

*Vulnerability Assessment  
of  
Low-lying Coastal Areas  
and Small Islands  
to  
Climate Change and Sea Level Rise*

**PHASE 2: CASE STUDY ST. LUCIA**

**Report & SIMLUCIA User Manual**

Report to UNEP CAR/RCU  
United Nations Environment Programme  
Caribbean Regional Co-ordinating Unit, Kingston, Jamaica

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Guy Engelen, Inge Uljee and Roger White  
Maastricht, October 1997

## Important Notice

Please take notice of the following remarks when installing **SIMLUCIA**.

1. **SIMLUCIA** has been developed for **United Nations Environment Programme, Caribbean Regional Co-ordinating Unit, Kingston Jamaica** (UNEP CAR/RCU) as part of the MOU between UNEP and CIMAS, Miami, Fl, US. **SIMLUCIA** has been developed by **RIKS bv**, P.O. Box 463, 6200 AL Maastricht, The Netherlands. Part of the modelling work has been carried out by Prof. Roger White, Geography Department, Memorial University, St. John's, Nfld, A1C 5S7 Canada.
2. If you have on your machine other RIKS applications, such as: **GEONAMICA**®, the **ISLAND** Demo, the **CELLCITY** Demo, **RAMCO**, **LOKMod**, **WadBOS**, or earlier versions of **SIMLUCIA**, then put the **SIMLUCIA** files in a dedicated directory different from the one(s) that contain(s) any of the other applications. Do not interchange files between the different applications as files may have the same names but different contents.
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5. Neither software development with the tools provided in the **SIMLUCIA** package nor the application of the **SIMLUCIA** package to a case study is permitted. Software or application development and further usage or marketing of the **SIMLUCIA** package will only be accepted following the purchase of a full version of the package.

Enjoy our Demos and please return your comments to us.

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# 1. Introduction

This report covers the activities of RIKS in *Phase 2* of the UNEP project '*Vulnerability Assessment of Low-lying Coastal Areas and Small Islands to Climate Change and Sea Level Rise*'.

The long term objectives of this project are to develop a methodology and operational procedure applicable on the level of the individual coastal country or island (1) to describe and analyse the impacts of climate change on their territory, their ecosystems, their social systems and their economic activities, and (2) to provide instruments or tools to design, explore and evaluate policy measures and policy interventions to prevent or alleviate undesirable impacts.

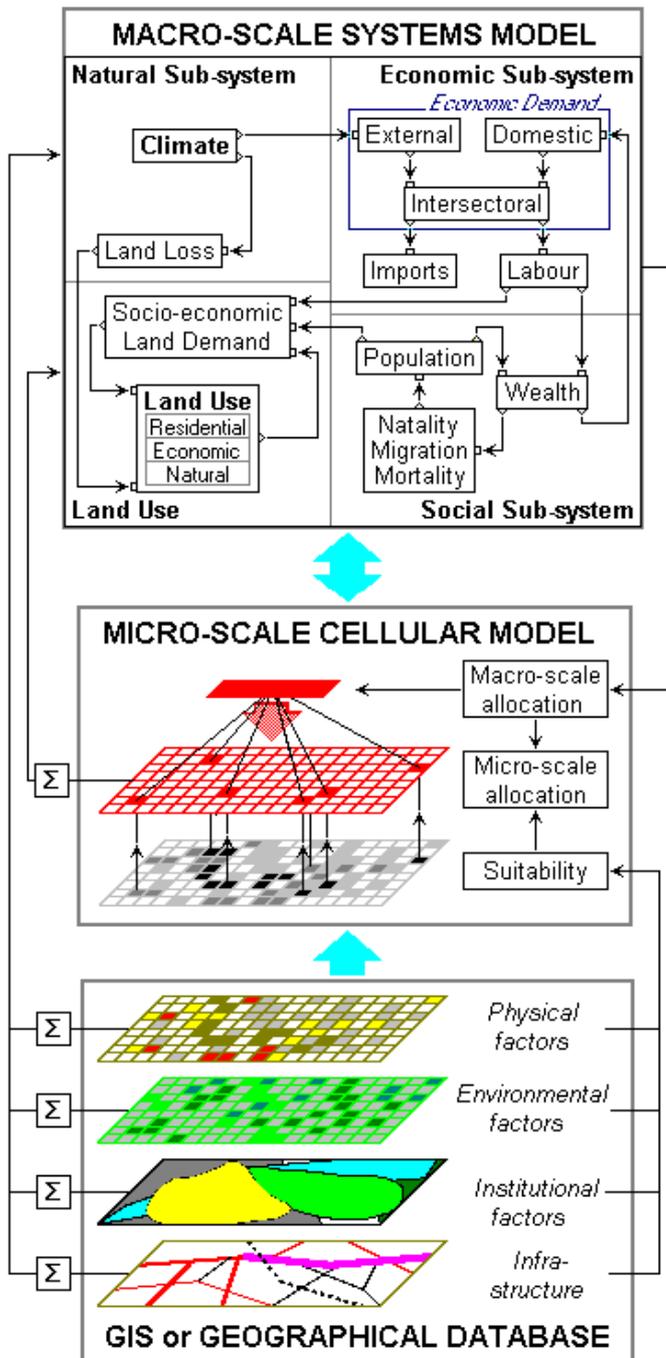
*Phase 1* of the project proposed a generic modelling methodology and decision support system judged to be capable of fulfilling, at least partially, both requirements posed in the objectives. More than being a theoretical exercise, the project produced a demonstrator version of the decision support system developed.

The specific objectives of *Phase 2* of the project are to apply the modelling methodology and decision support system to St. Lucia, West Indies and to adapt them to the extent required.

## 1.1. *Summary of the work carried out in Phase 1*

Climate change in the Wider Caribbean Region is expected to have an important impact on the physical, environmental, social and economic systems (Maul, 1993). Socio-economic systems in the region are already stressed considerably due to demographic, economic and environmental factors, and climate change will exacerbate this situation. Hence, formal instruments to study the effects of climate change on socio-economic systems require realistic representations of their actual state and of the mechanisms that will cause them to change in the future. Their temporal and spatial dynamics should be well represented, because climate change is affecting socio-economic systems through mechanisms at very different geographical scales: at the Macro-scale causing changes in the exchanges with the world system through changed demands, exports, imports and migrations; and at the Micro-scale causing the relocation and possible disappearance of activities.

With a view to realistically describe the effects of climate change on socio-economic systems we developed an explicitly dynamic (temporal) and spatial modelling framework operating at two geographical levels: the *Macro-level* describes the macro-economic and long-range spatial interactions, and the *Micro-level* describes the short-range interactions and location choices. This modelling framework has been applied to and tested on a theoretical, prototypical, island (named ISLAND) with characteristics typical of existing small Caribbean islands. At the Macro-level, ISLAND is modelled as a single region --as one point in space interacting with the external world. Hence, a single set of linked dynamic equations generates the evolution in time of the integrated socio-economic and



**Figure 1:** A modelling framework consisting of coupled models at the Macro-level and the Micro-level.

The economy is aggregated into five sectors. In the social sub-system the ISLAND demography is modelled as a single population group growing as the result of births, deaths, and migration. The birth rate is specified to follow a long term trend, while mortality and migration rates depend on both forecasted long term structural trends, and on the well-being of the island population as indicated by the employment participation rate. The natural sub-system consists of a set of linked relations representing the expected change in time of sea level and temperature, and their effects on the loss of land, on precipitation, storm frequency, and external demands for services and products. Later, the natural sub-system could be further developed to include a description of the growth of natural systems such as coral reefs, mangroves, and beaches. The model

environmental systems. The growth coefficients thus calculated are fed into a cellular model, operating on the Micro-level, which allocates the socio-economic growth to island cells of 500 by 500 meter. This allocation mechanism is based on Micro-level spatial interactions specified in cellular automata rules and based on physical suitability measures retrieved from a GIS. The cellular model will return the results of the allocation to the Macro-level, thus guaranteeing the full coupling of the macro and micro scales.

At the Macro-level essentially three coupled sub-systems are modelled: the natural, social, and economic sub-systems. The proposed modelling framework allows for different types of mathematical representations of each of these sub-systems, thus allowing for a more or less detailed description of certain aspects of the sub-systems. In the first phase of the project we have selected model representations that fit the application of the modelling framework to the hypothetical small island. It reflects the archetype nature of the work and leaves room for a number of improvements. The *economic sub-system* is modelled by means of a highly aggregated input-output model, coupled with the demographic model (through a wealth indicator and household demands), with the natural system (climate changes influence external demand) and with the Micro-level via a land density expression (activities require space).

provides the slots to plug in such modules, but further research will be required to develop and implement them.

At the Macro-level, the model calculates the changes in employment per sector and the growth of the population. New jobs and new people will require space to support their residential and economic activities. In the model the translation of economic and residential activity into space is performed by means of the *land density* expression. The land density is a function of the total amount of land available, the suitability of that land for the activities carried out, and the land (and its suitability) already occupied. Generally speaking, land density will increase if land is getting scarce. But it will decrease if the land occupied is getting marginal for use by the specific activity. The total amount of land required by each activity is used as an input to the Micro-level part of the model.

More than in the Macro-scale representation, the principle mechanism underlying the Micro-scale dynamics is the fact that socio-economic activities will interact with one another in geographical space. It is a well documented phenomenon in regional economics and is common to concepts such as economies of scale, agglomeration advantages, distance decay, push and pull forces. It translates the fact that activity *X* does not flourish in the neighbourhood of activity or feature *Y*, while *Z* does very well near *Y*. These push and pull forces are expressed in the cellular model by means of attraction-versus-distance functions for each pair of activities or land-uses modelled. But this functional appropriateness of a cell is not by itself sufficient to decide the likelihood that the cell will be occupied by one or the other activity. Its intrinsic physical suitability will also have to be right. The physical suitability of a cell is an aggregate measure calculated from a number of physical indicators (and may include infrastructural and legislative factors as well). These calculations are standard operations in state of the art (commercially available) GIS packages. Hence the coupling of the modelling framework with a GIS package is envisaged.

It is by means of Cellular Automata rules that we calculate the changing land-use on the Micro-level. Rules are applied hierarchically. The highest priority is given to user interventions, including the forced location of an activity in a specific area, or the development of an area for a specific use, etc. The next highest priority involves the elevation of a cell relative to the sea level. These rules decide on the total amount of land available for the different activities and on the physical suitability of such land. The lowest priority is for rules that calculate the aptness of a cell to receive a specific activity. This aptness is a function of the physical suitability of the cell and the activities already present in its neighbourhood.

The model thus defined is the core element of the DSS (Decision Support System) that we began to implement. In the DSS the model is complemented with user-friendly and interactive software tools which make it very easy to use and which facilitate the decision making process.

Phase 1 of the project involved the application and testing of the modelling framework on the basis of a theoretical application only. It suggested that the framework would be applied to a real case and that a thorough validation and calibration would be carried out.

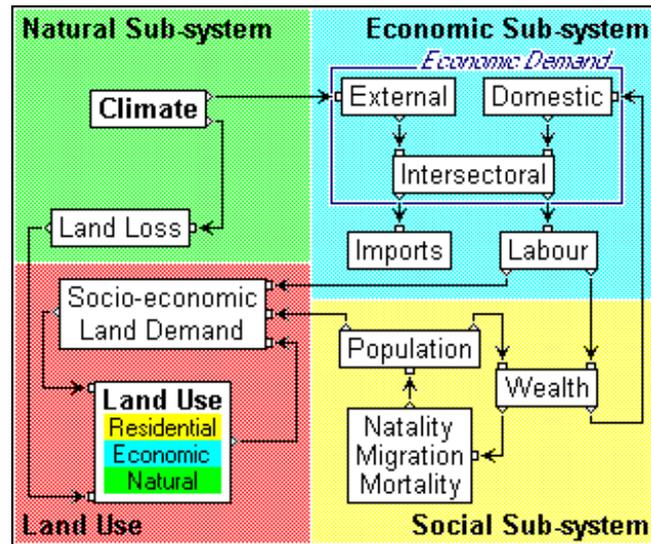
The results of phase 1 have been documented in Engelen et al., 1993a, Engelen et al., 1993b and Engelen et al., 1995. The demonstrator developed in phase 1, called ISLAND Demo, can be obtained from RIKS, or, for those having access to Internet, can be downloaded from the RIKS' homepage: <http://saturn.matriks.unimaas.nl>

## **1.2. Phase 2: SIMLUCIA**

The remainder of this report deals with the second phase of the project '*Vulnerability Assessment of Low-lying Coastal Areas and Small Islands to Climate Change and Sea Level Rise*', which mainly involves the application of the modelling and decision framework to the case of St. Lucia. The resulting model and software system has been given the name **SIMLUCIA**. In Chapter 2 the development and implementation of the models at the Macro-level is discussed, while Chapter 3 gives more details on the Micro-level models. Chapters 4, 5, 6 and 7 cover the contents of the user manual for **SIMLUCIA**, and finally Chapter 8 demonstrates the use of **SIMLUCIA** in a policy context.

## 2. Macro-Level Dynamics

The Macro-level model (Figure 2) essentially models three coupled sub-systems each represented by sets of linked variables: the natural sub-system, the social sub-system and the economic sub-system.



**Figure 2:** Schematic representation of the Macro-level of the model showing the loops linking the natural, the social and economic sub-systems.

### 2.1. The Natural sub-system

The natural sub-system consists of a set of linked relations expressing the change in time of temperature and sea level, and the effects of these on precipitation, storm frequency and external demands for services and products from St. Lucia. The hypothesis is made that climate change only affects the external demand for products produced in St. Lucia thus expressing changing world markets as well as the manner in which the island's products and services is perceived in the external world (e.g. by possible clients, tourists or investors). In this version of the model these relations are entered directly by the user and either represent state of the art knowledge, outputs of other models including global circulation models, climatic change models and greenhouse gas models, or the scenarios or sets of hypotheses with which the model is run.

#### 2.1.1 Climate

*definition:*

The expressions used in the Climate MBB<sup>1</sup> assume a simple and direct relation between two variables. However, the definition of changes in precipitation and storm frequency

<sup>1</sup> The acronym MBB stands for Model Building Block and refers to a sub-model. (See also Annex A.)

for example, as a function of temperature only is a strong simplification of reality. In more elaborate versions of the model, such relations could be replaced by dedicated sub-models capable of describing them at a deeper, causal level. Similarly, the model of the Natural sub-system could include a description of the growth of natural systems such as coral reefs, mangroves, sea grasses, riverine systems and beaches.

*mathematical formulation:*

$$T_t = f_T(t)$$

$$L_t = f_L(t)$$

$$P_t = f_P(T_t)$$

$$F_t = f_F(T_t)$$

$$E_{i,t} = e_{i,t} [1 + f(T_t) + f(P_t) + f(F_t)]$$

$$E_{tourism,t} = e_{tourism,t} \frac{1 - \beta \exp(-\alpha N_{beach,t})}{1 - \beta \exp(-\alpha N_{beach,t=0})} [1 + T_t + P_t + F_t]$$

*with:*

$t$  time

$f()$  function of

$E_{i,t}$  Vector of sectoral external demand; [million EC\$]

$T_t$  Temperature change; [Celsius]

$L_t$  Sea level change; [feet]

$P_t$  Precipitation change; []

$F_t$  Storm frequency change; []

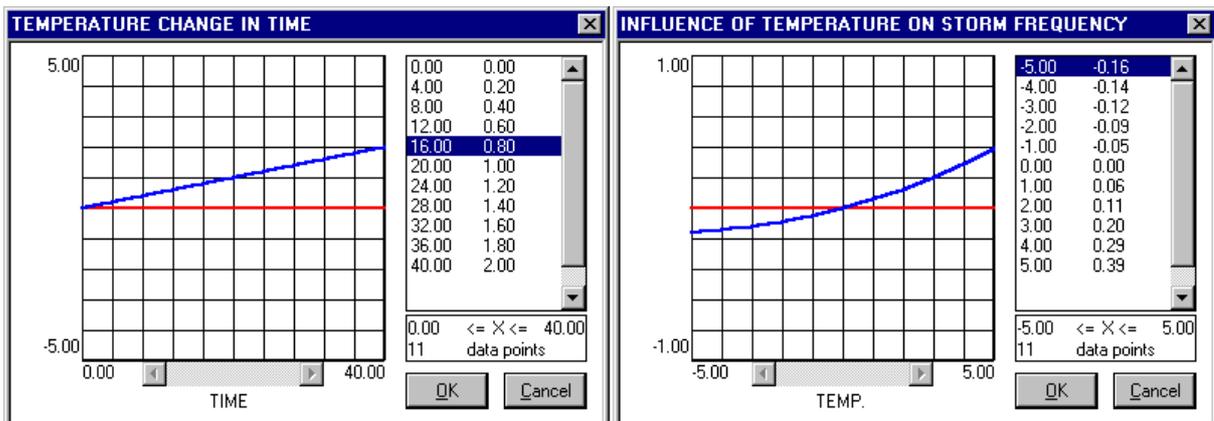
$N_{beach,t}$  Number of beach cells; [cells]

$e_{i,t}$  Vector of projected sectoral external demand ceteris paribus; [million EC\$]

$\alpha$  Resilience of tourism industry; []

$\beta$  Relative importance of beach tourism in total tourism industry; []

*calibration information:*



**Figure 3:** Most relations of the natural sub-system are defined as tables. The figure shows on the left the relation between time and temperature change and on the right the effect of temperature change on storm frequency.

