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Research Article

A Simple Board Game for Modeling the System Dynamics of Deforestation

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This article explores the dynamics of deforestation and reforestation through a simplified board game. Motivated by the urgent need to understand the impact of deforestation on biodiversity and climate, the study employs the Lotka-Volterra equations as a theoretical foundation to guide the game's mechanics. Two variants of the game were tested, revealing patterns that closely resemble predicted outcomes of rapid forest decline as well as forest recovery and oscillations between deforestation and recovery. While the initial findings are promising, indicating that the game successfully illustrates these ecological dynamics, further investigation is needed to statistically validate the observations. The author encourages collaboration and data sharing among players to build a robust dataset for future analysis. Ultimately, the game aims to enhance awareness of forest conservation issues and contribute to educational strategies that emphasize the importance of sustainable forestry practices.

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Introduction

Intact forests play a crucial role in the biophysical system of our planet. They function not only as carbon sinks[1], protection against soil erosion and habitats that support a diverse range of species but also provide recreational opportunities for humans. Furthermore, as highlighted by Makarieva and Gorshkov, forests significantly contribute to climate regulation through processes such as cooling the planet and generating precipitation, a concept encapsulated in their "biotic pump" theory[2]. In a similar vein, meteorologists have referred to the South American Low-Level Jet (SALLJ), which flows eastward over the Amazon at an altitude of 1.5 kilometers, as a 'flying river'[3][4]. It is thus not surprising that deforestation has been shown to result in a decline in precipitation in tropical regions[5]. In this context, de Laet and Bunyard underline the potential of forests to mitigate climate change, proposing strategies to harness these natural functions[6].

The principles of sustainable forestry management, as articulated by Hans Carl von Carlowitz in his seminal work "Sylvicultura Oeconomica"[7], further underscore the importance of maintaining healthy forest ecosystems to achieve a balance between economic needs and ecological integrity. Written in the 18th century, von Carlowitz's groundbreaking treatise laid the foundation for the modern concept of sustainability, advocating for the responsible management of forest resources to ensure their availability for future generations. His emphasis on the need to consider both environmental health and economic viability continues to resonate today, highlighting the critical role that forests play not only in supporting biodiversity and ecosystems but also in contributing to the economic stability of communities that rely on forest resources.

Given these vital functions of forests and the complex interplay between ecology and economics, it is unsurprising that deforestation remains one of the most pressing challenges facing global ecosystems[8][9][10][11][12]. The concept of Earth as a complex, interconnected system – often associated with James Lovelock's "Gaia Hypothesis"[13] – suggests that human activities, particularly deforestation, may lead to significant disruptions, potentially culminating in or at least contributing to societal collapse, as explored by several authors[14][15]. Some authors even state that current dynamics indicate that a catastrophic collapse in human population, driven by unsustainable resource usage, is the most likely future scenario[16].

One approach to understanding the temporal dynamics of deforestation and its interactions with various components of a complex system is system dynamics. Developed in the 1950s by Jay Forrester, this methodology combines qualitative and quantitative approaches to model dynamic interactions between various components of a system[17][18]. Based on a conceptual model of the system under investigation that outlines the key variables and their interrelationships a mathematical model is constructed using a set of differential equations that represent the relationships identified in the conceptual model. These models often include feedback loops and time delays that influence system behavior. System dynamics has proven to be a powerful framework for simulating the behaviors of complex systems, as demonstrated in seminal works like "Industrial Dynamics"[19] and "Limits to Growth"[20].

The author has identified several instances in which System Dynamics has been employed to characterize forest systems[21][22][23][24]. Nevertheless, it appears that the application of System Dynamics in the context of forest ecosystems remains relatively limited. This work specifically focuses on a particular aspect of System Dynamics models related to forest systems. Consequently, a comprehensive literature review is outside the scope of this study, indicating the need for further research to explore the broader applications and implications of these models in the context of forest ecosystems.

The methodology of System Dynamics presents certain challenges that may restrict broader applications. Firstly, the mathematical formalism required for System Dynamics necessitates a certain level of mathematical proficiency, which can significantly limit accessibility for potential users. This challenge is particularly pronounced among younger age groups, such as students in secondary schools, who may not yet possess the requisite mathematical knowledge to engage with the complexities of System Dynamics effectively. Secondly, while System Dynamics offers numerous advantages, the deterministic nature of its models—typically represented by coupled differential equations—serves as only an approximation of the complexities present in real-world systems. In the context of highly complex systems, such as forests and the societies that contribute to deforestation, it is unlikely that all relevant dynamics can be adequately captured through System Dynamics alone. Furthermore, outcomes that cannot be predicted by a purely mathematical model fall outside the scope of the model's results, highlighting the limitations inherent in relying solely on System Dynamics for comprehensive analyses of such complex interactions.

To mitigate these challenges and enhance accessibility while still capturing the essential features of system dynamics, operational games may offer a viable alternative. Proven cases, such as the "Beer Distribution Game"[17][19][25] and "Fishbanks"[26][27], illustrate how experiential learning can facilitate a deeper understanding of complex systems. The linkage between System Dynamics and games has been thoroughly described in the literature[28][29] and this work builds upon these existing linkages.

