Master's thesis

Rule compliance in public forests: A pilot experiment

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This thesis would not have been possible without the curiosity my parents have instilled in me ever since I was a child. It has been a curiosity that motivated me to move abroad many times and pushed me to study something as interdisciplinary as system dynamics. I thank them for teaching me the essence of logical reasoning and supporting me in every way possible.

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Abstract

Illegal logging is a serious issue that not only has dire environmental and social consequences, but also bring forwards the issue of poor governance of common pool resources. The purpose of this thesis is to contribute to understanding the causes of illegal logging. I integrated existing findings into one theoretical framework for rule compliance onto which I base my knowledge contribution. Further, by building a system dynamics model on aggregate forest and policymaking dynamics, I ran simulations calibrated on historical data. Model simulations showed general fit-to-behavior with discrepancies for the logging function, pointing to the need to study how logging decisions are made. Because of this I designed a multiplayer online simulation game whose rules include an incentive, monitoring and sanctioning mechanism tied together in a scoring function. The participants in the pilot experiment played the game and then reflected about their experience in an interview. Through cross-referencing participant performance and their expressed rationale, I was able to derive initial insights on reasoning behind compliance with the allowable annual cut. Results showed that participants differed in motivation (competitive or noncompetitive) and strategy (compliant and noncompliant). Overall, participants with a compliant strategy expressed more reasons justifying their behavior compared to noncompliant participants. Illegal gain was most often used as a justification for noncompliant behavior, pointing to the incentive structure as a leverage point. Receiving news that another player has been sanctioned reinforced the participants original strategy, which highlights the role of social norms. These initial insights broaden scholarly understanding of compliance and set the stage for running a full-scale experiment. This thesis also has a methodological contribution as it outlines the process of developing a simulation game based off a system dynamics model for the specific purpose of research. Moreover, it proves the usefulness of pilot experiments for studying decision-making reasoning.

Keywords: compliance, illegal logging, reasoning, public forest, system dynamics model, simulation game, pilot experiment

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Chapter 1: Introduction

1.1 Background

Ever since the publication of "Tragedy of the Commons" (Hardin, 1968), the public has realized that common-pool resources are prone to exploitation. The commons are rivalrous non-excludable resources, which means that it is not possible to prevent people from using them, yet they are exhaustive in the sense that there is less available for others when one user increases their use. Public forests, or rather wood from public forests, is a common pool resource. This means that they are prone to exploitation that could ultimately lead to their destruction, i.e. a tragedy that could have been prevented. In the context of public forests, the tragedy refers to an insufficient level of wood in public forests leaving loggers unable to meet any demand. In addition to this, the tragedy also includes a variety of negative environmental effects like biodiversity loss and climate change (Lawrence & Vadencar, 2015).

The latest issue of Forest Resources Assessment from the Food and Agriculture Organization of the United Nations (2020a) showed that there are 4.06 billion hectares of forest remaining. The global trend has shown a persistent rate of net forest loss, ever since the publication of the first official global statistic about net loss from 1980 to 1990 (FAO, 1995), albeit the rate of loss has gradually been slowing down since then.

The tragedy of the commons offers one plausible explanation for the reality of deteriorating forests. However, the tragedy of the commons is an example of an open access resource, i.e. a resource that is not owned by anyone and there are no relevant examples of socio-ecological systems that are truly open access. Even public meadows are de jure owned by national governments. Possible land tenures include private (state or individual), communal or some form of hybrid ownership structure. Most of the global forests are public, even though the percent of public forests has decreased to its current value of 73% (FAO, 2020a), which explains the focus on public forests in this thesis.

Faced with the deteriorating state of global forests and the fact that they are under land tenure agreements, as opposed to open access, it is worthwhile to examine the factors leading to their detriment. Forest use is impacted by population pressure and market mechanisms. This has already been captured in existing system dynamics research in the context of other common pool resources. A notable example is the Fishbanks simulator (Sterman, 2014), which describes the effect of market pressures on a fishing stock with no official owner.

Following up on this, Moxnes (2000) has set a hypothesis regarding misperceptions of feedback, which analyzes the case of a resource with a single owner. This research posits that a significant reason for mismanagement may simply be cognitive inability to appreciate the feedback present in socio-ecological systems. Put simply, given the existence of a market mechanism users are unable to manage the resource, despite goodwill, because of faulty strategies that do not take into account bioeconomic complexities. Rather, their strategies are a better fit to simpler control systems, like the impulse to remove one's hand from a hot stove in order not to get burned.

However, both these examples fail to include governance as a mediator of the effect of population pressures and market mechanisms. In fact, institutional efficiency has come out as the best predictor for forest sustainability according to field research (Agrawal, 1997). In the words of Ruiz-Pérez, Franco-Múgica, González, Gómez-Baggethun & Alberruche-Rico (2011), the Fishbanks simulator is a representation of "a tragedy of open access", as it only describes the effect of market pressures on a resource with no owner or governance regime. They were the only ones to run experiments with the Fishbanks simulator that accommodated institutions employing governing rules. Not surprisingly, they found that groups that formed institutions outperformed groups that did not.

In light of this, data on global forests shows that about a half of the remaining forests have official management plans (2.05 billion hectares). Yet, despite this, many forests are unsustainably managed, as evidenced by long-running global forest net-loss rate, pointing the finger to poor governance, rather than the lack of an official management plan, as the cause for deforestation, specifically in the tropics (Fischer, Giessen & Günter, 2020)

For the purpose of this thesis, I use the term governance as it was defined by the FAO: "the formal and informal rules, organizations and processes through which private and public actors articulate their interests" (2020b). In contrast to the concept of management, which addresses direct control over decisions, governance refers to a higher act of steering decisions. In the context of the commons, governance refers to the effect of the authority on individual decisions, while management refers to the effect of individual decisions on the resource.

On that end, it is worth exploring the causes of poor governance as well as defining what good governance is. For the purpose of this research, good governance is an equivalent of a regime that yields forest sustainability, i.e. a regime that establishes long-term resource non-deterioration (Floyd, Vonhof & Seyfang, 2001). As for the causes of poor governance, there is no panacea for governance of the commons. However, the causes of poor governance can be inspected in relation to the state of the resource and individual decision-making.

I have created a conceptual model to explain the context in which I will conduct this research (see Figure 1). As previously defined, the commons refer to socio-ecological systems that are composed of three parts: (1) a resource, (2) formal or informal rules governing its use and (3) individual decisions regarding extraction levels. Take the example of a public forest. Its state serves to influence governance rules through a rule-formation process. Next, individuals, or groups of individuals, may choose to comply with the governance rules or not against their better judgement. Finally, individual decisions directly influence the state of the forest through extraction.

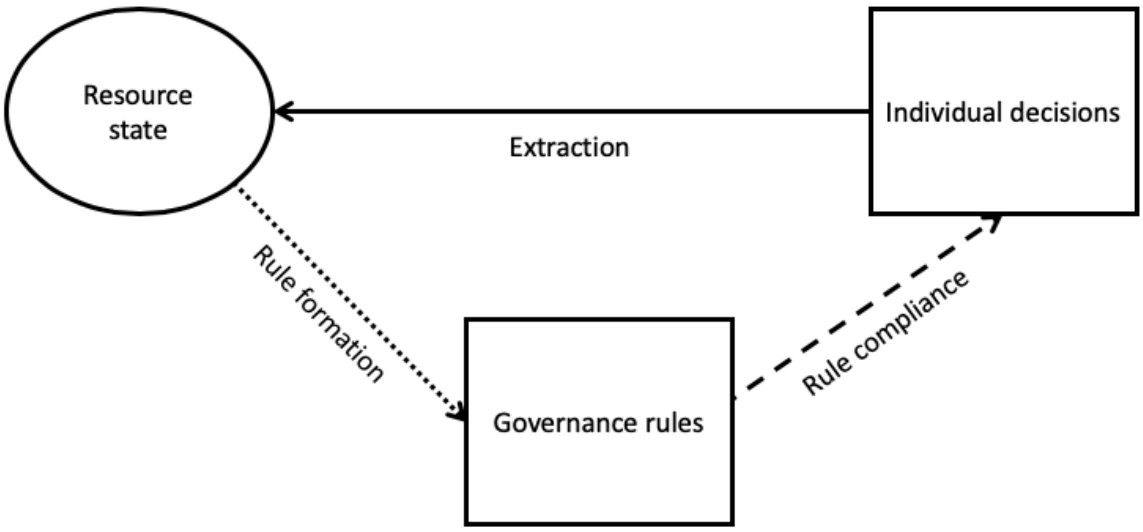

Figure 1. A concept model of the commons (Source: Author's representation). The circle denotes a physical variable, while boxes reflect non-physical variables. Similarly, the solid line stands for a physical process, while the dotted and dashed line are non-physical processes.

Notwithstanding, this diagram is a simplified abstraction and not an attempt to portray reality as it is. It may, for example, very well be that the resource is affected through factors not present in the conceptual model. However, the concept model serves solely the purpose of narrowing down the focus of this thesis to rule compliance. Based on this, rule compliance can be understood as the process through which governing rules influence individual decisions in the context of a certain resource state. One of the greatest contributors to the literature on governance rules for the commons is Ostrom (2005: 415), who identified seven broad types of rules as shown in Table 1.

Together, rules of these classifications make up a governing policy for the commons, although they may not always be formal or explicit. Despite this rich reality of governance rules, I will focus solely on compliance as the effect of choice, information and payoff rules on individual decisions. And I will make simplified assumptions for all the other rules. Specifically, choice rules will be represented through a quota, information rules will be represented through information about the resource state and the behavior of others, payoff rules will be represented as a monitoring and sanctioning mechanism as well as a scoring mechanism. The details of this are elaborated in the following chapters.

Rule type	**Description**
Position	Rules that specify the power hierarchy in the governance structure
Boundary	Rules that define the circumstances under which there may be a change in positions of the power hierarchy
Choice	Rule regarding the types of decisions individuals can make and their obligations
Aggregation	Rules that describe how governing decisions ought to be made in the presence of multiple positions with partial control
Information	Rules that characterize the types of information in the commons and its availability
Payoff	Rules that set the external rewards or sanctions as well as the conditions under which they are receivable
Scope	Rules that limit the range of possible outcomes

Table 1. Seven broad types of governance rules for the commons (based on Ostrom, 2005)

1.2 Extent and significance of the problem

When studying compliance, it is important to describe the extent of illegal behavior in public forests. INTERPOL (2019) estimates that up to 30% of global timber production is the result of illegal logging. The extent of illegal logging varies in different regions rising up to an estimated 90% of illegal logging in some tropical countries. The consequences of this can be staggering. There are economic costs on governments, who are being robbed off revenue, and on responsible loggers, whose income is lowered as a result of devaluation of the price of timber (European Commission, 2020; Yale School of Forestry and Environmental Studies, 2020), estimated to be up to 16% depending on the type of wood product (WWF, 2020). Further, the environmental effects of increased deforestation due to illegal logging are contributing to global warming and biodiversity loss. Finally, illegal logging is also detrimental to local and indigenous communities and has been shown to lead to violent conflict (Conterras-Hermosilla, 2002:16).

From a scientific perspective, illegal logging has been linked to poor policy, corruption and rising demand (FAO, 2005:7). Sutinen & Kuperan (1999) posited that “there is little or no recognition of how policies and the policy process may affect the extent of compliance with regulations” and that “policy analysis and formulation frequently assume perfect compliance can be achieved at no cost”. Hence, research on understanding the causes of noncompliance is ongoing and its significance lies in the fact that studying compliance can inform deterrence policies, avoiding costly and counterproductive action.

1.3 Objective

To study reasoning behind rule compliance in public forests by analyzing the behavior and reflections of players in a simulation game[1].

1.4 Research questions

RQ1: What relevant concepts and frameworks exist for explaining reasoning behind rule compliance in public forests?

RQ2: What system dynamics structure can be used to build a simulation game that mimics a situation where individuals make decisions to either comply with the governing rules of public forests or not?

RQ3: What initial insights can be derived about reasoning behind rule compliance from the pilot experiment?

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[1] This objective includes a description of cases of noncompliance and the justification people give for noncompliance.

1.5 Thesis structure

The organization of the thesis is as follows. First, Chapter 2 is a literature review that answers RQ1 by identifying existing theory on rule compliance. Next, Chapter 3 describes the methodology used in this study, delineating the method of data collection and analysis. Chapter 4 outlines the model while Chapter 5 describes the simulation game, which together answer RQ2. Next, the pilot experiment is described in Chapter 6, while its results are the subject of Chapter 7, answering RQ3. Finally, Chapter 8 presents an overview of the insights emerging from this study along with a discussion regarding its knowledge contribution, limitations and conclusions.

Chapter 2: Theoretical background

The aim of this chapter is to summarize existing research on the causes, or reasons for, compliance, making sure to provide definitions for all relevant concepts. At the same time, this chapter sheds light on major issues and debates in this area of research.

2.1 Overview

Compliance has been formalized as socio-economic theory by Sutinen & Kuperan (1999: 183). Similarly, Raakjær Nielsen (2003: 431) has developed a framework for compliance in fisheries management and Ramcilovic-Suominen & Epstein (2012: 7) have developed a framework of forest law compliance. These three frameworks share many similarities, albeit they sometimes use different words. As a summary, they describe two types of motivation for compliance (see Figure 2): extrinsic motivation, which is instrumental and utilitarian in essence, and intrinsic motivation, which encapsulates normative and social-context dependent motivation.

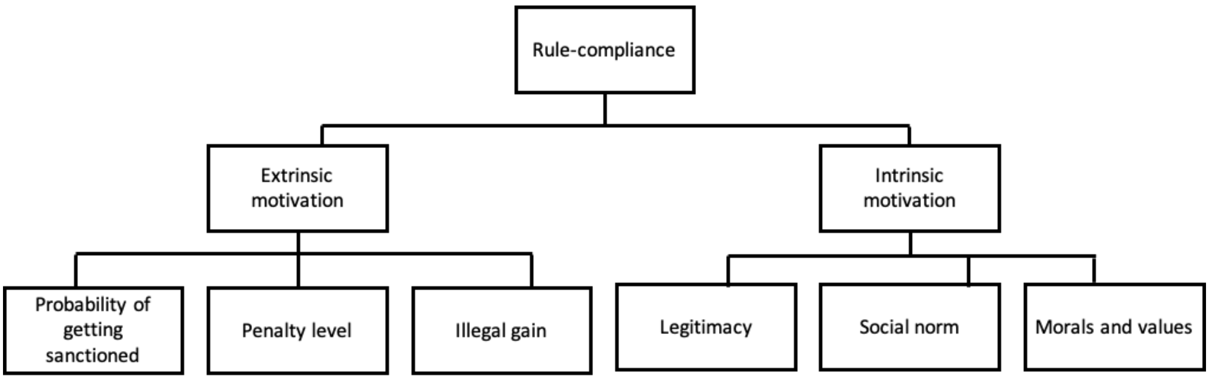

Figure 2. A theoretical framework for rule-compliance (Source: Author's representation)

2.2 Definitions

Specifically, extrinsic motivation describes the process of decision-making as one by weighting costs and benefits, taking into account their probabilities. On the other hand, intrinsic motivation refers to contextual social norms, legitimacy and morals and values. This discernment between extrinsic and intrinsic motivation, or between instrumental and normative reasons is mentioned both by Raakjær Nielsen (2003) and Epstein (2017).

Within extrinsic motivation, compliance can be looked at as a calculation that takes into account: (1) the illegal gain, or the payoff for successfully getting away with illegal activities, (2) the penalty level, or the expected sanction for getting caught, and (3) the probability of getting caught and sanctioned, which is the decision-maker's perception of the monitoring and sanctioning mechanism including their attitude to risk. These three pieces of information align with Expected Utility Theory. Hence, given information on these three concepts, a decision-maker would make the rational choice that results in the largest payoff.

Intrinsic motivation is characterized by: (1) the decision-maker's personal moral norms and values, which represent their evaluation of what is a just decision, (2) social norms, which reflect the types of decisions that are common in the social environment, and (3) the legitimacy of the governing rule, i.e. the decision-maker's perception regarding whether that rule is reasonable and fair in the social context.

The integration of all these concepts into one theoretical framework implies that a change in any one of these concepts may influence a change in the decision-maker's decision. In addition, they may all be used in the decision-making process or the decision might be based on only one of these concepts, which implies that these concepts are not mutually exclusive. However, it is considered that they are collectively exhaustive, which is to say that the framework is broad enough to integrate all known drivers of compliance.

2.3 Summary of existing research

Enforcement mechanisms like monitoring and sanctions are key for studying deterrence. Andersen and Stafford (2003) analyzed the relationship between sanctions and rule compliance and found that sanction severity, or the level of financial penalty, has a larger influence on rule compliance compared to probability of being sanctioned. In addition, past sanctions increased individual probability of rule noncompliance. This reinforcing behavior can be thought of as a norm where it becomes normal for individuals not to comply after they have been sanctioned once. In regard to the difference between endogenous and exogenous sanctioning mechanisms, Baldassarri & Grossman (2011) found that officially elected sanction executors resulted in higher contributions compared to randomly allocated sanction executors.

However, the probability of detection and the size of the penalty are not alone in influencing compliance, research has shown that the perception of legitimacy matters too (Viteri & Chavez, 2007), as processes in which a larger part of the population participates are seen as more legitimate. Similarly, Travers et al. (2011) conducted experiments with common pool resource games to study the level of cooperation within different institutional arrangements in

Cambodia. They found that treatments promoting self-organization had a significant positive effect on cooperation, i.e. on deterrence. In addition, Tyran & Feld (2006) find that mild law is more successful in ensuring rule compliance when it is endogenously chosen, i.e. self-imposed. Additionally, study results from forestry (Agarwal, 2009) have shown that a higher proportion of women in a governing body contributed to a better state of the resource, which may be interpreted as more participation given the assumption that a more diverse governing body is more representative of the pool of resource users.

Likewise, the idea that participation increases deterrence has also come up in a public good experiment (Kingsley and Brown, 2016). This is a powerful idea because it is much cheaper to involve groups in the rule formation process, than to invest in building capacity for rule enforcement. Translating this idea to public forests, it means that simply involving local communities in the governance process would significantly improve the state of many public forests.

Notwithstanding, other factors mentioned in the theoretical framework have also come out as relevant in scholarly research. Specifically, Peterson & Diss-Torrance (2014) have found that moral norms are significant when the cost of compliance, i.e. illegal gain, is low. In addition, demographic factors and dependency on the resource for livelihood, i.e. illegal gain, have come out as explanatory factors (Madrigal-Ballestero, Schulter & Lopez, 2013).

Coming back to the rule compliance framework (see Figure 2), Epstein (2017) disserts that there is a divide in the research community between more classically trained economists who favor extrinsic motivation and the rest of the social scientists who argue that intrinsic motivation is more important for explaining compliance behavior. Morgan, Mason & Shupp (2019) studied public goods and found that participation through comments had a positive effect on rule compliance only when accompanied by sanctions. This finding has also come out in the case of participation through voting, producing synergy between rule enforcement and participation in the rule formation process (DeCaro, Janssen & Lee, 2015). This was further confirmed in an experimental game with common pool resources. Rodriguez-Sickert, Guzmán & Cárdenas (2008) found that enforcement yielded compliance regardless of the social norm, whereas players followed the norm in the absence of enforcement.

Both extrinsic and intrinsic motivation are important, and these results pinpoint their interconnectedness and co-dependency. While in the past it was more common to see policymakers use economic models of extrinsic motivators, intrinsic motivation factors are now gaining research attention not as a superior, but as equally important, thus proving that these two types of motivation are complimentary as showcased by Hatcher, Jaffry, Thebaud & Bennett (2000) in the case of fisheries.

Last, just as there is no panacea regarding governance regimes so too there is no panacea regarding a set of mechanisms that promote rule compliance. This is clearly visible in the research of Ramcilovic-Suominen and Epstein (2015), who find inconsistencies in the factors affecting compliance in a forestry case study in Ghana. Rather than attempting to create the best explanatory framework for rule compliance, my research is a modest attempt to contribute to the debate on rule compliance and enrich scientific knowledge with unique insights.

Chapter 3: Methodology

The purpose of this chapter is to provide a general overview of the methodology used in this thesis. Since, different methodologies were applied in each phase of the research, the model development and the game development phase are described within this chapter. While, Chapter 6 is dedicated to describing the pilot experiment phase.

I used a mixed-methods approach during this research. Broadly, the research consisted of three phases:

(1) Model development phase
(2) Game development phase
(3) Pilot experiment phase

3.1 Model development phase

I used system dynamics for developing a model that describes a public forest use system. As such, the model described the interaction between the public forest, the governance policy in place and logging decisions. My rationale for choosing system dynamics as a method is because it is well suited to building aggregate models that capture dynamics arising from delays, nonlinearities and feedback, all of which are present in public forest use systems.

The modeling process loosely followed the steps outlined by Sterman (2000: 83). Specifically, I first established a model boundary, after which I developed a dynamic hypothesis in the form of model structure based on literature and official government documents. I iteratively modified the model structure as I calibrated the variables by partial model testing for calibration (Homer, 2012) using two datasets. I established model quality through comparison with historical data, extreme conditions testing, structure confirmation testing and behavior sensitivity analysis (Barlas, 1996). Apart from comparing with real-world data, I analyzed model behavior with the help of feedback analysis. Refer to Chapter 4 for a complete explanation.

3.2 Game development phase

Interactive simulators have been used to estimate decision rules within system dynamics research since the 1980s (Arango Aramburo, Castañeda Acevedo & Olaya Morales, 2012). However, the present study utilizes gaming, which differs from a traditional simulator because it includes game-like characteristics (van Daalen, Schaffernicht & Mayer, 2014) such as an imaginary context, characters, rules, goals etc. Moreover, it falls within the narrow area of using system dynamics gaming for experimental research (e.g. Moxnes, 2000) rather than for learning (e.g. Kopainsky & Sawicka 2010). Experimental games, which are not based on system dynamics models, have been widely used to study human behavior within the context of commons problems and contribute to building a multi-method understanding of the issue (Poteete, Janssen & Ostrom, 2009: 257). Thus, the rationale behind choosing gaming as a research method rests on the fact that system dynamics and gaming are a good fit, while gaming is a proven strategy for studying commons problems.

I developed the game with the help of a game design framework from Bots & van Daalen (2007), which informed my game design choices. In particular, I modified the model to include game-like characteristics, effectively building an incentive structure that facilitates a game experience. Moreover, I created an interactive interface with a specific theme and characters, which further add game-like character. Game calibration was based historical data, while the rest of the game design process was the result of my own creativity.

In order to study the usability of the game, I conducted game testing parallel during the entire game development process. Further, I analyzed the possible range of game behavior using model simulation. The full results of the game development process are visible in Chapter 5. However, the extent of analysis I could independently conduct on the game was limited. For this reason, I ran a pilot experiment, described in Chapter 6, which allowed me to analyze how real players interact with the game and consequently draw insights regarding rule compliance in public forests.

Chapter 4: Model

This chapter, along with Chapter 5, answers RQ2. Specifically, Chapter 4 describes and critically analyzes the behavior of a system dynamics model that can be used to build a simulation game, which is detailed in Chapter 5.

4.1 Overview

The model is an aggregate representation of a resource use system, specifically *a system of forest use for wood*. Thus, its value lies in its holism as it integrates both the biological and social aspects of this system. Figure 3 gives the full structure of the model and highlights parts of the structure according to the elements of the conceptual model (see Figure 1). These are the forest structure (highlighted in green), which corresponds to resource state; the governance structure (highlighted in yellow), which corresponds to governance rules; and the management structure (highlighted in blue), which corresponds to individual decision-making.

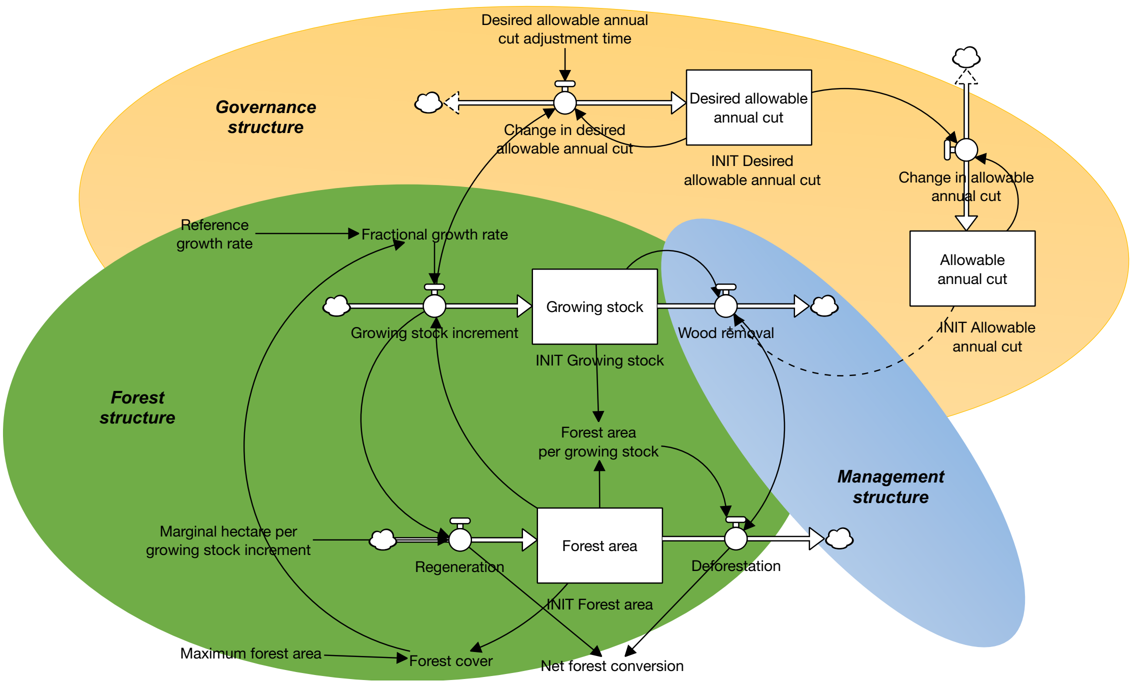

Figure 3. Overview of the system dynamics model

4.2 Structure description

The source material for building the model included a textbook on modeling forest growth and yield (Vanclay, 1994: 14), a textbook on system dynamics modeling (Sterman, 2000: 503) and government documents from the Government of British Columbia (2017, 2019, 2020). This data source was chosen in particular because Canada, and specifically British Columbia, had the most publicly available data on the forest governance process that was accessible to me at the time of writing. This section merely describes the structure, while elaborate details on the source material can be found in section 4.10.1. Additionally, the full model documentation can be found Appendix 1.

