ECOMAN - An Environmental Management Simulation Game

Paula Antunes, Rui Santos, Luís Jordão, Helder Alves and João Pedro Rodrigues
Department of Environmental Sciences and Engineering
College of Sciences and Technology
New University of Lisbon
Quinta da Torre
2825 Monte da Caparica
Portugal

Abstract

Environmental management is a complex dynamic process, which involves taking decisions regarding different environmental components and socio-economic agents. Within this context, simulation games are an extremely powerful learning tool, allowing the decision maker (player) to formulate and test the results obtained with the implementation of alternative environmental management strategies, which is often impossible to perform in real situations.

ECOMAN is a simulation game, where the players are environmental managers who are responsible for a region, trying to cope with the different agents, media and uses in order to achieve environmental quality and social welfare objectives.

The player has a limited budget to allocate to several environmental management tasks, which is dependent on the health of the economy of the region. Each year a score is computed taking into account environmental quality, service levels and economic activity.

The game is based on a system dynamics model developed in STELLA II, simulating the major interactions between the socio-economic and the environmental system. The model was implemented with a multimedia interface integrating numerical, graphical and qualitative information using Supercard and Quicktime for the display of video images.

ECOMAN — An Environmental Management Simulation Game

1. INTRODUCTION

The goal of environmental management is the compatibilization of economic development objec with the preservation of environmental quality, through the adoption of management meas designed to mitigate the environmental effects of human activities. This is a very complex pro because it involves taking into account the complete environmental cycle associated with problem, in order to select the optimal point of intervention (Adriaanse *et al*, 1989; Moffatt, 1990)

Environmental management is therefore a very complex dynamic process, which involves ta decisions regarding different environmental components and socio-economic agents. Simula games are an extremely powerful learning tool for environmental managers, allowing the deci maker (player) to formulate and test the results obtained with the implementation of alterna strategies, which is often impossible to perform in real world situations.

The utilization of games as a learning tool can be said to be a direct application of the Confu quote:

> "You hear, you forget,
> you read, you remember,
> you do, you understand"

As a matter of fact, it is generally acknowledged that human beings learn best through first h experience, by trial and error (Senge, 1990). The problems with experiencing in real world situat in environmental systems are related with the fact that, since they are usually complex systems, consequences (feedback) from our actions are neither immediate nor unambiguous, being ofter removed in time and space (Senge, 1990). On the other hand, the consequences of our experie can sometimes be rather damaging if they are performed in a real environmental system.

Games allow players the possibility to try in a simulated model of a system, thus learning thro experience. System dynamics models, implemented as microworlds for play, are an ideal tool for purpose, since they are a simplified version of the real system, compressing time and space, therefore allowing the establishment of a relation between the actions (decisions) of the player and behavior of the system. They also have the advantage of avoiding the cost of failed experiments.

2. DESCRIPTION OF THE GAME

ECOMAN is a simulation game, where the players are environmental managers who are respons for a region, trying to cope with the different agents, media and uses in order to achieve maxir environmental quality and social welfare objectives.

The objective of this game is to give the player an understanding of the major interactions betw the socio-economic and the environmental systems in a region. The major components of the so economic sub-system are urban centers (with population), industries and agriculture. environmental sub-system is described in terms of the quality of its components (air, water and sc and in terms of pollution control structures such as wastewater treatment plants and sanitary landfi

The beginning scenario of ECOMAN consists of the description of a region with two urban cen located in different points of the region, with the corresponding population and service levels v sanitation facilities. The region has already some industries, namely dairy production, pig raisi fertilizers, and textiles, which are characterized in terms of location, production, employment, generation of liquid effluents, air emissions and solid waste. There are also some agricultural area the region, which are described in terms of occupied area, production, employment and aver consumption of fertilizers and pesticides. The player has also information regarding the capacity existing water supply systems, wastewater treatment plants and sanitary landfills.