Weaving together the three aspects of forests, system dynamics, and operational games, the purpose of this article is to describe a simple board game designed to facilitate the exploration of deforestation and reforestation. By ensuring that the game is easy to implement, the author seeks to maximize its potential reach among diverse user groups, including educators, pupils, students, and policy-makers.

Moreover, the operational game should accurately reflect essential aspects of the temporal behavior of forest ecosystems, incorporating critical phenomena such as "overshoot and collapse"[20][30], which describe how unsustainable practices can lead to dramatic declines in ecosystem health. In addition, the game can serve as an educational tool to raise awareness of the complexities of forest management, the intricate relationships within forest ecosystems, and the socio-economic factors influencing deforestation.

One particularly relevant example upon which the present work is based is the "Moby Dick Game", developed by Ugo Bardi and Ilaria Perissi[31][32]. This game effectively simulates the dynamics of overfishing and is therefore comparable to the issue of deforestation, as it examines the dynamic behaviors associated with the overexploitation of a renewable resource. and illustrates the Hubbert curve, a concept introduced by Hubbert to describe resource depletion[33]. While the "Moby Dick Game" effectively demonstrates critical aspects that the author seeks to emulate – namely, accessibility and accurate qualitative representation of system dynamics – a significant limitation is that players cannot visualize the remaining number of "fish", as they are drawn from a plastic bag. Certainly, this approach mimics real-world fishing scenarios, where fishers usually cannot see fish stocks beneath the ocean surface. In contrast, in a forest setting, individuals can directly observe the consequences of deforestation, potentially prompting them to reconsider their actions upon recognizing that continued deforestation could potentially lead to ecological collapse. Therefore, it is worth investigating whether the direct

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visibility of prior actions' outcomes influences the system dynamics by reducing the likelihood of collapse in the context of an operational board game focusing on forests.

Introduction to the Theoretical Framework

The overexploitation of natural resources has emerged as a critical global challenge, particularly when it concerns renewable resources that are depleted at rates exceeding their natural regeneration. In his seminal work "The Tragedy of the Commons"[34], Garret Hardin described a concept illustrating how individuals, acting in their self-interest, ultimately deplete shared resources, thereby compromising the welfare of the community as a whole. This scenario is particularly relevant in the context of forest ecosystems, where unsustainable logging practices can lead to significant ecological degradation.

Temporal trends in forest cover across various countries have demonstrated patterns such as rapid decline (Figure 1, a) as well as recovery or even "oscillations" (Figure 1, b).

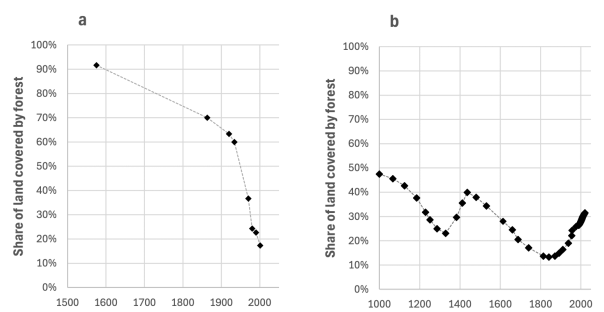

Figure 1. Temporal evolution of share of land covered by forests (a) showing a rapid decline as in the Philippines[35] and (b) recovery or even "oscillations" as in the case of France[36][37].

Besides the Philippines, a rapid decline in forest cover has been observed in countries such as Madagascar[38], Vietnam[39], Sri Lanka[40][41] and the Easter Island[42][43]. Recovery of a forest after the decline has been observed e.g. in Thailand[44], Costa Rica[45], in regions of the United States such as Ohio[46] or New England[47] as well as in England and Scotland[36].

While the temporal behaviors of rapid decline and recovery or oscillation certainly do not encompass all possible patterns of temporal development, the examples presented illustrate that these two scenarios effectively highlight realistic evolutionary trajectories of forest ecosystems in response to human activities.

The dynamics of forest population changes can be described through mathematical modeling frameworks, such as the Lotka-Volterra equations[48][49] that describe the temporal evolution of different stocks ("populations"). The classic model was originally formulated to represent predator-prey interactions, yet it has been adapted to describe various biological populations and ecological systems. One example was the population dynamics of Canadian lynxes (predator) and snowshoe hares (prey) [50] that show an oscillating behavior as described by the Lotka-Volterra equations and as observed in the above cited examples of forests. The same set of equations can also yield an outcome that resembles a scenario of rapid decline of the resources and its implications, as has been shown e.g. for general models[51] and societal collapse[52][53].