4.2.1 Forest structure

The forest is represented through a co-flow structure that describes the relationship between the amount of forested land (*Forested area*) and total volume of wood (*Growing stock*) in the forest. Namely, the forest undergoes logistic growth, which is limited by the physical space (*Maximum forest area*). So that, the state of the forest compared to its maximum size (*Forest cover*) affects natural expansion of the forest, together with an exogenously set reference growth rate (*Reference natural expansion rate*). Natural expansion is represented as an increase in volume of wood in the forest (*Growing stock increment*). The growth of new wood brings about an increase in forested land (*Regeneration*) through an exogenous average variable (*Marginal hectare per growing stock increment*), highlighting the principle that area grows as a result of growth in volume. Finally, the amount of wood decreases through logging (*Wood removal*), which corresponds to a decrease in forested area (*Deforestation*), according to the current average forest density (*Forest area per growing stock*).

4.2.2 Governance structure

The objective of the government is to maintain the forest in equilibrium, i.e. to only allow as much logging as there is estimated new growth in the forest. Hence, the governing policy (*Allowable annual cut*) is endogenously determined by comparing the current growth level of the forest (*Growing stock increment*) with the past policy objective in place (*Desired allowable annual cut*). The difference between these two is updated along a set timeframe so that the estimated growth level can be reached during that time (*Desired allowable annual cut adjustment time*). Finally, the objective (*Desired allowable annual cut*) is put into official policy (*Allowable annual cut*) every 10 years.

4.2.3 Management structure

The management structure is centered around logging (*Wood removal*). As defined in Chapter 2, the term 'management' refers to decision-making that directly affects the state of the resource as opposed to 'governance', which refers to decision-making that indirectly affects the state of the resource. In the model, it is assumed that the quota (*Annual allowable cut*) is logged up to total *Growing stock* depletion.

4.3 Purpose and time horizon

The purpose of the model is to serve as a base for developing a simulation game which can be used for studying reasoning behind rule compliance in public forests. With this specific purpose in mind, the model has been constructed to be representative of a hypothetical public forest use system, that is analogous to real-world public forest systems. Hence, the model structure is very aggregated in order to keep the model as simple as possible, while at the same time it is as representative of real-world systems as possible. The trade-off between these two requirements has resulted in the above-described structure.

A long time-horizon of 50 years has been chosen given that the focus of the model is to capture the relationship between the forest, policy and wood removal decisions. Specifically, the forest and policymaking are subject to slow-moving dynamics, i.e. it takes years before a visible change takes place. Within the model, the long delay time of *Desirable allowable annual cut adjustment time* and the low values of *Marginal hectare per growing stock increment* and *Reference growth rate* stand as witnesses of this.

4.4 Boundary

A boundary can be identified with the purpose of the model in mind. The main purpose of this model is to serve as a base for the development of a simulation game that can aid in researching rule compliance in public forests (RQ2). Given this purpose and the time available for this research project, an aggregate hypothetical model of forest use has been created.

Notably, many parts of reality have been omitted. For example, the governance process of determining the quota is within the boundary of the model, but the process of appropriating the quota to legal bodies on the basis of ownership structures (land tenure) is outside the boundary of this model. A full representation of model boundary can be seen in the Bull's eye diagram (see Figure 4). A Bull's eye diagram is a useful structure described by Ford (97:1990) that helps illustrate which variables are at the core of the model (endogenous), which are set through external assumptions or data (exogenous) and which are not considered relevant for the purpose of the model (excluded). System dynamics is specifically well-suited to studying the dynamics created through interconnected endogenous variables.

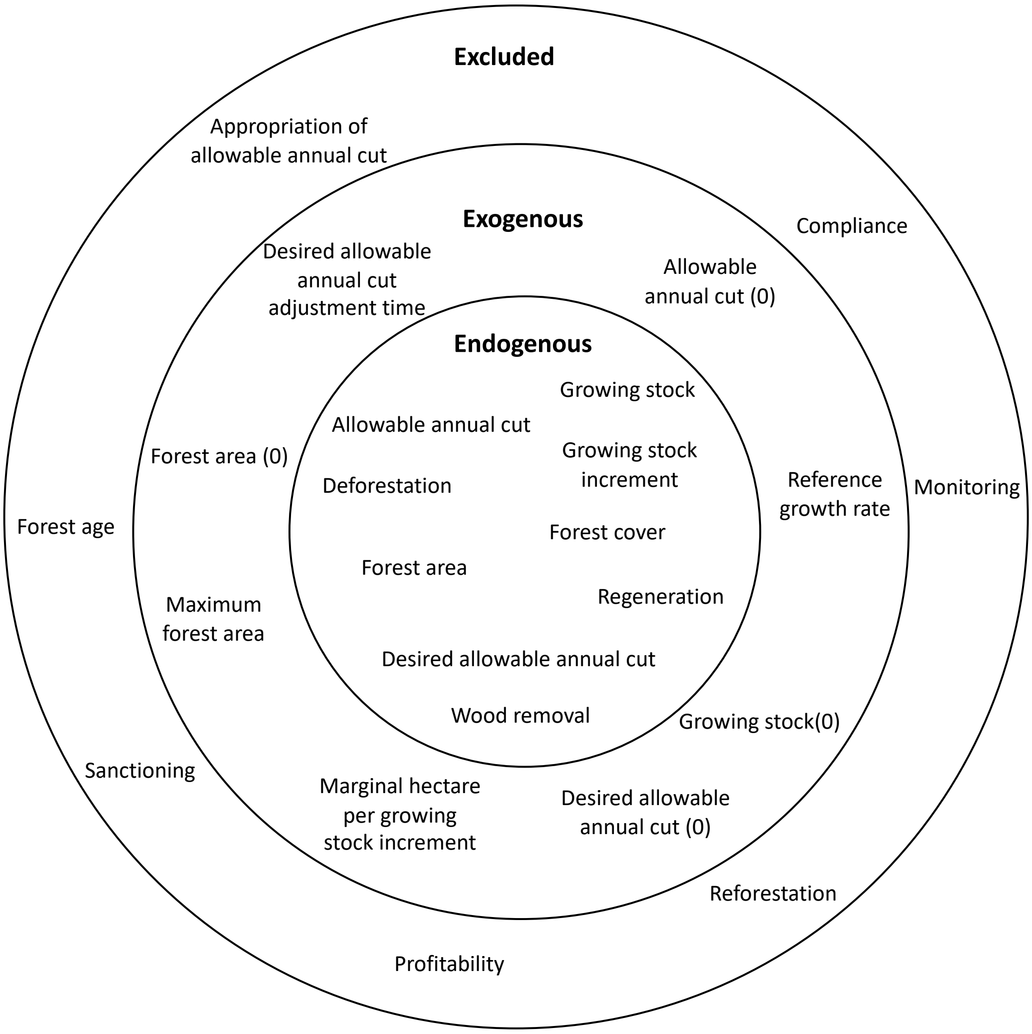

Figure 4. Bull's eye diagram for depicting model boundary

4.5 Assumptions

Many assumptions have been made for the sake of maintaining model simplicity. This means that the model has an aggregate structure that does not aim to realistically represent any real-world system, but rather to serve as a virtual laboratory (de Gooyert, 2018) so that different experiments can be made with the case of a hypothetical forest.

1) *Homogeneity.* The model assumes a homogenous forest, where each tree is presumably of the same species. Further, the age structure of the forest is not accounted for, so that

all trees in the system are considered to have the same age and the same yield in terms of wood.

2) *No competition for the landscape.* The model does not take into account any limits to growth apart from landscape capacity.

3) *Unchanging external conditions.* External conditions such as soil quality, pollution, water availability, natural hazards or the weather are considered static or perfect. Similarly, economic development or other factors affecting demand are not taken into account.

4) *No differentiation between wood removal strategies.* In reality many different silvicultural practices exist that dictate the exact trees and the manner in which they will be cut so as to limit the impact of logging on forest area. The model assumes a highly simplistic wood removal function that does not distinguish between the effect of different wood removal strategies on deforestation. Rather it models the average effect based upon the average forest area per growing stock.

5) *No afforestation or reforestation.* The concepts of anthropogenic forest plantation is outside model boundary because a report by the FAO that estimated that 90% of regeneration occurs through natural expansion (FAO 2010).

6) *Public forest.* The forest is considered to be public and thus wholly under the reign of the government.

7) *No corruption or political influence.* It is assumed that there are no bribes or similar political influence in the process of determining the allowable annual cut.

8) *Fixed Allowable annual cut for 10 years.* It is assumed that the allowable annual cut is changed every 10 years, not more, not less.

9) *Equal appropriation of Allowable annual cut.* While in reality, the allowable annual cut is appropriated among different entities, the model assumes only one entity that does the logging. Thus, the effect of differences in allowable annual cut appropriation

are not taken into account. This assumption will be changed during the design of the simulation game.

10) *No limit in wood removal capacity*. It is assumed that logging is completed if there is enough growing stock, no matter the size of demand or allowable annual cut.

11) Compliance. The model assumes that the allowable annual cut is always respected over demand. This assumption will be changed during the design of the simulation game.

12) *The forest grows most quickly at 50% forest cover*. In reality, it need not be that the growing stock increment is largest at 50% forest cover. This is different for every forest, but it serves as a useful assumption for our hypothetical model.

13) *Perfect information.* The information used for policy objective formulation does not suffer any error or bias. In reality this measurement is continually updated, with new insights driving changes in policy decisions. The reasoning behind this assumption is the fact that the aim of the study is to study compliance of government policy, rather than policy formulation. This assumption allows us to control for the effect of policy formulation on compliance, and subsequently on the sustainability of the forest.

4.6 Equilibrium condition

The following conditions apply to set the model in equilibrium:

$$\text{Maximum forest area} = 2 \times \text{Forest area (0)}$$

$$\text{Marginal hectare per growing stock increment} = \frac{\text{Forest area (0)}}{\text{Growing stock (0)}}$$

$$\text{Allowable annual cut (0)} = \text{Desired allowable annual cut (0)} = \frac{\text{Forest area (0)}}{2} \times \text{Reference growth rate}$$

4.7 Calibration

The values for *Forest area (0)*, *Growing stock (0)* and *Allowable annual cut (0)* have been calibrated according to two time-series datasets: one on global forests from the FAO (2009a,

2010) and one forests in Canada from the Canadian government (National Forestry Database, 2020a, 2020b; FAO, 2014; World Bank, 2020a, 2020b).

Marginal hectare per growing stock increment (0.0047-0.0053) and *Reference growth rate (0.95 – 1.05)* were calibrated using partial model testing for calibration (Homer, 2012). Specifically, their values were established by running the model with time-series data from the FAO and then searching for the range of values that showed best fit-to-data. The same procedure was undertaken with a different dataset from Canada's government (National Forestry Database, 2020a, 2020b; FAO, 2014; World Bank 2020a, 2020b) and proved consistent results.

Maximum forest area has been calibrated using partial model testing for calibration with the aim of getting the model to reproduce behavior that matches data for Net forest conversion (FAO, 2010) matches model behavior. Additionally, when working with the dataset from Canada, it has been calibrated by comparing model behavior to data for forest cover.

Desired allowable annual cut (0) has been calibrated to equal *Allowable annual cut (0)* at the time of the start of the simulation. This implies synchronization between the policy objective and the official policy at the start of the simulation.

Policy adjustment time (50 years), i.e. the timeframe to reach the policy objective was calibrated according to an analysis report of the Cascadia Timber Supply Zone (Government of British Columbia, 2019: 2). Further, partial testing for calibration confirmed that this value exhibits best fit-to-data.

4.8 Feedback analysis

Feedback analysis is a method of describing the circular causal connections in the model, which are called feedback loops and are useful for explaining model behavior. The stock-and-flow diagram (see Figure 3) has been translated into a causal loop diagram (see Figure 5) for the purpose of clearly presenting the loops in the model.

R1 – Forest growth

When there is an increase in the forest area, then the growing stock increment increases too. Next, an increase in the growing stock increment drives an increase in regeneration only to increase the forest area even further. These variables represent the growth of the forest area in the form of a reinforcing loop, which may either drive forest growth or forest decline depending on the conditions.

B1 – Limits to growth

On the other hand, an increase in forest area also increases the forest cover, which then lowers the fractional growth rate. In turn, this decreases the growing stock increment and subsequently decreases regeneration to ultimately decrease forest area. Together, these variables and their relations amount to a balancing loop that describes the natural limit of the forest. Namely, the forest can only grow up to its maximum size, and its growth slows down as it approaches this limit.

R2 and R3 – Wood removal increases forest growth

As explained before, an increase in forest area increases the forest cover and decreases the fractional growth rate. Further, this decreases the growing stock increment and thus the desired and actual allowable annual cut. This decrease of the allowable annual cut drives a decrease in wood removal and deforestation before finally decreasing the forest area even further. Alternatively, in loop R3, a decrease in the growing stock increment decreases the growing stock, which decreases wood removal and deforestation before reinforcing the increase in forest area. This reinforcing loop describes the effect of the allowable annual cut on the fractional growth rate. Wood removal, facilitated through the allowable annual quota, reinforce growth behavior in cases when the forest cover is past the mid-point level and the fractional growth is slowing down. However, it can also drive reinforcing forest decline if the variables go in the opposite direction.

B2 and B3 – Wood removal regulation

Last, an increase in forest area increases the growing stock increment, which then increases the desired allowable annual cut and allowable annual cut correspondingly. This increase of the allowable annual cut drives an increase in wood removal and deforestation before finally decreasing the forest area. Alternatively, in B3, an increase in the growing stock increment increases the growing stock and wood removal. This subsequently drives deforestation and decreases the forest area. In simpler terms, this balancing loop describes the way the negative effect of wood removal on forest growth is regulated through the allowable annual cut.

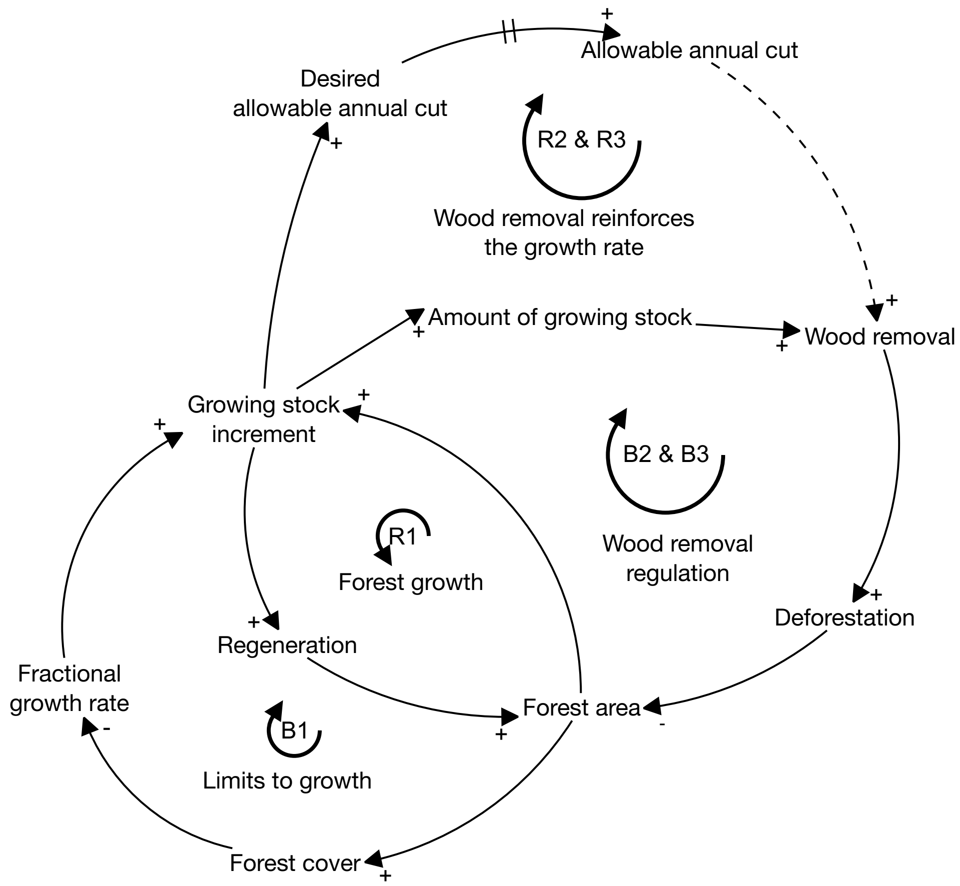

Figure 5. The model as a causal loop diagram. Note that some variables and minor loops have been omitted for presentation purposes.

4.9 Behavior description

The model was simulated using Stella Architect software, version 1.9.5. Three model runs were done using the following specifications:

- Time unit: Year
- Time step (DT): 1
- Time horizon: 1990 -2040
- Integration Method: Euler

4.9.1 Equilibrium run

The equilibrium run was calibrated according to the equilibrium condition in section 4.6. The resulting behavior can be described as a dynamic equilibrium of all stocks where a forest area of 150 hectares contains growing stock of $31250\mathrm{m}^3$ with a desired and allowable annual cut of $75\ \frac{\mathrm{m}^3}{year}$ (see Figure 6). This state is maintained as a result of the dominating effect of the balancing loops in the model. The equilibrium run serves as a base for conducting model structure tests.

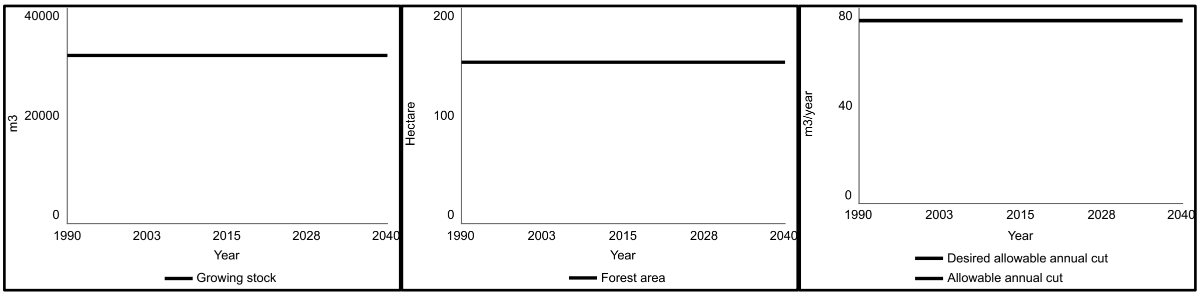

Figure 6. Equilibrium run

4.9.2 Global run

The simulation of the global run aims to recreate the use of forests on a global level with initial data calibration from the FAO (2009a, 2010). The behavior of the model can be compared with the reference mode, which is represented with data from 1990 to 2017.

One can see that the state of global forests is in decline, with decreasing forest area and growing stock. Further, the forest is becoming denser as the forest area is declining faster than the growing stock. This is due to wood removal strategies, which focus on preserving growing stock rather than forest area. Despite being in decline, the rate of decline is gradually slowing down, most visible in *Wood removal*, which is representative of goal-seeking behavior. This indicates the dominance of balancing loops (B2 and B3) which slowly stabilize the system by adjusting *Wood removal* to come to equal *Growing stock increment*.

The model seems to recreate this behavior well, as seen in Figure 7. However, there are some discrepancies between model behavior and the data for net forest conversion and *Wood removal*. Namely, the model exhibits lower values for net forest conversion than the data and lower values for *Wood removal*. This, in turn, implies that the difference between regeneration and deforestation is larger than the model represents. Given that there is no data on regeneration, we can only rely on data for afforestation and reforestation. We can see that the model exhibits a higher value of regeneration than the data for afforestation and reforestation, but not nearly high enough to match the observation that 90% of forest area expansion is through natural regeneration (FAO, 2010, 2020a). This might indicate that the value of

Marginal hectare per growing stock increment is calibrated with a value that is too low, or it might indicate an inconsistency in the data source.

Next, there are two datasets on wood removal from the FAO (2009, 2010) where one is on average 15% lower than the other due to difference in data collection. The model does not do a good job at re-creating the behavior. In fact, the model shows decreasing *Wood removal* whereas the data shows increasing wood removal from 2000 onwards. This is not surprising given the simplistic assumption that there is an annual allowable cut governing the forest and that it is complied with. Hence, this behavior further motivates the creation of a simulation game that can help us understand the link between *Annual allowable cut* and *Wood removal*.

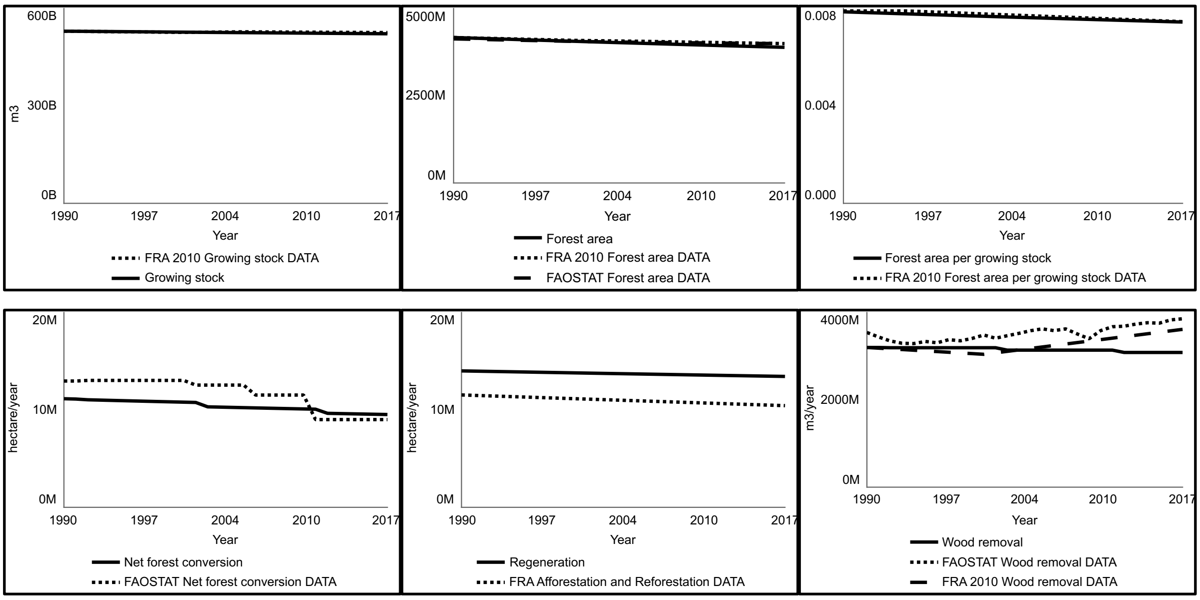

Figure 7. Global run

4.9.3 Canada run

The Canada simulation run is an effort to recreate the dynamics of forest use in Canada as compared to data up to 2017 (National Forestry Database, 2020a, 2020b; FAO, 2014; World Bank, 2020a, 2020b). The run is initially calibrated with data from 1990.

Contrary to the global picture, the forest area in Canada has remained quite stable over the last 30 years. The model captures this reality (see Figure 8), although it shows a slight decrease, which is due to discrepancy in *Wood removal* behavior. The same can be said for the behavior of forest cover, which is stable at 38% of land area. Disregarding the mismatch between model behavior and historical data, we can understand model behavior in a very similar way to the global run. Namely, the model exhibits goal seeking behavior, clearly evidenced in a declining wood removal rate, indicating dominance of the wood removal regulation balancing loops (B2 and B3). The difference between the global run and this run, in terms of model dynamics, is only that this run is closer to equilibrium.

Further, the model manages to recreate the declining trend in allowable annual cut which is visible in the data. However, it overstates *Wood removal*. This is understandable since the model assumes that all of the allowable annual cut is removed, whereas the data shows a significantly lower portion of the allowable annual cut being removed. This is consistent within more local data of the province British Columbia (Environmental Reporting BC, 2018), which also shows wood removal rates that are lower than the allowable annual cut. Naturally, this translated into a discrepancy between deforestation behavior in the model and corresponding data. Again, this behavior mismatch warrants further study on the link between the *Allowable annual cut* and *Wood removal*, which is the topic of this thesis.

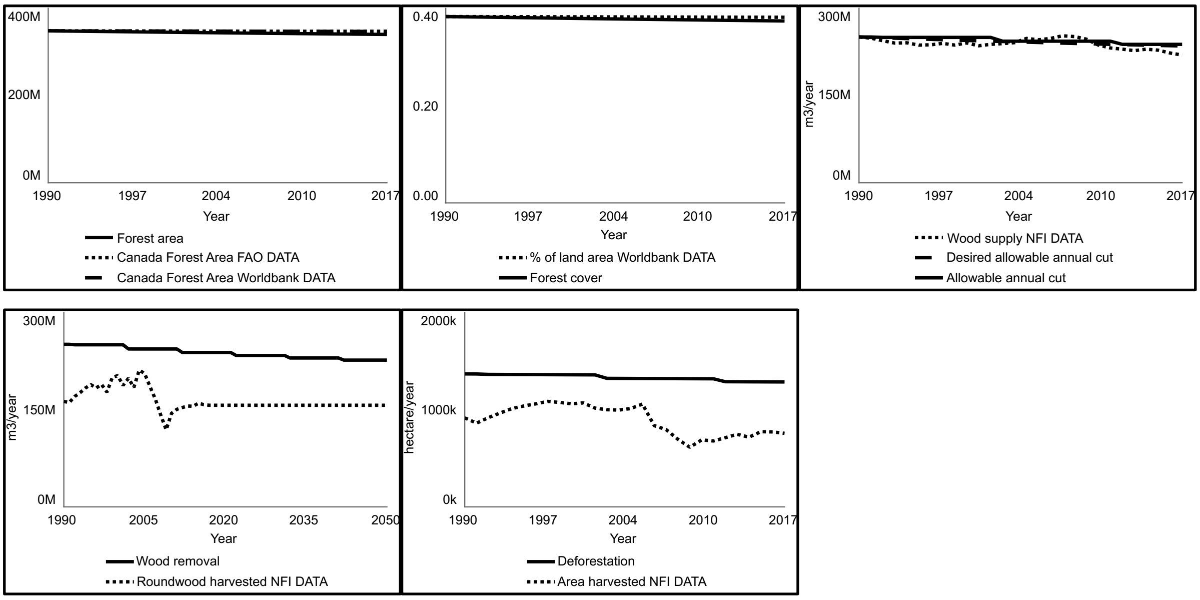

Figure 8. Canada run

4.10 Model quality testing

Model quality testing is an important part of any system dynamics project because it helps communicate the ways in which the model is or is not representative of the real-world system. Certainly, no model is a correct representation of the real world, and thus "all models are wrong" in an objective sense (Sterman, 2002). However, there are certain measures that a researcher can take to establish the *quality* of the model as a tool for studying reality and drawing conclusions about reality.