The player has a limited budget which he must allocate every year to several environmental management tasks. Every year (iteration) the player has to take decisions regarding:

- Industrial licensing in the region;
- Investment in wastewater collection and treatment facilities;
- Effluent discharge taxes and taxes for the utilization of treatment facilities;
- Investment in urban solid waste collection and disposal facilities;
- Investment in urban solid waste recycling programs;
- Pesticides and fertilizers application standards.

The budget that is available for investment every year is dependent on the health of the economy of the region, which in turn is dependent on his decisions regarding industrial licensing, taxes applied and pesticides and fertilizers application standards.

Each year a score is computed by calculating a weighted average of three categories:

- **Environmental quality** (which has a weight of 0.4 in the final score) is defined by an indice taking into account water, air and soil quality, with equal weights. Water quality is calculated as a function of the BOD of the stream, air quality is evaluated through the emissions generated, and soil quality is assessed by the percentage of contaminated soils in the region.
- **Service levels**, with a weight of 0.3 in the final score is measured in terms of population served with water supply (0.4), wastewater drainage and treatment (0.3) and collection and final disposal of solid waste (0.3).
- **Economic activity** indice, which accounts for 0.3 of the final score, and is computed considering the variables employment (0.5), industrial income (0.25) and agricultural income (0.25).

After the decisions have been entered, the score is computed as well as the state of the region in the beginning of the following iteration (year).

3. SYSTEM DYNAMICS MODEL

ECOMAN is based on a system dynamics model developed in STELLA II, simulating the major interactions between the socio-economic and the environmental system. Figure 1 shows a causal diagram showing the major interactions of the system dynamics model underlying ECOMAN.

The interactions in this diagram are quite straightforward: industrial, agricultural and population growth contribute to the resources available for investment in environmental control, and also to the economic activity indice of the region, but also contribute to environmental quality degradation, thus lowering the score of the manager.

On the other hand, the more money is invested in environmental control systems and recycling programs, the better the environmental quality and the population service levels, and therefore the better the score. Decisions regarding effluent discharge taxes and pesticides and fertilizers application standards do not have a direct cost, but have negative effects in industrial and agricultural production respectively.