To articulate the dynamics shown above, we can apply the Lotka-Volterra equations as a foundational framework. In the case of forestry with its trees (stock T, "prey") and the loggers (stock L, "predator"), the general Lotka-Volterra equations would look like shown in (1) and (2).

$$\frac{dT}{dt} = \dot{T} = k_1 \cdot T - k_2 \cdot T \cdot L \qquad (1)$$

$$\frac{dL}{dt} = \dot{L} = k_2 \cdot T \cdot L - k_3 \cdot L \qquad (2)$$

In equations (1) and (2), $\dot{T}$ and $\dot{L}$ represent the temporal change of the stocks of forest (resource $\dot{T}$) and loggers (L), k_1-k_3 represent the rate constants for the different flows. This model was successfully applied to a simple system dynamics board game for the simulation of overfishing[31][32].

However, these equations need to be modified to better reflect the complexities of forest management and the interactions between deforestation and regeneration. Firstly, as the growth of trees (order of magnitude: decades) is much slower than the logging of the trees (order of magnitude: months to years) this means for our model that $k_2 \gg k_1$ so that we may omit the first term in (1) or rather substitute it with a function f_A representing deliberate afforestation. Secondly, and in stark contrast to other examples like fishery, the number of trees that are felled is not proportional to the number of trees left, but only depends on the number of loggers. Taken together, equation (1) simplifies to equation (1a).

$$\frac{dT}{dt} = \dot{T} = f_A - k_2 \cdot L \qquad (1a)$$

A further complication arises when looking at the dynamics of the loggers. Although they are responsible for felling the trees, the number of new loggers (first term in equation (2)) is not directly related to the number of trees felled. Rather, we have to take into account deliberate

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decisions to invest a certain amount of the trees felled in creating new jobs for loggers, thereby increasing the number of loggers. For the sake of our model, we call this quantity $f_{L,in}$. Similarly, reducing the number of loggers is not directly proportional to the number of loggers, but rather depends on a decision by the logging company for staff reduction, called e.g. quantity $f_{L,out}$ in our case. Taken together, equation (2) then becomes equation (2a).

$$\frac{dL}{dt} = \dot{L} = f_{L,\mathrm{in}} - f_{L,\mathrm{out}} \tag{2a}$$

These modified Lotka-Volterra equations provide a first basis for exploring the intricate dynamics of forest ecosystems. However, it already becomes clear that further modifications are required (see following section) while already highlighting the need for simpler models to facilitate understanding and application.

Underlying model of the game

Based on the modified Lotka-Volterra equations (1a) and (2a) we can develop the model shown in Fig. 2. This model consists of four stocks (Trees T, Wood W, Loggers L and Capital C) that are connected by different flows. It is important to note that there is one positive feedback loop between the number of the loggers and the flow T_{out}, representing the second term in equation (1a). The flows $W_{out,T}$, $W_{out,L}$, $W_{out,C}$ and L_{out} (all indicated in red in Fig. 2) represent strategic choices made by the logging company (or by the players in our case).

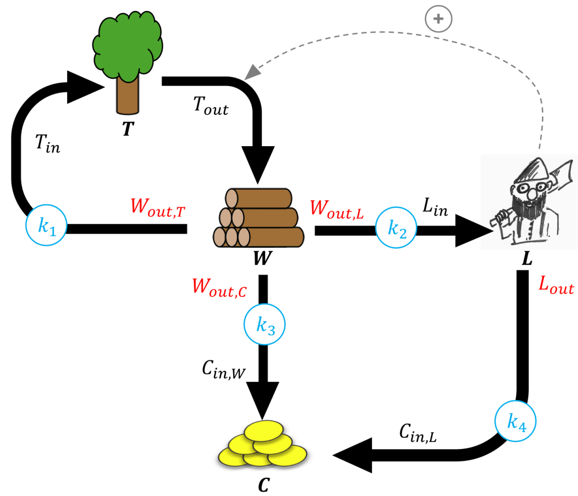

Figure 2. Representation of the System Dynamics Model Underlying the Game. The game consists of four stocks (T: Trees, W: Wood, L: Loggers, C: Capital) and nine flows (T_{out}: number of trees that are felled, equal to amount of wood added to the stock W, $W_{out,T}$: amount of wood that is invested in new trees, $W_{out,L}$: amount of wood that is invested in new loggers, $W_{out,C}$: amount of wood that is invested in victory points, T_{in}: number of new trees added to the stock T, representing afforestation, L_{in}: number of new loggers added to the stock L, representing growth of the Logging Company, $C_{in,W}$: number of victory points from investment of wood added to the stock C, representing distribution of dividends to shareholders of the company, L_{out}: number of loggers that are dismissed, representing staff reduction that increases dividends for shareholders, $C_{in,L}$: number of victory points from staff reduction added to the stock C). The flows $W_{out,T}$, $W_{out,L}$, $W_{out,C}$ and L_{out} represent decision points for strategic player choices, namely the allocation of stocks (W, L) into the flows. The rate constants k_1-k_4 determine the magnitude of the individual flows towards the four stocks.