First of all, it is important to address the purpose of the model in order to understand what type of testing would be most suitable to establish the quality of the model. Barlas (1996) distinguishes between two types of models: black-box, or models driven by data, and white-box, or theory-like, models. The present model falls somewhere in between these two broad categories. It is a classic system dynamics model in the sense that it attempts to not only produce behavior, but also explain how that behavior is produced, which is typical of 'white-box' models. However, within the scope of this study, its purpose is merely to serve as a base for creating a simulation game which can be used to research rule-compliance in public forests, which is exemplary of 'black-box' models, which are more focused on behavior prediction. Thus, this unique purpose asks for both structure and behavior tests, however more emphasis is put on behavior tests because of the similarity to black-box models.

According to Barlas (1996), the purpose of structure tests is to compare model structure with knowledge of the real-world system. With the structure confirmation test in particular, the model relations can be compared to datasets and literature that describe forest use. Next, the parameter confirmation test checks to see whether the parameters in the model are representative of the real-world both in their formulation and their calibration. Then, the extreme conditions test and behavior sensitivity analysis help establish structure robustness by comparing model behavior to expected model behavior.

4.10.1 Structure confirmation test

The forest is modeled to undergo logistic growth, limited by a carrying capacity described by the maximum forest size. This is typical of ecological models, including those of forests (Vanclay, 1994: 107). In addition, the relation between the forest area and growing stock is modeled using a generic co-flow system dynamics structure (Sterman, 2000: 503). The extent to which a co-flow structure is an appropriate representation of the relationship between forest area and growing stock is supported by the physical relationship between volume, of which growing stock is an expression, and area, indicated in the formula for calculating volume. Such a relationship necessitates a correlation between forest area and growing stock at the very least. In conclusion, while the structure does not do justice to the complex reality of a forest, it captures the most important aggregate links found in forest systems.

Next, the governance structure was built using data on British Columbia's governance process. In particular, British Columbia has divided its governance into smaller governing units called Timber Supply Areas (TSA), which are under the responsibility of the country's chief forester. The role of the chief forester is to determine the Allowable annual cut (AAC) for each Timer Supply Area at least every 10 years. This entire process is called the Timber Supply Review. Once the forester has made their decision, the Minister of Forests, Lands and Natural Resource Operations allocates the AAC to general types of forest licenses, yielding individual quotas. Thus, the full process is composed of two-stages: AAC determination, which is executed by the chief forester, and AAC appropriation, which is executed by the Minister of Forests, Lands and Natural Resource Operations (Government of British Columbia, 2017).

Specifically, the Timber Supply Review (or AAC determination) is of interest to this thesis (see Figure 9). Documents from the government show that it undergoes three stages. First a data package regarding the TSA is released, followed by consultation and review from the public. Next, an analysis report is released detailing the specifics of a base run from a model simulation on the TSA, which is again followed by a consultation with the public. Finally, the Chief Forrester makes a decision regarding the AAC for that TSA and publishes an official rationale for that specific decision.

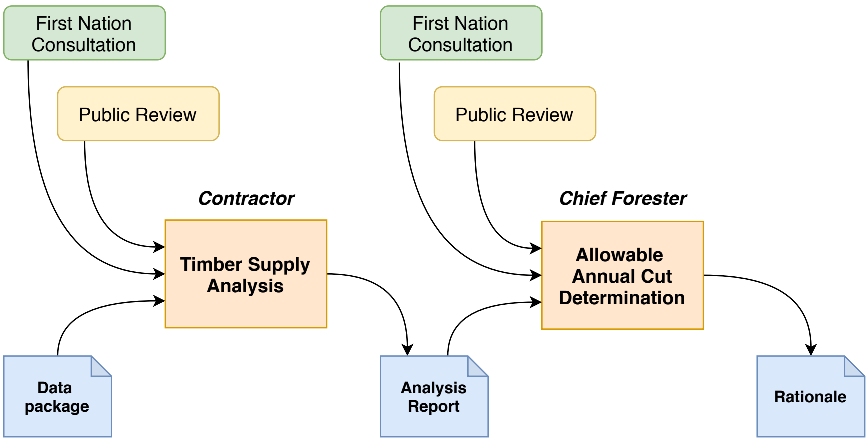

Figure 9. British Columbia's Allowable annual cut determination process (based on Government of British Columbia, 2017).

Looking at an example from a rationale of AAC Determination of TSA Cascadia, the objective is described to be "… to provide a harvest schedule that projects an orderly transition from the short-term harvest level to the highest possible even-flow harvest level..." (Government of

British Columbia, 2020: 7). This is in-line with the model structure, which aims to maintain a dynamic equilibrium (even-flow), while allowing the highest possible wood removal (harvest level).

The same information can be seen in the analysis report published prior to the decision (Government of British Columbia, 2019:29) where the model simulation shows gradual decreases in the AAC until an even-flow is reached in 50 years, which corresponds to the goal-seeking structure of *Desired allowable annual cut*.

Moreover, the governance structure shares similarities with the Gehrhardt Method (FAO, 1998), which is a method for determining the allowable annual cut. As such is given as an official guideline for forest management planning. Specifically, the Gehrhardt Method rests on estimating the values of growing stock and growing stock increment of a theoretically normal forest. The allowable annual cut is then determined as the sum between (1) the average of the current growing stock increment and the theoretically normal growing stock increment and (2) the gap between the current growing stock and the theoretically normal growing stock over an adjustment time. Although different, this formulation is goal-seeking, just like the governance structure in the model. The main difference between the two is that the Gehrhardt Method is based off an estimation of a theoretically normal forest, whereas the present model structure is based on an initial value of *Desired allowable annual cut*. Hence, it can be argued that both formulations aim to close a gap between the current state of the forest and the desired state of the forest in a given adjustment time. In that sense, the calibration of *Desired allowable annual cut* is very important as it encapsulates the estimation for a theoretically normal forest. However, even though this is legitimate way of describing forest governance, it would be incorrect to assume that this structure is representative of global forests, especially given that only half of the remaining forests have official management plans (FAO, 2020a).

In conclusion, it would be far fetching to claim that the governance structure is representative of all global governance systems. This is largely due to the fact that there is a huge variety of governance systems and attempts to aggregate them in a simple structure has yet to be successful. However, the model is representative of at least one specific governance situation regarding TSA Cascadia in British Columbia, and with that we can consider that it is representative of at least one case study, which can be indicative of more general propositions (Flyvbjerg, 2001:66) and is enough for the aim of this study.

Last, the management structure, or the link from *Annual allowable cut* to *Wood removal* does not have any backing in literature and thus fails to pass the structure conformation test. In fact, the data from Canada (National Forestry Database, 2020a) shows that wood removal is never exactly equal to the allowable annual cut, rather it is either above or below it. Further, illegal logging is not represented through this formulation. This is why the link is denoted with a dotted line representing a 'wishful thinking' link. Finally, this link is broken up in the design of the simulation game (see Chapter 5), as it is the exact data point that will be studied for the purpose of answering RQ3.

4.10.2 Parameters confirmation test

The names of the variables in the forest structure have been chosen to correspond to the terms used by the FAO. While those from the governance structure have been formulated based on terms used by the Government of British Columbia. Notably, this does not mean that every parameter represents something tangible in reality. But it can be established that the parameters establish concepts known and used in society, for most there is even data. Further, while the calibration of some parameters, such as the Desired allowable annual cut adjustment time have been based on specific case-study data, most others underwent partial model testing for calibration with comparisons across two datasets, as explained in 4.7.

4.10.3 Extreme conditions test

The following tests were run from a position of equilibrium (see section 4.9.1). All the values were increased and decreased by 20% as an extreme condition. See Table 2 for a summary of all the tests. In conclusion, the model is exhibiting plausible reactions to the shocks, therefore it has passed the extreme conditions test.

Variable	**Value**	**Expected behavior**	**Simulated behavior**	**Takeaway**
Wood removal	+STEP (60, 2000)	Forest decline, delayed decrease in AAC	Forest decline, extremely slow decrease in AAC.	Forest behavior as expected. AAC is less sensitive than anticipated.
	-STEP (60, 2000)	Forest growth, delayed decrease in AAC	Forest growth, extremely slow decrease in AAC.	
Marginal hectare per	+STEP (0.004, 2000)	Forest growth, delayed decrease in AAC	Decline in growing stock and AAC.	The shock affected only the stock of forest area, which

growing stock increment			Increase in forest area.	ultimately had the opposite effect on growing stock because of the balancing loop.
	-STEP (0.004, 2000)	Forest decline, delayed decrease in AAC	Decline in forest area and AAC. Increase in growing stock.	
Reference growth rate	+STEP (0.8, 2000)	Forest growth, delayed decrease in AAC	Forest growth and increase in AAC.	The shock changed the range of growing stock increment and thus it also changed the range of AAC.
	-STEP (0.8, 2000)	Forest decline, delayed decrease in AAC	Forest decline and decrease in AAC.	
Maximum forest area	+STEP (240, 2000)	Forest growth, delayed increase in AAC	Forest growth and increase in AAC.	The shock affected forest cover and thus AAC.
	-STEP (240, 2000)	Forest decline, delayed decrease in AAC	Forest decline and decrease in AAC.	
Desired allowable annual cut adjustment time	+STEP (40, 2000)	No change	No change	Behavior is as expected.
	-STEP (40, 2000)	No change	No change	

Table 2. Extreme condition tests

4.10.4 Behavior sensitivity analysis

I ran behavior sensitivity tests in order to investigate the relationship between model structure and model behavior. This helped me identify sensitive parameters and understand the role of the different feedback loops in the model. Starting from a position of equilibrium, I varied all exogenous variables from +20% to -20% of their equilibrium value. Out of all exogenous variables, the following proved sensitive: *Reference growth rate*, *Maximum forest area* and *Desired allowable annual cut (0)*.

Model sensitivity appears whenever the system is pushed out of equilibrium. In fact, all model reactions can be understood as tendencies of the model to bring itself back into a state of equilibrium. Thus, the conclusion from this sensitivity analysis is that the model is robust and highly dominated by balancing loops B2 and B3. See the full description of the sensitivity analysis in Appendix 2.

4.10.5 Conclusion

In conclusion the tests have confirmed that model behavior is robust under a fairly broad range of parameter values. This confirms the validity of model structure. However, model simulation runs have not been able to sufficiently explain historical data on *Wood removal*. This is indicative of the fact that the present formulation of *Wood removal* is not representative and to the general lack of understanding of the drivers of wood removal. Thus, model quality testing has demonstrated the need to develop a simulation game and direct experiment in order to elicit behavioral decision-making data (Sterman, 1987).

Chapter 5: Simulation game

5.1 Overview

A simulation game was created based on the model described in Chapter 4. It was designed for the purpose of gathering data for RQ3, which is to study reasoning behind rule compliance in public forests. Further, this purpose guided other design choices, as outlined in Table 3, which are elaborated on in this chapter.

Game property	Design choice
Purpose	To gather research data on rule compliance in public forests
Insights obtained	The researcher can obtain insights on reasoning behind rule compliance by analyzing post-game interview data.
Plot	A public forest is managed by the government through the allocation of a set quota for logging companies. However, the quota is not always in line with the demand experienced by logging companies, creating an incentive for the companies to log illegally and get greater rewards. Further, illegal logging is a risky activity because there is an unknown probability that the company might get caught and sanctioned by the government.
Players	Laypeople without direct experience in forest use
Roles	Logging companies (actual players) and the government (played by the model)
Rules	Players make decisions about how much they will log each round. No communication is possible between players.
Representation of physical system	The forest is represented virtually, so that the players see a delayed information about the forest cover, i.e. the amount of total land covered by forest, in every round.
Representation of inter-actor environment	Each round the players receive news if any one of the other players has been sanctioned for illegal logging or if they themselves have passed inspection or have been sanctioned by the government.

Table 3. Game design choices based on Bots & van Daalen (2007)

5. 2 Modification of the model

In order to convert the model into a game, the wishful thinking link between Allowable annual cut and Wood removal was broken up. Instead, players of the game are asked to set the value for Wood removal each round. In this way, loops R2 and B2 are broken up (see Figure 5), turning wood removal from an endogenous variable into an exogenous variable. The main differences between the model and the game (see Table 4) encompass the timelines, which are elaborated on in section 5.3, and the equation for wood removal. While the model assumed wood removal to be equal to the allowable annual cut, the game allows wood removal to be either below or above the annual cut, according to player decision-making.

Characteristic	**Model**	**Game**
Time horizon	50 years	40 years
Time step	1 year	1 year
Decision making interval	N/A	3 years
Wood removal formulation	Equals allowable annual cut	Summation of individual decisions

Table 4. Differences between model and game

In addition to these main differences, three new sectors were added to the model for the purpose of making the game more realistic: incentive, monitoring, sanctioning and scoring (see Figure 10).

5.2.1 Incentive structure

As part of the incentive, a player has to decide between logging the full demand or abiding by the government policy described by the allowable annual cut. Specifically, demand (*Demand*) is set to grow (*Increase in demand*) exponentially according to an external growth factor (*Fractional demand growth rate*). This conceptualization is based off the exponential growth of the logging industry (FAO, 2009b). The allowable annual cut (*Allowable annual cut*) is equally divided among players into individual quotas (*Individual quota*) and is bound to decline, as shown in Chapter 4. Each player sets their preferred logging level (*Extraction level*) which becomes the actual logging level (*Wood removal*) as long as there is growing stock from the forest left. This specific formulation of the incentive structure depicts an increasing gap between demand and the legal quota. The justification behind this formulation is that high demand has been identified as one of the root causes for illegal activities in the forest sector (FAO, 2005:7).

5.2.2 Monitoring and sanctioning structure

I added a sanctioning and monitoring mechanism in order for the game to be representative of a public forest with a quota enforcement system and in order to capture the effect of probability of getting sanctioned, which was identified as one of the listed reasons for compliance in the theoretical framework (see Figure 2). Monitoring is based on a uniform probability distribution (*Uniform probability distribution*) that generates a random sequence of monitoring events with a frequentist probability of 50%[2] (*Probability of being monitored*). From there, if a player is monitored (*Is monitored*) and found to log more than the individual quota, then they are sanctioned (*Sanctions in process*), leading to an increase in the total number of sanctions (*Cumulative sanctions*). In particular, the sanction consists of total retrieval of inventory by the government, thus preventing the player from satisfying any demand in that round (*Increase in losses from sanctions*), adding to the total experienced loss from sanctions (*Cumulative losses from sanctions*). The game also notifies players when one of their remaining players has been sanctioned, which captures an element of social norms, also found as a common reason for compliance (see Chapter 2). The full formulation of this can be seen in the game equations (See Appendix 3).

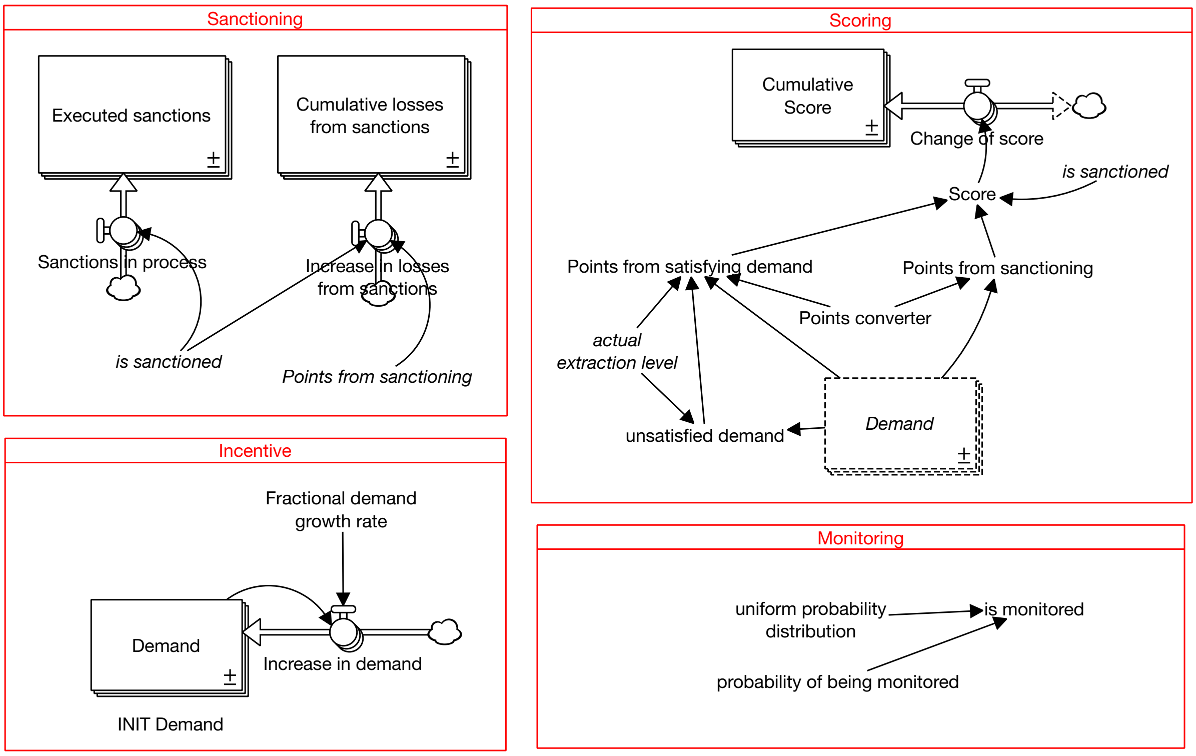

Figure 10. Game structure

5.2.3 Scoring structure

Further, each unit of satisfied customer demand is worth 1 point, while each unit of unsatisfied customer demand is worth -1 point (*Points converter*). There are no extra points for logging more than the demand. The points are calculated each round (*Change of score*) and added up

[2] Given that there are 13 rounds, the effective probability is 6/13.

to the total score (*Cumulative score*). This formulation depicts a reality of market pressures and opportunity costs, and at the same time it captures illegal gain and penalty level, which were mentioned as one of the main reasons behind compliance in the theoretical framework (see Figure 2).

Most of the variables are arrayed by player, which is to say that they hold and compute different values for each player. In addition, a number of game control variables have been added in order to create the interface, which are documented in the Appendix 3. Last, no specific structure or interface function has been added to stimulate reasoning stemming from moral and values or legitimacy because these are considered to be internalized perceptions.

5.3 Simulation timelines

There are two timelines running throughout the game. First, time proceeds as it did in the model described in Chapter 4 from 1980 to 2020 using the Euler integration method with a time step of 1 year. However, the additional sectors in the model have a timestep of 3 years starting with 1984. This is because of the decision-making intervals in the game, which take place every three years starting with 1980 up to 2016, resulting in a total of 13 rounds. The justification behind two timelines was in order to capture a longer time-horizon for model simulation (see reasons for this in section 4.3), while at the same time maintaining a short duration of game play of only 13 rounds, which is more user-friendly. For the players themselves, this means that although they make decisions for how one logging level every three years, they have effectively logged 3 times their stated logging level out of the forest before they have to make their decision again. This is representative of the real-world where management decisions are made periodically, while logging is continuous.

5.4 Players

Table 1 discussed two roles in the game: the government and logging companies. The game is designed to be played with 3 players who each represent a logging company (see Figure 11), while the role of the government is simulated by the model as described in Chapter 4. The logging companies were branded as birds mainly because of the neutral image of birds, in terms of gender and other identifiers, so that it would not influence the choices made by players given the research purpose of this game. A minimum of 2 players are required, Treecreeper and Nuthatch. In the case when the last role, Woodpecker, is not active, the model simulates the behavior of the 3rd player to imitate the behavior of player 1, Treecreeper.

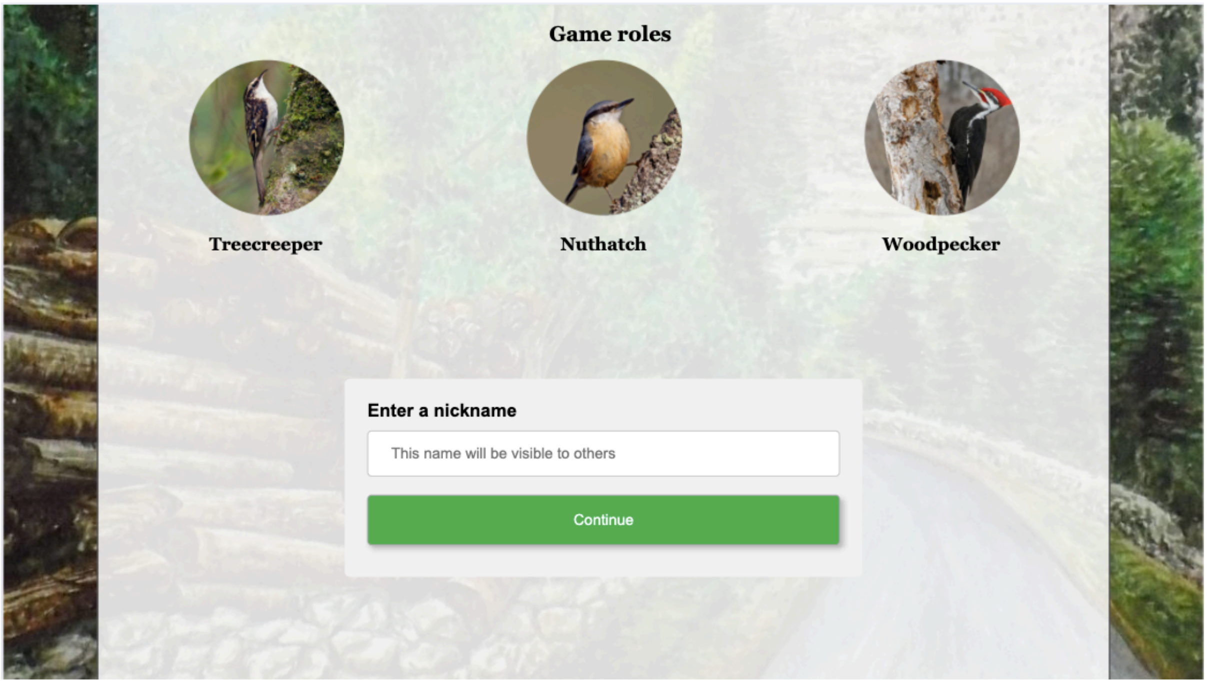

Figure 11. Three player roles representing logging companies

5.5 Game walkthrough

The game goes through three stages: introduction, logging task and debrief. See Table 5 for a full explanation.

Sequence of events	**Description**
Introduction	The context, the objective and the rules of the game are described (see Figure 12). The players are instructed to find the balance between satisfying the demand of Treezonians and abiding by the legal quota (see full instructions in Appendix 4).
Logging task	Each round the players are presented with information about the state of the forest, news regarding inspection and sanctioning in the game, the quota set by the government, the demand from the customers and their score (see Figure 13 for an example). The task of the player is to make a decision on their logging level before they proceed onto the next round.
Debrief	The results of the game are displayed in the final stage (see Figure 14). In addition, the players can see time-series information about the forest and each player's logging level.

Table 5. Game sequence

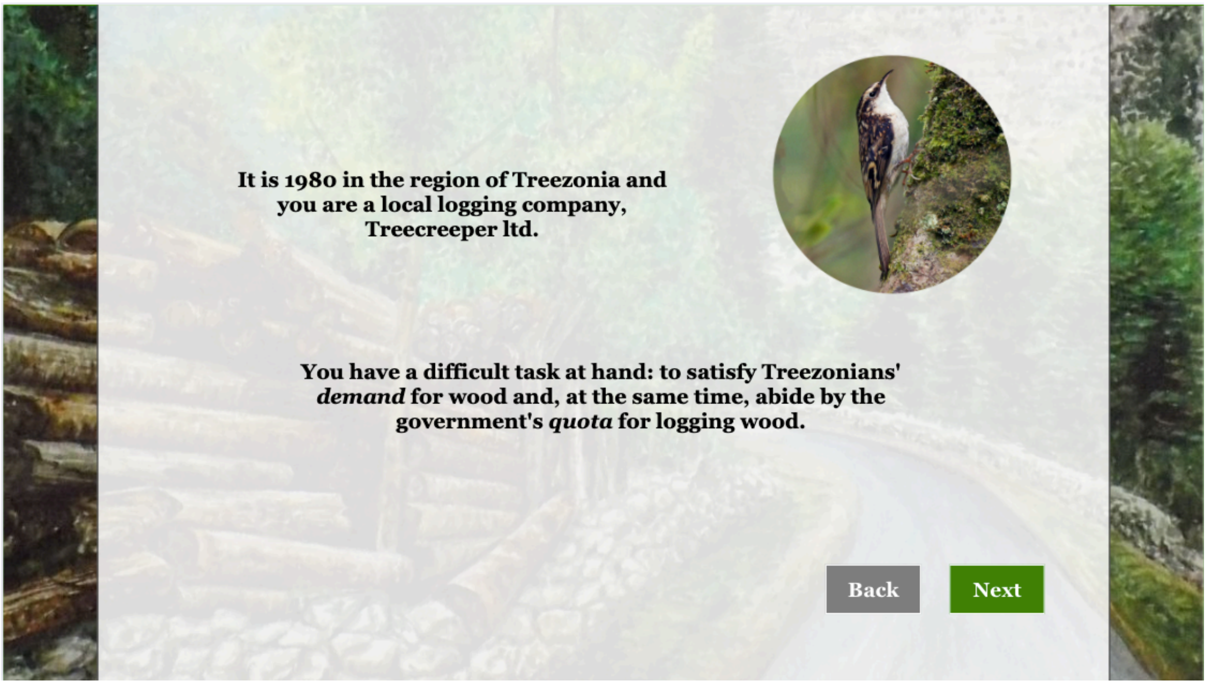

Figure 12. Introduction page

5.6 User interface and game availability

5.6.1 Overview

The user interface was designed using Stella Architect and published on the isee Exchange platform (https://exchange.iseesystems.com/) with all rights reserved through paid hosting from isee Systems from May 13th to June 13th. It was designed to be compatible with all devices, especially wide desktops and tablets (16:9).