The relations used in **SIMLUCIA** are pure hypothesis expressing how the economy could be influenced by climate change. Some general trends of these expressions have been discussed with the scientists and members of the *UNEP/IOC Task Team on the Implications of Climatic Change in the Wider Caribbean Region*. These trends are good estimates for the St. Lucian situation, without them being scientifically proven. They generally reflect the dependency of the agriculture and the tourism sector on the actual climatic conditions. The user is free to correct or replace the hypotheses with better information if it is available, or he can experiment with other hypotheses in order to find out how different climate related scenarios would (possibly) affect the St. Lucian economy.

Part of the natural sub-system concerns a measure of the physical and environmental suitability (or aptness) of each Micro-level region (called cells in the cellular model) of St. Lucia for receiving one of the activities modelled. This information is available from the GIS (Geographical Information system) and its digitised maps. Changing sea level will cause the loss (or gain) of low-lying coastal areas and will cause the total available area to shrink (or to grow). This mechanism of losing or gaining land is modelled in the Micro-level cellular automata model and is described in more detail in Chapter 3. Losing or gaining land will affect the total suitability of the land area and will put more or less stress on the land used by the different economic activities. This effect is expressed by means of the concept of land density and explained under that heading in this chapter. Hence, broadly speaking, the natural sub-system will translate the changes in temperature and sea level into changes in the total land area, changes in the suitability of that land area and in changed external demands for goods produced on the island.

### 2.1.2 *Beach loss*

*definition:*

Changing sea level will cause the loss (or gain) of beach area. This sub-model expresses the fact that beach area is a very important asset for the tourism industry. Hence, that the loss of beach might damage the industry a great deal. This is certainly the case for St. Lucia where tourism is mainly beach related and where the total beach area is limited. In the event that due to climate change beaches would disappear rapidly, St Lucia will quickly lose its image in the outside world and gradually the demand for tourism would fall.

*mathematical formulation:*

$$E_{tourism,t} = e_{tourism,t} \frac{1 - \beta \exp(-\alpha N_{beach,t})}{1 - \beta \exp(-\alpha N_{beach,t=0})} [1 + T_t + P_t + F_t]$$

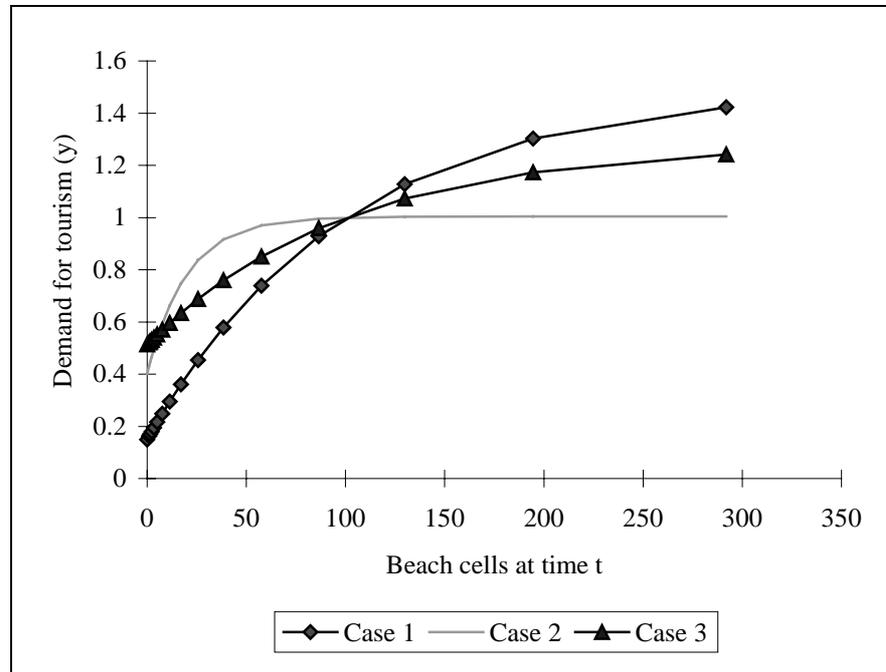
*with:*

$E_{tourism,t}$	External demand for tourism; [million EC\$]
$T_t$	Temperature change; [C]
$L_t$	Sea level change; [feet]
$P_t$	Precipitation change; []
$F_t$	Storm frequency change; []
$N_{beach,t}$	Number of beach cells; [cells]
$e_{tourism,t}$	Projected external demand ceteris paribus for tourism; [million EC\$]
$\alpha$	Resilience of tourism industry; []
$\beta$	Relative importance of beach tourism in total tourism industry; [%]

calibration information:

$$y = \frac{1 - \beta \exp(-\alpha N_{beach,t})}{1 - \beta \exp(-\alpha N_{beach,t=0})}$$

The two parameters in the expression take into consideration the effect of both (1) the relative importance of beach tourism in the total tourism industry (parameter  $\beta$ ) and (2) the sensitivity of the industry to the phenomenon of a disappearing beach (parameter  $\alpha$ ). In the graph underneath, three cases, representing different combinations of  $\alpha$  and  $\beta$ , are shown. Generally speaking, an old, well established or rich tourism industry will do whatever is in its power to prevent itself from vanishing (Case 2), while a young or poor industry does not have the possibilities to do so (Case 1). Case 3 shows the trend of the relation with the parameter values used for St. Lucia. Note however that the initial (at  $t=0$ ) number of beach cells in St. Lucia is only 34.



	Case 1	Case 2	Case 3
$\alpha$	0.01	0.05	0.01
$\beta$	0.9	0.6	0.6
Beach Cells at $t=0$	100	100	100

*default values:*

For St. Lucia, the values for the parameters are as follows:

$$\alpha = .05; \beta = .90;$$

these values reflect the fact that the tourism industry depends largely (90%) on the presence of beaches, but, that it has a high level of resilience to counteract the effects of beach degradation. In other words, it can afford to an extent beach nourishment or beach protection programmes.

## 2.2. *The Social sub-system*

The social sub-system describes the demography of St. Lucia and the social well-being of its population. The demography is modelled as a single population group growing exponentially as the result of births, deaths and migrations. The social well-being is expressed as the employment participation rate, meaning the proportion of people having a paid job.

### 2.2.1 *Population growth*

*definition:*

This sub-model calculates the population growth in St. Lucia. The population is growing exponentially as the result of births, deaths and migrations. The mortality rate and migration rate both have a structural component and an economic component. The structural component expresses the long term structural change which is valid for St. Lucia or the larger region of which it is part. It represents long term trends set in motion as a result of family planning policies, education, health care programs, etc. It reflects for instance improving (or worsening) living conditions that gradually penetrate the area (and affect the mortality rate), traditional migration trends and general evolution of the well-being of the neighbouring countries (which affect the migration flows). Grafted on this is a socio-economic component expressing improved living conditions and economic prosperity in St. Lucia itself.

*mathematical formulation:*

$$bb_t = f_b(t)$$

$$dd_t = f_d(t) \frac{[1 + \exp(-r3(u_t - u_{t=0}))]}{2}$$

$$mm_t = r4 + \frac{[1 - r5 \exp(u_t - u_{t=0})]}{[1 - r5]} - 1$$

$$\Delta p_t = p_t \times (bb_t - dd_t - mm_t)$$

$$p_{t+1} = p_t + \Delta p_t$$

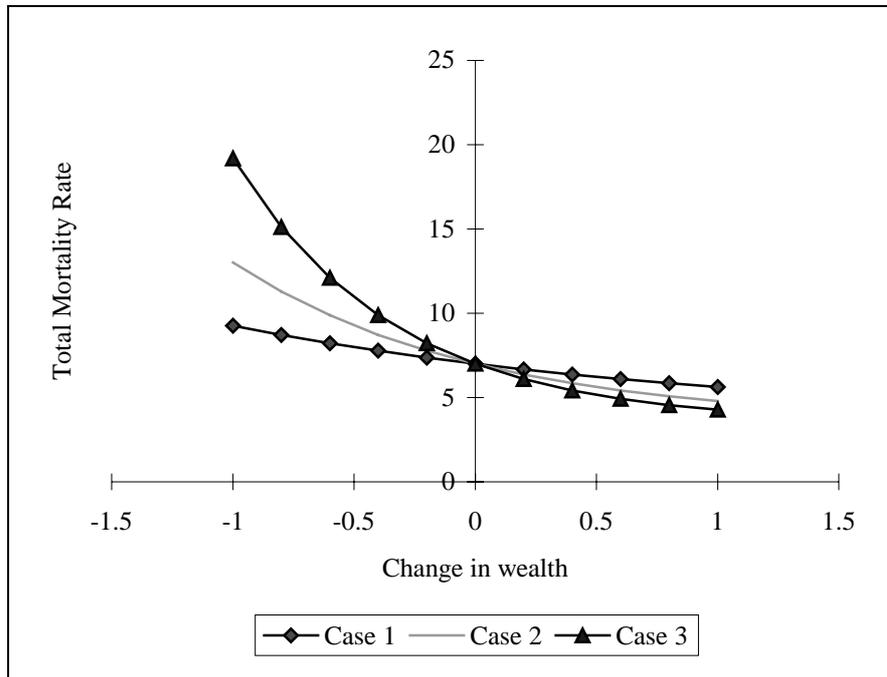
*with:*

$p_t$	Total population; [persons]
$bb_t$	Birth rate; [1/1000]
$dd_t$	Mortality rate; [1/1000]
$mm_t$	Migration rate; [1/1000]
$X_{i,t}$	Vector of sectoral employment; [persons]
$u_t$	Wealth or employment participation rate; []
$f_b(t)$	Structural reproduction rate; [1/1000]
$f_d(t)$	Structural mortality rate; [1/1000]
$r3$	Variable mortality rate; [1/1000]
$r4$	Structural migration rate; [1/1000]
$r5$	Variable migration rate; [1/1000]

*calibration information:*

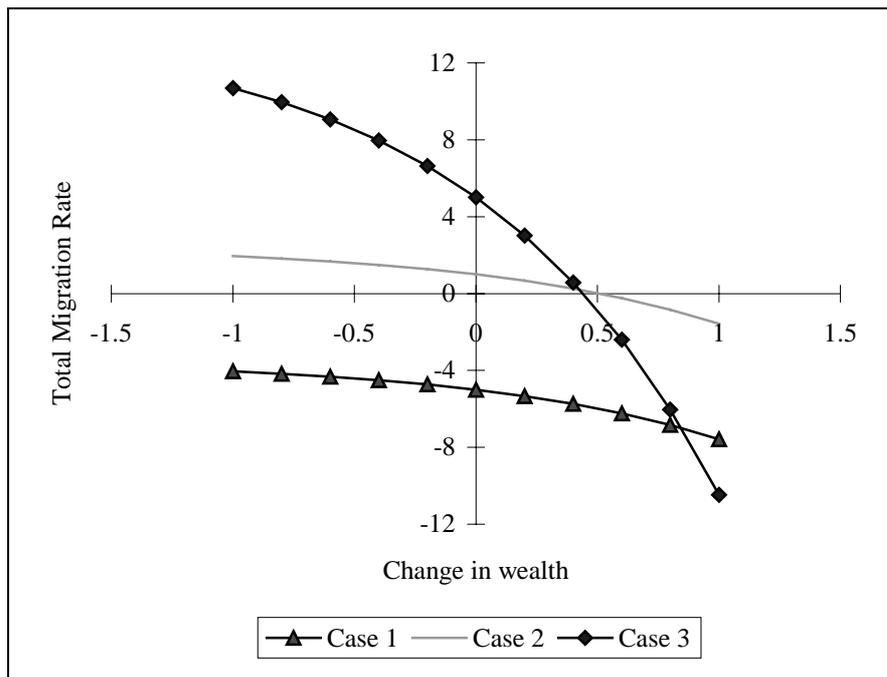
*expression:* 
$$dd_t = f_d(t) \frac{[1 + \exp(-r3(u_t - u_{t=0}))]}{2}$$

The total mortality rate is the sum of a structural component (parameter  $f_d(t)$ ) and a component reflecting the wealth of the population (parameter  $r3$ ). The graph shows different curves for different hypothesis concerning the latter.



	Case 1	Case 2	Case 3
$f_d(t)$	7	7	7
$r3$	0.5	1	1.5

expression: 
$$mm_t = r4 + \frac{[1 - r5 \exp(u_t - u_{t=0})]}{[1 - r5]} - 1$$



	Case 1	Case 2	Case 3
$r4$	-5	1	5
$r5$	0.6	0.6	0.9

Total migration rate is the sum of a structural component (parameter  $r4$ ) and a component reflecting the wealth of the population (parameter  $r5$ ). The figure shows the curves reflecting different cases.

*default values:*

The values used for St. Lucia have been calculated from the Annual Statistics Digest 1991 and personal communications from the Government Statistics Department.

### 2.2.2 Population

*definition:*

In **SIMLUCIA**, the assumption is made that there will be a growing concentration of the population in urban areas. There is however not an expression that will calculate the degree of urbanization on the basis of demographic or economic pressure. Rather, in this version of the model, the proportion of the population living in urban areas is read in as a scenario defined by the user.

*mathematical formulation:*

$$up_t = p_t f_u(t)$$

$$rp_t = p_t \left[ 1 - f_u(t) \right]$$

*with:*

$up_t$	Urban population; [persons]
$rp_t$	Rural population; [persons]
$p_t$	Total population; [persons]
$f_u(t)$	Proportion of the population living in urban areas; [%]

*default values:*

In the model the assumption is made that a growing percentage of the population of St. Lucia will be living in urban areas in the next 40 years. In 1990, the urban population was estimated (from the population statistics) to be 36.1 %, and the hypothesis is made that this proportion will increase to a value of 54.01 % in 2030.

### 2.2.3 Wealth

*definition:*

The social well-being is expressed as the employment participation rate, meaning the proportion of people having a paid job.

*mathematical formulation:*

$$u_t = \frac{\sum_i X_{i,t}}{p_t}$$

*with:*

$u_t$	Wealth or employment participation rate; [%]
$p_t$	Total population; [persons]
$X_{i,t}$	Vector of sectoral employment; [persons]

### 2.3. *The Economic sub-system*

The economy of St. Lucia is modelled by means of a highly aggregated input-output model which is coupled to the demographic sub-model. The input-output model describes the economy of the island as a set of linear equations. We use the input-output model in a quasi dynamic manner by evaluating it at each iteration: at each time step and for each economic sector new demand, generated externally or internally by the population and the economic sectors, is translated into new job opportunities and changed needs for imports. We have chosen to model the economic sub-system by means of an input-output model because of its representation of the interdependencies between economic sectors, and the way it integrates imports and final demands. Hence it describes well the economic multiplier effects and will show how changes in one economic sector will propagate throughout the whole economy. The input-output model used is of a type in which the technical coefficients do not change over time (non dynamic). This means that it is assumed that the economic mix does not change significantly in the period for which the model is applied. This is a very weak hypothesis, certainly for long term modelling and for economies which are highly technical in nature and where technological innovations and substitutions are very frequent (which has not been the case for St. Lucia in the past). In principle the model will have to be re-calibrated (that is the technical coefficients need to be recalculated) every time substitution has taken place. Else, the numbers generated have to be interpreted bearing in mind the fact that the model assumes constant input and output characteristics for each type of activity. Despite the many deficiencies of this type of model, it is one of the most widespread techniques to describe an economy and many national or regional planning and statistics agencies will use it (Richardson, 1978). Hence very often data for the model will be readily available.

*mathematical formulation:*

$$\Delta Y_{i,t} = \Delta Dom_{i,t} + \Delta E_{i,t}$$

$$Y_{i,t} = Y_{i,t-1} + \Delta Y_{i,t}$$

$$\Delta S_{i,t} = \sum_j A_{i,j} \Delta S_{j,t-1} + \Delta Y_{i,t}$$

$$S_{i,t} = S_{i,t-1} + \Delta S_{i,t}$$

$$\Delta M_{i,t} = I_i \times \Delta S_{i,t}$$

$$M_{i,t} = M_{i,t-1} + \Delta M_{i,t}$$

$$\Delta X_{i,t} = \frac{\Delta S_{i,t}}{B_i}$$

*with:*

$S_{i,t}$  Vector of total sectoral outputs; [million EC\$]

$Y_{i,t}$  Vector of final demands (domestic + external demand); [million EC\$]

$X_{i,t}$  Vector of sectoral employment; [million EC\$]

$M_{i,t}$  Vector of sectoral imports; [million EC\$]

$Dom_{i,t}$	Vector of sectoral domestic demands; [million EC\$]
$E_{i,t}$	Vector of sectoral external demands; [million EC\$]
$A_{i,j}$	Matrix of technical coefficients for endogenous sectors; []
$I_1$	Vector of import coefficients; [million EC\$]

*calibration information:*

Since no input-output model for the base year 1990 was available in St. Lucia, we have estimated a simplified 5-sector input output table on the basis of the following:

- Ministry of Agriculture, Lands, Fisheries and Forestry: Annual Agricultural Statistics Digest 1992
- Government Statistics Department: National Accounts 1977 to 1992
- Government Statistics Department: Annual Statistical Digest 1991
- St. Lucia Tourist Board: Selected Tourism Statistics
- St. Lucia Tourist Board: St. Lucia Stay Over Visitors Survey – Summer 1995

A detailed description of the estimation procedure can be found in Annex B of this report.