The graphical representation of the model can be converted into a system of coupled differential equations (3) – (6).

$$\frac{dT}{dt} = \dot{T} = T_{\mathrm{in}} - T_{\mathrm{out}} = k_1 \cdot W_{\mathrm{out},T} - k_{\log} \cdot L \tag{3}$$

$$\frac{dW}{dt} = \dot{W} = T_{\mathrm{out}} - W_{\mathrm{out},T} - W_{\mathrm{out},L} - W_{\mathrm{out},C} = k_{\log} \cdot L - W_{\mathrm{out},T} - W_{\mathrm{out},L} - W_{\mathrm{out},C} \tag{4}$$

$$\frac{dL}{dt} = \dot{L} = L_{\mathrm{in}} - L_{\mathrm{out}} = k_2 \cdot W_{\mathrm{out},L} - L_{\mathrm{out}} \tag{5}$$

$$\frac{dC}{dt} = \dot{C} = C_{\mathrm{in},W} + C_{\mathrm{in},L} = k_3 \cdot W_{\mathrm{out},C} + k_4 \cdot L_{\mathrm{out}} \tag{6}$$

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In the specific version of the game presented in this paper, the values of the rate constants are set as follows: $k_1 = 3, k_2 = 1/3, k_3 = 1/2, k_4 = 1$. The underlying logic is that players should be encouraged to invest a maximum of wood in new trees (high value of k_1) and a minimum of wood in new loggers (small value of k_2). Additionally, immediate investment in victory points (k_3) should be more attractive than first investing in new loggers and then "transforming" them into capital ($k_2 \bullet k_4$).

Exemplary simulations (N=10 for each scenario described below) based on the model described by equations (3)-(6) were performed using Microsoft Excel (version 2411). For effectively performing the simulations, a number of assumptions was made:

Scenario 1:

- $k_{log} = 1, 1\bar{6}$, corresponding to the average number of trees felled by one logger according to the game rules (see Appendix)
- A random number was introduced to decide whether the number of trees felled was rounded up or down
- Two variables were introduced to determine whether the player is investing in victory points or new trees (based on simple Yes/No decisions that were implemented as IF-THEN statements in the software)

Scenario 2 (like scenario 1, with the following additional modification):

- If the number of loggers exceeds the number of trees left in the forest, all trees felled in the respective round will be invested in new trees

Typical results of the simulation (Fig. 3) reveal distinct temporal dynamics that resemble the patterns illustrated in Figure 1.

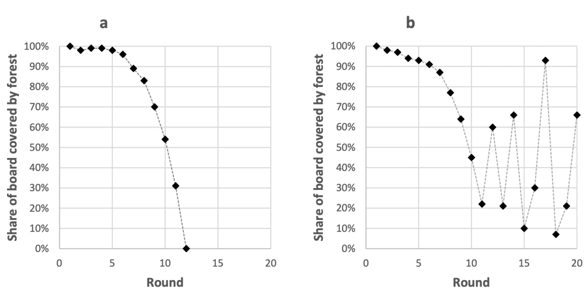

Figure 3. Exemplary results of simulations using the model equations. (a) Limited investment in new trees (scenario 1). (b) Significant investment in new trees once the number of loggers exceeds the number of trees left (scenario 2).

While this is certainly no proof that the model accurately represents reality, it is important to note that despite its simplicity and the limitations associated with the underlying assumptions made for test run 1 and test run 2, the model demonstrates a capacity to effectively simulate the scenarios of "Rapid Decline" and "Forest Recovery/Oscillation."

However, the inherent rigidity of the model when simulated in this way limits its capacity to convey the complete mathematical landscape of forest dynamics. This inflexibility undermines its effectiveness in applications that demand adaptability and nuanced decision-making. The simulation is characterized by numerous assumptions and several IF-THEN statements. While these elements provide a mathematically sound framework that is quite easy to implement, they may fail to capture the dynamic and often unpredictable nature of forest ecosystem management.

These intricacies illustrate the challenges involved in developing a model that accurately reflects the subtleties of real-world scenarios. Consequently, the flows with the rate constants $k_1 - k_4$ will not be explicitly modeled within the framework. Instead, the responsibility for these strategic decisions will be delegated to the players within a game context, drawing on principles from game theory literature[54][55][56][57]. This approach fosters a more flexible and engaging exploration of deforestation dynamics, allowing players to navigate the complexities of resource management while deepening their understanding of the underlying principles.

Additionally, by looking at equations (3)-(6), it should be obvious to the reader that running a model based on these equations alone requires a thorough understanding of the mathematical background such as e.g. solving differential equations iteratively. The required mathematical competence level is typically attained only after the completion of secondary education. In the author's view, this is considerably too late to foster awareness of the issue of deforestation and its dynamics. This emphasizes the necessity to provide a more accessible approach to the topic through the medium of a game, allowing for early engagement and understanding of the complexities surrounding deforestation and its impacts.

The Board Game

Based on the model outlined in equations (3)-(6) a simplified board game has been developed (for a detailed description, see Appendix). The mathematical model has been translated into specific game features to minimize the knowledge required for players before engaging with the game. These transformations include:

- The stocks of trees (T) and wood (W) are represented visually by green cones on the game board, while the stocks of loggers (L) and capital (C) are depicted with black and yellow counters, respectively. This design choice aims to enhance the tactile experience for players and foster a more immersive interaction with the game.