5.6.2 Timeline and forest cover

The uppermost part of the Dashboard (see Figure 13) depicts the year, which changes each round. Further, the forest cover is represented both as a number and visualized as trees. Each tree represents 10% of forest cover so that three green trees mean that the forest cover is at 30%.

5.6.3 Calculations

On the right part of the Dashboard page, there are the calculations which capture the performance of the player in the last round. The purpose of this section is to continuously explain how and why the score is updated.

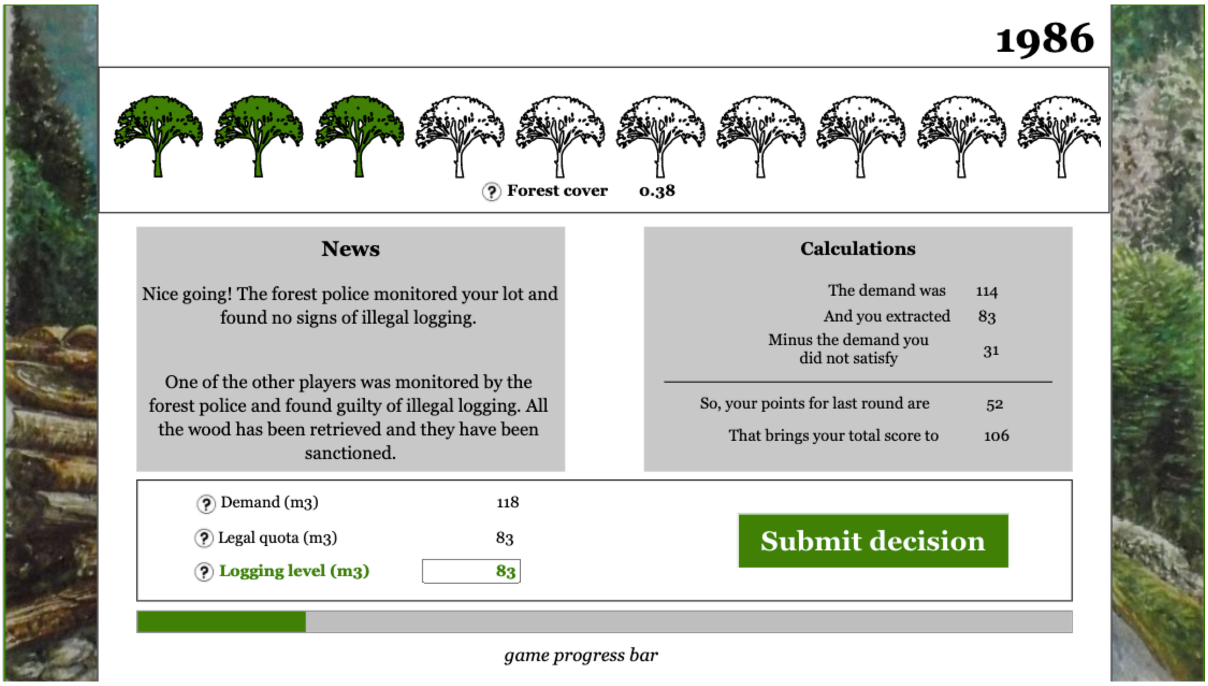

Figure 13. Dashboard page

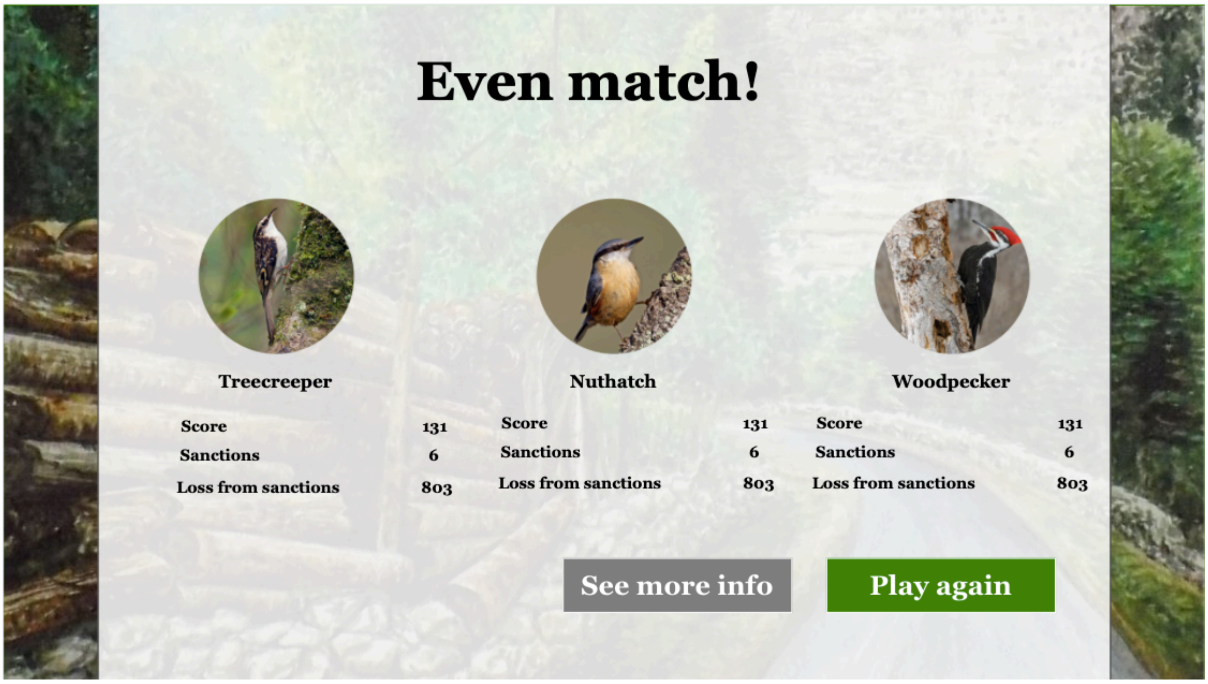

Figure 14. Debrief page

5.6.4 News

The news section is triggered whenever an event happens in the game. Events include: (1) a player successfully passing inspection, (2) a player getting away with illegal logging, (3) a player getting sanctioned, (4) one of the other players getting sanctioned or (5) no news. All news is presented simultaneously, as if it were on a newspaper front page.

5.6.5 Decision box

The decision box displays the quota and the demand for the upcoming 3 years. This is the part of the interface where the participants input their decision.

5.6.6 Game progress bar

Last, at the bottom of the screen there is a game progress bar depicting how far along in the game a player is.

5.7 Game assumptions

The simulation game has a research purpose (see Table 3). For this purpose, several assumptions have been made:

1) *Probabilistic monitoring.* The frequency of monitoring is determined according to a probability function, which is a simplified assumption of how monitoring decisions actually take place.

2) *Simultaneous monitoring.* In the game either all players are monitored or none of the players is monitored. This, again, is a simplified assumption which is not representative of the real-world where monitoring need not be simultaneous.

3) *All sanctions are executed.* In other words, there are no barriers to sanction execution. A player is sanctioned once caught logging illegally, with no exceptions.

4) *Perfect news.* News in the game are timely and correct. There are no instances of fake news and every passed inspection or instance of having gotten with illegal logging is reported privately, while every sanction is reported publicly.

5) *No communication.* Players are not able to communicate during the course of the game. Hence, they are not in a position to create side-agreements or disclose additional information.

6) *Score privacy.* I have assumed that players do not know one another's scores. The scores of all players are only revealed at the end of the game. The justification behind

this assumption is that loggers (or logging companies) do not have insights onto one another's earnings.

7) *Perfect information on forest cover.* I assume that players are not subject to any biases or barriers to information collection regarding the forest. Thus, they are presented with perfect information on the forest cover throughout the entire game.

8) *Finite number of rounds.* The players know the number of rounds in advance, which is only representative of fixed-term tenure agreements.

5.8 Game testing

The game development process was iterative, jumping between game building and game testing. Once the final version of the game was completed, I performed a series of test to ensure that the game is user-ready, both within Stella Architect and using the online version on the isee Exchange platform.

5.8.1 Scoring function test

The purpose of this test is to test the consistency between the score calculations displayed on the interface and the expected calculations solved manually. The test revealed slight discrepancies, which was due to integration being used as a calculation technique, which is more suited to continuous calculations as opposed to the discrete calculations displayed on the interface. For this reason, a rounding function was added to the equation for *Individual quota* (see Appendix 3) and I rounded all displayed numbers on the interface to a precision of 1.

5.8.2 News function test

Next, I did some game runs (including both compliant and noncompliant behavior) in order to test whether the interface displays news in the envisioned times. The test revealed proper of the functioning of the interface. In other words, participants were correctly informed when they passed inspection, got away with illegal logging, were sanctioned or when another player got sanctioned.

5.8.3 Player-specific information test

Moreover, I ran a test in order to examine whether the information displayed on the interface for each player is specific to the role chosen by the player. For example, I checked to see whether the Debrief page (see Figure 14) displayed the score and loss information for the appropriate player. The game passed this test successfully.

5.8.4 Interface sensitivity test

Last, I tested the sensitivity of the game to extreme values of *Extraction level*. The purpose of this was to see whether the game would behave correctly or crash when players exhibited unanticipated behavior. See Table 6 for the details of the tests conducted. The results of the test revealed that the game reacted appropriately with slight deviations. Most importantly, the game was not sensitive to an Extraction level that exceeded the quota by 1, indicating that if a player exceeds the quota by 1, they would not be caught for noncompliance despite getting away with a higher score. The reason for this bug is due to the rounding equations in the game (see Appendix 3).

Extraction level	**Expected behavior**	**Game behavior**
Extremely high value (1000)	Extremely high value (1000)	Extremely high value (1000)
Negative value (-5)	0	0
Non-integer (0.0001, 3.5)	Rounded values	Rounded values
Non-number character (a, b, !)	No expectation	Default extraction level (83)
Number exceeding quota by 1, 2, or 3 m^3	Notification of getting sanctioned or having gotten away with illegal logging. Correct calculations.	Notifications were as expected for 2 and 3, but not for 1. The calculations were correct.

Table 6. Game interface sensitivity tests

5.9 Calibration of the game

The game was calibrated based on data from Canada in order to be representative of a forest use system from the real world (see section 4.9.3). However, the numbers were divided by 1 million and rounded in order to provide a more user-friendly experience. Additionally, *Fractional demand growth rate* is calibrated to 1% due to an estimated average growth rate of 1% of the Canadian logging industry during the period 2015-2020 (IBISworld, 2020) and an average 1% annual change in the global wood industry (FAO, 2009b). The exact calibration is presented in Table 7.

Variable	Value
Forest area (1980)	350
Maximum forest area	910
Growing stock (1980)	63800
Allowable annual cut (1980)	250
Desired allowable annual cut (1980)	250
Individual quota (1980)	75
Demand	110
Reference growth rate	1
Marginal hectare per growing stock increment	0.0048
Desired allowable annual cut adjustment time	50

Table 7. Game calibration

5.10 Game behavior

The incentive structure in the game effectively yields two strategic choices to players: either to comply with the rules and get a small but secure gain or not to comply with the rules and risk getting a big gain or a big loss. Thus, the range of game behavior is either total compliance, total noncompliance and everything in-between.

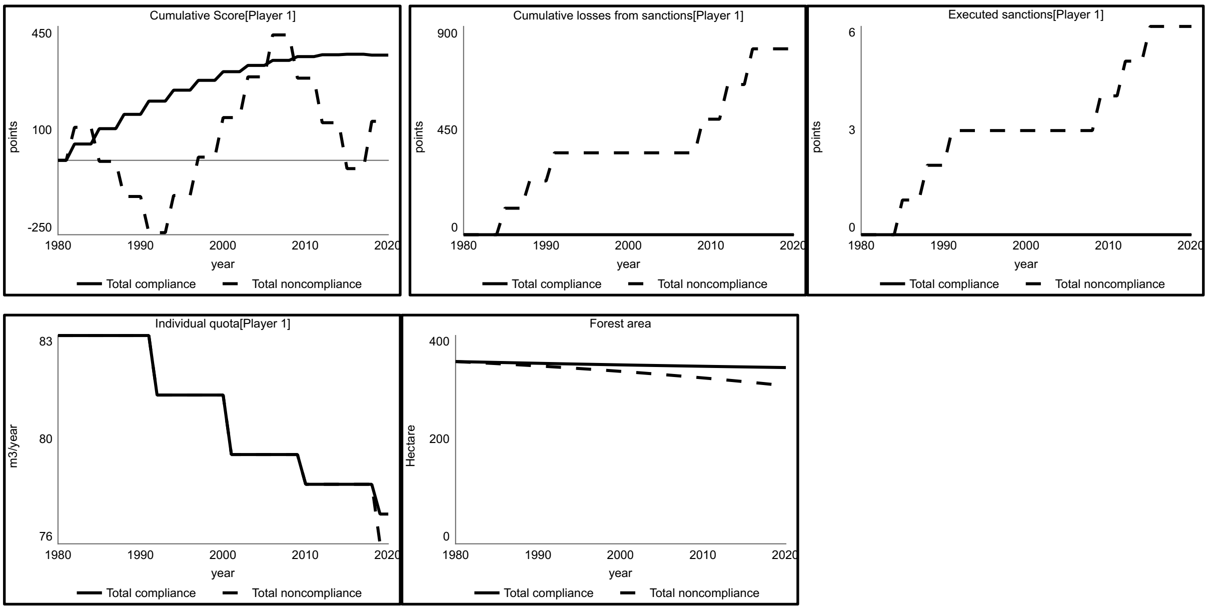

Figure 15. Game behavior

Figure 15 shows two extremes of game behavior – total compliance and total noncompliance. While, total compliance results in no sanctions or losses from sanctions and a decreasingly increasing game score, total noncompliance shows discrete increases in sanctions and losses from sanctions and oscillations in the cumulative score. The behavior of the score is due to the incentive structure (an ever-more increasing gap between the quota and demand), which slows down the increase in score of compliant players. While, the oscillations in score for noncompliant behavior are due to the presence of a monitoring and sanctioning mechanism.

The forest area for total compliance decreases very slowly, which is expected given that the game's calibration id based on the Canada run (see section 4.9.3). Whereas the forest area for total noncompliance decreases at an increasing rate, indicating that the situation is getting out of the government's hands. This behavior is due to the game structure, which effectively breaks loops B2 and B3, so the system is no longer dominated by these loops. Instead, the negative exponential drop in forest area is the result of dominance of the reinforcing loop describing exponential growth in demand.

Perhaps the most interesting part of game behavior is that of the individual quota. We can see that the individual quota is the same for total compliance and total noncompliance until 2018. After 2018, the individual quota for total noncompliance drops further than that for total compliance. Moreover, if we run the simulation longer, until 2050, we can see that the gap between *Individual quota* of each run is increasing. This is the 'tragedy of the commons' effect. The quota is gradually lowered as an attempt to bring the system to an equilibrium through wood removal regulation following the highest-first principle (see section 4.10.1). However, noncompliant player behavior, which is synonymous to treating the public forest as an open-access resource as described in the tragedy of the commons, decreases the quota more quickly and dramatically than compliant player behavior does, leading to total forest destruction.

Chapter 6: Pilot experiment

The aim of the pilot experiment is to test the usefulness of the game, described in Chapter 5, yielding insights on rule compliance in public forests for the purpose of answering RQ3. At the same time, it is important to emphasize that this is a *pilot* experiment, which can be understood as small-scale intervention in which both quantitative and qualitative data is collected for analysis. As such the pilot experiment is conducted in preparation of a full-scale quantitative experiment in a controlled environment (Saunders & Lewis, 2012: 114).

6.1 Rationale

The reason for using a pilot experiment was briefly mentioned in Chapter 4. Namely, the existing model structure was not able to fully explain *Wood removal* neither in the Canada run nor in the global run. Because of this I concluded that there is a lack of understanding about the drivers of wood removal decisions. Experiments performed with simulation games can help with behavior validation and elicit information on uncertain model structure (Sterman, 1987). Their findings can be used to both improve model structure and model calibration. However, I opted for a pilot experiment instead of a full-scale experiment because of the limited timeframe available for this research. In fact, Saunders & Lewis (2012: 115) praise the use of pilot experiments as a way of refining the data collection procedure and in that way improving the success rate of the eventual full-scale experiment. Moreover, the exploratory nature of RQ3 warrants the collection of qualitative data, which cannot be collected during a traditional experiment.

6.2 Participants

Participants were recruited from a population of laypeople, i.e. people who are not real decision makers in forest use systems. In addition, all participants had personal acquaintance with the researcher with the idea that this would maintain homogeneity and positively influence engagement and self-disclosure. No reward was given; hence participation was voluntary.

6.3 Sampling

A sample of 19 participants were recruited using the principal of theoretical saturation. Namely, recruitment stopped when no new concepts emerged from the pilot experiment. In addition, there was an attempt to control for diversity, yielding a homogenous sample, which is more likely to produce consistent results from which it would be easier to interpret meaning.

6.4 Design

All participants were part of a single group that followed the same procedure as is typical in pre-experimental designs (Salkind, 2010: 1258). This design does not test any specific hypothesis, but rather it is of an inductive nature, where data is collected during and post-intervention and then analyzed for the purpose of inducing hypothesis that can be testes in an experimental setting.

6.5 Procedure

The participants were recruited with the offer of playing a logging game online. No further instructions were given other than those on the interface of the game. After recruitment, the participants were asked to sign a consent form and sent a link to a join a specific game session. Each participant played the game online on their own, with the researcher as a second player and an automated player simulated by the model to copy the game play of the researcher.

Since the game is designed as a multiplayer game to be played with at least 2 and at most 3 players, I developed a standard scheme for the behavior of the other 2 players. The rationale behind the scheme, which is portrayed in Table 8, is to display a diverse range of behavior that would enable all the functions of the game, i.e. would enable the participant to experience the notification of the other player having been sanctioned. In addition, this specific scheme was developed to yield an estimate for a comparatively bad score. Specifically, the score for this player scheme equals 142 points, which is just a little above the score of a game run of total noncompliance as shown in Chapter 5 (131 points). The idea behind this was that the effect of winning the game would positively influence participant self-disclosure in the interview.

Year	1980	1983	1986	1989	1992	1995	1998	2001	2004	2007	2010	2013	2016
Action	Not comply	Comply	Comply	Not comply	Not comply	Comply	Comply	Comply	Not comply	Not comply	Not comply	Comply	Comply

Table 8. Scheme for player 1 and 3.

At the end of the game the participants were asked to join an online interview. The purpose of the post-game interview is to elicit data on how the participants used the information on the interface to justify their decisions in the game, thus answering RQ3. In particular, the interface contained varied information which represented the physical system and the inter-actor environment (see Table 3) and is expected to stimulate participant reasoning. Find the full interview guide in Appendix 6. Verbal statements were audio recorded and analyzed in reference to the results of the game run.

6.6 Data analysis

Pilot experiment data analysis helped identify initial insights regarding the reasons for compliance. In particular, I interpreted the reasoning for compliance in light of when noncompliant behavior took place and why.

6.6.1 Quantitative data analysis

Descriptive statistics for the pilot experiment results were sufficient to portray when noncompliance took place. In addition, I conducted some bivariate analysis in order to see whether there is any link between compliance and other indicators such as payoffs, score and forest cover. Moreover, I calculated the incidence of noncompliance when a participant received news notifications on the interface in order to see whether any particular notification resulted in a large incidence of noncompliance as well as to compare the incidences of noncompliance following different notifications. These analyses served to illuminate the reasoning of participants by identifying a pattern in quantitative data, which was informative of the triggers of compliance. See the full process in Figure 16.

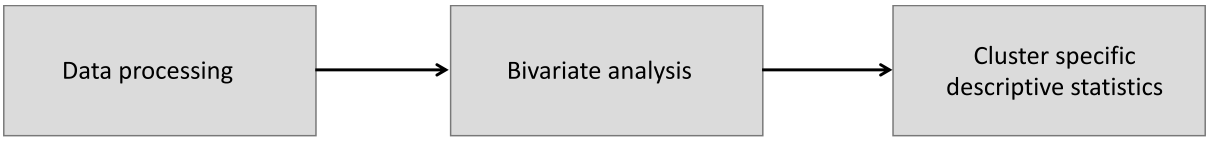

Figure 16. Description of quantitative data analysis process. The arrows denote sequence

6.6.2 Qualitative data analysis

Interview data was most useful for revealing why participants made their decisions, hinting at their reasoning. For this purpose, I first did a non-verbatim transcription of the interviews. Next, I deductively coded the transcript according to two frameworks: the theoretical framework for rule compliance (see Appendix 8) and a framework according to the interface (see Appendix 9). The latter was created in order to display the qualitative results in a manner that will allow me to cross-reference them with the quantitative results. Last, inductive axial coding was applied to the data in order to capture remaining insights (see Appendix 10). The full process of qualitative data analysis is visible in Figure 17.

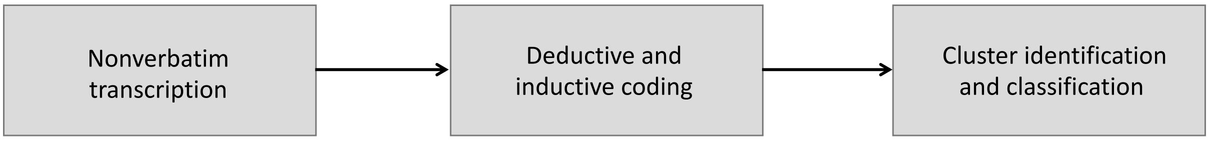

Figure 17. Description of qualitative data analysis process. The arrows denote sequence.

6.6.3 Cluster analysis

Since the data exhibited high variance, I conducted cluster analysis in order to make more meaning out of the data and see whether there are any cluster-specific features in the data. The clusters were first identified through inductive coding (see Appendix 11). Following this, each participant was ascribed to a cluster (see section 7.4). Finally, the quantitative results were presented for each cluster separately, with special emphasis on the effect of news notifications on compliance.

6.6 Research ethics

This thesis adhered to the Academy of Management code of ethics (Academy of Management, 2006) and those described in Denscombe (2012: 121), including:

Transparency

Participants were asked to sign consent forms for recording audio during the interview. In addition to this, participants were offered access to the final version of this thesis.

Non-identifiable data

No personal information that allows for identification of participants was recorded.

Confidentiality

All of data gathered during this research will is kept confidential and not shared with third parties under any circumstance.

Chapter 7: Results

The results of the pilot experiment are presented in this chapter. Their interpretation is the subject of Chapter 8.

7.1 Overview

Overall, participants showed a generally positive level of compliance[3] throughout the rounds, with values ranging from 69% to 90% in any given round (see Figure 18). The only information we can extract from this graph is that compliance behavior stabilized as the rounds progressed, suggesting that participants increased their commitment to a certain kind of behavior throughout the rounds. This overview should be looked at from the point of view of the individual as there was great variance between participant behavior. Specifically, the amount of illegal logging each participant did ranged from no illegal logging to 765m^3 (see Figure 19).

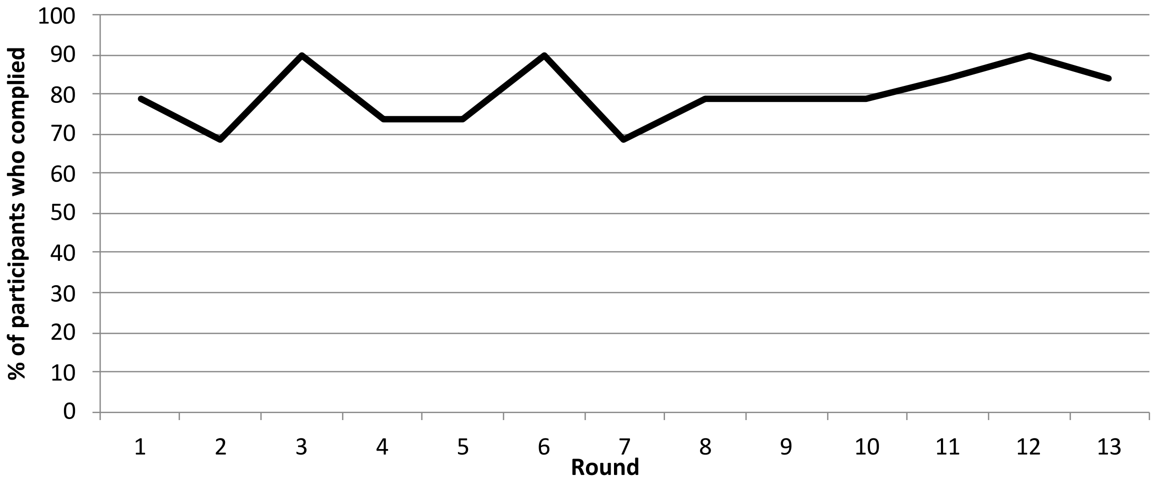

Figure 18. Compliance level throughout rounds

In regard to the extent of noncompliance, most participants played the game as it is designed. In other words, they either complied with the quota or logged the full demand. However, there were some participants who only logged a little, even though it is irrational to do so according to the game rules, stating that they were either 'scared to log more than a few m3 illegally' or that they 'thought that there was a link between the amount of illegal logging and getting monitored' as a reason for this behavior. This brought the average extent of illegal logging to

[3] Compliance is understood as logging either at, below, or 1 m3 above the level of the legal quota.

be only 75% of the full gap between the demand and the quota, which is considered as a reference value for illegal logging.