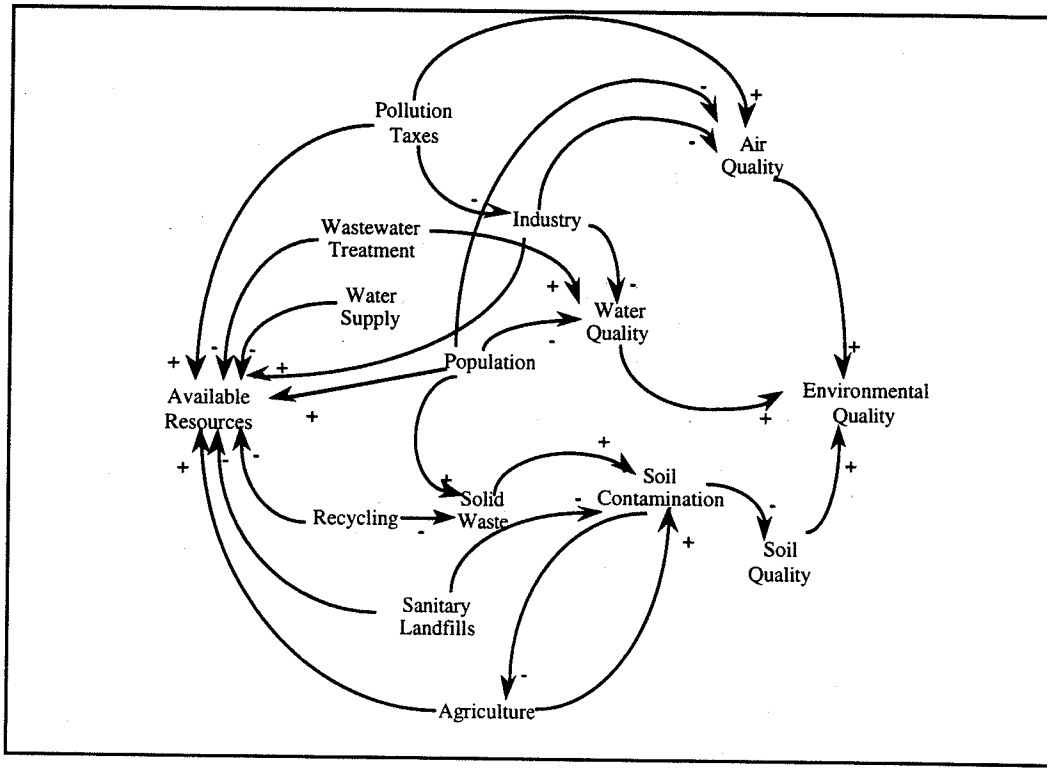

Figure 1 - Causal diagram

The general equations of the model were defined using emission/utilization factors and relyir graphical functions to establish ill-defined relations, such as effects between variables. For inst the soil contamination process and its effects in agricultural production are modeled in STELL shown in Figure 2.

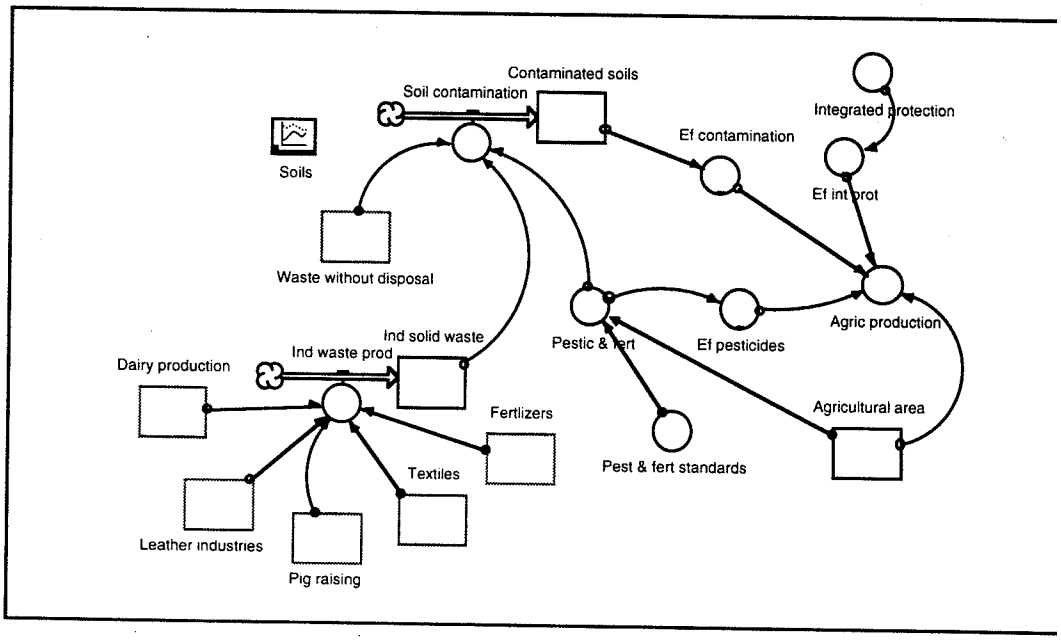

Figure 2 - Soil contamination and agriculture sector of ECOMAN

The game was implemented based on a system dynamics model developed with STELLA for which an interface was built using Supercard™ and Quicktime for the display of video images. The adoption of a hypermedia philosophy allowed the compatibilization of the need to have a simple interface, so that the player can focus on the fundamental aspects of the game, with the need to add real world details and fun, which was achieved by the integration of graphs, maps and video frames.

Preliminary versions of the game have been played by students of the Environmental Engineering Undergraduate Program with a considerable success.