- The rate constant k_{log} is determined by the roll of a die, with the results illustrated in a table titled "Dice Results" (for an example, see Figure 4). This element introduces an element of natural variation that mimics real-world occurrences (e.g., a broken axe, a logger unable to work due to illness, or a new saw that can cut twice as many trees as an older model). Additionally, this mechanism adds an entertaining aspect to the game to keep players engaged.
- The rate constants $k_1 - k_4$ are displayed in an Action Table (Figure 9), allowing players to intuitively grasp how to convert wood into loggers, victory points, or new trees.
- The flows $W_{out,T}$, $W_{out,L}$, $W_{out,C}$ and L_{out} are also linked in the Action Table, enabling players to immediately visualize the outcomes of their strategic decisions.

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Figure 4. Example of dice results illustrating the number of trees felled. The player has two loggers. One logger rolls a “6,” resulting in the felling of two trees. The other logger rolls a “4,” leading to the felling of one tree.

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Two different variants (see Appendix) of the game were tested, with each variant played three times. The first variant was conducted without any additional rules to investigate the outcome of the basic game. In all instances, the results revealed a rapid decline in forest cover (Figure 5), consistent with previous observations (Figure 1 a) and simulations (Figure 3 a).

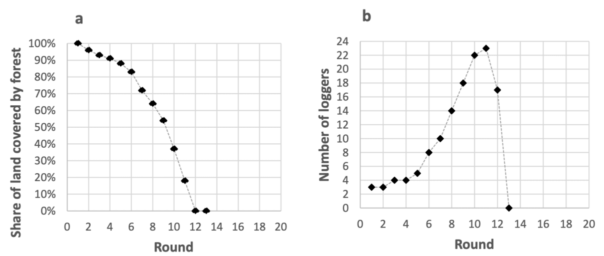

Figure 5. Exemplary results from the game variant "The Basic Game." (a) The proportion of land covered by forest (i.e., the number of trees on the board) and (b) the number of loggers as a function of game rounds.

In this variant, it is noteworthy that the evolution of the logger stock exhibits a curve characterized by a gradual increase, followed by a swift collapse. This phenomenon arises because, once all the trees are felled, the loggers become unemployed and lose their jobs. When considering the loggers as the "predators" in our initial Lotka-Volterra model outlined in equations (1a) and (2a), we encounter a compelling illustration of an "overshoot and collapse" scenario, that has been referred to as the "Seneca collapse" by Bardi[58].

In the second variant, "Promoting Sustainable Forestry," we observed a dynamic oscillation between deforestation and forest recovery, ultimately resulting in a viable forest at the end of the game (Figure 6).

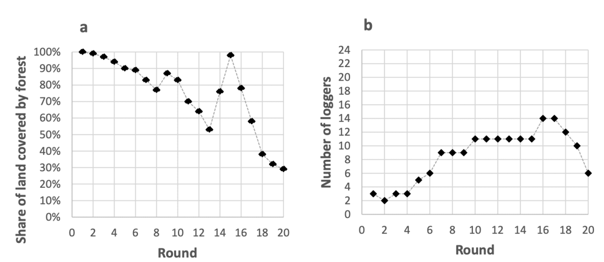

Figure 6. Exemplary results from the game variant "Promoting Sustainable Forestry." (a) The proportion of land covered by forest (i.e., the number of trees on the board), and (b) the number of loggers as a function of game rounds.

It is essential to highlight that in this variant, the total number of loggers did not exceed 14, which effectively limited the number of trees harvested per round, thereby preventing complete deforestation.

Further information regarding the number of trees planted and the total victory points obtained can be found in Table 1. There is a subtle indication that the number of victory points tends to increase in correlation with the investment in afforestation. However, additional data is necessary to more thoroughly assess these preliminary findings.

Game variant	Test run	Trees invested in afforestation	Victory points
The Basic Game	1	10	30
The Basic Game	2	2	39
The Basic Game	3	14	42
Promoting Sustainable Forestry	1	69	83
Promoting Sustainable Forestry	2	84	53
Promoting Sustainable Forestry	3	135	49

Table 1. Comparison of trees invested in afforestation and the victory points obtained in three test runs across the two game variants. Please note that for the "Promoting Sustainable Forestry" game variant, only the victory points acquired through player purchases were taken into account to ensure the comparability of the data.

Conclusion

The board game has effectively demonstrated its potential to yield outcomes that align with the predictions established by the Lotka-Volterra equations, as well as the observations documented by other researchers in the field. Although the initial results are promising, they do not constitute definitive proof; rather, they encourage a deeper exploration of the game's applicability and its potential as an educational tool.

Further investigations are underway to ascertain whether these observations can be statistically validated or if they should be considered with a greater degree of nuance. This rigorous analysis will enhance our understanding of the game's validity as a simulation of forest dynamics and its ability to accurately reflect the complexities of deforestation and reforestation.