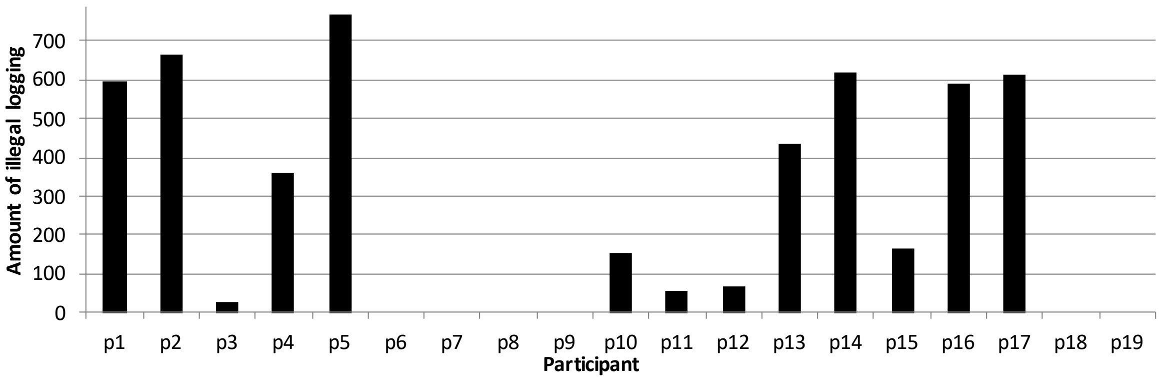

Figure 19. Total amount of illegal logging per participant[4]

All in all, 14 participants won and 5 lost the game, i.e. they performed worse than the scheme created for the other 2 players (see Table 8).

7.2 Quantitative results

Throughout the rounds of the game the payoff for compliance got smaller, while the potential gain from illegal activities became larger. In other words, the conditions became tougher as the game progressed with lower rewards for compliant behavior. As shown on the graph (see Figure 20), this did not have a significant effect on compliance. In fact, it can be seen that compliance is highest in the last rounds and lowest in the first rounds. Thus, on an aggregate level there isn't an effect of payoff on compliance. This issue will be analyzed thoroughly in the next chapter.

[4] Because the game proved insensitive to logging levels that exceed the quota by 1 (see section 5.8), those behaviors are not considered as illegal logging.

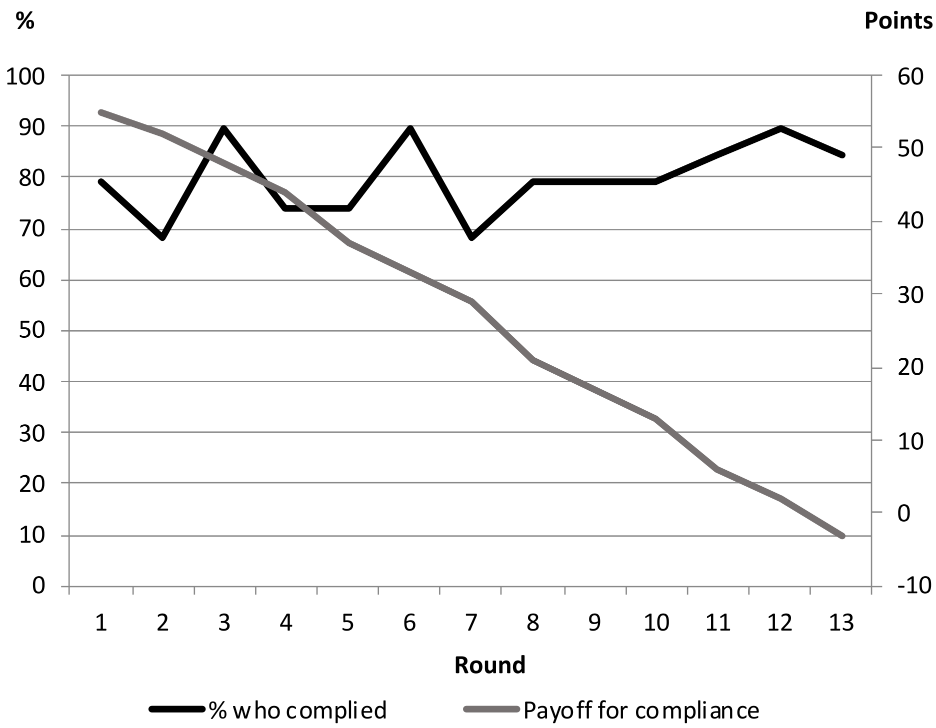

Figure 20. The relationship between compliance and payoff for compliance

Interestingly, even though the instructions (see Appendix 4) did not state that getting the highest score is the objective of the game, almost all participants played in a score-seeking manner. Similar to payoff, no significant trend can be seen in the relationship between compliance and the score (see Figure 21). Both negative and positive scores inspired noncompliant behavior. This result suggests the need for further cluster analysis, which will help highlight emerging insights from the data.

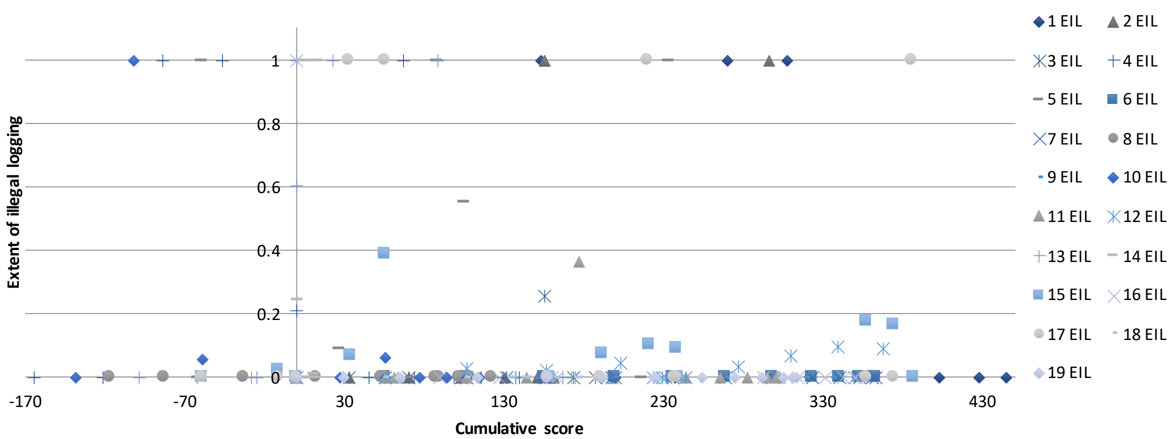

Figure 21. The relationship between extent of illegal logging (EIL) and cumulative score (CS)

Next, the effect of notifications on the interface on participant compliance was described by calculating the incidence of noncompliance in the rounds where such notifications were displayed to participants (see Table 9). Interestingly, the largest incidence of noncompliance was right after participants were notified that they got away with illegal logging and the lowest incidence of noncompliance was right after the participants passed inspection. This indicates that sanctioning is a key mechanism for influencing noncompliance. Further, receiving news that the other player got sanctioned also resulted in low incidence compared to the other types of news, signaling that this type of news had a comparatively positive effect on compliance. Last, there was less illegal logging when participants were sanctioned compared to when they had gotten away with illegal logging. But, at the same time, the incidence of noncompliance was larger after the receipt of sanction compared to after receipt of news of having gotten sanctioned. This is probably due to the fact that compliant participants never got into the situation of getting sanctioned, therefore they did not contribute to that statistic, whereas they frequently passed inspections and received news that the other player was sanctioned and thus brought down the incidence of noncompliance for those events. Again, little can be said about the significance of this result because of the small sample size, which is likely one of the drivers of variance in the data.

News	**Incidence of noncompliance**
Another player was sanctioned	0.16
Passed inspection	0.15
Sanctioned	0.23
Got away with illegal logging	0.3[5]

Table 9. Incidence of noncompliance as an effect of news notification

In addition, the news notifications were not mutually exclusive, so two news notifications could occur simultaneously. For example, a player might have been notified that they have been sanctioned and that the other player has been sanctioned too. Because of this I calculated the incidence of noncompliance for combinations of news notifications to see if any additional insights arise (see Appendix 7). Interestingly, the incidence of noncompliance was higher when

[5] A mistake was discovered in the middle of the data collection period. Namely, the notification regarding getting away with illegal logging was triggered in round 8 despite compliant behavior. This was fixed starting with participant 9. Hence, the data regarding this notification was processed twice. The number on the table is the result of modified data taking into account the instances of false triggering.

players were notified that they had passed inspection compared to when they were notified that they had passed inspection and that the other player has been sanction. Moreover, there was a larger incidence of compliance when players got sanctioned compared to when both they and the other player got sanctioned. The indication from this is that players felt re-assured when they read news about the other player and played either more cautiously or more opportunistically depending on what their previous move was.

In regard to the effect of forest area on compliant behavior, a stable pattern can be observed (see Figure 22). This suggests that there is no effect of forest area on illegal logging activity.

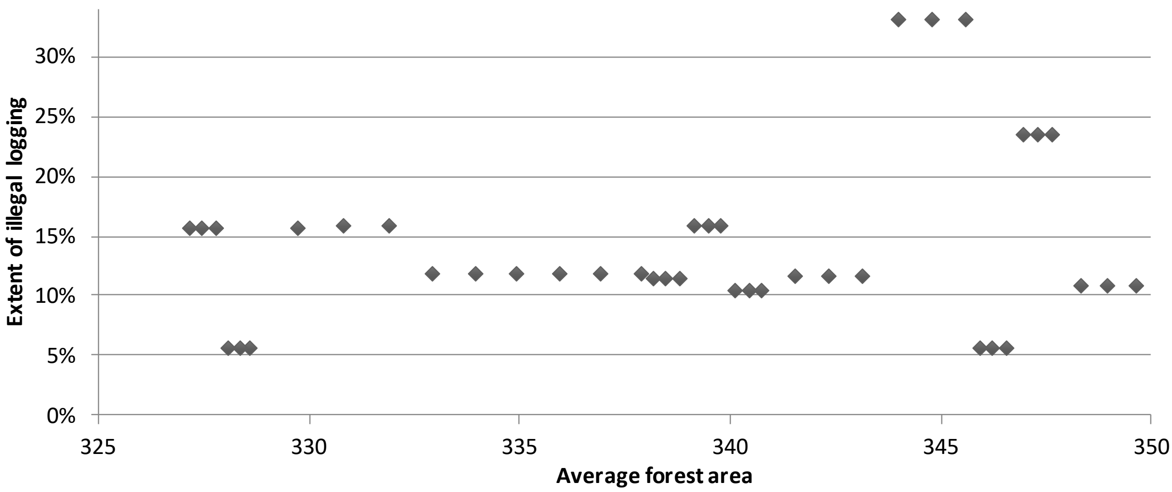

Figure 22. The relationship between average forest area and extent of illegal logging

7.3 Qualitative results

7.3.1 Insights on participant behavior based on interface framework

Most participants agreed that getting sanctioned motivated them to comply in the next round. Although, a few stated that they were not convinced by the first sanction since they did not think they would get monitored two times in a row. After getting sanctioned two times in a row, all participants stated that they had become convinced that illegal logging is not worth it. Of course, not all participants got themselves in a situation where they could get sanctioned. In fact, those that abided by the quota in all rounds portrayed a very negative perception of the sanction, claiming that getting all logs removed is a very detrimental penalty.

Further, the participants had a diverse range of responses to passing inspection. One stated that they did not have any reaction to it, while the others either found it rewarding or stated that it informed their calculation as part of their decision-making strategy. Those that find it rewarding complied in the next round and found it reinforced their strategy. While, others chose not to comply in the consecutive round, as they assumed that they would not get checked in the next round.

On the other hand, getting away with illegal logging motivated two types of responses. Those that continued to log illegally in the next round felt that they could get away with it again, while those that complied felt lucky and expressed that one sneaky success was enough for them.

Most of the participants stated that they were tempted to log illegally as a result of the increasing gap between the quota and the demand, but not all of them did due to difference in their strategies. Not all participants expressed such reasoning. Some justified the increase in demand as a result of previous illegal logging activity. There were a few exceptions of participants who said that they did not care for the increasing gap because they were only focused on other things, stating that they might have found it more influential if the change was more dramatic. Moreover, there were also those whose strategy was strict compliance that stated that they did not even pay attention to demand as their main attention was on meeting the quota. Similarly, those that were noncompliant stated that they did no pay too much attention to the quota, but rather on changes in demand. These comments were illuminating of a phenomenon of selective attention.

The most common reaction to a negative score was compliance as participants expressed a strong aversion to it. In fact, many stated that despite a general noncompliant strategy, they complied in order to build up a positive score which they deemed to be enough before they could take the leap to log illegally again. Similarly, there were some statements that once the participants reached a satisfactory score, they proceeded with a compliant strategy in order to maintain it. This means that participants expressed the biggest willingness to log illegally when they had a subjectively low positive score. Last, not all participants were influenced by the score as they stated that they did not feel like they were competing because they could not see the score of other players.

Most participants either completely disregarded the forest cover or claimed that they did not see any change in it, even though the forest cover fell by 1% during the rounds. In the word of one participant: “If you are focused on earning points you don’t really pay attention to the forest area". Further, there were two participants who were confused about the forest cover and how it was connected to the rest of the game, highlighting naivety on the issue. Notably, there were three participants that expressed that the forest cover was at the center of their attention, either because they felt it gave them valuable information about the behavior of others or because they were expecting the forest cover to increase as a result of their actions.

Last, many participants felt competitive when reading news that one of the other players had been sanctioned, stating that they felt happy and proud of their own performance in the game and at times comforted that they were not the only ones losing points. In addition, they used this information to inform their anticipation of when monitoring takes place, most often responding with compliance as a result of caution. There were also those who expressed that the information was not influential for them because they were playing the game noncompetitively. Interestingly, one of the participants expressed that the fact others got sanctioned inspired them to log even less as a form of compensation for protecting the forest cover. All in all, the participants stated that the other player was an important part of their experience and that if they could see that the other players were abiding by the quota, it might have influenced them to comply too.

7.3.2 Insights on participant behavior based on theoretical framework

In regard to extrinsic motivation, most participants stated that they took the probability of getting monitored into account when making their decisions, with most stating that they followed a specific heuristic and then calculated estimations for it accordingly and few who stated that this was done intuitively without much thought. Next, some of the compliant participants stated that the penalty level was very high, while the rest did not discuss the penalty level at all. Finally, some participants emphasized illegal gains as the reason for their noncompliant behavior, declaring that at the illegal gains were higher later on in the game. In light of this, there might be a possible link between the perception of the penalty level and the attitude to the probability of getting monitored, as those that perceived the sanction as too high did not bother with anticipating it, while those that did not perceive as too high either attempted to calculate it or anticipated it intuitively.

The legitimacy of the government quota emerged as intrinsic motivator for participants. One of them stated that they trust that the government has established a quota that is sustainable and therefore complied. On the other hand, two participants expressed doubts that the government quota is less than is actually sustainable and therefore used this as a reason to log less than the legal quota.

Several participants related to the notification that other players got sanctioned as a reason they overstepped the quota, with one emphasizing that they had been brought up playing games where the norm is to cheat. There were also expressions of despair regarding the norm of unethical behavior and one optimistic statement of a participant who said that they might have been more motivated to comply had they seen that others were complying too.

Apart from the social norm, morals and values were also expressed as motivators for participant behavior. Most of the participants who talked about the importance of law and the significance of protecting the environment did in-fact comply. However, there were a few exceptions of participants who did not comply but still mentioned morals in the interview.

7.3.3 Insights from axial coding

There were many remarks on the process of getting familiar with the game. Specifically, the majority of participants stated that they started off with compliant behavior initially just to get a sense of how the game works. In addition, few stated that they started gambling immediately, i.e. logging illegally, as a way of getting themselves acquainted with the mechanics of the game. And last, one participant stated that they immediately started experimenting with logging less than the quota in order to see whether the forest cover would rise as a way of getting more closely acquainted with the game.

Not only a way of learning how the game works, logging less than the quota was an experiment conducted by four participants, who were all disappointed to have their expectations unfulfilled, indicating a misperception of the delays in the system. Although one pointed the finger at the other players as the reason for their failed experiment.

Similarly, a few participants took the decrease in quota personally, stating that they had expected to be rewarded for compliant behavior with an eventual quota increase as opposed to experiencing tougher conditions later on in the game. In fact, one participant stated that this was the sole reason they changed their decision-making in the game from compliance to noncompliance.

On the topic of motivations for noncompliant behavior, several participants expressed that they felt that they should cheat at least once, just as an adventure, indicating exploratory curiosity as a motive.

A few common beliefs were expressed during the course of the interview, especially on the topic of monitoring. Some participants believed that monitoring was random, while others strongly believed that it was connected to their illegal activity. Many expressed that they did not believe that monitoring would take place in two consecutive rounds, although they were disproved, and one participant expressed a belief that monitoring would take place almost every round. Moreover, a few stated that they believed demand has risen only because they had not been able to meet past demand due to being sanctioned. A possible takeaway from this is regarding the tendency to ascribe personalized causal reasoning for changes in game conditions, especially when faced with uncertainty.

7.4 Analysis

In order to make more meaning out of the data, I applied inductive coding to the data and identified the following clusters (see Appendix 11):

- Competitive compliant
- Competitive noncompliant
- Noncompetitive compliant
- Noncompetitive noncompliant

Following this, I classified each participant in one of the four possible clusters by cross-referencing their verbal statements and quantitative results. The participants differed on two dimensions: whether they were competitive or not and whether they thought compliance or noncompliance was the way to reach their goal.

The first dimension, competitiveness, describes the goal of the participants. In particular, competitive participants aimed to finish the game with the highest score in order to be better than others, while noncompetitive participants had different goals such as maintaining forest cover, meeting demand as much as possible or simply abiding by the quota.

Next, the second dimension, describes the manner in which the participants aim to reach their goal. For example, competitive noncompliant participants strategically logged illegally in order to maximize their score and do better than the other players, while competitive compliant participants thought that the best way of beating others was not to maximize their score, but rather to abide by the quota and count on other players getting sanctioned, so that they come out as winners in the long run.

Further, noncompetitive noncompliant participants were driven to strategically log illegally in order to meet the most demand or just for the thrill of avoiding sanction, while noncompetitive compliant participants reasoned that the best way of reaching their individual goal was to comply and even log much less than the allowed quota.

It can be said that this cluster division describes two characteristics: strategy and motivation. Namely, participants either adopted a compliant or noncompliant strategy and their motivation was either competitive or noncompetitive (see Table 10).

		Strategy	
		Compliant	*Noncompliant*
Motivation	*Competitive*	Competitive compliant	Competitive noncompliant
	Noncompetitive	Noncompetitive compliant	Noncompetitive noncompliant

Table 10. Description of clusters

7.4.1 Competitive noncompliant

Competitive noncompliant logged illegally compared competitive compliant participants. This can be clearly seen though looking at the extent of illegal logging of each participant (see Figure 23, 24, 25 and 26). Participants who have been clustered as noncompliant have a higher average to maximum ratio when compared to compliant participants, i.e. they cheated more often than compliant participants.

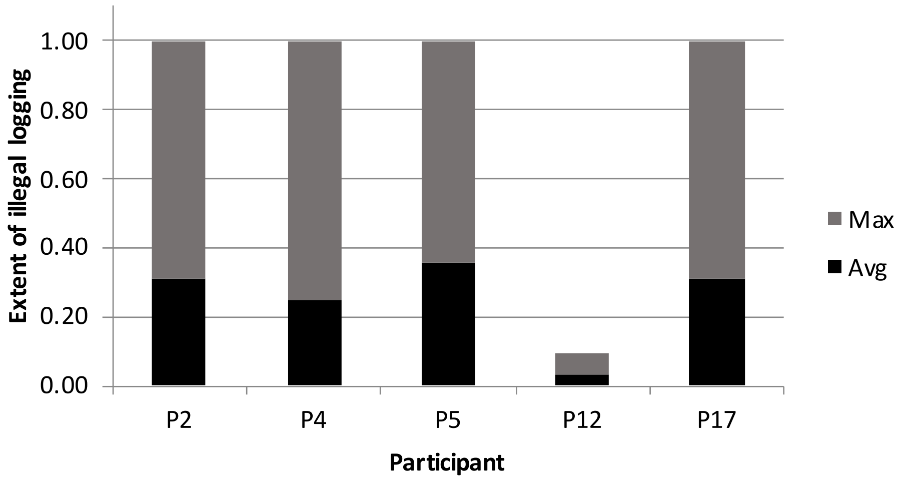

Figure 23. Extent of illegal logging of competitive noncompliant participants

These participants were clustered as competitive because they expressed that their main motivation came from beating others or beating the game. More precisely, they emphasized the importance of the score and the anticipation of monitoring as their main drivers. In the words of two participants:

"I wanted to earn points and the way to do that was to cheat"

"At first, I followed the rules in order to get a sense of the frequency of monitoring. But after not getting inspected in the first round I got eager and tried to cheat. You can say that my main strategy driver was trying to guess when monitoring took place."

7.4.2 Noncompetitive noncompliant

Similarly, noncompetitive noncompliant participants logged illegally compared to noncompetitive compliant participants (see Figure 23, 24, 25 and 26) as evidenced by the difference in average to maximum ratio. Next, noncompetitive noncompliant participants were not focused on beating others, but rather on meeting demand as best they can. In the words of one participant:

"I felt like people were waiting for me to provide."

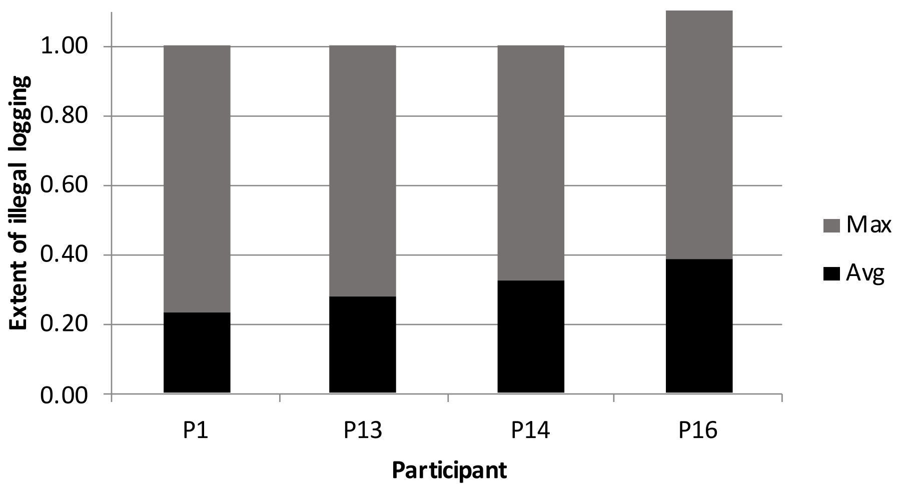

Figure 24. Extent of illegal logging of noncompetitive noncompliant participants

7.4.3 Competitive compliant

Competitive compliant participants did not log illegally, or they only did it once, as evidenced by the low average to maximum ratio (see Figure 25). Like competitive noncompliant participants, they too were motivated to beat others, but they thought that the best way to do that would be to log illegally. They expressed the score, seeing others get sanctioned and sanction avoidance as their main motivators that helped them reason through their strategy. Examples of their reasoning include:

"Something in me told me to follow the rules. I thought that if I went by the quota all of the time that that would eventually balance out and I would come out as a winner."

"My strategy was focused on occasionally point grabbing, but ultimately mostly driven by punishment avoidance."

"I wanted to win the game by beating others as opposed to maximizing my points. My biggest motivation was seeing others lose."

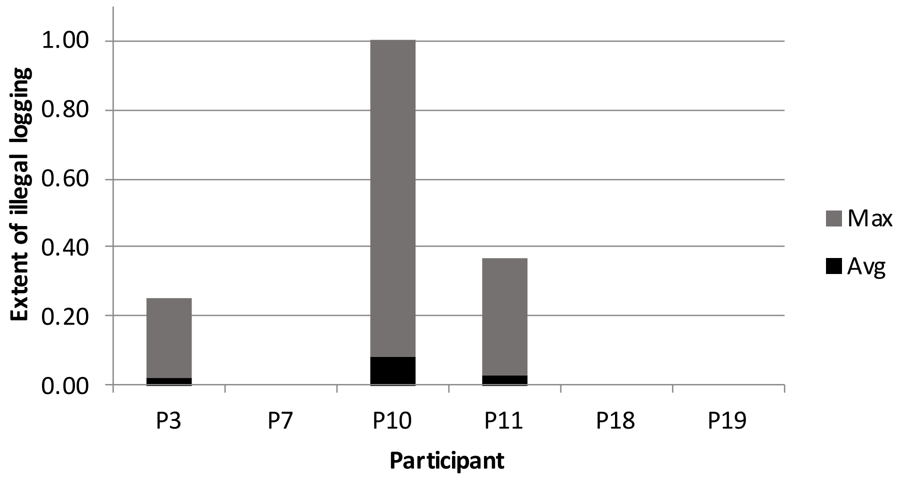

Figure 25. Extent of illegal logging of competitive compliant participants

7.4.4 Noncompetitive compliant

Last, noncompetitive compliant participants were not focused on beating others and tended not to log illegally (see Figure 26). One of these cases did log illegally but stated that they felt pushed to comply as the best way of satisfying demand, which is not a competitive motive.