### 2.3.1 External demand

*definition:*

The external demand per sector is defined as an externally provided time series. The time series per sector are to be derived from the long term economic forecasts and calculated under conditions of no climate change. If such forecasts are not available, the time series reflect best estimates, hypotheses or scenarios entered by the user.

*mathematical formulation:*

$$e_{i,t} = f_e(t)$$

*with:*

$e_{i,t}$  Vector of projected external demands ceteris paribus; [million EC\$]

*calibration information:*

Detailed long term economic forecasts per sector were not available in St. Lucia. The time series entered for the different economic sectors are pure hypotheses. They reflect a transition from an agriculture and tourism based economy towards a more industry and services based economy.

### 2.3.2 Domestic demand

*definition:*

This sub-model calculates the domestic demand as the product of the consumption per head of goods from each economic sector and the total population. The consumption per head varies as a function of the level of wealth, thus expressing the fact that people spend a larger proportion of their total budget on elementary goods (food) when the level of wealth decreases.

*mathematical formulation:*

$$\Delta Dom_{i,t} = C_i \times \exp(n_i \times (u_t - u_{t=0})) \times \Delta p_t$$

*with:*

$Dom_{i,t}$	Vector of sectoral domestic demands; [million EC\$]
$u_t$	Wealth or employment participation rate; [%]
$p_t$	Total population; [persons]
$C_i$	Vector of sectoral domestic demand coefficients; [million EC\$]
$n_i$	Vector of influences of wealth on domestic consumption; [million EC\$]

*calibration information:*

In order to estimate the effect of wealth on the consumption behaviour of people, a detailed survey is required. Such a survey was not available. As a result, no effect of wealth on the consumption behaviour is assumed ( $n_i = 0$  for all economic sectors)

### 2.3.3 Jobs

*definition:*

This MBB calculates the number of jobs in each sector as the labour input in the economy divided by the cost per job.

*mathematical formulation:*

$$\Delta X_{i,t} = \frac{\Delta S_{i,t}}{B_i}$$

$$X_{i,t} = X_{i,t-1} + \Delta X_{i,t}$$

*with):*

$X_{i,t}$	Vector of sectoral employment; [persons]
$S_{i,t}$	Vector of total sectoral outputs; [million EC\$]
$B_i$	Vector of employment coefficients; [million EC\$ / person]

*calibration information:*

See Annex B

## 2.4. Land density calculation

Newly born people or immigrants require space to live. Similarly, new jobs require suitable land for the associated production activities. Thus, new people and new jobs in each sector are translated into residential and sectoral demands for land, using current levels of land density. Land density is defined as the number of people who can live or work on 1 spatial unit (cell or ha). It varies in time as a function of the pressure on the land and the marginality of the land.

### 2.4.1 Socio-economic land demand

*definition:*

In the land density expression, land is treated as a Ricardian scarcity or a relatively scarce resource (Barbier, 1989). For each type of land-use --economic and residential-- and at each time step, land density is calculated. The suitability of the land will influence the spatial extension of economic or residential land-uses via two mechanisms. The first is the pressure on the land, which is an expression of the fact that with good land getting scarce activities will try to occupy less land to produce the same amount of

economic output. Pressure on land is defined as the amount of suitable land occupied by a sector as a proportion of the total suitable land available for that sector. The latter is the suitable land already taken in by the activity and land in the ‘Natural’ and ‘Forest’ state. The second mechanism concerns the marginality of the land, expressing the fact that as good land is getting scarce, activities will have to occupy less adequate --or more marginal-- locations and hence more land is required to obtain the same amount of output. The marginality of the land is the average suitability of the land occupied by the sector. The combined effect of both mechanisms is reflected in the land density calculation.

*mathematical formulation:*

$$W_{i,0} = \frac{X_{i,0}}{N_{i,0}}$$

$$W_{i,t} = W_{i,0} \left( \begin{array}{cc} SS_{i,t} & TS_{i,0} \\ TS_{i,t} & SS_{i,0} \end{array} \right)^{\sigma_i} \left( \begin{array}{cc} SS_{i,t} & N_{i,0} \\ N_{i,t} & SS_{i,0} \end{array} \right)^{\zeta_i}$$

*with:*

	the subscript $i$ includes the sector ‘residential’ otherwise represented as $p$
$W_{i,t}$	Vector of land densities; [persons /cell]
$SS_{i,t}$	Vector of suitabilities summed over the cells occupied by the activity; []
$TS_{i,t}$	Vector of suitabilities summed over all ‘Natural’ and ‘Forest’ cells; []
$N_{i,t}$	Vector of total cells required; [cells]
$X_{i,0}$	Vector of sectoral employment, including the sector residential; [persons]
$\sigma_i$	vector of sectoral sensitivities to land pressure; []
$\zeta_i$	vector of sectoral sensitivities to land quality (marginality); []

*Calibration information:*

In the model, the initial values for the land density ( $W_{i,0}$ ) are calculated from the land use map (to calculate the total amount of land taken in by each activity) and the data from the demographic and the economic sub-model. If the user changes the original land use map, the population or economic data, the model will automatically adjust the initial land densities. The parameters  $\sigma_i$  and  $\zeta_i$  have been calibrated based on data obtained from (personal communications) the Ministry of Agriculture (minimum and maximum area of farm and estate land per person employed) and the Ministry of Tourism (minimum and maximum hotel area per person employed).

## 2.4.2 Land use

*definition:*

The total demand for land is calculated as the total amount of jobs or residents that have to be allocated at a given density. These demands for land are then passed onto the Micro-level model for allocation on the basis of short range interaction mechanisms and environmental factors reflected in the suitability maps.

*mathematical formulation:*

$$N_{i,t} = \frac{X_{i,t}}{W_{i,t}}$$

$$N_{p,t} = \frac{P_t}{W_{p,t}}$$

with:

$N_{i,t}$  Vector of sectoral total cells required; [cells]

$P_t$  Total population; [persons]

$X_{i,t}$  Vector of sectoral employment; [persons]

$W_{i,t}$  Vector of land densities; [persons/cell]

## 2.5. *SIMLUCIA: an integrated model*

Although the sub-systems have been dealt with separately, they are strongly inter-linked with one another via the feedback loops that are built into the model. The most essential of these are shown in Figure 2. This scheme allows to follow through the calculations that the model performs at each simulation time step. It also allows to reason in a qualitative manner about direct and indirect impacts of climate change on the island. As an example of this, one can follow through the following chain of effects: (interpret the symbol ‘→’ as ‘this will have an effect on’): imagine a temperature rise of 2°C and sea level rise of 10 cm by 2025 → the external demand for tourism, namely: a drop in number of tourists → the total demand for hotel facilities and services → construction and maintenance of hotels, the creation of new services and the number of jobs (in the tourism and construction sector) → jobs → wealth → mortality and migration rates (e.g. a drop in the number of jobs in the tourist sector leads to higher unemployment rates, which influences people’s decision to migrate out, leading to a decreasing total population, which in turn decreases the amount of residential land required). Notice also the loop indicating the natural loss of available land due to the rising sea level.

Due to the globally non-linear character of the model and the high degree of linkage among the variables, the set of equations can not be solved analytically; rather their simultaneous solution is simulated numerically on the computer as a time trajectory for the state of the system.

In summary, in the Macro-level model the growth of the population is a result of long term demographic trends and the economic output. Growth in the different economic sectors is the result of changes in the demands for goods of these sectors. External demand is subject to the effects of climatic change. The density calculation will translate the growth coefficients of each sector in changing demands for land. The allocation of activities to specific locations takes place in the Micro-level of the model. The next chapter will deal with the modelling technique that performs this allocation on the basis of local interaction mechanisms.

### 3. Micro-Level Dynamics

In St. Lucia, like in most other small islands and coastal nations, activities are strongly concentrated in a narrow coastal zone. This results in conflicts of interest and competition for space and causes irrecoverable stress on the unique but fragile terrestrial and marine ecosystems of the coastal zone. Hence, it is very important to have a good understanding of the processes that affect the coastal zone directly but also indirectly. More than this, it is essential to know where the coastal zone will be affected, because socio-economic pressure is never 'average', nor is it 'constant' in time or distributed 'evenly' over the coastal zone. Rather, socio-economic pressure is variable in time and in space as it is the result of the interaction between mobile social and economic agents. Thus, even if we are able to learn from our Macro-level model that a particular economic sector, such as tourism, could be largely affected by changing climatic conditions, that would not tell us where on the island such changes would take place, nor what conflicts it would create with other activities. Clearly, the knowledge as to whether changes will concentrate in one location or another, or will spread out over large parts of the coastal zone is of great importance in estimating the real effects of the development.

#### 3.1. *Cellular Automata models*

At the descriptive level, some of this information can be captured in a Geographical Information System. Dynamic modelling and prediction, however, requires going far beyond the capabilities of a GIS. In our modelling framework, advantage is taken to the extent possible of the functionality offered by GIS, such as: data management, data transformation, data visualisation, cartographic modelling and spatial analysis. On the information rich GIS data-layers dynamic socio-economic and socio-environmental models are built that treat space as consisting of a two-dimensional matrix of small cells. On this grid we develop a Constrained Cellular Automata model representing the land use dynamics of the island.

Cellular Automata can be thought of as very simple dynamic spatial systems in which the state of each cell in an array depends on the previous state of the cells within a neighbourhood of the cell, according to a set of state transition rules. Because the system is discrete and iterative, and involves interactions only within local regions rather than between all pairs of cells, a Cellular Automaton is very efficient computationally. It is thus possible to work with grids containing tens of thousands of cells. The very fine spatial resolution that can be attained is an important advantage when modelling land use dynamics, especially for planning applications, since spatial detail represents the actual local features that people in a city experience, and that planners must deal with.

A cellular automaton consists of (Langton, 1986):

1. an *Euclidean space* (two-dimensional in our application) divided up into an array of *identical cells*;
2. each cell is surrounded by a *neighbourhood* of the same size and geometrical shape,
3. each cell is in one of *n discrete possible states* (land-uses in our application),

4. *transition rule(s)*, possibly of a hierarchical nature, describe the new state of a cell as a function of its own state and the state of the cells in its neighbourhood,
5. time progresses uniformly, and at each *discrete time step*, all cells simultaneously change state as defined in the transition rule(s).

In purely practical terms the cellular model will calculate how land use is changing from year to year. To that end it will perform a calculation for each cell of the grid. This calculation will be done within the neighbourhood of the cell, which consists of a circular neighbourhood covering the 196 cells that are nearest to the cell. The calculation will look primarily at the types of land use present in the neighbourhood and will estimate on that basis what the best use of the cell would be given the composition of its neighbourhood. In addition, and for the cell proper, it will take into account its suitability to support a specific land use and its position relative to the road network, to estimate whether the cell should be taken in one or the other land use.

Although Tobler (1979) called cellular automata ‘geographical models’, they have hardly been used for modelling socio-economic phenomena. They have been applied more extensively to model spatial flow and diffusion processes: surface and sub-surface water flows, forest fires, and starfish outbreaks (Bradbury et al. 1990).

The approach has several advantages in the study of spatial phenomena. In the context of this report we mention:

1. Cellular automata allow extreme spatial detail.
2. They tend to produce complex (Wolfram, 1986; Langton, 1986) and frequently fractal patterns.
3. They show, at least at the functional level, apparent similarities with the overlay analysis known in GIS (Tomlin and Berry, 1979) and their (conceptual and technical) linkage with GIS is feasible.
4. Expanding on the previous point, the approach permits a straightforward integration of physical and environmental qualities in economic and social modelling; in contrast, practically all regional models currently postulate uniform background conditions. This integration of socio-economic and environmental variables is certainly of major importance in our modelling exercise.
5. Building a cellular automaton model and calibrating it are done in one and the same process. They are both accomplished with the definition of the correct rules for the transition functions.

### 3.2. *A Cellular Automata model for St. Lucia*

For the application to St. Lucia, the Cellular Automata model is specified as follows:

1. St. Lucia and its surrounding coastal waters is represented by means of a matrix of 186 (N-S) rows by 121 (E-W) columns and 22,506 cells. A cell size of 250 m has been chosen. This size represents well the actual plot sizes for tourism, industrial, service and residential land use. However, a cell size of 250 m is hardly detailed enough to represent well the relief of St. Lucia. This relief is typified by very strong changes in elevation over very short horizontal distances. Due to the grid representation, only one elevation reading per cell is possible; in general an average for the whole cell. This has in particular an effect on the representation of the sharp peaks (such as both Pitons) and the beaches, which in general cover an area smaller than 250 by 250 m. Peaks, get an elevation which is lower and beaches an elevation which is higher than their real elevation. Since the calculation of sea level rise is directly related to the elevation of coastal cells, one should be careful in interpreting

the amount of land that is really at risk. Also the representation of the (remnants of) mangrove areas is difficult in this type of grids.

2. Each cell is in one of 15 states ( $y$ ), each representing a land-use (including natural land-cover and sea). We distinguish between the state variables for which the Macro-level model calculates the changes:
  - (1) natural vegetation (mainly bush);
  - (2) forest (mainly secondary forest);
  - (3) agriculture;
  - (4) industry and quarries;
  - (5) trade and services;
  - (6) tourism;
  - (7) rural residential;
  - (8) urban residential;

and a number of additional land-uses for which (at this moment) the Macro-scale model is not calculating growth coefficients:

- (9) forest reserve,
  - (10) mangroves
  - (11) sea,
  - (12) beach,
  - (13) coral reef,
  - (14) terminals, ports, airports, etc.,
  - (15) infrastructure, water, electricity.
3. The geographical (physical, environmental, institutional, infrastructural, ...) characteristics of St. Lucia are represented in the relief map, the suitability maps, and the (road network) accessibility maps.
  4. The fate of a cell at each iteration depends on the state of the cell itself and the cells in its Cellular Automata neighbourhood. The neighbourhood consists of 196 cells, each of which falls within one of 30 discrete distance categories (see Figure 5).
  5. The net number of cells  $T_z$  required by each economic or residential function  $z$  at each time step is determined by the land density calculation in the Macro-level model. It is imposed upon the Cellular Automaton model as a constraint.

The Cellular Automata transition rules that decide on the fate of a cell are ranked hierarchically according to the priority with which they are applied. There are 3 priority-levels:

Rules of **priority 1** are the user interventions. They reflect decisions imposed on the system by the user (and invoked by means of one of the editors that the user has at his disposition). They include interventions such as imposing a land-use on a specific cell (e.g. extension of the airport), man-made levelling-up of the land (in the relief map), investment and infrastructure works to change the suitability or the accessibility of a cell, etc. These rules are typically limited to the cell itself (neighbourhood of only 1 cell), they apply only once (for one time step). A rule of priority 1 overrules all other possible changes made by rules of priority 2 or 3.

