Raising Awareness of Climate Change Impact and Mitigation – The *MyWorld* Simulation Game

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Abstract. As climate change increasingly impacts natural systems and living conditions all over the world, it becomes even more important that members of the public understand the probable course of climate change, its impact on world-wide and local ecology and living conditions, and the extent to which mitigation measures can alleviate that impact. Researchers can contribute to this by developing simulation models of the course and impacts of climate change, and make them available to the general public, packaged with a user-friendly interface and progressively detailed information.

This paper introduces *MyWorld*, a simulation-based game that enables the player to experience the course and impact of climate change and to experiment with potential mitigation measures. The freely available game aims at facilitating a better understanding of the probable progression of climate change and its impact on living conditions in the world in general and specific countries in detail.

Introduction

Climate change increasingly impacts all areas of human existence, including such diverse fields as urban infrastructure systems and housing [1], century-old cultural heritage assets [2][3], medicine and human health [4], and agriculture [5]. With the range and velocity of climate change increasing, it becomes even more important that the general public understands its impacts and potential remedies.

Here, simulation can help. Wrapped in a user-friendly game-like environment, a (simplified) simulation model of global climate change and its impacts on living conditions, broken down to a user's local environment and extended by estimates of the effectivness of mitigation measures, can increase the awareness of changes ahead and improve decision quality regarding potential changes in economy, societal organization, and personal lifestyle. To reach those goals, a model does not have to be as precise as an analytical simulation for the validation of real-world decisions and strategies. In return, players have no patience to wait for hours for the conclusion of a simulation run – an underyling simulation model has to be fast, even at the cost of precision.

This paper presents the *MyWorld* simulation-based game [6] aimed at facilitating a better understanding of the probable progression of climate change and its impact on living conditions in the world in general and specific countries in detail, as well as the effect of potential mitigation measures on those living conditions. The game presents the players with a visualisation of the course of climate change in any specific country, gives them the opportunity to experiment with mitigation measures, and simulates the impact of those measures on the CO2 balance and the further course of climate change itself. Playing the game thereby raises awareness of climate change impacts, potential mitigation measures and their effects and interdependencies.

Literature describes a number of serious games in the area of climate change and sustainability (for an overview, see Stanitsas et al. [7] or Gerber et al. [8]). Only a minority of approx. 10 % of those primarily aim at raising awareness [8], many of the others are more oriented towards strategy design [9], collecting data [10][11], or direct behavioral change [12]. Some are table-top games without computer support [9][13][14][15], while others are at least partially computer-supported [10][12][16][17][18][19][20]. Many of those examine specific (sub-) systems, like water management [17][19], household energy efficiency [12], and cultural heritage protection [20].

A few of these serious games warrant a closer examination: Van Pelt, et al. [17] describe a simulation-based game aimed at conveying the inherent uncertainties of climate change in the area of water management to expert stakeholders; their experimental setup includes ex ante and ex post surveys and control groups. They conclude that simulation-based games can be valuable in supporting the communication of climate change uncertainties.

The game proposed by Gangollels, et al. [12] aims at facilitating behavioral change in the area of household energy conservation, specifically at affordable housing communities. Based on their observations, they identify a significant potential for greenhouse gas savings that could be realised by individual behavior change. They propose to facilitate that behavior change by exposing members of the general public to a simulation-based game.

Bontchev, et al. [20] examine, based on the example of their own computer-based game, what factors robustly contribute to the awareness of climate resilience, especially in the area of built heritage sustainability. They find that learnability factors, e.g., ease of understanding the mechanics and gameplay, consistency in its mechanics, and direct feedback to a player's actions, contribute strongly.

De Kraker, et al. [19] propose the usage of a multiplayer game to foster social learning, based on an example of river water management. They find that the game facilitates a convergence of perspective in stakeholders from various backgrounds especially if the simulation model's mechanics and intermediate computational results – and therefore, by extension, the underlying interdependencies of the real-world system – are clearly communicated and not hid as a black box.