In addition, the author extends an open invitation to researchers, educators, and players to engage with the game in diverse environments and contexts. By sharing their experiences and results, participants can contribute to the development of a statistically robust database, allowing for a more comprehensive evaluation of the game's effectiveness and educational value.

Ultimately, it is the author's hope that this game will serve as a valuable tool in fostering a deeper understanding of the intricate dynamics of deforestation. Furthermore, by stimulating discussion and reflection on the pressing issues surrounding forest conservation and sustainability, the game aims to raise awareness among participants, inspiring them to become more informed advocates for the protection of our forests.

Appendix: Rules of the game

The Basic Game

This section outlines the comprehensive rules governing the foundational version of the game. The materials needed to engage in the gameplay are easily accessible, as they can typically be sourced from household items or procured from office supply retailers. (Figure 10).

The game requires the following material:

1. Game Board (Fig. 7)
2. 100 halma cones (preferably green, representing the trees of the forest)
3. Black counters (representing the loggers) and yellow counters (representing victory points), with approximately 100 of each color recommended.
4. One or more six-sided dice.
5. Table for dice results (Fig. 8) and Action Table (Fig. 9).
6. Paper and pencils for keeping track of the game records.

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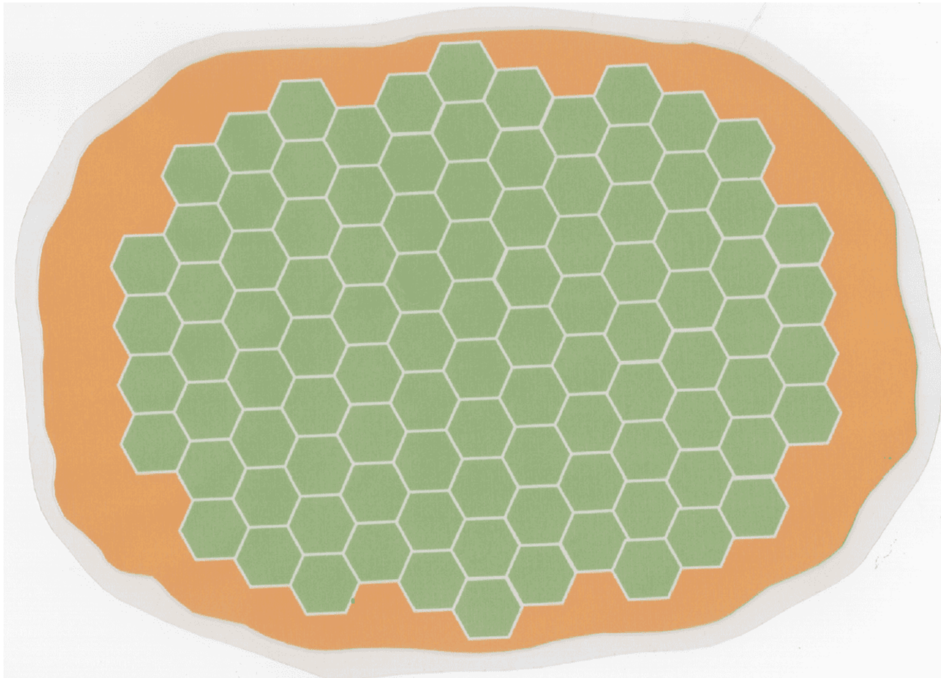

Figure 7. Game board for the basic version. 100 hexagonal spaces represent the locations where the cones ("Trees") are to be positioned.

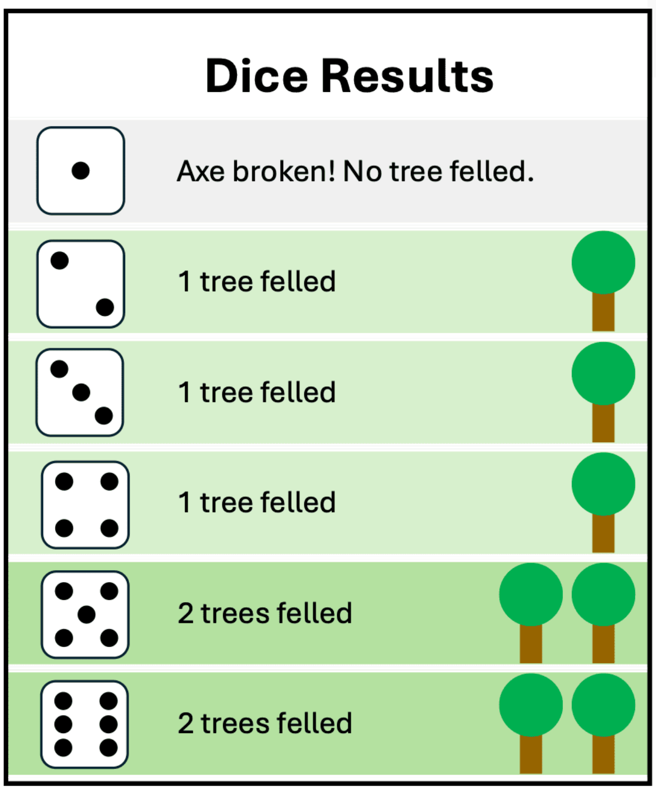

Figure 8. Table with dice results.

