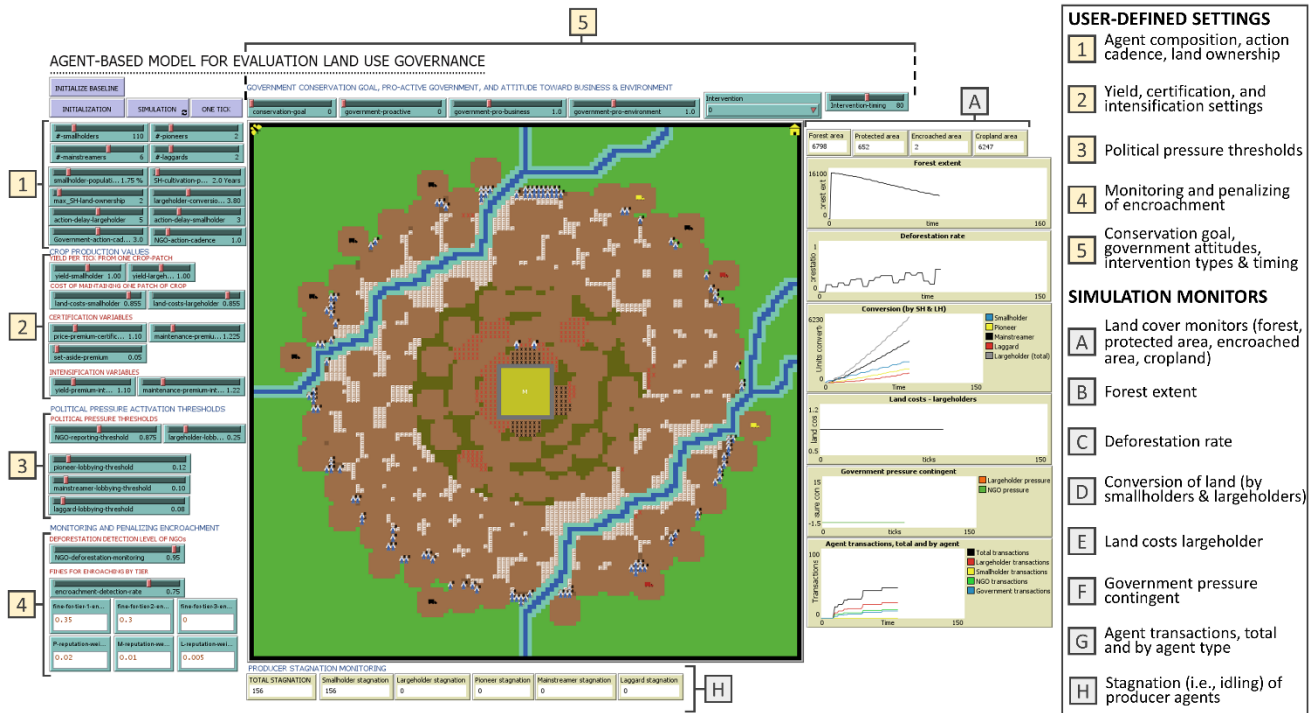


Figure 2: The graphic user interface of the ABSOLUG after the first 20 years of a 40-year baseline simulation, monitoring information related to business performance, agent transactions, and deforestation.

Simplifications include full demand for all produced commodities without any intermediaries or traders, a stable population of growers throughout the simulation, and consistent yields over space and time. The initialization does otherwise not vary among simulations and initial values are based on empirical data derived from the scientific literature, prior model calibration, or user preferences (Table 1).

Table 1: Parameter overview for a baseline scenario. Parameter value range is informed by literature and final values are based on the baseline scenario calibration.

Process	Parameter	Baseline value	Source
Initialization	Simulation period	40 years	Andersen et al. (2017) Valbuena et al. (2010) An et al. (2005)
Land use	Conversion per action - smallholder	1 patch	Maas & Wolfensen (2013) USDA Foreign Agricultural Service (2009) FAO (2015) Feintrenie et al. (2010) Bymolt et al. (2018)
Land use	Conversion per action - largeholders	45 patches	USDA Foreign Agricultural Service (2009) Cattelan & Dall'Agnol (2018) IBGE (2017)
Land use	Set-aside percentage of protected area in concession	34.87%	Scriven et al. (2019) Hoyle (2015)
Land use	Crop to fallow period	2 years	Hauser & Norgrove (2013) Pelzer (1945)

Land use	Fallow to forest period	5 years	Mertz <i>et al.</i> (2009) Hauser & Norgrove (2013) Pelzer (1945) Mertz <i>et al.</i> (2009)
Governance	NGO campaigning threshold	0.60%	Landsat data (2014)
Governance	Conservation goal	0	SCBD (2011)
Business	Net present value discount period	∞	Expert judgement
Business	Net present value discount rate	5%	Expert judgement Heilmayr <i>et al.</i> (2020)
Business	Eco-certification price premium	10%	Furumo <i>et al.</i> (2020) Lambin & Rueda (2013) Fenger <i>et al.</i> (2017) Lakhal <i>et al.</i> (2008) Hutabarat <i>et al.</i> (2018) Glasbergen (2018)
Business	Eco-certification costs	21%	Calo & Wise (2005) Setboonsarng <i>et al.</i> (2008)
Business	Eco-certification cut-off value	20 years	RSPO (2018) Hospes (2014)
Business	Intensification yield improvement	10%	Rhebergen <i>et al.</i> (2020) Hipólito <i>et al.</i> (2018) Antoneli <i>et al.</i> (2019) Mueller <i>et al.</i> (2012)
Business	Intensification costs	20%	Modeling decision based on scenario calibration
Business	Set-aside maintenance premium	0.03	Modeling decision based on scenario calibration
Internal	Action cadence smallholder	3	Hidden model parameter
Internal	Action cadence largeholder	5	Hidden model parameter
Internal	Pioneer importance of reputation	0.02	Hidden model parameter
Internal	Mainstreamer importance of reputation	0.01	Hidden model parameter
Internal	Laggard importance of reputation	0.005	Hidden model parameter
Internal	Largeholder lobbying threshold	10%	Hidden model parameter
Internal	Largeholder lobbying while idle	0	Hidden model parameter
Internal	Government favoring business	1	Hidden model parameter
Internal	Government favoring environment	1	Hidden model parameter
Internal	Tier 1 encroachment fine	0.2	Hidden model parameter
Internal	Tier 2 encroachment fine	0.1	Hidden model parameter
Internal	Tier 3 encroachment fine	0.0625	Hidden model parameter