Based on that – admittedly, non-comprehensive – literature review, there seems to be a research gap regarding an awareness-raising game that covers the whole climate system and allows players to experiment with the impact of mitigation measures as they are discussed in politics and media. The review also showed that a simulation-based game should be clear about the underlying model's mechanics, should contain information on any sub-system and parameter that can be accessed by a player if they desire so, and should expose the player to direct feedback regarding every decision they make. The *MyWorld* game aims to fill that gap.

The paper continues with a short introduction to the *MyWorld* game as seen by the user (Section 1), followed by a description of the underlying simulation model (Section 2). It concludes with some thoughts on the context the game can be used in and an outlook on further research (Section 3).

1 The *MyWorld* Game

MyWorld offers a number of main views on the developments and dependencies of the underlying climate change model; it tries to convey to the user a sense of what those developments might actually mean to them and their local context. The main views are a world map and country information, a local and global 'climate press', the CO2 balance of the world or specific countries, and the mitigation measures selected by the user. While aimed at being easily understood by novice users, *MyWorld* also puts a focus on offering detailed information on all aspects of climate change.
The game can be downloaded freely from its web site [6].

1.1 World Map and Country Information

The first major view depicts a world map on which the player can select a country. Detailed data on that country will be shown in the country data area on the right of the map (see Figure 1). A date slider enables the player to select a year – between 1960 and 2100 – for that they would like to examine data. Beneath the data slider an info area depicts in what years, given the current set of parameters and mitigation measures, the model estimates that global temperature will break the 2 °C, 3 °C, 4 °C, and 6 °C thresholds.

The country data area provides a wide range of both world-wide and country-specific data for a selected year, including population data, CO2 emitters, energy production, societal and humanitarian factors, climate- and weather-related data, ecologic and economic data. Each of these items provides an information button revealing progressively more detailed information of the parameter and the underlying interdependencies, and a thumbnail-sized graph that depicts its development over time. The graphs can be expanded for each variable for closer examination.

1.2 Climate Press

To increase the degree of immersion and to give a better understanding of course and impact of climate change as well as the effect of mitigation measure, *MyWorld* includes a 'simulation' of both local and regional press articles. These 'articles', for any combination of simulation time, selected country, and selected mitigation measures, give a summary of current developments world-wide or. Technically, these 'articles' are composed out of simple boilerplate text modules based on the current development of the simulated climate and living conditions at any point in simulation time.

Figure 1: A screenshot of *MyWorld* showing a world map with the active country (left, Austria), a date slider (right at the top) and a number of world-wide and country-specific data points (right, bottom) regarding the active country at the specified point in time.

This is a significantly shortened example of the 'news article' localized for Germany for the year 2030 with some activated mitigation measures:

"Germany wants to be climate neutral by 2045 – By 2039, a 75 % reduction is targeted. Food and tabacco industry, chemical industries, agriculture and livestock, and cement manufacturing will be equipped with filters for carbon capture and storage of 75% of all emissions. Power generation will be CO2eq-free by 75%, with at least 901 TWh CO2eq-free energy generated. For this purpose, at least 128,742 wind turbines or 64 nuclear power plants are required. The purchasing power of the population will be reduced by 5.8%."

1.3 CO2 Balance

For each point in simulation time, as indicated with the date slider, the game depicts the CO2 balance resulting from the currently simulated climate system, including the mitigation measures selected by the user (see Figure 3). *MyWorld* distinguishes between all major carbon sources and sinks, including oceanic CO2 uptake, human-caused emissions and carbon capture and storage (CCS), photosynthesis, freshwater, weathering, vulcanic eruptions, as well as other natural sources. The game also summarizes whether the CO2 level in the atmosphere under the given conditions is growing or shrinking, i.e., whether the mitigation measures selected by the user are sufficient to stop climate change in the long run.