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Senge, P. M., 1990; *The Fifth Discipline. The Art & Practice of the Learning Organization*, Doubleday Currency, New York.

The problem of the different time scales associated with some environmental processes, such as water quality in a river, where the transport of a pollutant downstream is a matter of hours, and the time step of the decisions of game, which is one year, was dealt by considering water pollution as a converter, varying instantaneously, instead of being a stock, which is its "real" nature. Therefore, the different stretches of the river existing in the region are represented as converters, instead of stocks, and the flows between them are represented as information rather than material flows.

4. IMPLEMENTATION OF THE GAME

ECOMAN was implemented with a multimedia interface integrating numerical, graphical and qualitative information using Supercard™ and Quicktime™ for the display of video images. This interface was designed relying on the hypermedia principles of organization of information, keeping decision and results screens as simple as possible, and giving additional information to the user only when it was requested.

Figures 3 and 4 show the major information and decision sheets of ECOMAN. They both consist mainly on text fields where information is displayed, on buttons where decisions and/or requests are entered.

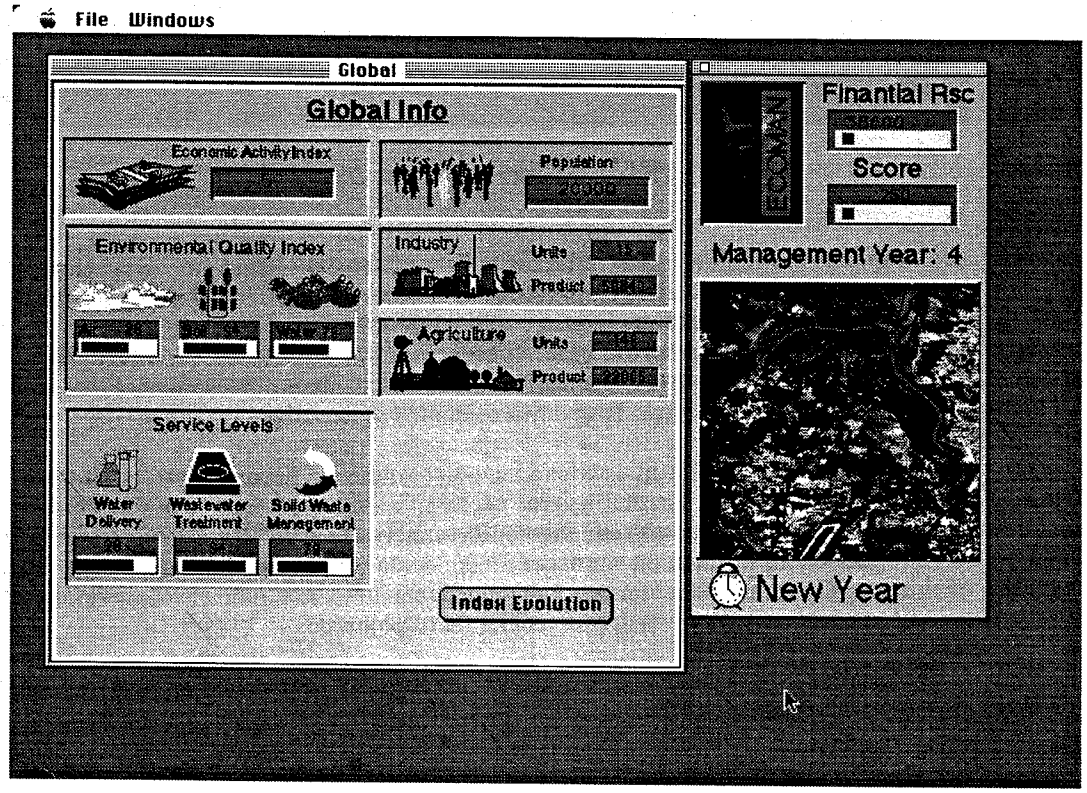

Figure 3 - Global information screen

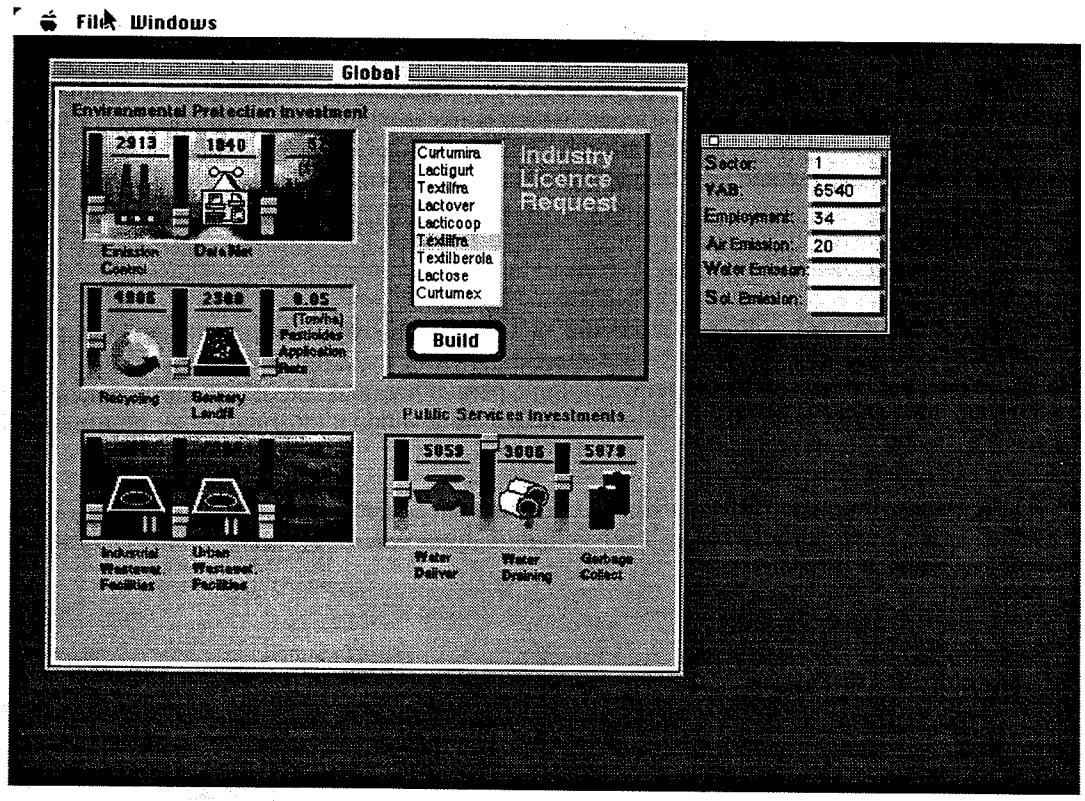

Figure 4 - Decision sheet

In the global information sheet the player has information regarding the values of the indic economic activity, environmental quality and service levels, as well as information regarding the important stocks of the system: population, industry and agriculture. By clicking some o information boxes the player can have access to further information. The score window, which c displayed at any time, shows the score and the financial resources available for investment, as w a map of the region which can be zoomed in to have a more detailed view.

The decision sheet consists of a series of handles where the player indicates his decisions, in ter investment and standards established, on the several sectors: water pollution, solid wast pollution, sanitation levels and soil contamination. The decision sheet has also a list of industrie have requested an installation license, and the manager must decide which ones are authorize clicking on the name of each industry the player can have information regarding the characteristi the industry, namely its production, employment and generation of pollution.

After the decisions for one year have been entered, the values for next year are computed an results displayed in a new information window.

5. CONCLUSIONS

As stated above games are an ideal learning tool for complex systems, such as environm systems, where the consequences (feedback) from the actions of a decision maker can not be assessed directly. ECOMAN is a game designed to provide insights on the interactions betwee economic and the environmental system, which is fundamental for the success of any environm management effort or strategy.