Rules of **priority 2** are rules related to the elevation of a cell above sea level. These rules govern largely the evolution of the additional land-uses (Beach area, Mangrove area, Natural land and Sea) in the cellular model. These rules are as follows:

A cell is or will change to 'Sea' ( $Z_{sea}$ ) if its elevation ( $h$ ) is below sea level ( $h < 0$ ). All the other cells (elevation above sea level:  $h > 0$ ) are 'Land' ( $Z_{land}$ ). A land cell ( $Z_{land}$ ) with an elevation not higher than 0.5 meter ( $h \leq 0.5$ ) is or will change to 'Mangrove'

( $Z_{mangrove}$ ) if it has among its 8 nearest neighbours ( $N8$ ) more mangrove cells than beach cells. Otherwise it is or will change to 'Beach' ( $Z_{beach}$ ). A land cell with an elevation above 0.5 meter ( $h > 0.5$ ) is or will change to 'Natural' ( $Z_{natural}$ ) or to 'Forest' ( $Z_{forest}$ ) and will change further subject to rules of priority 3 (Equation 1). The choice between 'Natural' and 'Forest' is determined on the basis of the suitabilities of the cell. If the suitability for 'Forest' ( $S_{forest}$ ) is higher than the suitability for 'Natural' ( $S_{natural}$ ), the cell will become 'Natural', if not it will become 'Forest':

$$\begin{aligned}
 & \text{if } (h < 0) \text{ then } Z_{sea} \\
 & \text{if } (0 \leq h < 0.5) \text{ then } \left[ \text{if } \left( \sum_{N8} Z_{mangrove} > \sum_{N8} Z_{beach} \right) \text{ then } Z_{mangrove} \text{ else } Z_{beach} \right] \\
 & \text{if } (h \geq 0.5) \text{ then } \left[ \text{if } (S_{forest} > S_{natural}) \text{ then } Z_{forest} \text{ else } Z_{natural} \right]
 \end{aligned}$$

The changes in the sea level not only alter the actual land-use of a cell, but also affect its suitability values. In the model the suitability values for cells that rise above sea level can be set by the user in the 'Land loss' dialog. The default values are given in the table below (which is a screen dump of the Land loss-dialog).

	from sea or coral to		from beach to		from mangroves to	
	beach	mangroves	natural veg.	forest	natural veg.	forest
natural vegetation	1.0	1.0	1.0	0.5	1.0	0.5
agriculture	0.1	0.1	0.5	0.5	0.8	0.8
industry and quarries	0.1	0.1	1.0	1.0	0.1	0.1
trade and services	0.1	0.1	0.5	0.5	0.1	0.1
tourism	0.2	0.1	0.9	0.9	0.1	0.1
rural residential	0.1	0.1	0.9	0.9	0.6	0.6
urban residential	0.1	0.1	0.7	0.7	0.4	0.4
forest	0.5	0.5	0.5	1.0	0.5	1.0

Rules of **priority 3** apply to the 'Natural', 'Forest', 'Agriculture', 'Industry and Quarries', 'Trade and Services', 'Tourism', 'Rural Residential', and 'Urban Residential' cells. Except for 'Natural', and 'Forest' which are the 'no-use' states, these are the land-uses reflecting the state variables of the Macro-scale model. Rules of priority 3 calculate for each cell a transition potential for each activity. The transition potential is an expression of the 'strength' with which a cell is likely to change state to the state for which the transition potential is calculated. Transition potentials are calculated as weighted sums:

$$P_z = f(S_z) \cdot f(A_z) \cdot \sum_d \sum_i (w_{z,y,d} \times I_{d,i}) + \varepsilon_z \quad (\text{eq. 1})$$

- $P_z$  potential for transition to state  $z$ ,  
 $f(S_z)$  function ( $0 \leq f(S_z) \leq 1$ ) expressing the suitability of the cell for activity  $z$ ,  
 $f(A_z)$  function ( $0 \leq f(A_z) \leq 1$ ) expressing the accessibility of the cell for activity  $z$ ,

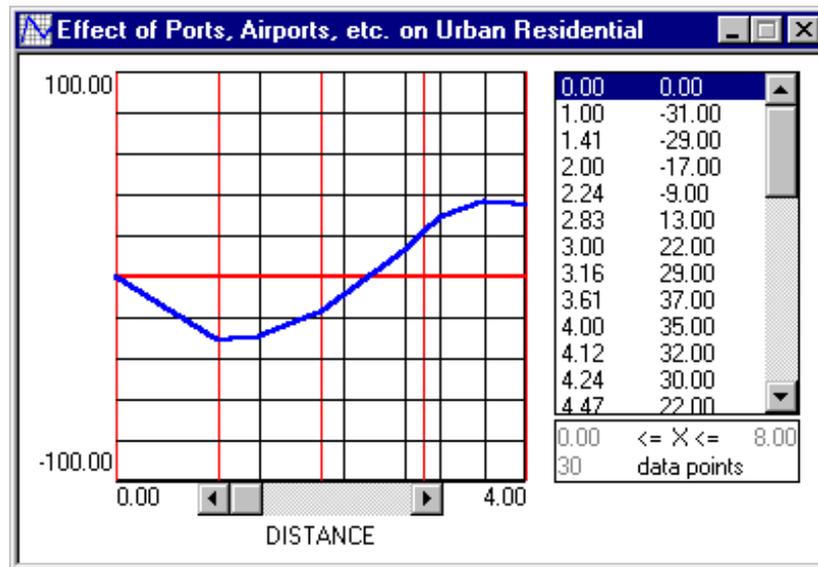
$$f(S_z) = S_z; \text{ if } \sum_d \sum_i (w_{z,y,d} \times I_{d,i}) > 0 \quad (\text{eq. 2})$$

$$f(S_z) = (1 - S_z); \text{ if } \sum_d \sum_i (w_{z,y,d} \times I_{d,i}) < 0 \quad (\text{eq. 3})$$

- $w_{z,y,d}$  is the weighting parameter applied to cells with state  $y$  in distance zone  $d$  ( $0 \leq d \leq 30$ ),
- $i$  is the index of cells within a given distance zone  $d$
- $I_{d,i} = 1$  if the state of cell  $i$  in distance zone  $d = y$ ,
- $I_{d,i} = 0$  if the state of cell  $i$  in distance zone  $d \neq y$ ,
- $\varepsilon_z$  is a stochastic disturbance term.

Thus, cells within the neighbourhood are weighted differently depending on their state  $y$  and also depending on their distance  $d$  from the centre cell for which the neighbourhood is defined. Since different parameters can be specified for different distance zones, it is possible to build in weighting functions that have distance decay properties similar to those of traditional spatial interaction equations. To reflect the unknown factors in location decisions, the deterministic transition potentials are subjected to a stochastic perturbation,  $\varepsilon_z$ .

$$\varepsilon_z = 1 + [-\ln(\text{rand})]^a$$



**Figure 4:** A function editor is used to click-in the weighting parameters of the transition expression (eq.1). The graph shows the influence of the proximity of ‘Terminals, Ports, Airports, etc.’ in the possible transition of a cell to ‘Urban Residential’.

The Cellular Automata transition functions will be entered graphically by means of a tool, mainly consisting of an X-Y graph, in which the user can draw, by mouse-clicking, the distance decay function defining the weight coefficients used in the calculation of the probability for transition to any type of land-use. Figure 4 shows the tool used. Negative values express push factors or repulsion effects, and positive numbers express pull factors or attraction effects. Transition weight coefficients are relative numbers. This is true for weights defined within one transition function as well as across functions and land-uses. For example in the transition pair of Figure 4, a value -9 on the ordinate at  $d = 2.24$  has to be read as 4.11 times less important than +37 at  $d = 3.61$ . Furthermore it represents a repulsion rather than an attraction effect. Both values represent the total weight accorded to the whole distance ring. Hence, the weight of -9 is the total weight of the 8 cells of ring 5 (the centre cell is distance ring 1), while the value +37 is the total importance of distance ring 9 and spread over the 8 cells (see Figure 5). The

neighbourhood of the cellular automaton incorporates 197 cells, including the centre cell. All cells of the neighbourhood are in 1 of 30 distance rings between 0 and 8 cell diameters away from the centre.

To select the  $T_z$  cells to receive the function  $z$  at each iteration, the potentials calculated for all cells for transition to all states are ranked from highest to lowest. Starting with the highest value from this list, the  $T_z$  cells with highest potentials for transition to each state  $z$  are identified and the transitions are executed. Hence, a cell will change to the state for which its potential is highest, unless it is not among the  $T_z$  highest potentials in which case it might change to a state  $z'$  for which its potential ranks second, and so forth. All the cells for which potentials are not among the  $T_z$  highest for any of the  $z$  states will remain in or return to the 'Natural' or 'Forest' state.

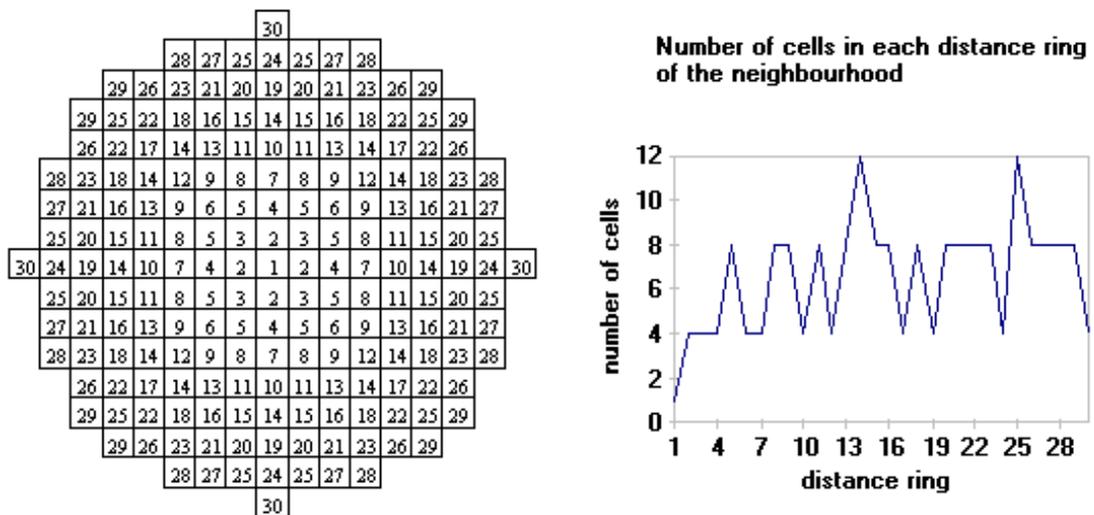


Figure 5: Left: all cells in the Cellular Automata neighbourhood are in 1 of 30 distance rings. Right: Number of cells in each of the 30 distance rings.

### 3.3. GIS information in SIMLUCIA

In addition to the neighbourhood calculation, the transition potentials take also into consideration the intrinsic suitability of a cell as well as its accessibility.

#### 3.3.1 The Suitability Calculation

The suitability  $f(S_z)$  of a cell is a measure of the capacity of that cell to support the activity (land use) of type  $z$ . Suitability calculations are rather standard operations in GIS. It is a composite measure, a weighted sum or product, of a series of physical, environmental, and institutional characteristics (called factors) of each cell. Factors are unique characteristics of a cell, such as: its topography, its quality of soil, its rainfall, its sensitivity to erosion, its planning regulations, its legal restrictions on land use, etc. Most advanced GIS packages have overlay analysis or cartographic modelling techniques (see e.g. Wright, 1990) available to perform the calculations required to produce suitability maps. In SIMLUCIA, the suitability calculations have been performed by means of IDRISI. The data and the macros required to perform the calculation, are available on the SIMLUCIA diskettes. For the calculation of the suitabilities the following factor maps have been retained:

- (1) RELUSE.IMG Land use and vegetation (Atlas of St. Lucia 1/50.000)

- (2) LANDUSE.IMG Land use in 1990 (Atlas of St. Lucia 1/50.000; Topographic sheets of St. Lucia 1/25.000; St. Lucia Tourist Map, Ordnance Survey 1/50.000; Map established as part of UNDP project STL/001/86 National Physical Development Strategy, 1/25.000; Personal observations)
- (3) ELEVAT.IMG Elevation (Topographic sheets of St. Lucia 1/25.000, St. Lucia Tourist Map, Ordnance Survey 1/50.000; Imray-lolaire Yachting Chart of St. Lucia, 1/72.000)
- (4) SLOPEC.IMG Slopes (calculated from (3))
- (5) RELZONE.IMG Life zones (Atlas of St. Lucia, 1/50.000)
- (6) RELDIS.IMG Land Tenure (Atlas of St. Lucia, 1/50.000)
- (7) RELCAP.IMG Land Capability (Atlas of St. Lucia, 1/50.000)
- (8) RSURFACE.IMG Rainfall (Atlas of St. Lucia, 1/50.000)

Variations within a factor, such as the degrees of slope, land capability classes, etc. are referred to as factor types. A factor map is a map showing the geographical location and distribution of factor types for a given factor. Factor maps can be combined in various ways to generate a composite map depicting the relative capability of a cell to support a specific land use. The technique used in **SIMLUCIA** is known as 'linear combination'. It is a common factor combination technique, which requires the analyst to define both a rating table and a weighting table. The rating table depicts the relative suitability of the various types within a factor. For example, slopes greater than 20% are rated 0, between 10% and 20% are rated 5, and less than 10% are rated 10. The weighting table depicts the relative importance of the various factors in determining the overall suitability of the cell. For example, slope might be twice as important as the depth of the bedrock. The ratings for each type are multiplied by the weight for each factor and the result is summed. In **SIMLUCIA**, the suitability values are further normalised in order to obtain suitability values that are in the range 0-10 for all suitability maps.

The table in Annex C is a Microsoft Excel Workbook named SimLucia.XLS, containing the 8 factors that have been retained for the calculation of the suitability maps for each land use function of the Cellular Automata model. The rows of the table represent the types within the factors, and the columns represent the land use functions of the model. The values in the table, are the factor type ratings. For example, row 58, column D contains a rating of 8 (In **SIMLUCIA** we work with values in the range 0 to 10) for the capacity of a 'Land Capability Class II'-cell to support land use 'Agriculture'.

At the end of the table, there is a section entitled 'Factor Weights'. This section contains the weights accorded to each factor (and to all the types of that factor) in the final weighting of the factors. For example the value 4 in 126, column D, means that Land Capability is considered twice as important as 'Land elevation' (weight 2 in row 130, column D). The values in the workbook SimLucia.XLS can be altered by the user. In addition to the table, it features an Excel Macro, that will generate all the files required to run the IDRISI macro named LucMac.IML. This IDRISI macro, will generate the suitability required to run the model. To that end these maps have to be imported in the model, as explained in the manual in Section 6.1.4.

While the model is running, the suitability values for all cells actually occupied by a particular land use are monitored. Changes in the total and average suitability for each land-use are passed back to the Macro-level and result in further changes in the land density variables. In other words, the detailed land suitabilities and land-use patterns in the Micro-level model have their effect in processes that are modelled at the Macro-level.

The geography at the Micro-level thus affects the global dynamics directly and continually.

The user can view (and edit) the different suitability maps used in **SIMLUCIA**.

### 3.3.2 *The Accessibility Calculation*

The accessibility calculation  $f(A_z)$  of a cell is a measure of the proximity of that cell in relation to the road network. The accessibility calculation takes into consideration the needs of a particular activity to have good road access. It is an expression of the fact that, for example, commercial activities have to be located in the immediate vicinity of a road in order to be commercially viable, while quarries can be located further away from the road (if need be a dirt track will be constructed to allow trucks to come and get the materials mined).

The accessibility for activity (land use)  $z$  in a cell is calculated by means of the equation:

$$A_z = \frac{1}{\left(1 + \frac{D}{a_z}\right)}$$

$D$  is the Euclidean distance from the cell to the nearest cell on the road network and  $a_z$  is the coefficient expressing the importance of good road access for activity  $z$ . This equation will return accessibility values that are in the range (0-1).

The user can view the accessibility maps for each activity in **SIMLUCIA**. He can also change (Edit Menu, when the Network map is shown) the values for  $a_z$  to evaluate the importance of good access for different types of land use. Finally, when selecting the Network map, he can draw new roads or erase existing ones.

## 4. Installing SIMLUCIA

This chapter explains how to install **SIMLUCIA** on your computer and how to start up the program. It also describes the main features of the user interface.

### 4.1. *What is included in the SIMLUCIA package ?*

This package consists of this printed document and two 1.44 Mb diskettes labelled *SIMLUCIA disk 1/2* and *SIMLUCIA disk 2/2*. On *SIMLUCIA disk 1/2* you will find a series of compressed files and 1 executable Setup.EXE that is used to install **SIMLUCIA**.

### 4.2. *Installing SIMLUCIA*

This section reviews the hardware and software requirements for running **SIMLUCIA** and describes the steps to install it.

### 4.3. *Hard- and Software Requirements*

**SIMLUCIA** runs on personal computers equipped with an Intel 80486 or Pentium processor. To use the **SIMLUCIA**, your computer should have the following hardware components:

- At least 8 Mb of RAM (16Mb recommended)
- A hard disk with at least 4 Mb free (for **SIMLUCIA** only)
- A SVGA video card and screen (recommended: resolution 1024\*768 pixels, 16 colours, size 17 inch or more)

To run the applications, macro's and exercises, which we describe and provide the files for on the demo diskettes, you should have the following software packages installed on your computer:

- Microsoft® Windows 95© (or Windows 3.1x with Win32 version 1.3 extension)
- Microsoft® Excel (version 6.0)© (optional)
- IDRISI for Windows© (version 2.0 or later) (optional)

### 4.4. *Installation procedure for Windows 95*

The following is a description of the step by step installation of **SIMLUCIA**. The installation/un-installation of **SIMLUCIA** follows the standard for Windows 95. If your

operating system is Windows 3.x then move immediately on to Section 4.5 Installation procedure for Windows 3.x.

If you have a previous version of **SIMLUCIA** software installed on your machine, it is better to un-install it first. If you want to keep it though, make sure to put **SIMLUCIA** in a separate distinct directory. During the installation you may encounter a message asking you whether to keep certain files or replacing them. It is preferred to replace them for the use of **SIMLUCIA**. Keeping the old ones may cause malfunctioning of the software.