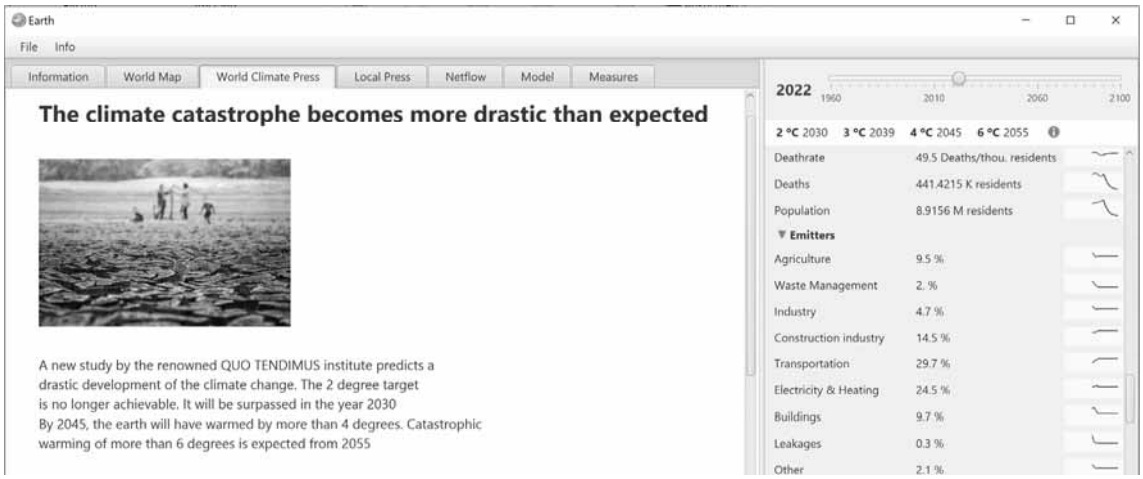

Figure 2: *MyWorld* offers both word-wide and local 'news articles' regarding the course and impact of climate change and the effect of user-selected mitigation measures.

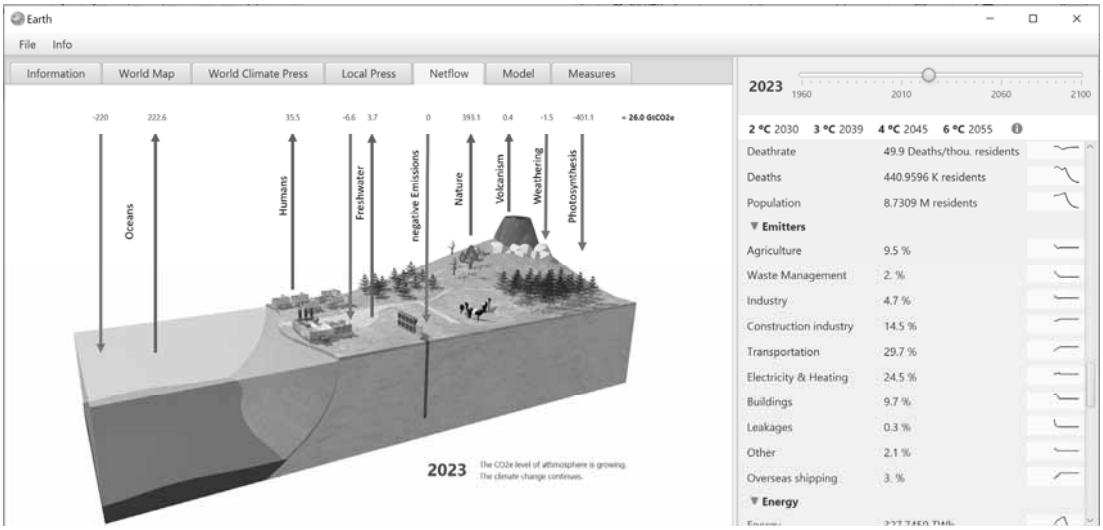

Figure 3: A screenshot of *MyWorld* showing the flow of CO2 equivalents for a selected country and point in time as a sum of the flows to and from, among others, the oceans, human activities, freshwater, photosynthesis, and CCS activities.

1.4 Mitigation Measures

MyWorld offers its users the opportunity to define and implement mitigation measures at any point in simulation time and enables them to investigate how these measures might influence the further course of the earth's climate. As a starting point for tinkering, the model presets the measures that various nations agreed upon as part of their Nationally Determined Contributions (NDCs). To be easily understood, measures form English sentences, e.g., "For Australia, phase out CO2e down to 0.1 times the value of 1990 by the year 2040, starting in 2025."