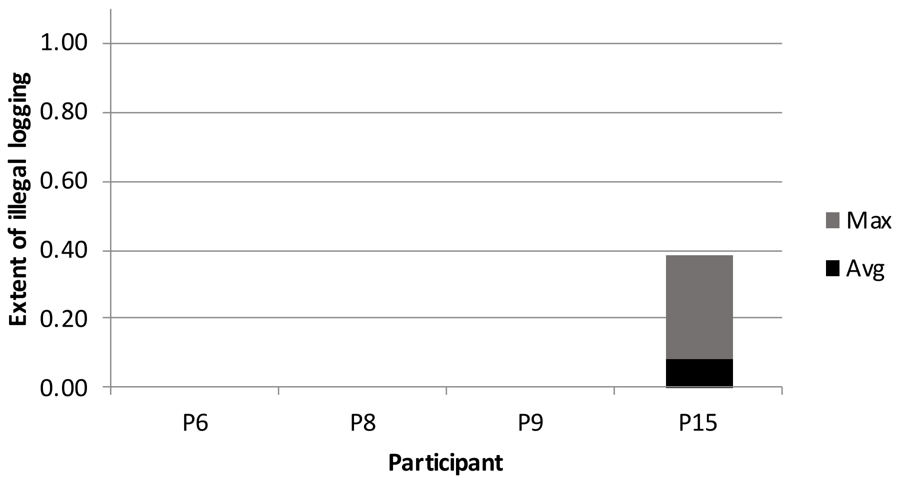

Figure 26. Extent of illegal logging of noncompetitive compliant participants

Their specific statement was:

"Overall, I wanted to satisfy the people. I was really scared and risk averse. In my reflection I realized that I would have been better off just complying with the quota.".

Others emphasized the forest cover or the quota itself as their main motivation. Their words included:

"My strategy was: abide by the rules, don't be greedy and then you'll be all good."

"My goal was to keep the forest cover as high as possible."

7.4.5 Effect of news on clusters

Noncompliant participants with both competitive (p5 and p17) and noncompetitive (p1 and p14) motivation logged illegally after receiving news that the other player had been sanctioned (see Figure 27). It can be said that competitive participants logged illegally more often than noncompetitive participants because of the higher average extent of illegal logging. Additionally, one noncompetitive compliant logged illegally after receiving this notification (p15).

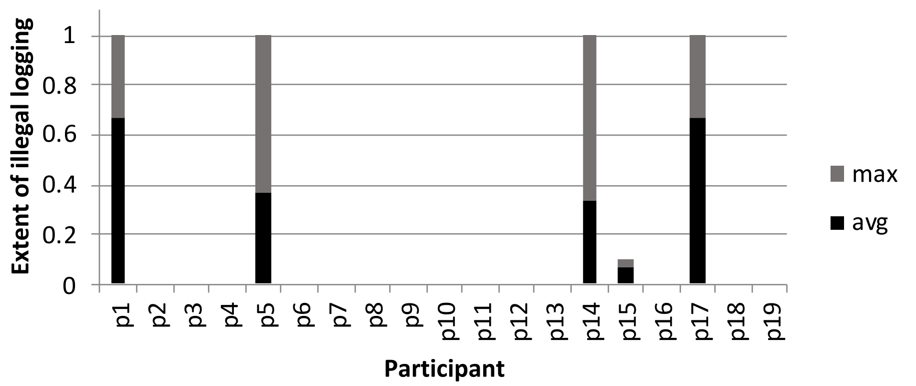

Figure 27. Extent of illegal logging as a response to receiving news that the other player has been sanctioned

Next, almost all noncompliant participants (with the exception of p4 and p12) reacted with noncompliance to having passed inspection (see Figure 28). Notably, noncompetitive participants logged illegally more often when they received this notification compared to competitive participants. Further, two compliant participants reacted with noncompliance to having passed inspection, one with competitive motivation (p3) and one with noncompetitive motivation (p15). Compared to receiving news that the other player got sanctioned, it can be seen that the participants complied more as a response to passing inspection.

This is visible due to the fact that the averages are higher on Figure 27 compared to Figure 28, which indicates that a few select participants were very reactive to receiving news that the other player got sanctioned, even though there was more noncompliance after participants received news that they had passed inspection. This is also in line with the incidence calculation (see Table 9), as the incidence for noncompliance is lower after having passed inspection compared to after receiving notification that the other player got sanctioned.

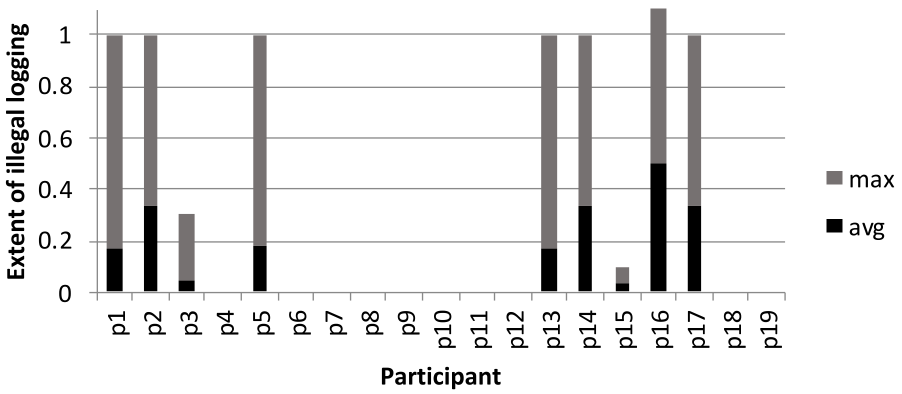

Figure 28. Extent of illegal logging as a response to receiving news of having passed inspection

Getting sanctioned inspired compliance in most participants (see Figure 29) apart from a few noncompliant participants with both competitive (p4 and p5) and noncompetitive motivations (p1 and p14). Moreover, there was one competitive compliant participant reacted with noncompliance to getting sanctioned (p10). It can be seen that there was more illegal behavior after passing inspection than after being sanctioned.

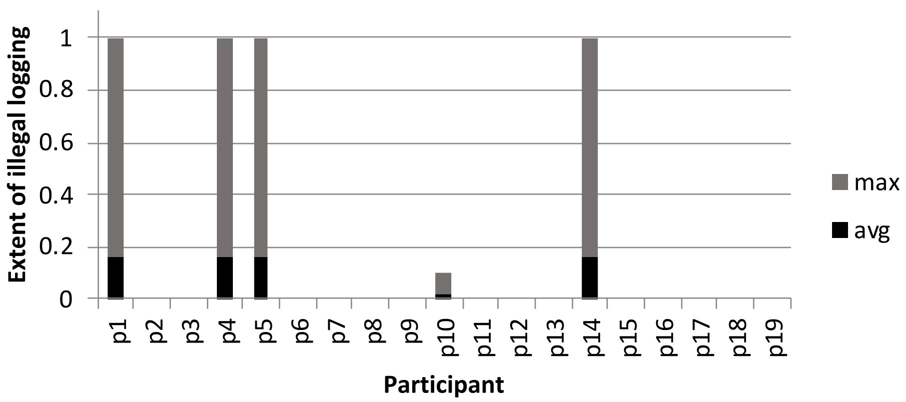

Figure 29. Extent of illegal logging as a response to receiving news of having been sanctioned

Last, receiving news of having gotten away with illegal logging motivated four noncompliant participants to log illegally, out of which three were with a competitive agenda (p2, p4, p12), one noncompetitive (p13). In addition to this, there was one noncompetitive compliant participant (p15) who acted on the temptation. This wide-spread distribution of noncompliance among the clusters (see Figure 30), taken together with the relatively high incidence rate (see table) indicates that getting away with illegal logging is a powerful motivator of noncompliance.

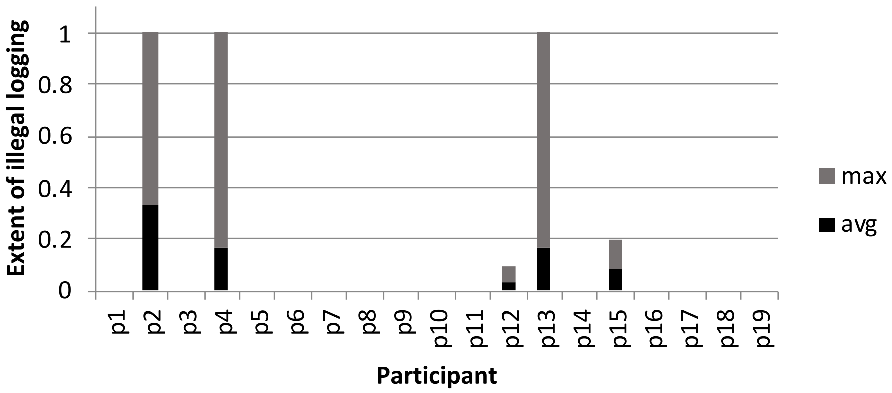

Figure 30. Extent of illegal logging as a response to receiving news of having gotten away with illegal logging[6]

[6] This representation takes into account false triggering

Chapter 8: Discussion and conclusions

I started this thesis with the aim of studying reasoning behind rule compliance in public forests. I focused on wood as a specific resource and the allowable annual cut as a governing rule (see Chapter 1). This quest led me through a deep dive in academic literature, yielding a theoretical framework explaining the drivers of rule compliance (see Chapter 2). Following this, I consulted reports on the state of global forests and documents detailing their management procedures, which I used as source material for constructing a model (see Chapter 4). Next, I proceeded with the development of a multiplayer online simulation game of a public forest (see Chapter 5). The game enabled me to design a pilot experiment for the purpose of reaching my research aim (see Chapter 6). Finally, the results of the pilot experiment (see Chapter 7) yielded rich data on which I discuss my contribution in this chapter.

8.1 Answers to research questions

RQ1: What relevant concepts and frameworks exist for explaining reasoning behind rule compliance in public forests?

There are two streams of thought describing reasoning behind rule compliance: instrumental and normative. The instrumental stream represents concepts which serve to explain compliance as a utilitarian act which seeks to maximize gain. As such, these concepts are also referred to as extrinsic motivators and are the subject of neoclassical deterrence models. Among them are (1) the illegal gain from noncompliance, defined as the perceived value of gain for a successfully pulled off act of noncompliance, (2) the probability of getting sanctioned, representing the individual's perception of the functioning of the enforcement mechanism and their personal attitude to risk, and (3) the penalty level, which is the perceived value of the sanction for noncompliance. Next, normative reasoning describes social and personal norms, which are irrespective of the economic context, and can be thought of as internal motivators. The social norm, or the perceived actions of others, legitimacy, representing the perceived fairness of the governing rule, and morals and values, which are perceived internalized principles, all come together to influence decision-making. These concepts come together in a theoretical framework (see Figure 2). Refer to Chapter 2 for a full summary of existing research on compliance.

RQ2: What system dynamics structure can be used to build a simulation game that mimics a situation where individuals make decisions to either comply with the governing rules of public forests or not?

A system dynamics model that describes the relationship between the state of the public forest and the annual allowable cut was built for the purpose of simulating a decision-making situation for studying compliance behavior.

The model captured the dynamics of the forest, including forest growth represented through a reinforcing 'forest growth' loop and a balancing 'limits to growth' loop, and the effect of policy on the forest, through a balancing 'wood regulation' loop and a reinforcing loop encouraging growth when the forest is above the maximum sustainable yield level. The source material used for building the model was a textbook on forest growth and yield modeling for the forest structure, and government documents for the policy structure. Next, the model was calibrated through partial-model calibration using a dataset on global forests from the FAO and a dataset on Canadian forests from the government of Canada. This resulted in three model simulation runs: Equilibrium, Global and Canada run. The equilibrium run was used for analysis of model structure, while the Global and Canada run were compared with the corresponding datasets. While the model could successfully reproduce much of the data, it was not a good explanation for the wood removal function, highlighting the importance of the aim of this study.

While, Chapter 4 elaborates on the model, Chapter 5 describes a simulation game that elicits information on rule compliance in public forests. Several modifications were added to the model and an interactive interface was created for this purpose. Namely, an incentive structure representing increasing demand for wood, probability-based monitoring, a sanctioning structure and, finally, a scoring structure that ties all of them together. This specific game formulation created an environment where players are faced with increasing potential payoffs for noncompliance, decreasing payoffs for compliance and an uncertain monitoring mechanism. It is important to note that the game was multi-player, so players could receive notifications that one of the other players has gotten sanctioned.

RQ3: What initial insights can be derived about reasoning behind rule compliance from the pilot experiment?

Overall, the takeaway from pilot experiment is that the possible range of reasoning for compliance was wider than that for noncompliance. This means that compliant participants varied in their reasoning, while noncompliant participants tended to emphasize the same reasons. Specifically, the most commonly used reason for noncompliance was illegal gains, with some noncompliant participants also emphasizing the probability of getting sanctioned, social norms and morals and values as a reason for their decisions.

Results of the pilot experiment (see Chapter 7) showed a somewhat stable level of compliance throughout the rounds, ranging from 80% to 90% of participants complying in any given round. At first glance, the quantitative results could not be explained through changes in payoffs, score or forest cover. Additionally, the qualitative results depicted big variance in participant responses. In light of this, clustering analysis was done for the purpose of deriving some insights on the research question. Specifically, the clustering analysis was done through inductive coding of qualitative data whereby each participant was classified in one of four possible clusters.

The cluster analysis divided participants according to their strategy: compliant and noncompliant, and their motivation: competitive and noncompetitive. Competitive participants emphasized the score in their reasoning, while noncompetitive participants emphasized demand and forest cover. Interestingly, both competitive and noncompetitive participants emphasized sanction avoidance as part of their reasoning. Noncompliant participants emphasized the score, anticipation of monitoring and demand as their reasons, while compliant participants focused on the score, sanction avoidance, seeing others sanctioned, forest cover and demand while explaining their decisions.

Verbal statements were first coded according to the theoretical framework and then cross-referenced with the cluster analysis in order to create an overall view of the theoretical reasons for compliance used by each cluster (see Figure 31). On the whole, it is visible that noncompetitive noncompliant participants had fewest reasons for their behavior, while competitive compliant and noncompetitive compliant participants had a plethora of reasons for justifying their behavior. Overall, it is clear that noncompliant participants used less reasons to justify their behavior than compliant participants.

In terms of specific reasoning, illegal gains were used exclusively by noncompliant participants, while the penalty level and legitimacy were used exclusively by compliant participants. On the other hand, the probability of getting sanctioned, social norms and morals and values were used by both compliant and noncompliant participants as well as both competitive and noncompetitive participants.

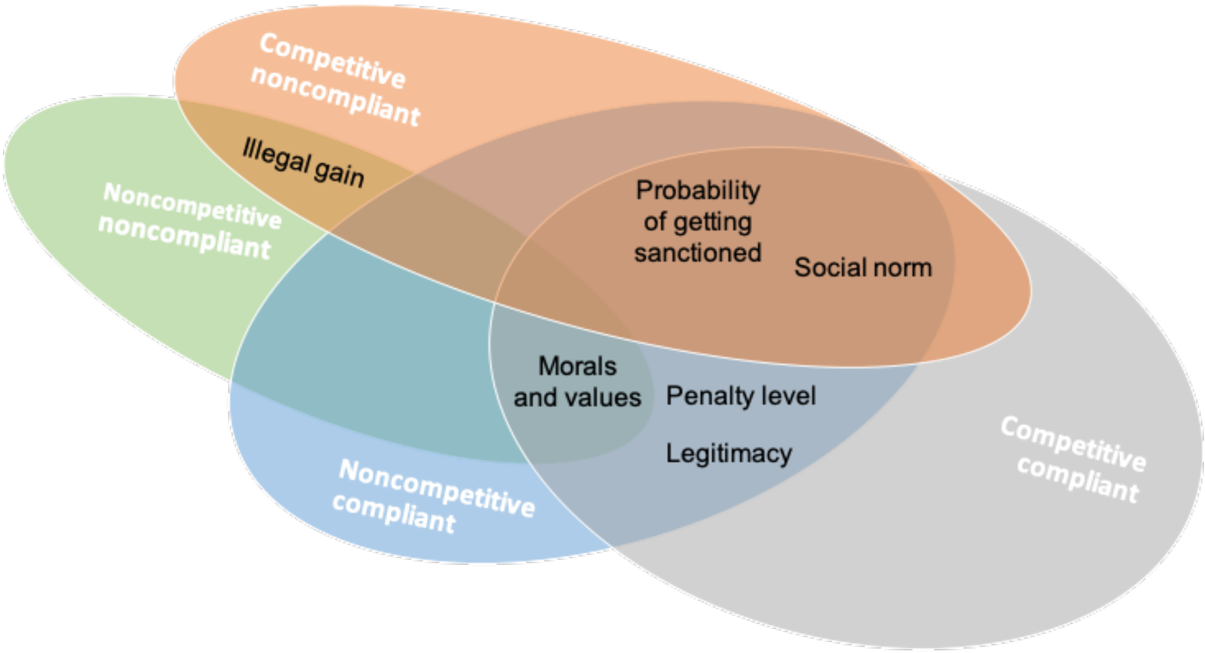

Figure 31. Reasoning based on theoretical framework

If we take the events of receiving news in the pilot experiment as reasons and the threshold of at least 2 participants in a cluster to react to an event with noncompliance, then we can see the following patterns emerge (see Figure 32). Naturally, noncompliant participants had more reasons for noncompliance than compliant participants. Passing inspection, getting sanctioned and seeing that the other player got sanctioned were all used as a reason for noncompliance by noncompliant participants. However, competitive noncompliant participants also used the fact that they got away with illegal logging as a reason for noncompliance. This difference might be informative of a strategical difference between noncompliant participants that is driven by motivation. In particular, getting away with illegal logging inspired risk seeking behavior in competitive participants and risk averse behavior in noncompetitive participants.

Last, some insights emerged regarding the role of social norms emerged from quantitative data (see Appendix 7). Namely, participants logged illegally more often when both they and the other players got sanctioned compared to when they were the only ones sanctioned. Moreover, there was more noncompliance when they passed inspection compared to when they passed inspection and received notice that one of the other players has been sanctioned. In other words, the additional news that someone else has been sanctioned increases compliance when participants have passed inspection and decreases compliance when participants have gotten sanctioned. The indication from this is that seeing other people get sanctioned reinforces the participants' original strategy. Thus, social norms, as a reason for compliance, should not only be understood as information about what the other players are doing, but rather as individual decision-making in relation to decision-making by others in the group.

Notwithstanding, these results should be received with caution, as they are merely preliminary results of a pilot experiment. Firmer inferences about the meaning of this data can be made with a full-scale experiment.

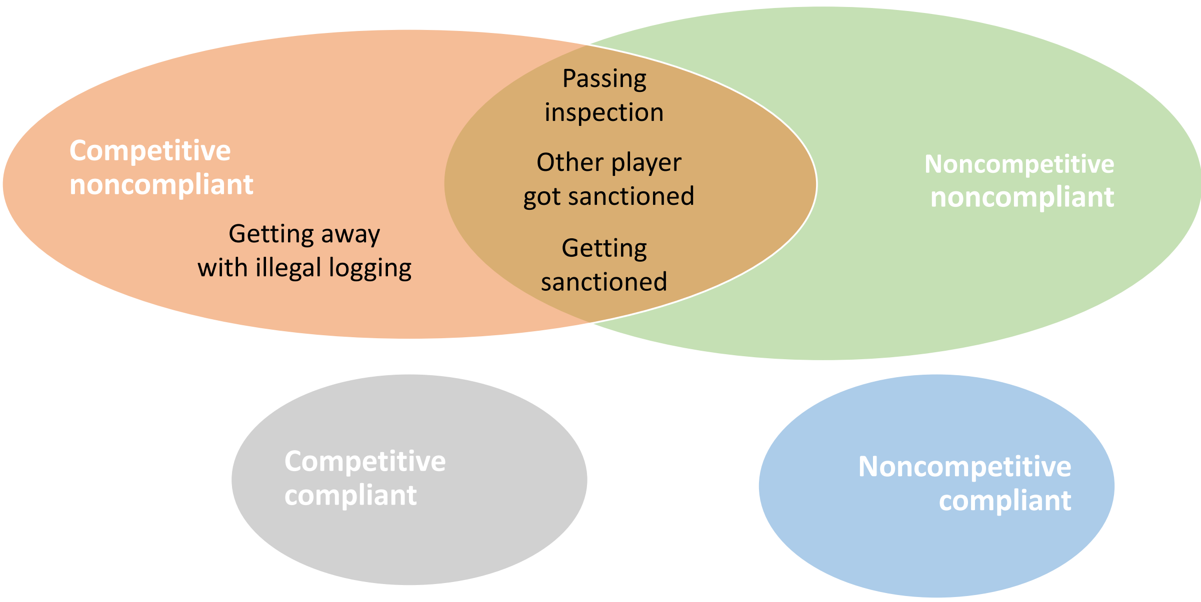

Figure 32. Reasoning for noncompliance according to news notifications

8.2 Theoretical implications

One of the theoretical implications from this research is a confirmation of the complexity of the issue of compliance. While earlier works (Becker, 1968) understood compliance as a result of utilitarian calculations, this research is more in line with contemporary studies that understand compliance as a result of both hard and soft motivators (Peterson & Diss-Torrance, 2013). The following comments describe the knowledge contribution of this thesis in relation to comparable works.

To begin with, Xepapadeas (2005) used modeling to show the possibility of a steady-state equilibrium consisting of both cooperative and non-cooperative behavior. The pilot experiment revealed two strategies analogous to this: compliant and noncompliant behavior. Further, aggregate compliance level statistics showed stable-like behavior at around 80% of participants complying (see Figure 18) in any given round, which is supportive of that proposition.

Harvey, Bell & Birjulin (1993) found that punishment had an influence on compliant behavior while feedback about the state of the resource pool did not. This was confirmed by the pilot experiment as very few participants mentioned that they actively took the forest cover into account when making decisions, while the majority reasoned about the possibility of getting sanctioned.

Anderson & Stafford (2003) found that sanction severity, or the penalty level, was more influential to compliance compared to the probability of getting sanctioned. The results of the pilot experiment provided additional explanations for that finding as participants who viewed the penalty level as too high did not engage in estimating the probability of getting sanctioned, suggesting that the perception of illegal gain is what leads to the probability of being sanctioned being used as a reason to justify decisions. Further, they found that past sanctions increased noncompliance, however this was not the case in the pilot experiment. Generally, participants complied as a response to getting sanctioned, with a few exceptions of participants with a noncompliant strategy. The interviews also revealed that although past sanctions would sometimes inspire further noncompliance, this effect was eliminated with the second sanction.

Cardenas (2004) found that social norms are more influential to compliance compared to the penalty level. The pilot experiment was supportive of this finding because the penalty level was not mentioned as often as the behavior of others when participants reasoned through their decisions. Moreover, other scholars (Baerlein, Kasymov & Zikos, 2015; Hatcher, Jaffry, Thebaus & Bennett, 2000; Tavoni, Schulter & Levin, 2011; Janssen, Bousquet, Cardenas, Castillo & Worrampimphong, 2013) have emphasized social norms as an important predictor of compliance. As an example, Rodriguez-Sickert, Guzmán & Cárdenas (2008) found that social norms were most influential in situations where there was a lack of enforcement. The pilot experiment captured a situation where there is enforcement and the social norm was represented through the recipience of news whether someone else has been sanctioned. There was a higher incidence of noncompliance after participants received a notification that both they and the other player got sanctioned compared to when they were the only ones sanctioned. Similarly, there was a lower incidence of noncompliance when players received a notification that the other player got sanctioned in addition to passing inspection, compared to just passing inspection. The resulting insight from this is that social norms have a more complex relationship with enforcement mechanisms.

Chaudhuri (2011) found that a large group of public good experiments participants are "conditional cooperators', which is to say that they cooperate only when they know that others are cooperating too. This is analogous to the participants found to have a competitive strategy in the pilot experiment, which is to say that they were driven by the development of the score which allowed them to compare themselves to the behavior of others.

Bouriaud (2005) concluded that poverty is a significant driver of illegal logging. Comparative to this, the pilot experiment showed that the most commonly used reason for noncompliance was the illegal gain in terms of demand, supporting Bouriaud's finding.

Considering Ostrom's seven broad types of governance rules for the commons (see Table 1), this thesis illuminated some insights about the effect of information rules on compliance in public forests. Specifically, it found that the forest cover has little to no effect on compliance, while information about others has an effect on compliance. Choice rules, or rather the gap between quota and demand, was expressed in participant reasoning but no such pattern was identifiable in the quantitative data. Payoff rules, or the scoring mechanism in the simulation game was found to be influential in participant decision-making, although no precise conclusions about the exact way the scoring mechanism influences compliance can be drawn from the pilot experiment.

Moreover, the results from the pilot experiment confirmed the hypothesis on the misperception of bioeconomics (Moxnes, 2000). The evidence from this is that some participants logged below the quota, expecting to see an increase in forest cover, while not taking into account the inherent delays, nonlinear growth function or the behavior of others.

Last, some insights emerged regarding the participants' attitude to the uncertain probability of getting sanctioned. They reasoned about the probability of getting monitored either by referring to gut feeling, heuristics or Bayes-like calculations. Thus, the contribution of this thesis is that a simulation game like the one described here can be used to study compliance in behavioral economics. Moreover, many participants referred to the score as a reference point in their decision-making, reasoning that they were risk averse when they had a negative score and risk-seeking when they had a positive score. They further explained that they had switched to being risk averse once they had achieved what they deemed as a sufficient score. These findings from the interview point toward a potential application of prospect theory (Tversky and Kahneman, 1986) for studying compliance behavior.

8.3 Practical implications

Understanding reasoning behind compliance is of tremendous significance not only to national forest industries, but also to transnational initiatives like UN REDD+ projects or European Union's FLEGT Action Plan. Some recommendations can be made to public forests that are experiencing increases in demand for wood products and decreases in the allowable annual cut due to environmental regulation, while at the same time dealing with detrimental noncompliance levels or transitioning from a forest without a management plan to a forest with a management plan.

Namely, the recommendations are regarding the tradeoff between investment in enforcement regulation or investment in strategies to influence the social norm and governance process legitimacy. The former can provide short-term improvement results, while the latter helps maintain long-term results. Therefore, it is recommended that the focus be on enforcement rather than social projects in cases where noncompliance is high. This can be done through decreasing potential illegal gains, increasing the penalty level or improving the effectiveness of monitoring and sanctioning mechanisms. In cases where capacity for enforcement is low, or noncompliance is not at an alarmingly high level, it is recommended to invest in governance transparency and stimulating participation in the governance process. Specifically, this research showed the importance of stimulating a positive social norm through publication of compliant behavior as well as publicizing instances of executed sanctions.