- 1 Start Microsoft Windows 95.
- 2 Insert the disk labelled "**SIMLUCIA disk 1/2**" into the drive.
- 3 Click the **Start** button in the Windows 95 Task bar. Move the mouse pointer to the **Settings** command and move on to select the **Control Panel** option. As a result the **Control Panel** Dialog box will open. Select from the list the **Add/Remove Programs** by double clicking it. Next click the **Install** button in the **Install/Uninstall** view of the **Add/Remove Programs** Dialog box.
- 4 Next, the Windows 95 installation program will be started and will request you to click the Next button until (1) the program has selected your disk drive as the installation medium, and (2) until it will have found on the diskette the **Setup.EXE** program for **SIMLUCIA**. Then, the command line "**a:\setup.EXE**" will appear in the edit field of the install window. Hit Finish to have the program continue the installation.
- 5 Continue clicking "Next" until the "**Read Me**" screen appears. Make sure to read this page. After clicking "Next" again, a second dialog box appears asking you where to install **SIMLUCIA**. You can accept the default path which is "**c:\SIMLUCIA**" or replace it in the edit box by one of your choice. You may use the "Browse" button to select this path as well.
- 6 To go on, press the "**Next**" button. Otherwise to cancel the installation process, press the "**Cancel**" button. **SIMLUCIA** will ask whether you use Windows 95 or Windows 3.x. Select **Simlucia for Windows 95**. If your PC is equipped with Windows 3.x, then follow the instructions in Section 4.5.
- 7 Next the installation program suggests to add **SIMLUCIA** to the new Program Group **SIMLUCIA**. You are free to create another Group or to choose an existing one from the list shown.
- 8 From that moment the installation application is decompressing the necessary files and puts them in the directory structure of **SIMLUCIA**. At a certain point in time you will be asked to insert disk #2 in the drive. Insert at that moment the disk labelled "**SIMLUCIA disk 2/2**".
- 9 If everything went OK, a last dialog box will inform you about the fact that the installation is finished. Once the installation on the hard disk is completed, the program creates a group named "**SIMLUCIA**" under the Start button and Programs command. It contains an item labelled "**SIMLUCIA**". When you double click this item, **SIMLUCIA** will be started and the "About" window will appear. Click "OK" to enter the Application Window.

#### **4.5** *Installation procedure for Windows 3.x*

If you have a previous version of **SIMLUCIA** software installed on your machine, it is better to un-install it first. If you want to keep it though, make sure to put **SIMLUCIA** in a separate distinct directory. During the installation you may encounter a message asking

you whether to keep certain files or replacing them. It is preferred to replace them for the use of **SIMLUCIA**. Keeping the old ones may cause malfunctioning of the software.

#### **4.5.1 *Running SIMLUCIA under Microsoft Windows 3.1x***

**SIMLUCIA** has been developed to run under Microsoft Windows 95. However, it is possible to run it under Windows 3.1x as well. In order to do so, you need to install Microsoft Win32s version 1.3.

Microsoft Win32s is an extension of the operating system that allows Win32 applications for Microsoft Windows NT and Microsoft Windows 95 to run on Microsoft Windows version 3.1x and Microsoft Windows for Workgroups.

You need to have Microsoft Win32s version 1.3 installed on your system **before** you can install **SIMLUCIA**.

If you don't have Microsoft Win32s version 1.3 installed on your computer ask your system administrator to help you installing it.

#### **4.5.2 *How to get Microsoft Win32s version 1.3***

Microsoft Win32s is available from the Microsoft Software Library (MSL) as PW1118.EXE. You can download it via anonymous FTP from Microsoft:

1. C:\ftp ftp.microsoft.com
2. Change to the Softlib/Mslfiles folder
3. Get PW1118.EXE

You can also use the Microsoft Network or the Microsoft Download Service (MSDL).

PW1118.EXE is a self-extracting file containing the Win32s files in a compressed form. To install Win32s from PW1118.EXE:

1. Create a temporary install directory on your computer and copy PW1118.EXE to this directory.
2. Execute PW1118 (by double-clicking PW1118.EXE in the file manager). This decompresses the Win32s files into an installation layout (setup program) in your temporary install directory.
3. Run the Setup program (by double-clicking Setup.EXE). The setup program installs (or upgrades) Win32s and restarts the Windows operating system to update the system files.
4. Delete the temporary install directory and its contents

#### **4.5.3 *Installing SIMLUCIA under Microsoft Windows 3.1x***

It never harms to make a copy of your installation diskettes before starting the installation procedure. If you have a previous version of **SIMLUCIA** software installed on your machine, it is better to un-install it.

The following is a description of the step by step installation of **SIMLUCIA**.

- 1 Start Microsoft Windows.
- 2 Insert the disk labelled "**SIMLUCIA disk 1/2**" into the drive.
- 3 Select File from the Program Manager menu bar and choose the **Run...** command.
- 4 A dialog box appears. Enter "**a:\setup.EXE**" in the edit field. Next, click the **OK** button or press ENTER.

- 5 The screen turns blue and a second dialog box appears asking you where to install **SIMLUCIA**. You can accept the default path which is "C:\SIMLUCIA" or replace it in the edit box by one of your choice.
- 6 To go on, press the "Next" button. Otherwise to cancel the installation process, press the "Cancel" button. When given a choice between installing under Windows 95 or Windows 3.1 choose the latter.
- 7 From that moment the installation application is decompressing the necessary files. At a certain point in time you will be asked to insert disk #2 in the drive. Insert at that moment the disk labelled "SIMLUCIA disk 2/2".
- 8 If everything went OK, a last dialog box will inform you about the fact that the installation is finished. Once the installation on the hard disk is completed, the program creates a group named "SIMLUCIA" in the Program Manager. It contains an item labelled "SIMLUCIA". When you double click this item, **SIMLUCIA** will be started.

#### 4.6. Starting SIMLUCIA

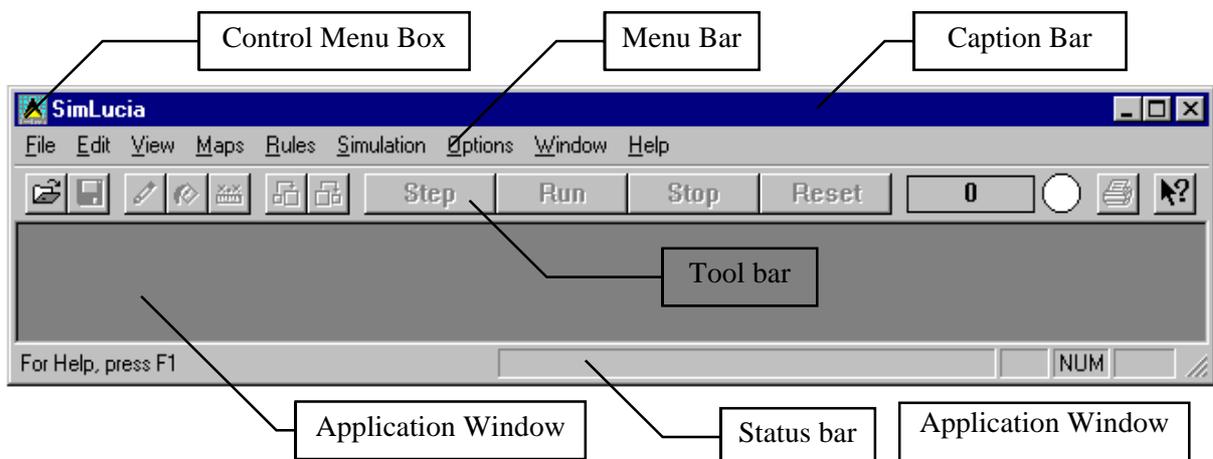
To invoke the complete environment



- 1 Start Microsoft Windows.
- 2 Under the Windows 95 Start button and the Programs group, you will find a group called **SIMLUCIA**. Double-click on the **SIMLUCIA** icon in the **SIMLUCIA** group.
- 3 **SIMLUCIA** will be started and you will see the **SIMLUCIA** Application window on your screen.

#### 4.7. Screen Layout

When you start **SIMLUCIA**, you will enter immediately in the Application Window of the simulation environment. This is the window in which you will run your models. Before a simulation file is opened, the screen is empty except for its top part. Below we will describe the different components of this screen.



#### 4.7.1 The Control Menu Box

The Control Menu box contains the Application Window Control Menu, which controls how windows are arranged on the desktop. The list below summarises the Control Menu Commands.

Use this command	To
<b>R</b> estore	Restore the window to its previous size
<b>M</b> ove	Move the window using the arrow keys.
<b>S</b> ize	Change the size of the window. You can use the mouse or the arrow keys to change the size.
<b>M</b> inimize	Shrink the window to an icon
<b>M</b> aximize	Enlarge the window to the full size of the screen
<b>C</b> lose	Close the application window

#### 4.7.2 The Caption Bar

The Caption Bar, also Title Bar, of the Application Window displays “SIMLUCIA”.



To the left of the Caption Bar three buttons are positioned that enable you to re-size the Application window.

- The Minimize button allows you to shrink the window to an icon (same as Minimize in the Control Menu Box);
- The Maximize button allows you to enlarge the application window to the full size of the screen (same as Maximize in the Control Menu Box);
- The Close button allows you to close the application window, and thus quit the application (same as Close in the Control Menu Box)

#### 4.7.3 The Menu Bar

The Menu Bar of the Application Window contains SIMLUCIA’s main Menu. The commands are logically organised in the menu so that you will quickly become comfortable with the various functions of the program. The menus are summarised in the table below; subsequent chapters elaborate on the description. Chapter 6 gives an overview of all menu commands.

Use this menu	To
<b>F</b> ile	Manage your simulation files. The printing facilities are also located in this menu, and if you want to exit the program, you can do it from here.
<b>E</b> dit	Edit the maps that are part of the Micro-scale model. All commands for editing are located here. Depending on the type of map that is active, the appropriate edit features are listed and accessible.
<b>V</b> iew	Enables to change the way a map is displayed. Commands to zoom in and out as well as commands to display information on the foreground or background of the maps are part of this menu.
<b>M</b> aps	Open a new window with one of the maps of the modelled region.
<b>R</b> ules	Define the model at the Micro-level by means of the Cellular Automata transition rules.
<b>S</b> imulation	To control the simulation. The commands in this menu are the same as the ones represented by means of the buttons in the Tool bar.
<b>O</b> ptions	To customise the workspace. Commands permit among others to display or remove the Status bar and/or Tool bar, and to (DDE) link the simulation package to Excel.
<b>W</b> indow	Manage your windows on the screen
<b>H</b> elp	Invoke the on-line Help facilities.

#### 4.7.4 The Tool bar

The Tool bar, also known as Speed Bar, gives a faster access to some of the more frequently used commands which are also accessible via the menu.



Use this Button	To
	Open a simulation file from the disk.
	Save a simulation file to disk.
	Change the pointer to a pen. The pen is used to pick a value from the legend and enter it in a cell on the map.
	Change the pointer to a bucket. The bucket is used to pick a value from the legend and enter it in larger, contiguous areas on the map.
	Change the pointer to a ruler. The ruler is used to enter detailed information in a cell. When a cell is clicked, a dialog will open to enter the exact value.
	Zoom-in. Increase the size of the map on the display.
	Zoom-out. Decrease the size of the map on the display.
	Advance the simulation with one simulation step.
	Advance the simulation till the next pause is reached (as set with the Pauses ... command).
	Stop the simulation.
	Reset the simulation. State variables of the model and maps take their initial values, parameters keep their actual values.
	To print the Micro-scale dynamics window.
	Access the context sensitive help cursor. The next click action on a command will invoke the context sensitive help on this command.

The Tool bar also displays the simulation clock. Each time step, the clock is updated. The figure indicates the years simulated in the range 0 to 40.

The Tool bar command in the View Menu allows to display or hide the Tool bar in the SIMLUCIA Application Window.

#### 4.7.5 The Status bar

The Status bar is displayed at the bottom of the Application Window. This zone provides information to the user on his actions while he is working with the application. The left area of the status bar describes actions of menu items as you use the mouse or arrow keys to navigate through menus. This area similarly shows messages describing the actions of toolbar buttons when pressed. The right area of the status bar indicates which of the following keys are latched down:

Indication	Description
CAP	The Caps Lock key is latched down.
NUM	The Num Lock key is latched down.
SCRL	The Scroll Lock key is latched down.

The Status bar command from the View Menu allows to display or hide the Status bar in the **SIMLUCIA** Application Window.

#### **4.8. *Getting Help***

**SIMLUCIA** comes with a very concise on-line Help facility. Its structure and operation is in accordance with the Microsoft Help standards. Hence, using Help should pose no problems for those familiar with Windows.

To get Help, press “F1” or the key sequence ALT-H

The Help menu has 3 items:

- 1 “Index” gives an access to the index of the help guide.
- 2 ”Using Help”, gives the general instructions on how to use the Windows Help System.
- 3 “About **SIMLUCIA** ...”, gives information about the copy of the **SIMLUCIA** that you are using.

#### **4.9. *Exiting SIMLUCIA***

Closing **SIMLUCIA** is simply done by selecting the Exit command from the File menu. If you have simulation files open when you select Exit, the application will ask whether you want to save simulation results. If you confirm to be interested in saving results you will get the Save Dialog box. More information on saving simulation results is given in the next chapter.

#### **4.10. *If you experience problems***

If you experience problems in installing or running **SIMLUCIA**, contact:  
Research Institute for Knowledge Systems bv.  
To the attention of **Inge Uljee** or **Guy Engelen**  
P.O. Box 463  
6200 AL Maastricht  
The Netherlands  
Tel: +31 43 388.33.22  
Fax: +31 43 325.31.55  
E-mail: info@riks.nl

## 5. Running SIMLUCIA Simulations

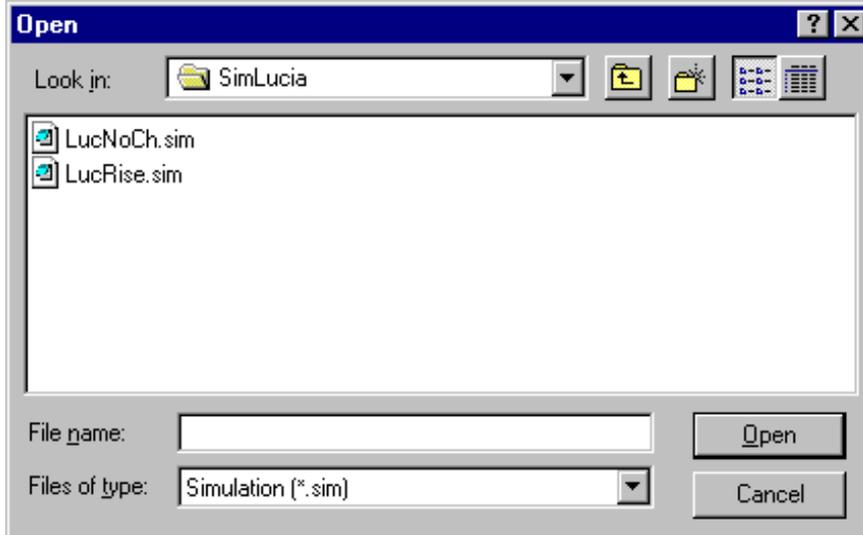
This chapter describes how to run simulations with **SIMLUCIA**. In the previous chapter we explained how to install and run **SIMLUCIA**. We assume from now on that you have read this information, that you have knowledge of the different technical terms introduced, and that you have successfully installed **SIMLUCIA** on your computer.

### 5.1. Running a simulation



Click the Start button in the Windows 95 Task bar and point the cursor to the Programs group. Move through the cascading menu into the **SIMLUCIA** group and open **SIMLUCIA** by clicking the **SIMLUCIA** icon. If the software has been installed successfully, the Application Window will open. Immediately the About Information Window will open. Push the O.K. button (or the **SIMLUCIA** icon) after having read the information and warnings in the About Window. Immediately the Open dialog box will open. If not, push the Open Simulation file button.

Look in the Open dialog box for files with a .SIM extension.