2 The *MyWorld* Simulation Model

To be of use in a near real-time game environment, the simulation model has to be executed fast, therefore putting limits on its complexity and preciseness. Simplifications are justifiable, as the model is not aiming at evaluating real-world decisions and strategies for their effectiveness and efficiency, but to give the user an impression on what impact climate change might have on their living conditions, and what effect mitigation measures might have on the further course of climate change.

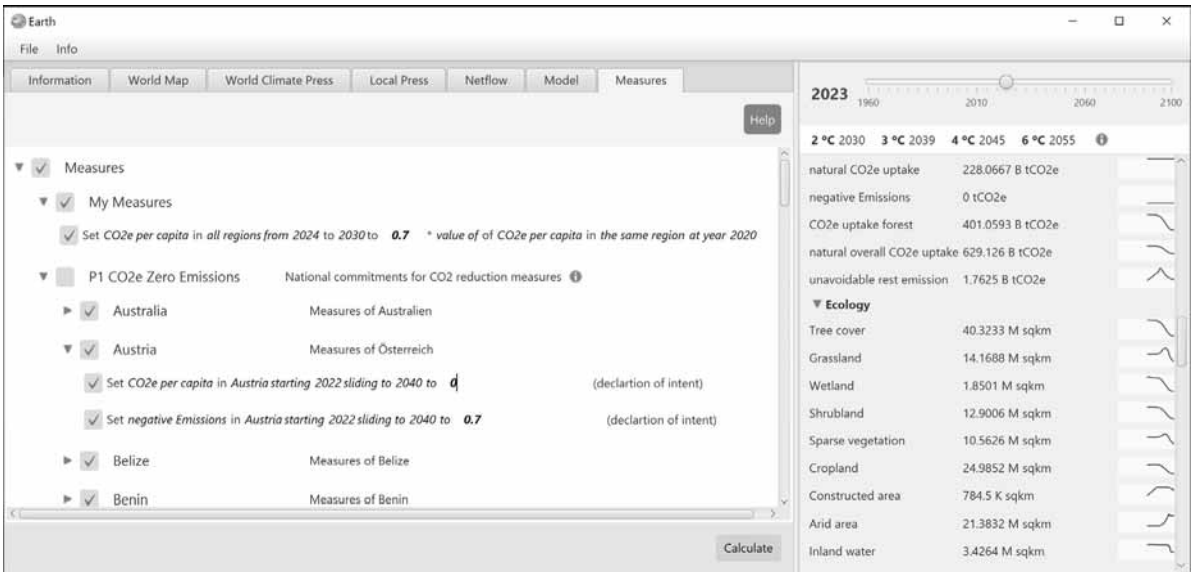

Figure 4: A user can define mitigation measure by selecting a country (or the world) and composing the elements of an English sentence from text elements. An example would be: "For Australia, phase out CO2e down to 0.1 times the value of 1990 by the year 2040, starting in 2025."

The following sections first describe the sources of the utilized data, then the basic simulation model based on a set of difference equations [21][22], and finally details the way potential mitigation measures selected by the user are integrated with the calculations.

2.1 Data and Constant Sources

For the *MyWorld* climate model, only data and constants from reputable data sources such as the UN, IPCC, WorldBank, or Our World in Data, are used. A separate view enumerates the sources of all data, including where to find them on the internet (see Figure 5). As with most complex models, experts disagree on some of the constants, such as certain demographic indicators. These constants can be adjusted by the player to suit their needs. The following paragraphs exemplarily describe some of the most important data series, their sources, and the way of integration with the *MyWorld* model.

The **CO2e-level** in the atmosphere is continuously measured by NOAA [23]. CO2e stands for "CO2 equivalents" and contains the greenhouse gases listed by the International Panel on Climate Change (IPCC) [24], primarily water vapour (H2O), carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and ozone (O3) as well as entirely human-made greenhouse gases, such as halocarbons and other chlorine- and bromine-containing substances, like sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

Data on the **energy mix** per world region is collected by Our World in Data [25], albeit incompletely. Some of the data series show erratic trends, which is due to the fact that the data sets are incomplete. *MyWorld* estimates the future energy demand of a nation based on the current energy consumption per inhabitant. This method is inherently inaccurate as it does not take into account whether energy consumption per capita will increase or decrease. The current trends are diverging for different nations, so that an exact prediction seems hardly possible.