8.4 Methodological contribution

Chapter 5 outlines the development of an online system dynamics simulation game for the purpose of conducting research. Notably, Moxnes (2000) has developed simulators, while Sterman (1987) and Lara-Arango (2018) have developed games for the purpose of experimental research. However, their game development process has not been explicitly outlined. Thus, the game development methodology described in Chapter 5 had no precedent. In my experience game development shared many similarities with model development. Specifically, both required: (1) the identification of purpose and time-bound context, (2) explicit assumptions, (3) testing, (4) calibration and (5) behavior analysis. In addition to this, game development necessitated the creation of (1) an imaginary context, (2) player roles, (3) game rules, (4) incentive structure and an (5) interactive interface. I found the work of Bots & van Daalen (2007) particularly helpful as it helped me include all the elements that modified the model into a game (see Table 3). Thus, this thesis has contributed towards the marriage between system dynamics and serious gaming.

The difference between a game for learning and a game for research in terms of methodology is that games for learning place more emphasis on debriefing and game facilitation, while games for research are focused on behavior analysis. Section 5.10 was crucial for me to build expectations about participant behavior, which served as a reference point for conducting my analysis and fulfilling my research purpose. All in all, this thesis sets the stage for the development of a methodology for designing simulation games based off system dynamics models for the specific purpose of experimental research.

Further, I used a pilot experiment as a research method. Pilot experiments are a mixed method as they incorporate the analysis of both quantitative and qualitative data. My inspiration for using this particular method was based on Jensen & Brehmer (2003) and it proved as a great method for studying participant reasoning. Specifically, the process of cross-referencing qualitative and quantitative data allowed me to derive powerful insights through better understanding what participants thought about and how that translated into their specific decisions. While the resulting insights from this research do not hold any statistical significance, they can be very useful for theory building and qualitative theory testing.

8.5 Limitations

By design, simulation games are a form of argument by analogy. In other words, the game is intended to serve as an analogy of the real-world system. Thus, any conclusions drawn from research using the game is used as a base to infer insights about real world behavior should be received with caution. However useful, arguments by analogy are flawed. The reason for this can be interpreted through Kahneman's theory of the dichotomy between fast and slow thought (2011). Decision-making in the pilot experiment takes from seconds to minutes, while, in the real world, that decision can take from a week to a year. Hence, while decision-making in simulation games can mimic situations that require thinking "fast", it might not do as good of a job replicating situations where thinking is "slow".

Another important limitation of this research is that it failed to include income reliance as a cause for noncompliance, even though there has been research highlighting its importance (Madrigal-Ballestero et al., 2013). Arguably, income reliance is represented through illegal gain in the theoretical framework, however the illegal gains in this game did not correspond to illegal gains in the real world. In fact, participation in the pilot experiment was completely voluntary, so participants had nothing significant to win or lose, apart from a mere notification on whether they had won the game.

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Appendix 1: Model documentation

The model has been documented according to the preferred model reporting guidelines outlined by Rahmandad and Sterman (2012). See Table 11.

Formulations and comments	Units
$Forest\ area(t) = Forest\ area(0) + \int_0^t [Regeneration(s) - Deforestation(s)]ds$	$hectare$
The stock Forest area represents the total amount of land that is forested. It increases through regeneration and decreases through deforestation.	
$Regeneration = Growing\ stock\ increment \times Marginal\ hectare\ per\ growing\ stock\ increment$	$\frac{hectare}{Year}$
Regeneration, or the increase in forest area, represents the natural expansion of the forest. The forest is regenerated linearly for every new m^3 of growth.	
$Deforestation = Wood\ removal \times Forest\ area\ per\ growing\ stock$	$\frac{hectare}{Year}$
Deforestation, or the decrease in forest area, is driven by decrease in growing stock from logging and the current density of the forest. The forest area decreases non-linearly depending on its current state.	
$Growing\ stock(t) = Growing\ stock\ (0) + \int_0^t [Growing\ stock\ increment(s) - Wood\ removal(s)]ds$	m^3
Growing stock is a concept used by UN FAO (2006) and denotes the total volume over bark of all living trees more than a certain size. As such, it increases through natural growth of the trees and decreases through logging.	
$Growing\ stock\ increment = Forest\ area \times Fractional\ growth\ rate$	$\frac{m^3}{year}$
Growing stock increment is the rate at which growing stock increases. It is based upon the concept of Net Annual Increment as defined by OECD (2005) and it is driven by the forest area and a fractional growth rate.	
$Wood\ removal = \left(MIN\left(Allowable\ annual\ cut, \frac{Growing\ stock}{DT}\right)\right)$	$\frac{m^3}{year}$

Wood removal represents the rate of logging, i.e. removing wood from the forest. The model assumes that the allowable annual cut is logged every year, except in the case when it is higher than the growing stock. In this case the whole forest is logged, which is less than the allowable annual cut.

$$Forest\ cover = \frac{Forest\ area}{Maximum\ forest\ area} \qquad dimensionless$$

Forest cover represents the % of total land that is forested.

$$Forest\ area\ per\ growing\ stock = \frac{Forest\ area}{Growing\ stock} \qquad \frac{hectare}{m^3}$$

Forest area per growing stock represents the density of the forest, so that a very dense forest has a low value of this variable and vice versa.

$$Fractional\ growth\ rate = Reference\ growth\ rate \times (1 - Forest\ cover) \qquad \frac{\frac{m^3}{hectare}}{year}$$

Fractional growth rate is the based upon the concept of Mean Annual Increment (FAO, 1997), and describes the volume of wood growing on one hectare of forest during a given year. As such, the fractional growth rate is driven by the current size of the forest so that it is higher when the forest is further away from its maximum size and vice versa.

Marginal hectare per growing stock increment $\qquad \frac{hectare}{m^3}$

Marginal hectare per growing stock increment describes how much the forest area grows per every unit of growth in wood volume.

Reference growth rate $\qquad \frac{\frac{m^3}{hectare}}{year}$

Reference growth rate is an externally set growth rate that describes how quickly the forest would grow if it's area would be a little above 0 hectares. In other words, it is the maximum possible growth rate.

Maximum forest area $\qquad hectare$

Maximum forest area is the natural limit of the forest size. It denotes the total land available for the forest.

$$Change\ in\ desired\ allowable\ annual\ cut = \frac{Growing\ stock\ increment - Desired\ allowable\ annual\ cut}{Desired\ alloable\ annual\ cut\ adjustment\ time} \qquad \frac{\frac{m^3}{year}}{year}$$

Change in desired allowable annual cut represents the process of creating a policy objective for the allowable annual cut, which maintains a steady growing stock in a set timeframe. This process is done through highest-first principle, so that changes in the objective become more gradual as the growing stock approaches equilibrium.

Desired allowable annual cut adjustment time *year*

Desired allowable annual adjustment time is the timeframe in which the government aims to fulfill its objective – to equalize wood removal and growing stock increment.

$$Desired\ allowable\ annual\ cut\ (t) = Desired\ allowable\ annual\ cut\ (0) + \int_0^t [Change\ in\ desired\ allowable\ annual\ cut] ds \qquad \frac{m^3}{year}$$

Desired allowable annual cut is the objective, or goal, regarding the allowable annual cut.

$$Change\ in\ allowable\ annual\ cut = IF\ (TIME\ MOD\ 10 = 1)\ THEN \left(\frac{Desired\ allowable\ annual\ cut - PREVIOUS(Allowable\ annual\ cut)}{DT} \right) ELSE\ (0) \qquad \frac{\frac{m^3}{year}}{year}$$

Change in allowable annual cut is the process of updating the official government policy for how much wood can be legally extracted from the forest. The allowable annual cut is changed only every 10 years.

$$Allowable\ annual\ cut\ (t) = Allowable\ annual\ cut\ (0) + \int_0^t [Change\ in\ allowable\ annual\ cut] ds \qquad \frac{m^3}{year}$$

Allowable annual cut is the official quota for logging set by the government. As such it represents the official policy.

$$Net\ forest\ conversion = Deforestation - Regeneration \qquad \frac{hectare}{year}$$

Net forest conversion is the annual net change in forest area.

Table 11. Model documentation

Appendix 2: Sensitivity analysis

Overview

I conducted sensitivity analysis on the model (see Figure 33). Starting from a position of equilibrium, I varied all exogenous variables from +20% to -20% of their equilibrium value. Out of all exogenous variables, the following proved sensitive:

- Reference growth rate
- Maximum forest area
- INIT Desired allowable annual cut

Model sensitivity appears whenever the system is pushed out of equilibrium. In fact, all model reactions can be understood as tendencies of the model to bring itself back into a state of equilibrium. Thus, the conclusion from this sensitivity analysis is that the model is robust and dominated by balancing loops B2 and B3.

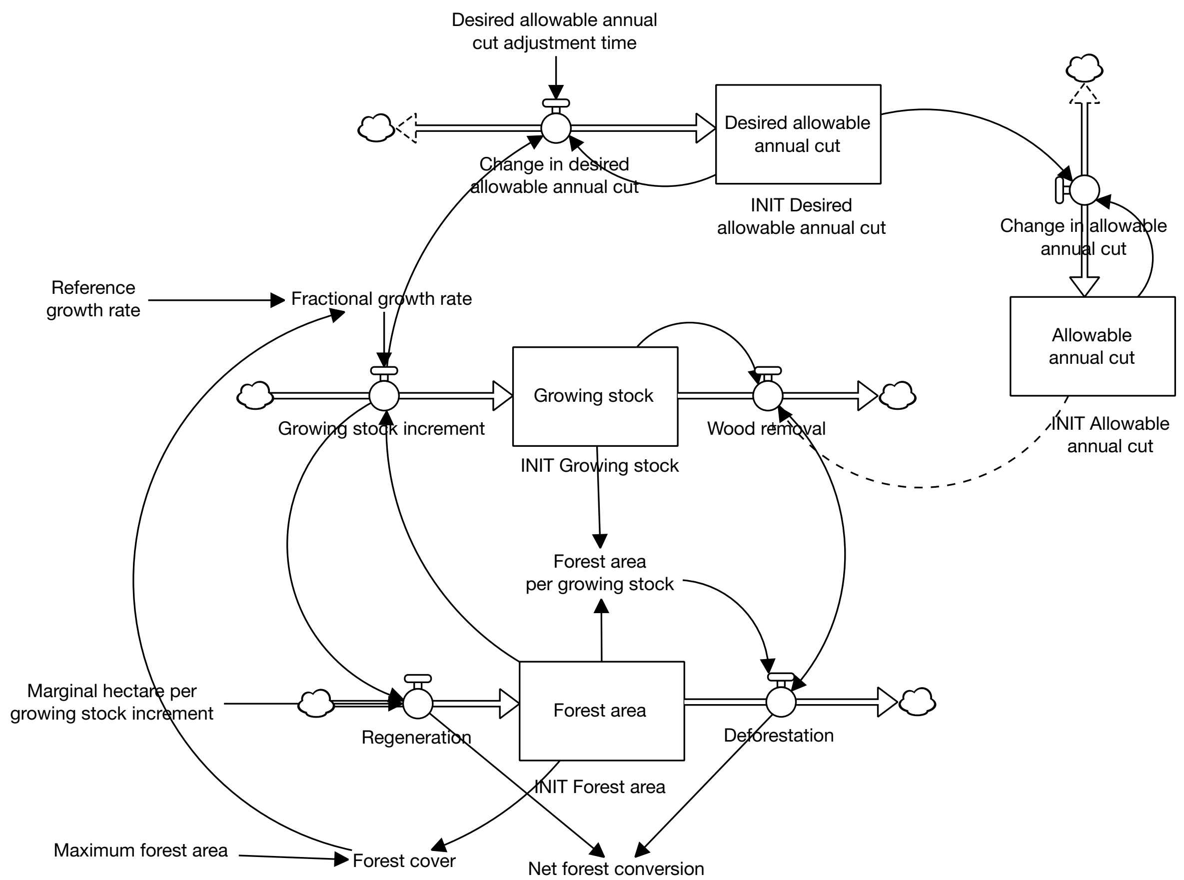

Figure 33. Model

Reference growth rate

The model was sensitive to changes in Reference growth rate (see Figure 34). When I changed the growth rate to a value higher than the equilibrium value, then Allowable annual cut increased. Whereas, the Allowable annual cut decreased when I changed the growth rate to a value lower than the equilibrium value. The response was not immediate because of the long delay time (Desired allowable annual cut adjustment time). This sensitivity is due to the balancing loops (B2 and B3) which work to maintain the system in equilibrium. Hence, they push the Allowable annual cut in the same direction as the growth rate.

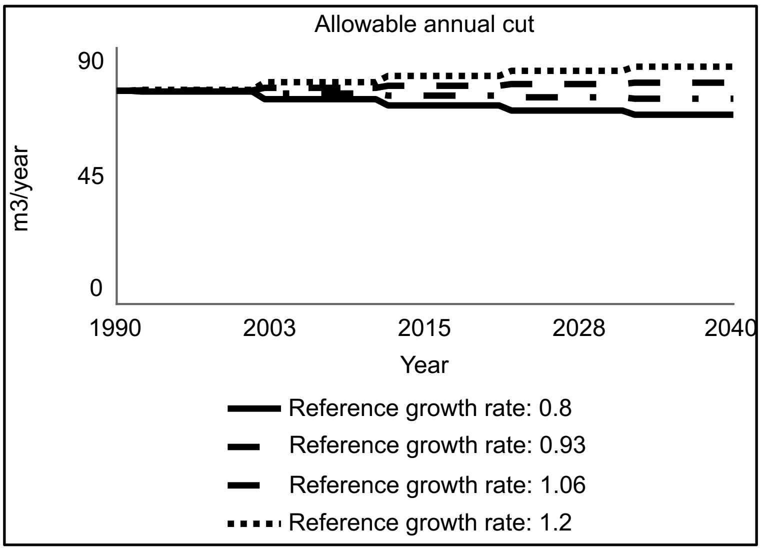

Figure 34. Change in Allowable annual cut when Reference growth is changed from its equilibrium value

Maximum forest area

The model showed sensitivity to changes in Maximum forest area (see Figure 35). Namely, the Allowable annual cut responded by moving in the same direction as the change in Maximum forest area. Whenever Maximum forest area increased, so too did the Allowable annual cut and vice versa. Similar to the sensitivity to the Reference growth rate described above, the response of Allowable annual cut is not immediate because of the delay time (Desired allowable annual cut). This sensitivity can be understood in terms of the wood removal regulation loops (B2 and B3), which move the system towards an equilibrium. Essentially, the response of the Allowable annual cut to changes in Maximum forest area is due to the goal of these loops, which is to equalize Wood removal and Growing stock increment.

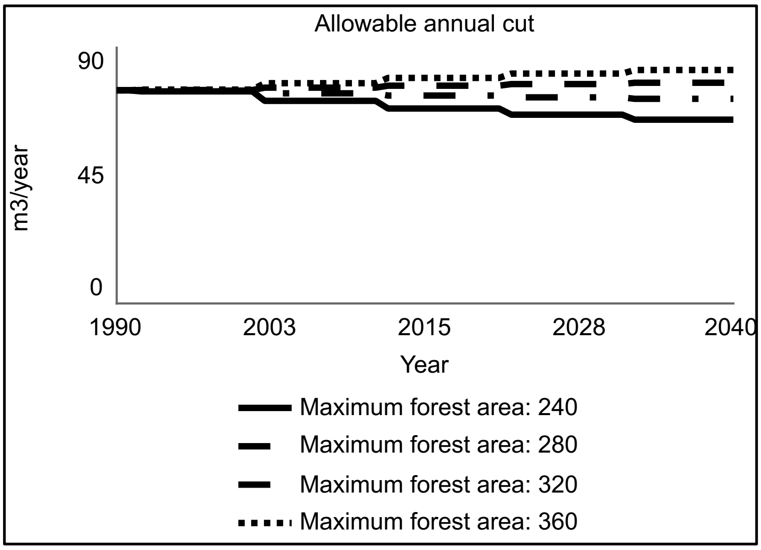

Figure 35. Change in Allowable annual cut when Maximum forest area is changed from its equilibrium value

INIT Desired allowable annual cut

Very similar to the cases describes above, the model is reactive to slight changes in INIT Desired allowable annual cut (see Figure 36). These changes are a result of B2 and B3, i.e. the system's tendency to go toward an equilibrium.

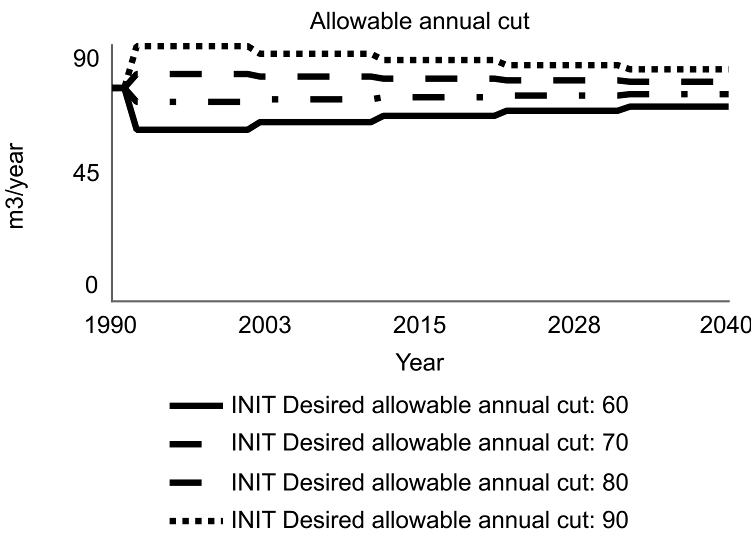

Figure 36. Change in Allowable annual cut as a response to changes in INIT Desired allowable annual cut

Appendix 3: Game equations

Incentive sector

Demand[Player] = Individual_quota/0.75

UNITS: m3/year

Increase_in_demand[Player] = Demand*Fractional_demand_growth_rate

UNITS: m3/year/Year

Fractional_demand_growth_rate = 0.01

UNITS: unitless/year

Monitoring sector

is_monitored[Player] = IF uniform_probability_distribution >= probability_of_being_monitored THEN 0 ELSE 1

uniform_probability_distribution[Player] = UNIFORM(0, 1, 1)

UNITS: unitless

probability_of_being_monitored[Player] = 0.5

UNITS: unitless

Sanctioning sector

Executed_sanctions[Player](t) = Executed_sanctions[Player](t - dt) + (Sanctions_in_process[Player]) * dt

INIT Executed_sanctions[Player] = 0

UNITS: points

Sanctions_in_process[Player] = IF (is_sanctioned=1) AND (TIME MOD 3=1) THEN (1) ELSE (0) {UNIFLOW}

UNITS: points/year

is_sanctioned[Player] = IF (is_monitored=1) AND (is_cheating=1) THEN (1) ELSE (0)

UNITS: unitless

Cumulative_losses_from_sanctions[Player](t) = Cumulative_losses_from_sanctions[Player](t - dt) + (Increase_in_losses_from_sanctions[Player]) * dt

INIT Cumulative_losses_from_sanctions[Player] = 0

UNITS: points

Increase_in_losses_from_sanctions[Player] = IF (is_sanctioned=1) AND (TIME MOD 3=1)THEN (Points_from_sanctioning) ELSE (0)

UNITS: points/year

Scoring sector

Cumulative_Score[Player](t) = Cumulative_Score[Player](t - dt) + (Change_of_score[Player]) * dt

INIT Cumulative_Score[Player] = 0

UNITS: points

Change_of_score[Player] = IF (TIME MOD 3=1) THEN (Score) ELSE (0)

UNITS: points/year

Points_from_sanctioning[Player] = Demand*Points_converter

UNITS: points/year

Points_from_satisfying_demand[Player] = (IF (actual_extraction_level>Demand) THEN (Demand) ELSE (actual_extraction_level-unsatisfied_demand))*Points_converter

UNITS: points/year

Score[Player] = IF (is_sanctioned=1) THEN (-Points_from_sanctioning) ELSE (Points_from_satisfying_demand)

UNITS: points/year

Points_converter = 1

UNITS: points/m3

unsatisfied_demand[Player] = MAX (0, Demand-actual_extraction_level)

UNITS: m3/year

Model modifications

Individual_quota[Player] = ROUND(Allowable_annual_cut/SIZE(actual_extraction_level))

UNITS: m3/year

actual_extraction_level[Player] = IF (is_active=1) THEN (extraction_level) ELSE (automated_player_extraction_level)

UNITS: m3/year

extraction_level[Player] =83

UNITS: m3/year

automated_player_extraction_level = extraction_level[Player_1]

UNITS: m3/year

Wood_removal = MIN(Growing_stock/DT, SUM(actual_extraction_level)) {UNIFLOW}

UNITS: m3/year

is_active[Player] = 0

UNITS: unitless

Game controls

game_advanced = IF (TIME MOD 3=1) THEN (1) ELSE (0)

UNITS: unitless

DOCUMENT: AND (game_over=0) AND (TIME>1980)

game_over = IF (STOPTIME - TIME < DT) THEN (1) ELSE (0)

UNITS: unitless

is_cheating[Player] = IF ((actual_extraction_level-Individual_quota)>1) THEN (1) ELSE (0)

UNITS: unitless

last_cumulative_score[Player] = HISTORY (Cumulative_Score, TIME-2)

UNITS: points

last_demand[Player] = HISTORY(Demand, TIME-2)

UNITS: m3/year

last_extraction_level[Player] = HISTORY (actual_extraction_level, TIME-2)

UNITS: m3/year

last_individual_quota[Player] = HISTORY(Individual_quota, TIME-3)

UNITS: m3/year

last_points_from_sanctioning[Player] = HISTORY(Points_from_sanctioning, TIME-2)

UNITS: points/year

last_score[Player] = HISTORY(Score, TIME-2)

UNITS: points/year

last_unsatisfied_demand[Player] = HISTORY(unsatisfied_demand, TIME-2)

UNITS: m3/year

no_news[Player] = IF (other_was_sanctioned=0) AND (was_sanctioned=0) AND (passed_inspection=0) AND (was_not_sanctioned=0) OR (TIME=1980) THEN (1) ELSE (0)

UNITS: unitless

other_was_sanctioned[Player_1] = IF (was_sanctioned[Player_2]=1) OR (was_sanctioned[Player_3]=1)THEN (1) ELSE (0)

UNITS: unitless

other_was_sanctioned[Player_2] = IF (was_sanctioned[Player_1]) OR (was_sanctioned[Player_3]=1)THEN (1) ELSE (0)

UNITS: unitless

other_was_sanctioned[Player_3] = IF (was_sanctioned[Player_2]=1) OR (was_sanctioned[Player_1]=1) THEN (1) ELSE (0)

UNITS: unitless

UNITS: unitless

passed_inspection[Player] = IF (was_monitored=1) AND (was_sanctioned=0) THEN (1) ELSE (0)

UNITS: unitless

satisfy[Player] = IF (did_not_satisfy_demand=0) THEN (1) ELSE (0)

UNITS: unitless

was_monitored[Player] = IF (HISTORY(is_monitored, TIME-2)=1) THEN (1) ELSE (0)

UNITS: unitless

was_not_sanctioned[Player] = IF (cheated=1) AND (was_monitored=0) THEN (1) ELSE (0)

UNITS: unitless

was_sanctioned[Player] = IF (was_monitored=1) AND (cheated=1) THEN (1) ELSE (0)

UNITS: unitless

winner_notification[Player_1] = IF (Cumulative_Score[Player_2]<Cumulative_Score[Player_1]) AND (Cumulative_Score[Player_3]<Cumulative_Score[Player_1]) THEN (1) ELSE (0)

UNITS: unitless

winner_notification[Player_2] = IF (Cumulative_Score[Player_1]<Cumulative_Score[Player_2]) AND (Cumulative_Score[Player_3]<Cumulative_Score[Player_2]) THEN (1) ELSE (0)

UNITS: unitless

winner_notification[Player_3] = IF (Cumulative_Score[Player_1]<Cumulative_Score[Player_3]) AND (Cumulative_Score[Player_2]<Cumulative_Score[Player_3]) THEN (1) ELSE (0)

UNITS: unitless

did_not_satisfy_demand[Player] = IF (last_unsatisfied_demand>0) AND (was_sanctioned=0) THEN (1) ELSE (0)

UNITS: unitless

even_match[Player] = IF ((Cumulative_Score[Player_2]-Cumulative_Score[Player_1])=0) THEN (1) ELSE (0)

UNITS: unitless

cheated[Player] = IF (HISTORY(is_cheating, TIME-2)=1) THEN (1) ELSE (0)

UNITS: unitless

Appendix 4: Game instructions

Welcome to the logging game. This game is intended to recreate a situation in which a group makes decisions about the use of a forest.

It is 1980 in the region of Treezonia and you are a local logging company, Woodpecker ltd. You have a difficult task at hand: to satisfy Treezonians' *demand* for wood and, at the same time, abide by the government's *quota* for logging wood.

Each round you have to make a decision about how much you will log and receive points for past performance. Rounds take place every 3 years, so you will make a decision every 3 years. There are 13 rounds representing the progression from 1980 to 2019.

You receive 1 point for every cubic meter (m3) of demand you manage to satisfy. There are no extra points for logging more than the demand. But, there are negative points (-1 point) for every cubic meter (m3) of demand you do not satisfy.

Sometimes the demand for wood may be higher than the legal quota, which may tempt you to log more than is allowed. Be careful, you will get sanctioned if you get caught! As a sanction, the government will take away all your logged wood and you will not be able to meet any demand for that round.

Appendix 5: Consent form

Consent form

I volunteer to participate in a research project conducted by Ema Gusheva, from University of Bergen. I understand that the project is designed to gather information for academic purposes.

My participation in this project is voluntary. I understand that I will not be paid for my participation. I may withdraw and discontinue participation at any time without penalty.

I give permission to be audio-recorded during the interview.

I understand that I will not be identified by name in any report using information obtained from this study, and that my confidentiality as a participant in this study will remain secure.