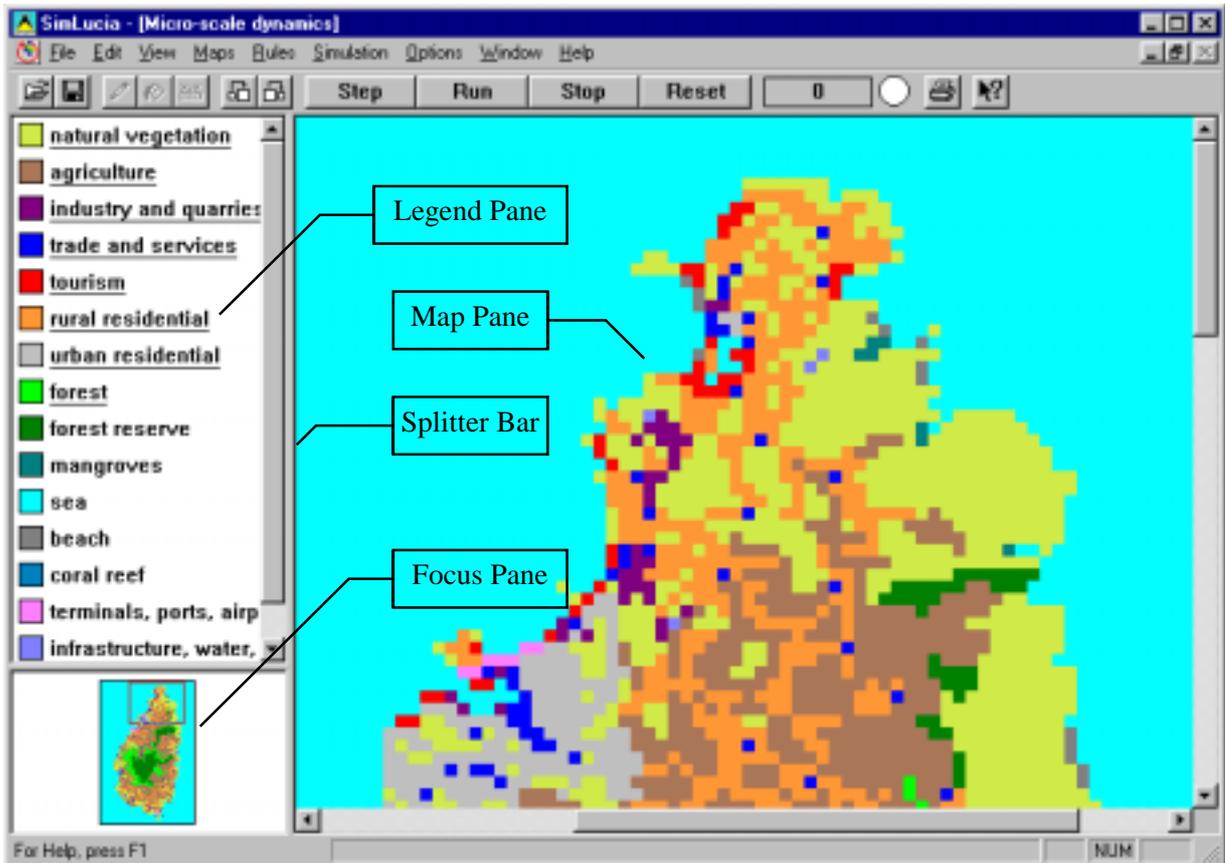
By means of the standard Windows 95 manipulations you can navigate through the directories on your hard disk, or on another computer in the network, in search of the simulation file of your choice. Once the name of the file appears in the Open Dialog Box, select it and press the Open button or double click the file icon.

In fact the .SIM file contains references to all the files that are required to run a model. Later in this chapter we will give more details about the contents and composition of the .SIM files.

Once all files have been loaded, two windows will appear in the Application Window: one titled Micro-scale dynamics and the other Macro-scale dynamics.

### 5.1.1 The Micro-scale dynamics Window

The Micro-scale dynamics Windows is split into 3 viewing areas, called Panes. Panes are separated from one another by means of Splitter Bars. You can displace the Splitter Bars to change the size of the Panes. To this end, position the cursor over the Splitter Bar. The cursor changes to the Split Pointer (see Annex D for the pointer shapes). With the left mouse button clicked down, the Splitter Bar can be moved and the size of the Panes are adjusted accordingly.



The Pane on the left of the Micro-scale dynamics Window --called the Map pane-- contains a map representation of the modelled region. More in particular the actual land use of the region is mapped. The legend of the map is displayed in the upper left pane --called Legend pane--. The lower left Pane --called the Focus pane-- shows the mapped region in small. In the upper part of this small map you will see a wire-frame (an inverted rectangle). This shows the area (called focus) that is displayed in the Map pane. If the mouse is placed inside this wire-frame, the frame can be moved while holding the left mouse button clicked down. While the wire-frame is moved, you will notice that the focus of the map in the Map pane is changing accordingly. The focus of the map can also be changed by means of the scroll-bars of the Map pane. The Legend pane too is equipped with a vertical scroll bar.

When a simulation is running, the Micro-scale dynamics Window will be updated and the resulting land use will be displayed in the Map pane.

The commands of the View Menu permit to change the manner in which Micro-scale results of the model are displayed in the Map pane. Display options include among other: Zoom in, Zoom out, and 3-D representation. For a complete overview, consult the View Menu in Section 6.3 of this User guide.

Most features of the Micro-scale models are accessible via the menu structure of the system. Details on the different menu options is given in Chapter 6 of this guide. Here we will focus on a number of elements that are essential to understand the functioning of the Micro-scale model and to change its parameters.

At this moment, **SIMLUCIA**'s Micro-level model (see for details Chapter 3) calculates and displays the changing land use. The legend of the map explains the meaning of the different colours. A distinction is made in the model (and the legend) between the dynamic elements of the land use and the non-dynamic elements. Dynamic elements -- also called *Land-use Functions*-- are represented in the legend of the map with their name underlined. The static elements --also called *Land-use Features*-- are represented with their text not underlined.

<b><u>Land Use Functions:</u></b>			
Forest	Natural vegetation	Agriculture	Urban Residential
Rural residential	Trade and services	Industry and quarries	Tourism
<b><u>Land Use Features:</u></b>			
Sea	Forest Reserve	Mangrove	Beach
Coral Reef	Terminals etc.	Infrastructure etc.	

Land use features will not change as the result of Micro-scale dynamics. That is to say they will not change location: they will not expand or will not disappear due to the expansion of other activities. Yet, they influence the dynamics of the Land use functions, and will interfere in the allocation process of the land use functions. For example the Land use function 'Tourism' will be influenced by the presence (or absence) of the land use feature 'Beach'.

Rules.

The dynamic land-use calculation is based on a number of elements which can be changed (in principle at the least) by the user of the model. First and most important are the Cellular Automata transition rules. These represent the dynamic element of the Micro-model. For each cell in the cellular space they will calculate how its land use will change throughout the simulation period. The transition rules are accessible via the Rules menu. The rules are written as distance functions, expressing the manner in which land uses influence one another by attracting or repelling one another in their vicinity. These rules are defined for each possible combination of land uses. The model is very sensitive to the values entered for most rules. Hence, changing rules can have drastic effects on the Micro-scale dynamics. We advice not to change the transition rules unless you have gained a lot of experience with running the model. An overview of the complete set of rules can be seen when selecting Overview from the Rules menu.

Next to the transition rules, the intrinsic characteristics of the cell itself will influence its potential for change to another land-use. These are represented in the model by means of maps, namely the Elevation map, the Suitability map and the Network map. All the maps are accessible via the Maps menu.

Elevation.

The elevation map is displaying the relief of the modelled region. It is important for the model to the extent that land below sea level is not suitable for socio-economic use and that this land can not be allocated to one or the other land use activity. Indirectly, the elevation will influence the suitability of a number of activities. Select Elevation from the Maps menu to have it displayed in a new window on the screen. The View Menu

allows to change the manner in which the map is displayed. The possibility exist to Zoom in, to Zoom out or to change the elevation categories with the Legend Dialog box.

Suitability.

For each land-use function a suitability map is present in the model. It shows how suitable each cell in the region is to support the particular land use. Suitability calculations are rather standard GIS operations. Suitabilities are composite measures that involve the manipulation of so called Factor Maps. In **SIMLUCIA** a linear combination of factors has been applied: the importance of a factor type (for a specific land use) is first rated and next, the factors are weighted and summed. In Annex C an overview of the factor type ratings and factor weights is given. The calculations required to produce the suitability maps have been carried out by means of IDRISI for Windows Version 2.0 (Eastman, 1997), and the resulting maps have been imported in **SIMLUCIA**.

The suitability map of each land use function can be selected from the Maps menu and the way the map is displayed can be altered by means of the View and Edit menu.

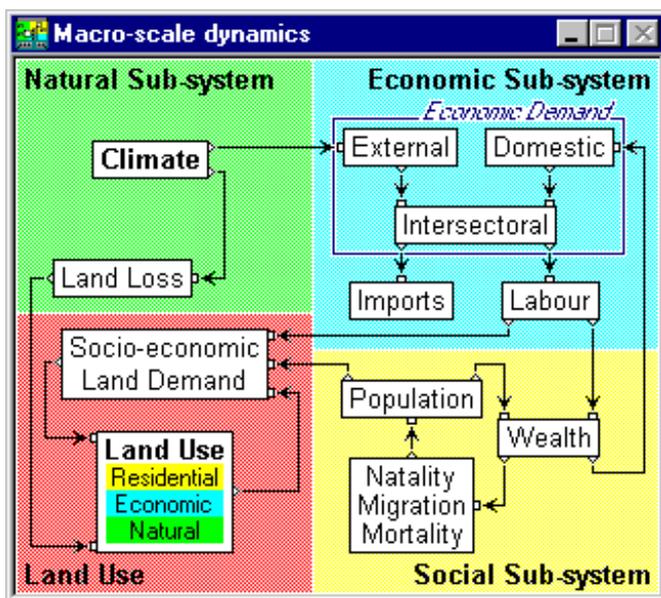
Network.

For each land-use function an accessibility map is present in the model. It shows how accessible each cell is in relation to a network. The network can be --in principle at least-- any network. In this version of the model, the network included is the road network. For some activities, such as Trade and services, the direct access to the road system is more important than for other, such as Agriculture. The maps are the result of an accessibility calculation of the parameters which are accessible via the Edit Menu.

The user can freely open and close maps (except for the land use map in the Micro-scale window). We warn the user that opened windows are updated while the simulation is running and that this does take-up processing time, hence that the program will be slowed down.

More details on the use of Cellular Automata for modelling geographical phenomena at the Micro-scale can be found in Chapter 3 and in the publications in the reference list.

**5.1.2 The Macro-scale dynamics Window**



The Macro-scale dynamics Window is the graphical interface to the Macro-scale model. It shows an overview of the structure of the system modelled at the most synthetic level. It allows access to all the details of the model at this level, but even so at lower levels. You should learn to use the graphical representation as a graphical explorer of the model.

In this prototype, the model structure, nor its graphical representation can be changed by the user.

**SIMLUCIA** has been developed by means of the simulation package GEONAMICA (see Annex A for details). The model consists of so-called Model Building Blocks (MBB's)

--the rectangles in the system diagram-- connected to one another by means of MBB Connectors --the arrows connecting the rectangles--. A MBB contains the code required to calculate and execute mathematical operations varying from a single operation (such as the summation of two numbers) to a list of operations (set of mathematical equations). In order to improve the readability of the system diagram, it is possible to group parts of the model into a Super MBB and represent it in the diagram as a single block.

*Model Building Blocks (MBB's).*

The system diagram allows the user to understand the structure of the model and to access parts of it. Model building blocks are represented by means of a rectangle with the name of the MBB in it.



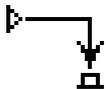
Active Model Building Blocks appear in black on the display. When the user moves the mouse pointer on top of such a MBB, its colour will invert. If the user clicks the mouse, the response will depend on the type of MBB. If the MBB clicked is not a SuperMBB, then a dialog box will open. This dialog box has the function of both receiving the data entered by the user and of communicating model results to the user. If the MBB is a SuperMBB, then a more detailed diagram is shown in which each of the MBB's will act as explained.

*Connectors and Connections.*



In-Connector  
Out-Connector

Variables and parameters can be passed from one MBB to the other via Connections, or Pipes. MBB's will dispense variables or parameters with the rest of the model via *Out-connectors*, and will take-in information from other MBB's via *In-connectors*.



Connection

The actual exchange between MBB's is possible when a *Connection* (or Pipe) is drawn between an Out-connector of the issuing block and the In-connector of the receiving block. For each variable or parameter that is being exchanged, one connection is drawn (except if one of the MBB's is a SuperMBB) in the diagram.

*Dialog boxes.*

Each MBB has a dialog box attached to it. This dialog box is the vehicle that permits the interactive exchange of information between the user and the Model Building Block. The MBB will communicate the results (output) of its numerical operations to the user and it will accept the data entered (input) by the user that are required for the execution of the MBB. The latter are internal to the MBB.

Model results and model inputs are presented in Edit Fields. The difference between input and output fields is indicated by the colour of the text in the edit field: green for state variables (to be entered as initial values and for the remainder output of the MBB); purple and blue for intermediate variables; black for variables or parameters copied from other MBB's (output of the MBB); and finally red for internal parameters of the MBB (input for the MBB).

Colour of text in the Edit Fields of MBB-Dialog Boxes	Description
RED	<u>Input</u> . Parameter value (can be changed during the entire simulation) or State variable at the initial state.
PURPLE	<u>Input</u> . Variable value. If the edit field is clicked, a dialog will pop-up requesting input necessary for the calculation of the

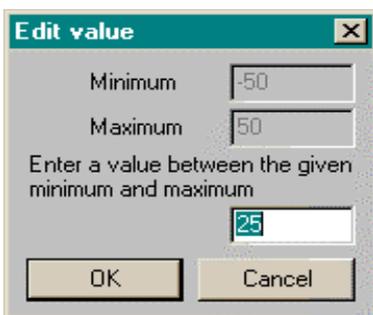
GREEN	variable
BLUE	<u>Input / Output</u> . State variable which can be changed at the start of the simulation, and which display output for the remainder.
BLACK	<u>Output</u> . Variable value. (read-only)
	<u>Output</u> . Values copied from other MBB's. (read-only)

A simple way of finding out whether a field will accept input or not is by simply moving the mouse over it. If the field can be edited, the mouse pointer will change shape in function of the type of data that is to be entered. If the mouse is clicked, the appropriate editor is opened. In Annex D, the meaning of the different pointers is explained.

One of four editors will open:



*A single value numerical editor.*



This editor allows the user to enter a single numerical value. More precisely it will display a default setting --the result of the calibration of the model-- with the request to change it with a value within the range specified:

$$\text{Minimum} \leq \text{value entered} \leq \text{Maximum}$$

If values outside this range are entered, the user is warned.



*A table (of values) editor*

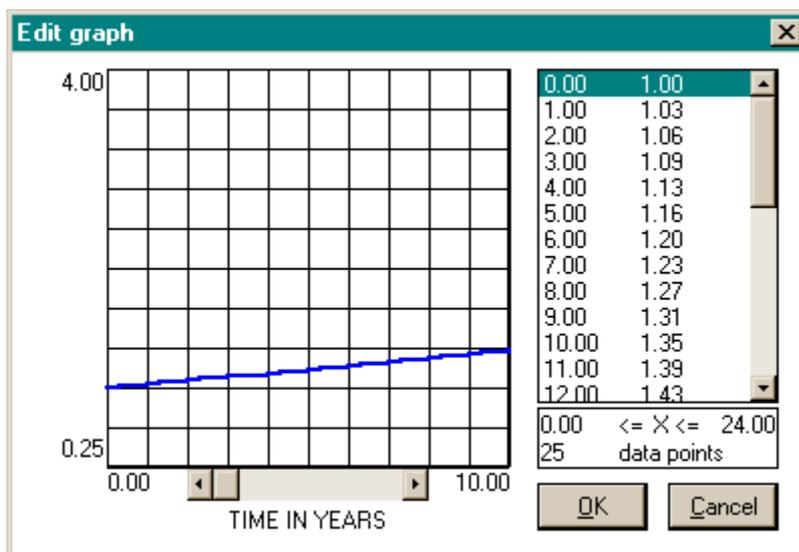
This editor allows the user to enter a series of numerical values. More precisely it will request the user to change default values. The values entered will all have to be inside a range specified:

$$\text{Minimum} \leq \text{all values entered} \leq \text{Maximum}$$

If values outside this range are entered, the user is warned.



*A graph editor.*



This editor is used extensively in **SIMLUCIA** --in both the Micro-scale and Macro-scale model-- to change two-dimensional relations: time series, distance decay functions, etc. It has two main parts: to the left a graphical representation of the two-dimensional relation, and to the right a list box with the coordinate pairs defining the relation. The relation can be edited in each of the two parts.

1. The easiest way to enter data is via direct manipulation of the graph. Move the cursor to the abscissa position for which you want to enter a new (ordinate) value. The pointer will change to a pen symbol indicating that it is positioned correctly on top of a vertical grid line for which it will accept an ordinate value. Move the pointer to the vertical position equal to the ordinate value which you want to enter. Then click the left mouse button to enter the new ordinate of the point on the graph.
2. The second manner of editing is handy if you have to enter exact numbers rather than trends or approximate numbers. It consists in clicking in the list box the co-ordinate pair that you want to change. Then a dialog box will open in which you can enter the new ordinate value. The changes made in one part of the graph editor are immediately visible in the other part. The number of values to be entered as well as the range is displayed.



#### *A Dialog editor.*

In order to enter values for specific variables (printed in purple) a dialog window is opened. In this dialog the user is to enter a number of data that are required to calculate the value of the variable. In **SIMLUCIA** this type of editor is used to define variables that are required to calculate the number of jobs in each economic sector.

## **5.2. Starting the simulation.**

Once the Micro-scale dynamics and the Macro-scale dynamics windows have been opened, the program has read-in the default values for all the parameters as well as the initial values for all the state variables of the model. The program is ready to run a simulation.

### **Step**

Verify this by pushing the Step button from the Tool bar. **SIMLUCIA** will now go through a number of essential phases (such as the initialisation and testing of its inputs) which are of no direct interest to the user before it will make one simulation step. This will take a while. You will notice that the action is finished when the simulation time changes from 0 to 1 and the land-use map in the Micro-scale dynamics window is being updated.

### **Reset**

Undo the simulation step by pushing the Reset button from the Tool bar. This action will reset all the state variables of the model to their initial value, but will not do so for the values of the parameters. These are not influenced by Reset and remain unchanged. Since we have not changed parameter values the latter is of no importance now, but it will be an important issue once you will be changing parameter settings while running the models.