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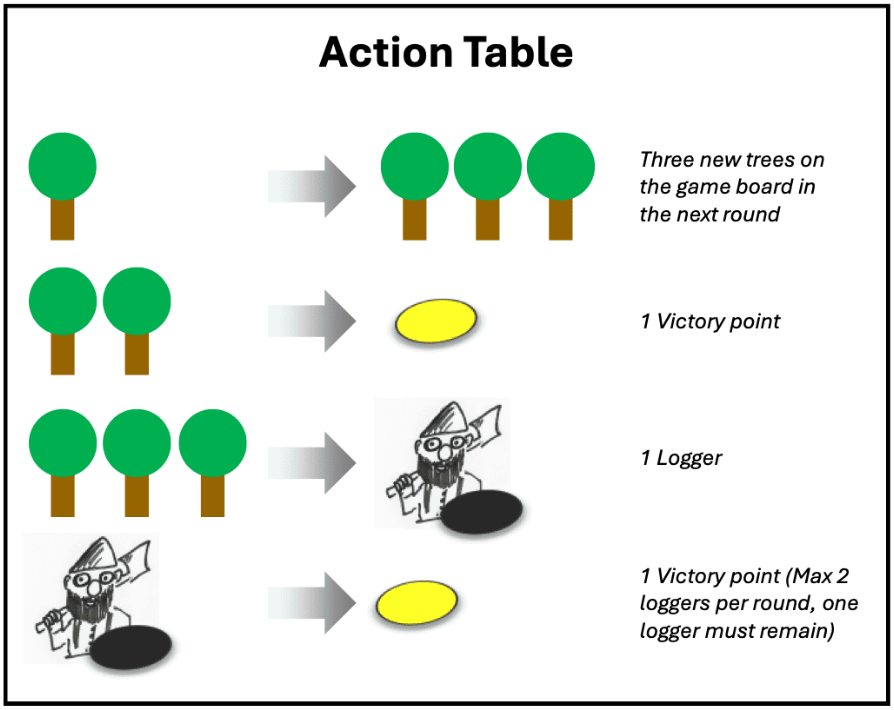

Figure 9. Action Table.

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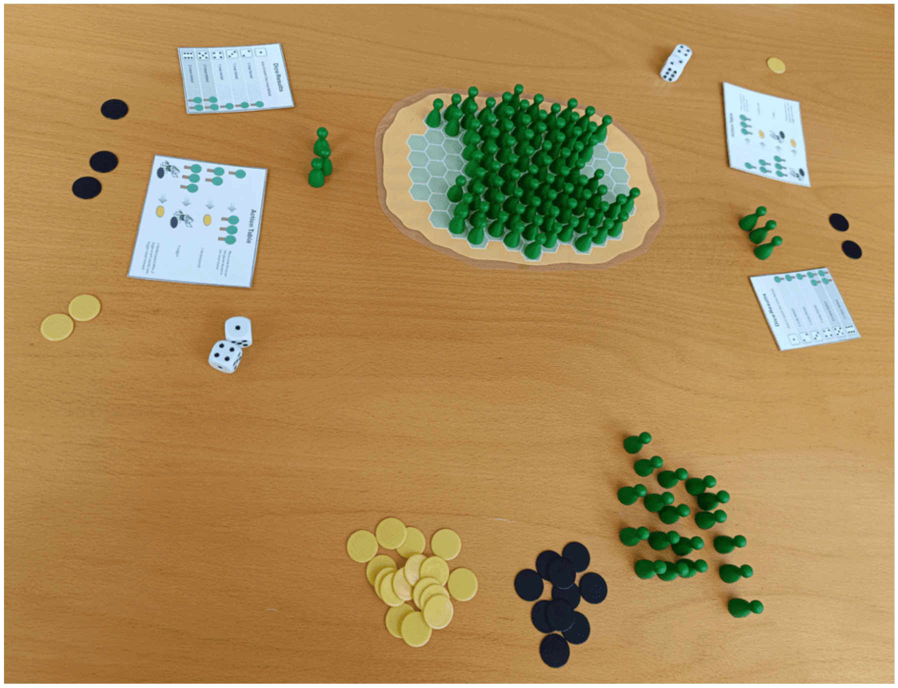

Figure 10. Overview of game equipment: game board, green cones, black and yellow counters, dice, table for dice results, and action table.

The 100 cones are placed on the board, with each cone positioned on a hexagonal space. The game can accommodate any number of players (1,2, etc.); however, it is recommended to have a minimum of two players to effectively explore the influence of different strategies on the actions of others. At the start of the game, each player receives a table for dice results and an action table, as well as one black counter (representing one logger). One participant assumes the role of the game master, who is responsible for recording the game activity.