Date:

Name:

Signature:

Appendix 6: Interview guide

Introduction

Thank you for volunteering to participate in this pilot experiment and thank you for signing the consent form. I want to remind you that you do not have to answer my questions if they make you feel uncomfortable. You are also free to leave at any time. As was written in the consent form, some of your statement may be quoted in my research, but it will be anonymous, so confidentiality is maintained.

Questions

1. Can you describe your experience of playing the game?

2. What was your reaction to these events in the game? and why?
    … changes in demand?
    … change in quota?
    … changes in score?
    … changes in forest area?
    … getting sanctioned?
    … passing inspection?
    … getting away with illegal logging?
    … receiving news about the other player getting sanctioned?
    … no news?

3. Overall, how would you describe your strategy in the game?

4. What was your main motivation to adopt this particular strategy?

Closing Remarks

Thank you so much for contributing to me research. It has been very insightful. I would be happy to send you the outcome of my study if you are interested.

Appendix 7: Incidence of illegal logging

Figure 37 presents the extent of illegal logging of each participant in each round color coded according to the type of news displayed on the interface. See Figure 38 for the color code legend. It is clear (see Figure 39) that the highest incidence of illegal logging occurred when participants were notified that they have gotten away with illegal logging (shown in blue), while the lowest incidence was when they passed inspection and the other player got sanctioned (shown in orange).

	Extent of illegal logging per participant																		
Rounds	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0	0	0	0.2	0	0	0	0	0	0	0	0	0.6	0.3	0	1	0	0	0
2	0	0	0	1	1	0	0	0	0	0.1	0	0	1	0	0.4	0	1	0	0
3	0	0	0	1	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0
4	0	1	0.3	0	0	0	0	0	0	0	0	0	1	1	0	3	0	0	0
5	0	0	0	0	0.1	0	0	0	0	0	0	0	0	1	0.1	0	1	0	0
6	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
7	1	0	0	0	0.6	0	0	0	0	0	0.4	0	0	0	0.1	1	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0.1	1	0	0.1	0	1	0	0
9	0	1	0	0	0	0	0	0	0	0	0	0.1	0	1	0.2	0	0	0	0
10	0	1	0	0	1	0	0	0	0	0	0	0.1	0	0	0.2	0	0	0	0
11	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0
13	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Figure 37. Extent of illegal logging per participant color-coded according to the type of news displayed in each round

Legend	
A	There are no news this round
B	Phew! The forest police did not monitor your lot this round. You got away with illegal logging!
C	Nice going! The forest police monitored your lot and found no signs of illegal logging.
D	You have been sanctioned for cutting wood illegally. The forest police took your all your logging away and you are not able to meet any of the demands from this r
E	You have been sanctioned for cutting wood illegally. The forest police took your all your logging away and you are not able to meet any of the demands from this round. One of the other players was monitored by the forest police and found guilty of illegal logging. All the wood has been retrieved and they have been
F	Nice going! The forest police monitored your lot and found no signs of illegal logging. One of the other players was monitored by the forest police and found guilty of illegal logging. All the wood has been retrieved and they have been sanctioned.

Figure 38. Color code legend

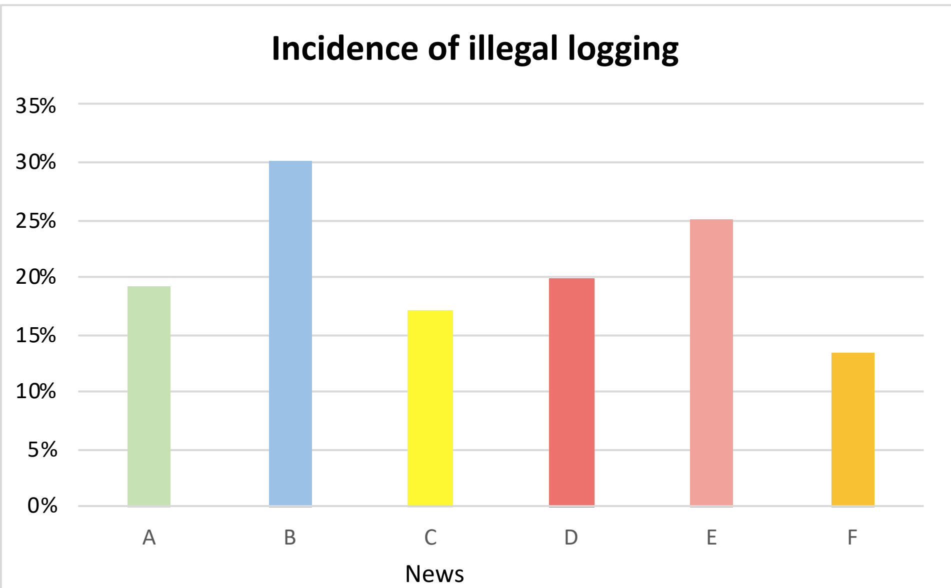

Figure 39. Incidence of illegal logging according to news display

Appendix 8: Coding according to theoretical framework

The qualitative data was coded deductively using the theoretical framework described in Chapter 2. See Table 12. The results of this coding procedure are described in Chapter 7.

Theme	Code	Example of paraphrased verbal statement
Extrinsic motivation	Probability of getting sanctioned	I didn't know how often I got monitored. I tried to get a sense of it, but I couldn't hack that.
		I didn't know how often the police intervened.
		If I had a way of knowing when I would get monitored, then I would have risked more. But I thought it was random, so there was no point in cheating.
		I got caught when I only overstepped by 1 and didn't get caught when I overstepped by 60. That didn't make sense to me.
		I tried to guess when I would be monitored by the government and deceive the system. It was mostly intuitive.
		I anticipated the probability of getting caught based on gut instinct, not calculations. I would wait for the police to monitor 3 times before I cheated.
		I would try to cheat right after I got monitored.
		I didn't think the police monitored in 2 consecutive rounds.
		I thought that the amount I log illegally is connected to the probability of getting monitored.
		Seeing others get sanctioned helped me figure out the probability of getting monitored the next round.
		I thought that there was a connection between how much you overstep the quota and whether you got monitored. Reading that the others got sanctioned made me question how much they went overboard.
		I started calculating a little bit. I thought that I wouldn't get checked twice in a row.
		I thought that monitoring was either done randomly or connected to the amount I log. In fact, once I overstepped by a lot just to see if monitoring is connected to the amount I log. I got caught, so it confirmed my suspicion. I didn't want to cheat in the end of the game when the gap was biggest because I believed that that's when I have the biggest chance of being monitored.
		I thought that the chances of getting caught are really high, almost certain.
	Penalty level	If you break the rules all the logs will be taken away.
		I thought the sanction was too high. I could cheat but the return wasn't worth it.
		It didn't matter if I logged below the quota, as long as I didn't lose my logs because of the sanctioned.
	Illegal gain	There was only one round in which I cheated (quota error) because I thought that the payoff was worth it.
		The increasing demand motivated me to cheat later on in the game (middle) in order to get more points as a result of cheating.
		I wanted to earn points and the way to do that was to cheat.
Intrinsic motivation	Government legitimacy	My assumption was that the quota is slightly above what is actually sustainable.

		I was wondering if the government's quota was properly calculated or is it was less than what is sustainable. I was wondering if the government's quota was properly calculated or is it was less than what is sustainable.
		The laws are there for a reason – to protect the environment.
		I thought that logging according to the quota is sustainable. The government must have calculated it. So, we should respect it.
	Social norm	Our generation grew up playing games whose whole point was to cheat the rules you had.
		I realized that unethical behavior would happen regardless of my actions.
		Seeing that the other player got sanctioned further reinforced my ambition to log very little.
		If there had been news that other players were abiding by the quota, then that would have motivated me to abide by the quota too.
		I felt good to hear that the other player got sanctioned, especially if I got sanctioned that round too. It was good that I wasn't the only one losing points.
		Reading that the other players got sanctioned prompted me to cheat again. It felt ok to cheat because the competition was also doing it.
	Morals and values	I thought that that's what a law-abiding citizen would do. It is not in my nature to be a criminal and cheat.
		I tried to rationalize and do what I do mostly in life, which is to follow the legal quota. I believe in the system and the value of having jurisdiction. I felt like I owed it to myself and the legal system to abide by the rules. My instinct is to follow rules.
		I tried to abide by the rules not only because of the fact that they are rules, but also because of the environment.
		The reason I abided by the law is because I would do that in real life. In general, I don't take risks when it comes to the law.
		I didn't look at the tree cover because it made me uncomfortable. I don't like being the bad guy.
		There were two choices: either to do what is right or to do what is required.
		I tried to use a conservative approach because it is ethical to do so. I didn't feel comfortable overstepping the quota.
		I didn't want to be greedy.
		If the forest is what I am making profit off I shouldn't risk that being taken away from me in the long-term.
		I wanted to aim for sustainability.
		I wanted to spare the forest.
		I want there to be enough forest to maintain wildlife.
		I tried to abide by the rules not only because of the fact that they are rules, but also because of the environment.

Table 12. Coding according to theoretical framework

Appendix 9: Coding according to interface

First, the themes were created according to the interface and the interview guide. Next, the qualitative data was coded according to the themes. At the end, inductive coding was applied within each theme, highlighting emerging patterns in the data (see Table 13). The results of this coding procedure are described in Chapter 7.

Theme	Code	Example of paraphrased verbal statement
Effect of sanction	Compliance	Getting caught made me think that the police is keeping an eye on me, so I just stuck with the quota in the next round.
		Once I got a penalty, I was sure that I was never going to overstep again
		I responded to getting sanctioned by complying.
		Getting caught made me comply.
		Whenever I got caught, I started complying.
		When I got sanctioned it made me comply.
		Getting sanctioned made me angry. It immediately made me comply.
		Getting sanctioned motivated me to comply.
		My reaction to getting sanctioned was to comply.
	Noncompliance	Getting sanctioned motivated me to cheat again.
		I was not convinced by the first sanction, it made me think I wouldn't get sanctioned twice in a row.
	Effect of getting sanctioned twice	The second sanction was convincing, and I decided to comply.
		Getting sanctioned multiple times pushed me to comply.
		Getting caught twice in a row made me decide that cheating is not worth it.
	Negative sanction perception	If you break the rules all the logs will be taken away.
		I thought the sanction was too high. I could cheat but the return wasn't worth it.
		It didn't matter if I logged below the quota, as long as I didn't lose my logs because of the sanctioned.
Effect of passing inspection	Rewarding	I liked passing inspection because it reinforced my strategy.
		Passing inspection felt rewarding so it motivated me to comply.
		Passing inspection and reading that others got sanctioned made me comply.
		If I hadn't received notifications that I passed inspection, then I would probably cheat more.
	Calculating	Passing inspection informed my intuitive guess about the monitoring frequency.
		Passing inspection motivated me to cheat in the next round
		Passing inspection motivated me to cheat because I thought that I wouldn't get checked twice in a row.
	No reaction	I didn't react to passing inspection.
Effect of getting away with illegal logging	Feeling lucky	When I got away with illegal logging, I thought it was plain luck. It made me cheat in the next round.
		I once cheated accidentally (quota error), but that only made me more careful to comply.
		Getting away with cheating made me feel lucky and inspired me to comply.
		I had one sneaky success in cheating and then that motivated me to comply.
		Whenever I got away with cheating, I got the sinking feeling that my luck wouldn't last, so I resorted to compliance.

		After getting away with it I didn't want to continue cheating. It was enough for me.
		Getting away with illegal logging gives you a sense of success. But I didn't cheat in the next round.
		When I won (got away with illegal logging) once I felt satisfied and that motivated me to comply in the next round.
	Encouraged to cheat	When I got away with illegal logging, I thought it was plain luck. It made me cheat in the next round.
		When I got away with illegal logging it motivated me to cheat more.
		Getting away with illegal logging made me think that I can meet the demand.
		Getting away with illegal logging made me cheat again.
Response to changing demand and quota	Temptation to cheat due to increasing gap between quota and demand	Frustrated by increasing gap. It would be hard to survive the year like that.
		The increasing gap made the game more difficult and tempted me to cheat, but I didn't.
		The increasing gap made it more difficult to obtain points by complying, so it pushed me to cheat. When you have lost so much you risk even more.
		The increasing gap assured me that it is better to cheat later on in the game, but I didn't.
		The increasing gap was frustrating. It encouraged me to cheat in order to get points.
		The increasing gap made me more desperate to cheat.
		The increasing demand motivated me to cheat later on in the game (middle) in order to get more points as a result of cheating.
		My reaction to the increasing gap was to log illegally.
		The increasing gap guided my decision as I mostly tried to get a positive score each round.
	Disregard for increasing gap between quota and demand	My decisions weren't connected to the increasing gap.
		I understood that there was a tension between quota and demand, but it was always quite high, so I didn't respond.
		I didn't care much about the demand. I also didn't care about the decreasing trend in the quota.
		I wasn't influenced by changing demand. It would have had a bigger reaction if the demand had risen more aggressively.
		Increasing demand didn't influence me.
	Focus on quota	The payoffs didn't influence my decision. I didn't even pay attention to the demand, only to the quota.
		I mostly focused on what I could log – quota. I didn't think about the payoffs.
		I didn't care about the demand. I just went for how much I could take.
	Focus on demand	I felt like people were waiting for me to provide. I just wanted to meet the demand no matter what.
	Justifying demand increase	I was wondering whether logging more than the quota had some effect on the demand. In the real world the increasing gap must be though, but I suspect it would still be profitable.
		I wondered if rising demand is connected to the fact that I got caught.
		The increasing gap felt unfair. I felt forced to lose points, but I also felt that I had enough points by then. I was hopeful that the quota would increase.
Effect of score	Noncompetitive	I couldn't compare my score to anyone else's score, so it didn't mean much.

		I wasn't influenced by the score because I didn't feel like I was competing with anyone.
		I didn't know what the score meant so I didn't base my decisions on it.
	Effect of negative score	When I lost most of the points it motivated me to gamble less and stick with the quota.
		I was getting less points, but my score was still positive, so there wasn't a huge incentive to cheat.
		Having a negative score made me want to get a positive score through more aggressive behavior (compliant behavior)
		When I got sanctioned with negative points I tried to compensate by cheating. I guess this a spiral where having a negative score makes you cheat, which further makes you have negative points. After complying for several rounds and building up a positive score (which I thought were enough) I tried cheating again.
		Having a negative score influenced me to comply.
		Getting a negative score made me comply. I didn't want a negative score.
		Having a negative score made me comply.
		Having a negative score motivated me to comply.
	Effect of positive score	At first, I wanted to keep my score positive by staying close to the quota, but then I switched focus and disregarded the score.
		When my score rose, I tried to keep it high by complying.
		It was important for me to maintain a positive score. I mostly tried to get a positive score each round.
Effect of change in forest cover	No perceived changes	I only looked at the forest cover twice, but I didn't notice changes. If I had noticed a drastic change in the forest cover, then that would have influenced my decision.
		I didn't pay attention to the forest area and didn't notice any change there.
		I didn't see any change there
		I looked at the forest cover, but I didn't notice a change.
		I paid attention to the forest cover. I expected that it would change but it didn't.
		I didn't take the forest cover into account because it wasn't dramatically decreasing.
	Disregard for forest cover	I didn't take into account the forest area.
		The forest area did not influence my decision.
		I wasn't affected by the forest area.
		I didn't look at the tree cover. It made me feel uncomfortable.
		I didn't look at the forest cover. I was caught up in the numbers.
		I didn't look at the forest cover.
		I didn't look at the forest cover.
		I didn't take the forest cover into account when making decisions.
	Confusion about forest cover	I looked at the forest cover and wondered how exactly that is connected to the quota.
		I didn't look at the forest cover. I didn't understand what it meant.
	Reactive	I was mostly looking at the forest cover. The drop motivated me to further log below the quota.
		The forest cover went down, so I thought that it is better to log less.
		I thought that it is important to watch the forest cover to get a sense of the logging level of the other players.

Effect of seeing others get sanctioned	Feeling better than the other	I was happy to receive news that others got sanctioned and it informed my choice about whether to cheat or not. It stopped me from my desire to cheat.
		It made me feel better than them and thus tempted me to cheat more, but I didn't act on it.
		I felt a weird sense of satisfaction when I received a notification that the other person got sanctioned. It made me feel like I had the upper hand.
		Knowing that other got sanctioned made me feel better about myself.
		I was happy when the other player got caught.
		Seeing the other player get sanctioned made me feel proud and reinforced my compliance.
	Calculating or competitive	Reading about the other player reminded me that it is a competition, so I had to do well. It brought me hope that I might win. I compared the number of times the other player got sanctioned and compared it to the number of times I got sanctioned.
		Seeing that other had gotten sanctioned tempted me to cheat. I was wondering if I was going to lose because of this.
		When I read that others got sanctioned made me feel watched, but I still logged illegally after that.
	Adaptive	Seeing that the other player got sanctioned further reinforced my ambition to log very little.
		If there had been news that other players were abiding by the quota, then that would have motivated me to abide by the quota too.
	Caution	Reading that the other player got sanctioned reminded me not to take more than I am allowed to.
		Reading the news about other made me especially careful to comply.
		Reading that the other player got sanctioned motivated me to comply.
		Reading that the other player got caught made me more careful to comply.
	No influence	Seeing that the other player got sanctioned didn't influence me.
		I wasn't influenced by others.
		Information about the others didn't compel me to cheat.
	Feeling comforted	I felt good to hear that the other player got sanctioned, especially if I got sanctioned that round too. It was good that I wasn't the only one losing points.
		Reading that the other players got sanctioned prompted me to cheat again. It felt ok to cheat because the competition was also doing it.

Table 13. Coding according to interface

Appendix 10: Axial coding

The qualitative data was coded inductively for the purpose of identifying codes and themes that are not captured through the other coding framework. First, the data was coded openly, creating a set of open codes. At the same time, I noted some interconnections between these open codes in the form of axial codes (see Table 14). The results of this coding procedure are described in Chapter 7.

Axial code	Open code	Paraphrased example
Getting familiar with the game	Playing it safe	In the first year I was obeying the rules until I got upset when the quota fell, and demand rose.
		At the beginning I just wanted to stick with the quota.
		At first, I followed the rules in order to get a sense of the frequency of monitoring.
		At first, I was going by the book in order to learn the mechanics of the game.
		I started complying with the quota in order to see how the game worked.
	Experimenting	In the begging I logged as low as possible in order to see if the forest cover would increase.
		I started gambling immediately.
		I started gambling immediately to get a sense of the mechanism of the game.
		I started with lower than the quota just to see if the forest cover would increase and to understand the mechanics in the game.
Unfulfilled expectations	Expectation of reward	I expected the quota would be higher or the same as last year, especially since I was following the quota in the first years.
		I looked at the score and I wondered why I am getting lower points for making the right decision.
	Expectation of impact	I also got discouraged that my actions to log less than the quota did not have the desired impact of increasing the forest cover.
		I logged less than the legal quota twice to see whether the forest cover would change but it didn't.
		I was disappointed to see that the forest cover decreased despite the fact that I was logging below the quota.
		I wanted to see if the forest cover would increase if I logged below the quota. It didn't.
Attitude to risk of getting monitored	Adventure of cheating	I felt that I should cheat at least once (as an adventure).
		I cheated once just to see what would happen.
	No opinion	I didn't think about the probability of getting monitored.
		I didn't bother with this because I thought the sanction was too high.
	Intuitive	I tried to guess when I would be monitored by the government and deceive the system. It was mostly intuitive.
		I anticipated the probability of getting caught based on gut instinct, not calculations. I would wait for the police to monitor 3 times before I cheated.
	Calculating monitoring	I would try to cheat right after I got monitored.
		I didn't think the police monitored in 2 consecutive rounds.

		I thought that the amount I log illegally is connected to the probability of getting monitored.
		Seeing others get sanctioned helped me figure out the probability of getting monitored the next round.
		I thought that there was a connection between how much you overstep the quota and whether you got monitored. Reading that the others got sanctioned made me question how much they went overboard.
		I started calculating a little bit. I thought that I wouldn't get checked twice in a row.
		I thought that monitoring was either done randomly or connected to the amount I log. In fact, once I overstepped by a lot just to see if monitoring is connected to the amount I log. I got caught, so it confirmed my suspicion. I didn't want to cheat in the end of the game when the gap was biggest because I believed that that's when I have the biggest chance of being monitored.
		I thought that the chances of getting caught are really high, almost certain.
Participant hypotheses	Probability of getting monitored is connected to amount of illegal logging	I thought that the amount I log illegally is connected to the probability of getting monitored.
		I thought that there was a connection between how much you overstep the quota and whether you got monitored.
		Monitoring is connected to the amount I log.
		I got caught when I only overstepped by 1 and didn't get caught when I overstepped by 60. That didn't make sense to me.
	Random monitoring	But I thought it was random, so there was no point in cheating.
		I thought that monitoring was done randomly.
	No consecutive monitoring	I thought that I wouldn't get checked twice in a row.
		I didn't think the police monitored in 2 consecutive rounds.
		Initially I didn't think I would get monitored 2 times in a row
	Certain monitoring	I thought that the chances of getting caught are really high, almost certain.
	Effect of illegal logging on demand	I was wondering whether logging more than the quota had some effect on the demand.
		I wondered if rising demand is connected to the fact that I got caught.

Table 14. Axial coding

Appendix 11: Coding according to clusters

To begin with, the clusters were created by inductively coding the qualitative data. I looked at the data of each participant as a whole, and then focused on the paraphrased example for classifying each participant into a cluster. The same procedure was undertaken for coding the data according to reasoning variables (see Table 15). Namely, I scanned each participant's data holistically and then scrutinized the paraphrased example to determine the main variable the participant used while reasoning about their behavior. The results of this coding procedure are described in Chapter 7.

Cluster	Reasoning variable	Paraphrased example
Competitive noncompliant	Score	I wanted to earn points and the way to do that was to cheat. At first, I was going by the book in order to learn the mechanics of the game. Then, I was focused on earning points. My strategy was like that in poker. The only way you can win is by bluffing. The reason I chose this strategy was because I knew I was competing with someone. If it had been only me, then I would have probably just complied all the time.
		At the beginning I just wanted to stick with the quota. Then I just wanted to risk it and see if they would really catch me. I got competitive, but I was still quite risk averse. Once I got 'enough points' I resisted the temptation to cheat from the increasing gap.
	Anticipation of monitoring	At first, I followed the rules in order to get a sense of the frequency of monitoring. But after not getting inspected in the first round I got eager and tried to cheat. Getting sanctioned twice brought me to a cautious state of mind. You can say that my main strategy driver was trying to guess when monitoring took place.
		I wanted to win but I didn't want to get caught. I was mostly motivated by the sanction. At the beginning I complied in order to avoid getting caught. Then I started risking it logging more each round. But then I got sanctioned which made me decrease my logging level little by little again.
		I first started logging legally and then I tried to log illegally sometimes to see if I would get fined. Overall, I wanted to keep my score positive and get enough points.
Competitive compliant	Score	I followed the legal allowance and only tried to go over the quota once by little (10m3) because I wanted to see what would happen if I gambled. The winning mentality made me follow the rules. I wanted to win, and I didn't know what the other player was doing (Winning is getting more points than the opponent), but something in me told me to follow the rules.
		I tried to stay as close to the legal quota as possible because I knew the demand would be higher anyway. I thought that if I went by the quota all of the time that that would eventually even out if I risk it and lose a few times. The reason behind this

		strategy is because I am not a gambling person and consider myself unlucky.
		I wanted to abide by the quota because I thought that that was going to get me the most points. I'm always for the less risky investments. My motivation was to make profit while preserving the land. It's an important issue.
		My plan was to stay in the positive range by abiding by the quota in the beginning and then log less to spare the forest.
	Sanction avoidance	I was really paranoid about getting caught. I am not a risk taker by nature. I adopted a conservative strategy. My strategy was focused on occasionally point grabbing, but ultimately mostly driven by punishment avoidance. I chose it because I am a coward.
	Seeing others get sanctioned	I started with lower than the quota just to see if the forest cover would increase and to understand the mechanics in the game. I wanted to win the game by beating others as opposed to maximizing my points. My biggest motivation was seeing others lose. My strategy was low risk and I was counting on others failing.
Noncompetitive noncompliant	Demand	In the first year I was obeying the rules until I got upset when the quota fell, and demand rose. So, emotion drove my decision to switch my strategy. Then, I tried to figure out how frequently there was inspection and tried to cheat as much as I can, to get a bigger payoff.
		I tried to get away with what I could in order to satisfy the demand. My decisions were based on gut instinct. I felt like people were waiting for me to provide. Out of all things my decisions were most influenced by getting sanctioned. My strategy was 50% gut instinct and 50% being careful.
		I started complying with the quota in order to see how the game worked. But then I thought I needed more. However, getting sanctioned made me comply. I was scared to log the full demand (more than 10 above the quota). Overall, I wanted to satisfy the people. I was really scared and risk averse. In my reflection I realized that I would have been better off just complying with the quota.
		I started gambling immediately to get a sense of the mechanism. My strategy was quite reactive. Getting caught made me comply. Not getting caught made me cheat. My main motivation was to meet the demand and get points.
		My strategy was to log the full demand in the middle of the game because I believed that monitoring is connected to my logging level. The goal was to satisfy the demand using the greedy approach. My personality was my motivation.
Noncompetitive compliant	Sanction avoidance	I abided because if you break the rules all the logs will be taken away.
		My strategy was to be safe and abide by the law. I would do that in real life and I didn't want all of the logs to get removed by the police. It's a big penalty, so it's not worth it. If I had info on the probability of getting monitored, then I might have bothered cheating.

	Forest cover	My goal was to keep the forest cover as high as possible. I logged as low as possible in order to see if the forest cover would increase. But I soon realized that there were other loggers. So, I lost hope that it would increase. So, I just shifted my expectation to slow down the rate at which the forest cover decreases. I switched my strategy because the forest cover dropped and the fact that there were only 3 trees left out of 10.
	Demand	I started complying with the quota in order to see how the game worked. But then I thought I needed more. However, getting sanctioned made me comply. I was scared to log the full demand (more than 10 above the quota). Overall, I wanted to satisfy the people. I was really scared and risk averse. In my reflection I realized that I would have been better off just complying with the quota.

Table 15. Coding according to clusters