Current and future **population numbers and birth rates** per region are estimated by the UN Department of Economic and Social Affairs [26]. While the estimates by principle cannot be exact, the UN data collection is generally seen as the most reliable available.

Types of landscapes, especially percentage of **tree cover**, are monitored by the OECD [27]. *MyWorld* models changes in land cover as a simple function of deviation of temperature to the historical mean. This approach is very simplistic because it does not consider geography, global flow systems, or peculiarities of different nations. Predictions on local levels can therefore be inaccurate.

2.2 Basic Model

Climate change will have a significant – potentially devastating – impact on future living conditions. That said, the authors of the game want to avoid *MyWorld* presenting an overly pessimistic view of the future.

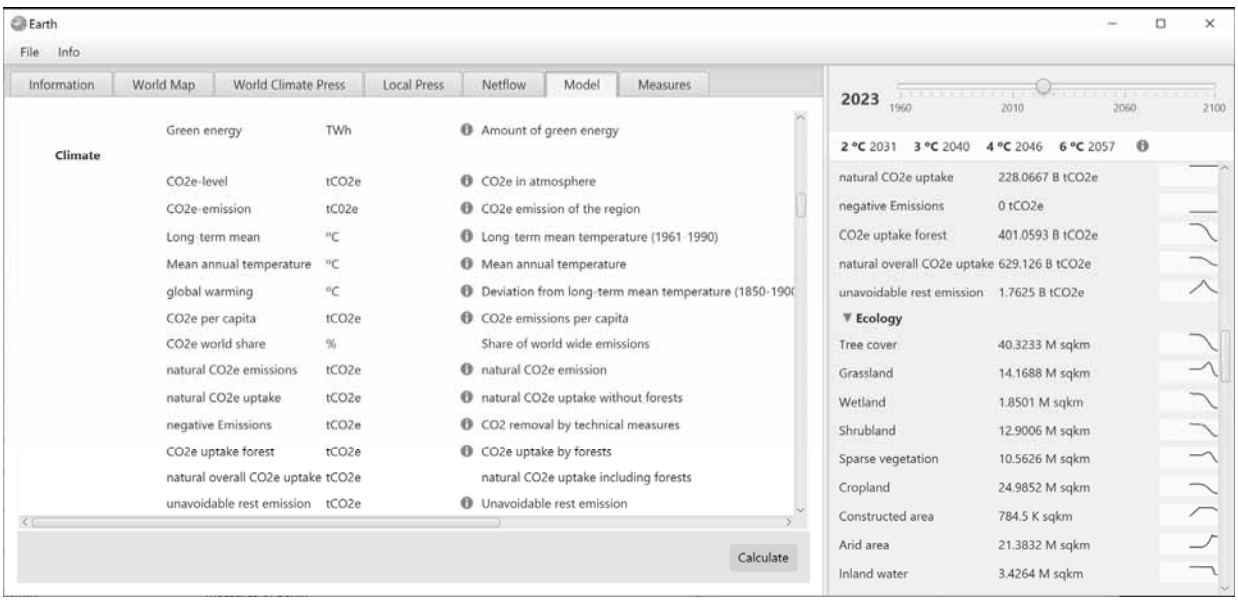

Figure 5: *MyWorld* informs the user on data used in the underlying climate model, including data sources.

The game therefore estimates the impact of climate change on natural systems and living conditions on the conservative side, turning optimistic when modelling the capacity of nature and society to mitigate the impact and to adapt to it.

The underyling simulation model employs an iterative difference equation system [28]. The system calculates the values of approx. 60 variables with an increment of one year from 1960 up to 2100. The variables come from the fields of population, climate, energy, CO2 emitters, society, ecology, and economy, and are explained to the player in detail. An individual difference equation is defined for each variable, which allows the most probable extrapolation of the value curve. Some equations use heuristics and constants taken from publications of the highest available quality, as described above. The historical variables collected from the data sources are in some cases used to adjust the parameters of the heuristics as well as possible, given the goals stated above regarding erring on the positive side.

All equations and heuristics can be controlled and partially changed in the 'Model' view (again, see Figure 5) by the user. That view also indicates for each equation whether it is based on historical data, is generated by a reliable approximation method, or consists of a plausible but basically uncertain estimation.