The Micro-scale dynamics and Macro-scale dynamics Windows can not be closed by the user (the Close-Window-icon in the Title Bar of both windows is greyed out). The user can only minimize or maximize their size by clicking the respective icons in the Title Bar. The results of the Micro-scale models is always shown by means of the map in the Micro-scale dynamics Window. You can personalize the Micro-scale map by means of the command in the View and Options menu. It is possible to add overlay information to it, such as the road system and the boundaries of the administrative regions. If the region boundaries are drawn, it is possible to pick-up information per region from the map by clicking the left mouse button in the region of your choice. An Information Window will show an overview of the land use within the region. While the simulation is running, this

overview is updated dynamically, thus permitting to get an impression of the changes affecting the region.

The output of the Macro-scale models is not visible unless the user has opened the parts of the model that he wants to see. As an example we will see what the model has to offer in the Wealth MBB. Move the mouse to the MBB named Wealth. As soon as the mouse is inside the borders of the MBB, the colour of the MBB will invert. Now click the left mouse button. The following Dialog Box will open.



Now have the simulation make one simulation step again while watching the values displayed in the box. Notice that the value of the variable named "Population" is updated whenever the next simulation step is taken. Finally, the Micro-scale dynamics Window is updated. This demonstrates the fact that models developed with **SIMLUCIA** have coupled micro- and macro-components running simultaneously. For variables preceded by a white check-box, such as 'Total jobs' in the Wealth dialog, the model allows to make a time-graph. All you need to do is to click in the check box and the graph will open. As long as it is open, it will be updated at each simulation time step. To close it, you should click the Close-Window-icon in the title bar of the Graph window.

### 5.3. *Viewing model output*

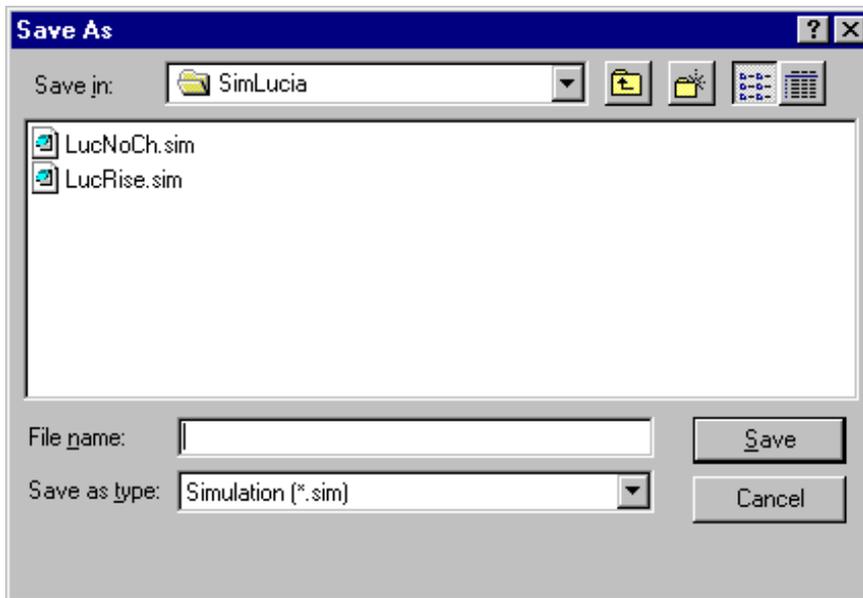
The user of **SIMLUCIA** has a lot of freedom in selecting and organising the in- and output windows. There are tens of windows containing information related to the model. These windows are all accessible in the manner explained: Macro-scale dynamics; Micro-scale dynamics; Dialog boxes; Graphs, and Maps. A window, map or dialog will be opened by the user and will stay open until it is minimized or closed by the user. While the simulation is running all the windows that are opened are updated. This has the great advantage of displaying information from linked MBB's simultaneously and allow the user to see how changes occur in different parts of the model.

However, the user should learn to manage output windows carefully and to close as much as possible the windows he is not directly interested in. If not, his screen will be overloaded with 'left-over' information which he is not really using, but also, every window opened is updated by **SIMLUCIA** and the act of updating takes execution time and memory space. Hence the program might slow down considerably. Certainly when maps are displayed, it is imperative to close as much as possible the maps that are not of immediate interest to the user.

Moving the mouse with the left mouse-button clicked-down in the Title Bar of a window, will permit to move it around. It is good practice to organise the screen in such a way that the dialogs are all grouped on one side of the screen and the map(s) on the other side. This will permit to see simultaneously macro- and microscopic results of the simulations.

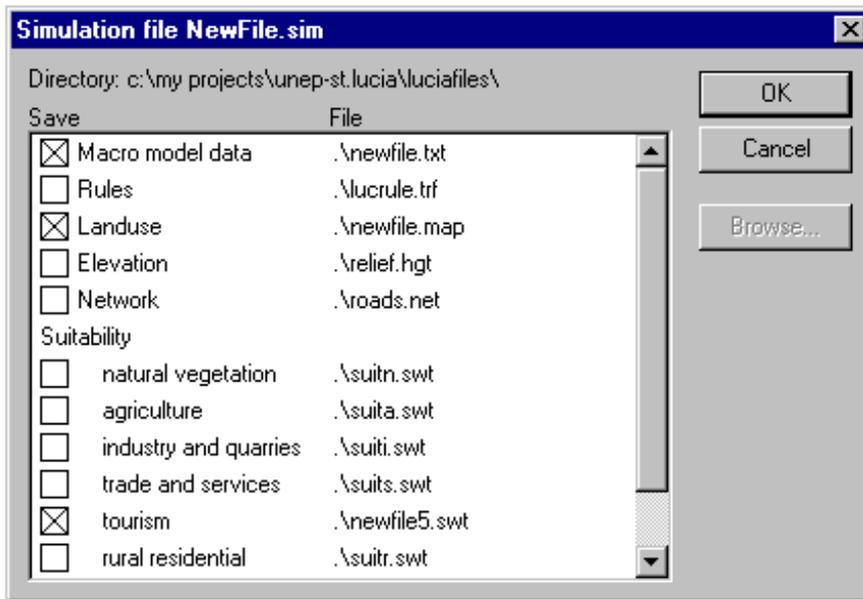
#### 5.4. *Saving simulation results*

Working with Decision Support Systems is not in the least a learning process: the decision maker is exploring different combinations of policy alternatives to learn interactively which interventions are likely to satisfy his policy criteria. These explorative exercises require a possibility to store simulation results in an efficient manner.



The Save simulation command from SIMLUCIA's File menu allows the user to store simulation results in more or less sophisticated manners. More in particular it allows the user to manage efficiently the different kind of files that constitute a single simulation. Indeed, a simulation requires not just one, but 10 to 20 data files, hence, saving a large number of simulation runs might require a large storage space on your hard disk(s).

When the user selects Save Simulation from the File menu, the Save Dialog box will open, requesting the user to enter the name of the file. If the name of the current simulation file is entered, then it will be overwritten, and the original values will be lost. Overwriting files can be avoided by simply choosing a file name different from the current one. Once the name of the file is entered and the Save button has been pressed, the system will display the Simulation file ... .SIM Dialog box. If you are a relatively new user of SIMLUCIA, simply press the OK button to complete the action of saving the simulation and skip the remainder of this section. If however, you are more experienced with the system this Dialog box will help you to change the composition of your simulation file before saving it.



The dialog box shows an overview of all the files types --and their respective names-- that are used by the simulation. In the box, the files are preceded by a check box. Files preceded by a crossed check box will be saved with the name mentioned to their right. The program keeps track of the actions that the user has performed during a session and knows what files are affected by it.

These files are shown with their check-box crossed, and that is why the program suggests to save them. If however you do not want a new copy --for example because the corrections you made are not important-- then you simply cross out the check box. Although this procedure might seem cumbersome at first, it will become a great help to you once you are more familiar with the system. **SIMLUCIA** saves its output in exactly the same format as its inputs. Hence, you can always use saved simulations as the input for a new run. Keep in mind however that the simulation clock will be set back to 0 when you continue a simulation in this way.

Save simulation will only save final results of the model (current values of state variables and parameters). It will not store intermediate results. To save these, you should make use of the Log ... and the Link to Excel commands from the Options menu.

Log ... will save Micro-scale simulation results. More in particular it will store maps on a .LOG file. When the Log ... command is selected, the user will have to enter the interval for which he wants to store maps.

The Link to Excel command permits to send simulation data to a Microsoft Excel Workbook. More in particular the values of a number of the most important state variables will be sent to Excel. It is possible to save this Workbook (using the Excel commands) and thus store them for further analysis.

### 5.5. *Printing simulation results*

Printing simulation results can be done in different manners. **SIMLUCIA** supports very directly the printing of maps. From the File menu, you will use the commands Page Setup, Print preview and Print for that matter. Select first Page Setup to decide on the number of cells which you want to print out per unit of measurement (for example 4 cells per cm for a map of St. Lucia at a scale of 1/100.000), then select Print Preview to get an idea on how the printed maps will look like, and finally push the Print button in the Print Preview window or from the Tool bar to print the maps.

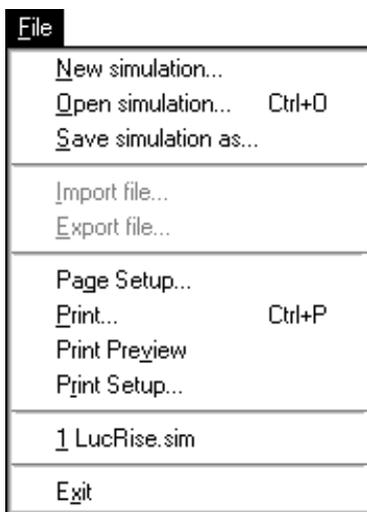
Printing results from the Macro-level model can be done by selecting Link to Excel from the Options menu and use the Excel print functions to get the results on paper. If you

want a printout from a particular MBB, then click it to open its Dialog box. Once the Dialog box is open, key-in Alt + Prt Sc. This will put the Dialog on the Windows Clipboard. Now open your Paintbrush, Paint or Word Processing package and select Paste from its Edit menu. Once the Dialog window has been pasted, Print the dialog by using the print facilities of the receiving package. This procedure works not only for dialogs, but for all **SIMLUCIA**'s windows. It is handy to print among other the 3 D representation of the study area.

## 6. The SIMLUCIA Menu System

This Chapter explains the different commands that are available in **SIMLUCIA**'s Menu System. The Menus will be treated as they appear in the Menu Bar from left to right.

### 6.1. The File Menu



Use the File menu to create a new simulation file or open an existing one, save and print files, and to exit **SIMLUCIA**.

**SIMLUCIA** saves simulation files with a .SIM extension attached to the filename.

#### 6.1.1 New simulation Command

Use the New simulation command to create a new simulation file.

This option is not available in **SIMLUCIA** for the model has been designed by RIKS for the specific use on St. Lucia.

#### 6.1.2 Open simulation Command

Use the Open command to open a simulation file stored on a disk. You can open only one simulation file at the time. Use the Windows menu or the mouse to switch among the different windows opened by the simulation.

When you choose Open simulation, the Open Dialog box appears. If the name of the file of your choice is not visible in the list box, use the scroll bar to move through the list of filenames in the directory or disk you are working in. If the file you want to open is not in the current directory or on the current disk, use the scroll list or browse symbols in the section named 'Look in:' to change directories, drives or network site.

Double-click the name of the file you want to open. You can also type the name and path of the file in the Filename box. Choose open after you have typed the name of the file.

### **6.1.3 *Save simulation Command***

Use the Save simulation command to save a simulation to a disk. When you save a simulation, **SIMLUCIA** displays a Save Dialog box. This box shows an overview of the different files that constitute one simulation. The file names that are preceded by a crossed check box, have been changed by the user during the session and will be newly saved. If the user wants to save them under a different name, he can click in the name and enter the new name. Be careful not to change the extension of the files.

### **6.1.4 *Import file... Command***

Use the Import file command to import a file from disk into the simulation. Importing and exporting files is possible for all maps that can be edited in the system (Land Use, Suitability, Network, and Regions map). The type of map has to be selected from the menu and has to be in the active window before the Import file... command will be active. When active, Import file... will open a Open Dialog box displaying all the files in the working directory with the correct extension. If the user changes the type of file to import in the appropriate scroll list, he will be able to import IDRISI files with .IMG extension.

### **6.1.5 *Export file... Command***

Use the Export file... command to export a file from the simulation to disk. Exporting and importing files is possible for all maps that can be edited in the system (Land Use, Suitability, Network, and Regions map). The type of map has to be selected from the menu and has to be in the active window before the Export file... command will be active. When active, Export file... will open a Save Dialog box displaying all the files in the working directory with the correct extension. If the user changes the type of file to export in the appropriate scroll list, he will be able to export files with the .IMG extension to IDRISI .

### **6.1.6 *Page Setup Command***

Use the Page Setup command to decide on the size and scale at which you want **SIMLUCIA** to print the simulation results of the Micro-level model.

### **6.1.7 *Print Command***

Use the Print command to print the maps generated by the Micro-level model.

### **6.1.8 *Print Preview Command***

Use the Print Preview command to get a preview on the screen of the printed document.

### **6.1.9 *Print Setup Command***

Use the Print Setup command to arrange the setup of your Printer, so that simulation results will be correctly printed by **SIMLUCIA**.

#### **6.1.10 List of Recent File (1, 2, 3, 4)**

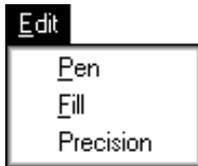
**SIMLUCIA** keeps track of the 4 most recent files opened by the program. It will display those in the File menu. If you select one of the 4 files, it will be opened.

#### **6.1.11 Exit Command**

Use the Exit command to quit **SIMLUCIA** and return to Windows.

If you have made changes to simulation files since the last time that you saved the simulation, a dialog box appears asking whether you want to save the simulation file before exiting **SIMLUCIA**.

## 6.2. *Edit Menu*



Use the commands on the Edit menu to edit the maps of the Micro-scale models. The first three commands on the Edit menu are standard, but for each type of map one or more commands will be added to permit specific edit operations. These will be explained in more detail in the Map menu.

**Be careful, SIMLUCIA is not equipped with the an Undo command. Hence all corrections made are definite !**

### 6.2.1 *Pen Command*

Use the Pen command to pick a value from the legend of the map (by clicking the radio button next to a reading) and enter it in the map by clicking the cell of your choice.

This command will change the pointer in a pen. It is identical to selecting the Pen icon from the Tool bar.

### 6.2.2 *Fill Command*

Use the Fill command to pick a value from the legend of the map (by clicking the radio button next to a reading) and enter it in larger, contiguous areas of the map. The Fill command will change the values all contiguous cells that have the same colour as the one that is clicked. It will give them the value selected from the legend.

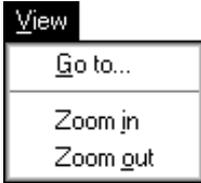
This command will change the pointer in a bucket. It is identical to selecting the Bucket icon from the Tool bar.

### 6.2.3 *Precision Command*

Use the Precision command on the Edit menu to enter detailed information on a cell by cell basis. When a cell is clicked, a dialog will open to enter the exact value.

This command is identical to selecting the Ruler icon from the Tool bar.

### 6.3. View Menu



Use the View menu to change the manner in which the different maps of the Micro-scale model are displayed. The first three commands on the Edit menu are standard, but for each type of map one or more commands will be added to specify views. These will be explained in more detail in the Map menu.

#### 6.3.1 Go to... Command

Use the Go to... command to move the cursor to a specific location on the map. Selecting this command from the View menu will open a dialog box requesting to enter the coordinates of the location.

#### 6.3.2 Zoom in Command

Use the Zoom in command to increase the size of the map on your screen by a factor 2. This command is identical to selecting the Zoom-in icon from the Tool bar.

#### 6.3.3 Zoom out Command

Use the Zoom out command to reduce the size of the map on your screen by a factor 2. This command is identical to selecting the Zoom-out icon from the Tool bar.



When the Micro-scale dynamics Window is the active window, the View menu is completed with four additional commands: Show regions, Show transportation network, Show elevation and 3D settings. These commands allow the user to draw overlay information on top of the Micro-scale simulation window.

#### 6.3.4 Show regions Command

Use the Show regions command to draw (or remove) the boundaries of the regions, as defined in the regions map, on top of the land uses in the Micro-scale dynamics window.

#### 6.3.5 Show network Command

Use the Show network command to draw (or remove) the network, as defined in the network map, on top of the land uses in the Micro-scale dynamics window.

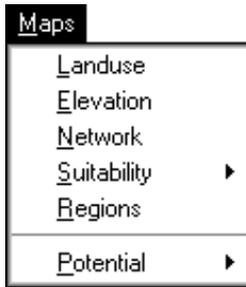
#### 6.3.6 Show elevation Command

Use the Show elevation command to change the flat land use map of the Micro-scale dynamics window into a 3 D representation. The relief of this representation is as defined in the elevation map.