Before the game begins, the game master presents the objective to the players: “Maximize your victory points.” At first glance, this goal may seem straightforward. However, achieving this objective involves a crucial element: investing in new trees to prevent complete deforestation. By comparing players' strategies to the actual outcomes of the game, we can initiate a meaningful conversation about sustainable forest management and the importance of balancing competitive success with environmental stewardship. This discussion allows players to reflect on their choices and consider the broader implications of their actions, both in the game and in the real world.

All players roll the dice at the beginning of the game to determine who gets to take the first action. The player with the higher roll begins, and the subsequent players take their turns in a clockwise direction. In the event that all players roll the same number, the dice are rolled again until a distinction is made.

All game rounds follow the same sequence outlined below.

Procedure of a Game Round:

1. Logging Trees: All players take turns rolling a six-sided die for each logger. Based on the result of the roll, players log a corresponding number of trees as indicated in the "Dice Result" table (Figure 8). These trees are removed from the game board and placed in front of the player.
2. Decision Making for Actions: Depending on the number of harvested trees, players can select from various actions outlined in the Action Table (see Figure 9). Each action requires players to "pay" the game master a specific number of trees corresponding to their chosen action. Alternatively, players have the option to retain the trees they have already harvested and choose not to invest them. The actions are as follows:
    1. Reforestation: For each tree invested by the players, three new trees are placed on the game board in the subsequent round. There is no limit to the number of trees a player can invest in reforestation. However, at the start of a new round, there can be a maximum of 100 trees on the board. Any additional new trees "decay"

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(due to insufficient space for growth beyond 100 trees).
2. Purchasing Victory Points: For every two trees a player invests, they receive one victory point from the game master. This simulates the payout to shareholders of the logging company. There is no limit to the number of victory points a player can earn per round.
3. Hiring New Loggers: For every three trees a player invests, they receive one new logger. The player may roll for this new logger starting in the subsequent round. This simulates the hiring of new loggers for the logging company and, more generally, the growth of a population reliant on forest logging. There is no limit to the number of loggers a player may hire per round.
4. Dismissing Loggers: A player may dismiss a maximum of two loggers per round. To do this, they return the corresponding number of black counters to the game master and receive one victory point for each dismissed logger. At the end of each round, however, at least one logger must remain.

3. Record Keeping: The game master notes the following information in each round:
    1. Number of trees on the game board at the start of the round
    2. Number of new trees placed on the board due to investment from the previous round
    3. Number of loggers per player at the beginning of the round
    4. Number of logged trees per player
    5. Number of new victory points per player
    6. Number of trees invested per player in new trees
4. End of the Game: The game ends automatically after the 20th round (as communicated to the players at the start) or immediately when there are no remaining trees on the board following the logging phase. The player with the most victory points wins the game.

This variant typically results in intense competition among players. A critical factor for the "survival" of the forest is whether players invest in reforestation alongside logging at any given moment. It is anticipated that fierce competition in the basic version of the game will lead to a Nash equilibrium[54], wherein both players either do not invest in reforestation or do so inadequately or too late, resulting in the forest collapsing well before reaching the 20th round. Thus, the expected outcome of the basic version of the game is a scenario characterized by "overshoot and collapse."

Variant: Promoting Sustainable Forestry

In this variant of the game (see game board in Figure 11), the following modifications are implemented:

1. A black cone is positioned on the outer numbering ring around the game board. Initially, it is placed on "1" (1st round) and is moved one space forward in each subsequent round. This cone represents a forest ranger who checks the number of trees in the forest every five rounds.
2. At the beginning of each fifth round (5th round, 10th round, 15th round, and 20th round), the number of trees on the game board is determined.
3. In these rounds, each player receives one victory point for every 10 trees that remain on the game board.
4. In the 20th round, a player receives three victory points for each tree they invest in new trees.
5. If the forest is completely logged at any point, a player may possess a maximum of one logger. For each additional logger, they incur a "penalty" of one victory point. This rule reflects the fact that loggers can no longer be paid from cash flow (which is proportional to the number of logged trees) and must instead be compensated from the company's equity.

Through these modifications, the aim is to create an incentive for sustainable forest management. Preventing deforestation should become more attractive to players than logging. These rules are designed to reflect initiatives known as Reducing Emissions from Deforestation and Forest Degradation (REDD) projects. These projects aim to make deforestation financially less attractive than forest conservation, for example, through the sale of carbon credits for a forest that continues to sequester CO_2 instead of releasing it through logging. However, these projects have not yet met their expectations[59]. A concrete example is the company C2O GmbH[60], which sold so-called climate points in exchange for not logging certified forest areas. The dissolution of the company at the end of 2023 could indicate that the business model has struggled to gain traction in the market.

Additionally, the "penalty" at the end of the game is designed to prevent unchecked growth in the number of loggers and uncontrolled deforestation. This should ensure that the number of loggers remains within a controllable range.

This game variant is expected to lead to a stronger emphasis on sustainable forest management overall. It is anticipated that the incentive systems will facilitate sustainable practices, resulting in the forest not being logged by the end of the game.

Figure 11. Game Board for the Variant "Promoting Sustainable Forestry"

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