The predictive significance of iterrated differential equations decreases with increasing t [29]. Therefore, as already described, the *MyWorld* simulation model used does not produce exact predictions of the future. Rather, it is aimed at creating plausible scenarios and developments that give the player an understanding of dependencies in the world climate system and the general impact of climate change on their future living conditions.

2.3 Mitigation Measures

As its main gaming element, *MyWorld* allows the player to define their mitigation and adaptation strategy by defining countermeasures in the 'Measures' view.

For this purpose, the player can switch on and off the default measures committed by individual countries or change their parameters, such as percentages or time targets. In additional information boxes, the player can find out how binding the commitments of the nations are, e.g., whether they are anchored in law or merely non-binding declarations of intent.

In addition to those default measures, the player can define their own measures by influencing the course of certain variables. For example, they can stipulate that a particular nation will reduce certain emissions by a fixed factor by a certain date. Depending on the adjustment of the mitigation measures, the simulation engine calculates a new course for all variables and adjusts all views accordingly. As a result, the player can develop an understanding of which measures work how well, and how ambitious the world's mitigation measures have to be to avoid negative impacts on living conditions and natural systems. That didactic effect includes also an understanding of the timeframe in which certain measures have to be implemented in order for the entire ecological and societal system to thrive in the upcoming decades.

The following model variables can be modified by user-defined measures:

Birth rate: *MyWorld* assumes that human-induced climate change is directly related to the number of people living on earth. If the user does not modify this variable, the model assumes the UN-predicted birth rates [26].

Death rate: The death rate, along with the birth rate, is also an important factor for the size of the world population. Unmodified by the user, *MyWorld* assumes that the death rate stays at the level of 2020.

State Fragility: The Fragile State Index [31] is a measure of a nation's internal security. By default, this factor assumes changes in fragility dependent on the development of the nation's gross domestic product.

Gross Domestic Product: The gross domestic product is a measure of a nation's productivity and thus of the standard of living of its citizens. By default, *MyWorld* adapts the gross domestic product dependent on the mean annual temperature of a nation.

Forestation: Forested areas are an important factor influencing the removal of CO2 from the atmosphere. If a user changes this factor by planning (de-)forestation campaigns, *MyWorld* automatically adjusts the land use of the nation. This means that the other landscape types (i.e., grassland, wetlands, shrubland, desert, sparse vegetation, and cropland) are adjusted so that the total area remains unchanged. Without specific measures present, this factor is derived from the temperature-dependent utilization model.

CO2e per capita: In *MyWorld*, this factor is the central control variable for influencing the CO2e balance of a nation. More detailed factors, such as the energy mix or the mix of emitters, cannot be influenced directly by the user, as only insufficient models exist describing how changes in more detailled factors affect a nation.

Negative Emissions: This factor indicates how much CO2e is removed from the atmosphere by human activities. For such a carbon capture and storage strategy, various methods are potentially feasible. However, currently there are no significant capacities of negative emissions [32][33], so they are assumed to be zero by default. Since it is also currently unclear whether and when such processes could be used on a global scale, *MyWorld* does not make any pre-assumptions but leaves them to the player to schedule.

MyWorld does not prescribe in detail how targets set by mitigation measures are achieved, or why the targets might be feasible or unfeasible to reach. For many of the mentioned variables (e.g., forestation, negative emissions, and state fragility) no detailed understanding of their feasibility of implementation or impact on the course of climate change exist yet.

However, to get a better understanding of the course and impact of climate change, it is sufficient to show to a user what might happen if certain targets are reached or not reached – independent of the means of their implementation.

3 Conclusion

This paper presented *MyWorld*, a simulation-based computer game that aims at facilitating a better understanding of the progression of climate change and its impact on a user's regional living conditions, as well as the effect of potential mitigation measures on climate change and those living conditions. The paper described the game both from the user's point of view as well as the underlying simulation model.

The simulation model has been developed, implemented, and verified. A user-friendly graphical interface has been developed, giving users access to the model parameters and results. The game now is ready for extensive evaluation with stakeholders. In further research steps, the game will therefore be co-evaluated with university students from the earth sciences, municipal climate protection managers, other stakeholders, and the general public.

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