### **6.3.7 3D settings Command**

Use the 3D settings command to change the manner in which the 3D diagram is represented. When this command is selected, the user will get a Dialog box allowing him to specify the angle of rotation, the perspective and the vertical exaggeration of the diagram.

## 6.4. Maps Menu



Use the Maps menu to select the different maps and their respective editor that are being used in the Micro-scale model. The land use, suitability, network and elevation maps will open in their own windows and with their own editors.

### 6.4.1 Land use Command

Use the Land use command to select the land use map and its editor in the Land use Window. With the Land use editor it is possible to change the land use map as cells can be given a different land use.



When the land use map is selected, the Edit menu will get one additional command named Change land use. This command allows to change the name and colour of the land use functions. When it is selected a Change Land use Dialog box will open.

The View menu is not changed and contains the 3 commands explained in Section 6.3.

### 6.4.2 Elevation Command

Use the Elevation command to select the elevation map and its editor in the Elevation Window. With the Elevation editor it is possible to change the elevation map as cells can be given a different height.



When the land use map is selected, the View menu will get one additional command named Legend. This command allows to change the classes that are used to display the elevation of the area. When it is selected a Legend Dialog box will open. It will request the user to enter the maximum of the highest class, the interval of values above sea-level, the minimum of the lowest class, and the interval of classes below sea-level.

The Edit menu is not changed and contains the 3 commands explained in Section 6.2.

### 6.4.3 Network Command

Use the Network command to select the network map and its editor in the Network Window. With the Network editor it is possible to change the network as network links and network nodes can be added to the network or removed from it.

Accessibility parameters  
Compute accessibility

When the network map is selected, the Edit menu will get two additional commands named: Accessibility parameters and Compute accessibility.

When Accessibility parameters is selected, an Accessibility parameters Dialog box will open which will request the user to enter a number per land use function, reflecting the sensitivity of the function to good access to the network.

When Compute accessibility is selected, new accessibility values per cell and per land use function are calculated. Compute accessibility should be invoked every time the accessibility parameters have been changed, or when the network has been changed.

White background  
• Landuse  
Accessibility: agriculture  
Accessibility: industry and quarries  
Accessibility: trade and services  
Accessibility: tourism  
Accessibility: rural residential  
Accessibility: urban residential

When the network map is selected, the View menu will get a number of additional commands. These permit to change the background colour of the network map. Backgrounds will either be blank (White background), the actual land use (Land use, the standard option), or the accessibility for one of the land uses.

**6.4.4 Suitability Command**

Use the Suitability command to select one of the suitability maps and its editor in the Suitability Window. With the Suitability editor it is possible to change the suitability map as cells can be given a different suitability value.

Show features

When a suitability map is selected, the View menu will get one additional command named Show features. This command allows to display the cells occupied by a land use feature by means of a special symbol. These cells are not available for the allocation of functions (because they are treated as static land uses in the model).

**6.4.5 Regions Command**

Use the Regions command to get a display of the Regions map in the Regions Window. The Regions map shows the different geographical entities for which the model will generate regional sums. The Regions map can not be changed by the user.

Indicator...

When the Regions map is selected, the Edit menu will get one additional command named Indicator... When this command is clicked, a Dialog box will open requesting the user to enter a weight for each land use. These weights are multiplied with the total number of cells of that type and presented in the information window which can be opened by clicking in a region. Thus, the number of cells can be translated in another measure (i.e. if the component is the surface of a cell in ha, the totals generated will be the area in ha taken in by the land use function.)

#### 6.4.6 *Potential Command*

Use the Potential command to select one of the Potential maps in the Potential Window. The Potential maps are displaying the transition potential of a cell to change to the land use specified. It is on the basis of transition potentials that each cell will get a new land use in the next simulation step.



When a potential map is selected, the View menu will get one additional command named Show function. This command allows to display the cells taken in by the land use function for which the potential is displayed on the map. It allows the user to get an idea to what extent the land use function is indeed present in high potential cells.

## 6.5. Rules Menu



Use the Rules Menu to view or enter the forces that specify the spatial interaction of each possible pair of land uses.

### 6.5.1 (land use) Command

Select from the menu the land use function (LU1) for which you would like to enter, edit or view its interaction with another land use (LU2). Select this other land (LU2) use by pointing at it in the cascading menu that will open and by clicking it. As a result the Graph editor will open. From its title bar you will read what interaction is to be entered: 'Effect of (land use LU2) on (land use LU1)'.

### 6.5.2 Overview Command

Use the Overview command to get an overview of the complete set of interaction rules defined in the model. The colours representing the different land uses are the same as those in the Micro-scale window.

## 6.6. *Simulation Menu*



Use the Simulation menu to control the simulation.

### 6.6.1 *Init Command*

Use the Init command to initialise the simulation. After the model has been initialised all the variables display the correct initial condition (values) of the model. If the Step or Run command is selected the simulation will be automatically initialised if this has not been done manually.

### 6.6.2 *Step Command*

Use the Step command to advance the simulation with one step. This command is identical to clicking the Step button from the Tool bar. Once the model has been initialised all the windows display the correct initial condition (values) of the model. If the Step or Run command is selected the simulation will be automatically initialised if this has not been done manually.

### 6.6.3 *Run Command*

Use the Run command to advance the simulation till the next pause tab has been reached. This command is identical to clicking the Run button from the Tool bar. Once the simulation is running, it can be halted by the user by selecting the Stop command from the Simulation Menu or by pressing the Stop button from the Tool bar. The default simulation run will take 40 years. The Macro-model and Micro-model are updated on a yearly basis.

### 6.6.4 *Stop Command*

Use the Stop command to interrupt the simulation. This command is identical to clicking the Stop button from the Tool bar. Once interrupted, the simulation will halt till the user selects the Step or Run command from the Simulation Menu or till the Step or Run button from the Tool bar is pushed.

### 6.6.5 *Reset Command*

Use the Reset command to reset the simulation to the initial state. This command is identical to clicking the Reset button from the Tool bar. Selecting Reset will set the simulation clock equal to 0. The state variables and maps are set equal to their initial

values (hence the changes made during the simulation are lost); and the parameters keep their actual value.

#### **6.6.6 *Pauses ... Command***

Use the Pauses... command to set the pause tabs of the simulation. When Pauses ... is selected, a Dialog box will open requesting the user to enter the time interval (in years) for which he wants the simulation to halt.

#### **6.6.7 *Random ... Command***

Use the Random ... command to run the simulation in stochastic mode. When Random ... is selected, a Dialog box will open requesting the user to set a value for the  $\varepsilon_z$  parameter as well as the seed value for the random generator (see Chapter 3 for more on this).

## 6.7. Options Menu



Use the Options Menu to personalise your workspace.

### 6.7.1 Grid ... Command

Use the Grid ... command to draw a (major) grid in the maps. When Grid is selected from the Options menu, a Dialog box will open. The user is requested to switch on or off the Major grid check box. Next he is to enter the size of the grid expressed in number of cells. Finally he can offset the origin of the grid by a certain amount of cells (for example in order to fit a reference system of some sort).

### 6.7.2 Font ... Command

Use the Font ... command to change the font, font style and font size of the character set used to print the legends of maps and the informative windows.

### 6.7.3 Link to Excel ... Command

Use the Link to Excel command to link the simulation with the Microsoft Excel Workbook SIMLUCIA.XLS. This link is a DDE (Dynamic Data Exchange) link. Via this link **SIMLUCIA** is sending model output to the Workbook while the simulation is advancing. Note that in order to establish a successful link, it is required that Excel is installed on your machine and that Excel appears in the PATH statement of your AUTOEXEC.BAT. If **SIMLUCIA** can not find Excel, the menu option will be greyed out. The Workbook SIMLUCIA.XLS is at the disposal of the user once the simulation is finished. It can be used for further analysis of the simulation data.

### 6.7.4 Log ... Command

Use the Log ... command to store the land use maps produced by the Micro-level model in a file. When Log ... is selected, a dialog box will open requesting the user to enter the name of the .LOG file and the interval for which simulation results are written to the file.

.LOG files can be analysed by means of the ANALYSE utility program (see Section 7).

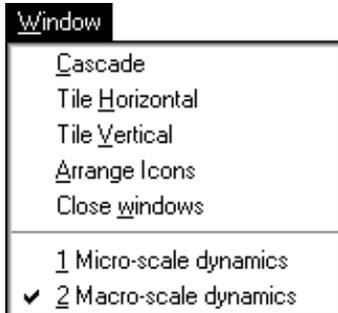
### 6.7.5 Tool bar Command

Use the Tool bar command to view or hide the Tool bar in the Applications window.

### **6.7.6 *Status bar Command***

Use the Status bar command to view or hide the Status bar in the Applications window.

## 6.8. Window Menu



Use the Window menu to arrange the contents of the screen and to activate one of the opened windows.

### 6.8.1 Cascade Command

Use the Cascade command to arrange multiple windows in an overlapped fashion so that the Title bar of each window is visible.

### 6.8.2 Tile Horizontal command

Use the Tile Horizontal command to vertically arrange multiple opened windows in a non-overlapped fashion so that all windows are visible.

### 6.8.3 Tile Vertical Command

Use the Tile Vertical command to arrange multiple opened windows side by side in a non-overlapped fashion so that all windows are visible.

### 6.8.4 Arrange Icons Command

Use the Arrange Icons command to arrange the icons for minimized windows at the bottom of the screen. If **SIMLUCIA'S** windows are positioned at the bottom of the screen, then they can hide some or all of the icons.

### 6.8.5 Close windows Command

Use the Close windows command to close all the opened windows except for the ones that can not be closed (in particular the Micro-scale dynamics and Macro-scale dynamics windows).

### 6.8.6 List of Windows (1, 2, 3, 4, ...)

At the bottom of the Windows menu a list of open windows is presented. A check mark appears in front of the document name of the active window. Choose a name from this list to make the window active.

## 6.9. Help Menu



Use the Help menu to select the type of Help you want **SIMLUCIA** to display on the screen. The different commands in this menu will permit to look up information about **SIMLUCIA**, its commands, options, and tools.

In this version of **SIMLUCIA** the on-line Help is very incomplete.

### 6.9.1 Index Command

Use the Index command to get the opening screen of the Help file of **SIMLUCIA**. From the opening screen, you can jump to step-by-step instructions for using **SIMLUCIA**. Double click the topic you want help on. A Help screen will appear. Once you open Help, you can click the contents button whenever you want to return to the opening screen.

### 6.9.2 Using Help Command

Use the Using Help command for getting general instructions on how to use the Windows Help System.

### 6.9.3 About ... Command

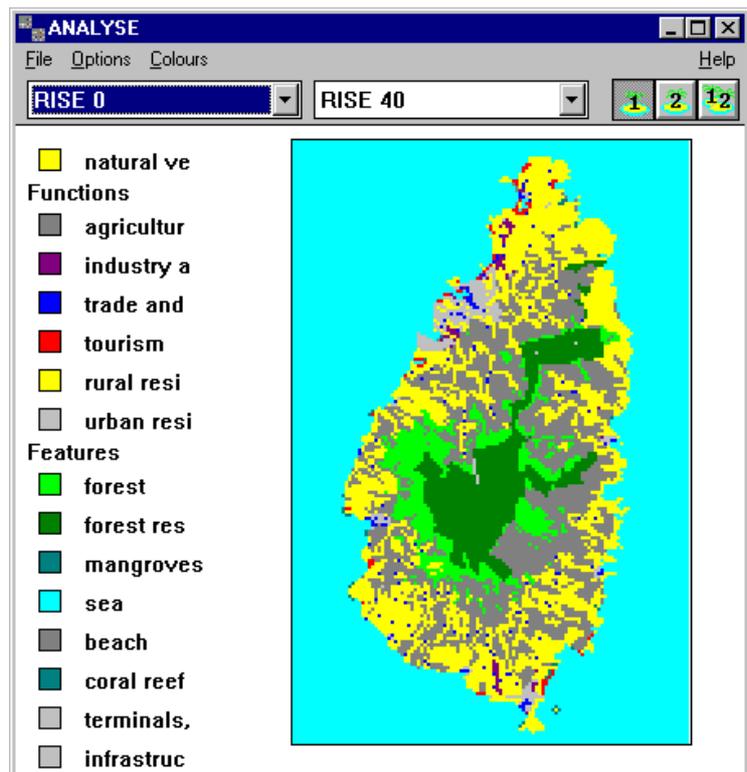
Use the About ... command to get the copyright notice and version number of the **SIMLUCIA** application which you are using. The latter is important if you need assistance with the software from the developers or when you request an update of the software.

## 7 ANALYSE

The program **ANALYSE**, which is also on the **SIMLUCIA** Demo diskette, can be used to analyse .LOG files created with **SIMLUCIA**. To run **ANALYSE** click on the Start button in the Windows Task bar, move to the **SIMLUCIA** Programs Group and finally select the **ANALYSE** icon.

### 7.1 *Basic concepts and features*

A .LOG file consists of a sequence of maps generated by a simulation. The name of a map in such .LOG file consists of the concatenation of the name of the .LOG file and the iteration number of the simulation. With **ANALYSE** you are able to compare any two maps within the .LOG file, and see the differences expressed graphically on a map as well as in numbers presented in a table. Also the comparison of maps from different .LOG files is possible.



The **ANALYSE** window has a menu bar with the menus: **F**ile, **O**ptions, **C**olours and **H**elp.

The **F**ile menu contains commands to Open and Close .LOG files, to Print the contents of the Application Window, and to Exit. Select **O**pen to open a .LOG file. If there is already a .LOG file open, the program will append (up to a maximum of 42 maps) the

maps of the newly opened file to the current list. Thus you will have the possibility of comparing maps from different simulation runs. Select **C**lose to close all the .LOG files opened. Select **P**rint to send the contents of the **A**NALYSE window to the default printer using the default printer setup of your Windows environment. Select **E**xit to quit the program.

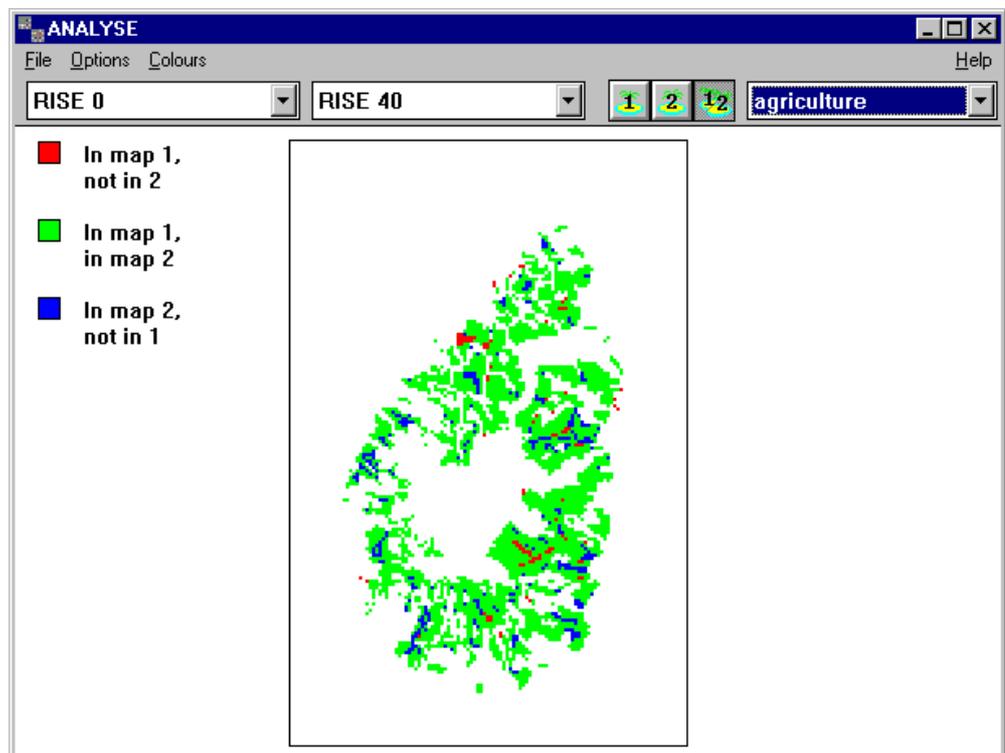
The **O**ptions menu gives you the possibility to overlay a grid on the map (select **S**how **g**rid/**H**ide **g**rid), to represent each cell by a circle instead of a square (select **C**ircle/**S**quare), and to hide or show the legend (select **H**ide **l**egend/**S**how **l**egend).

The **C**olours menu allows you to change the colours of all the features and functions that are displayed on the map. The **C**olours menu will only be accessible when maps are displayed in the Application Window.

The **H**elp menu only contains an **A**bout option.

Just underneath the menu bar there is a Tool bar. It contains three list boxes and four picture buttons.

- Pushing the first button  will display the map selected in the first (left) list box
- Pushing the second button  will display the map selected in the second (middle) list box.
- Pushing the third button  will display differences between the two maps selected in the first (left) and the second (middle) list box. Differences are displayed for the land-use selected in the third (right) list box. The comparisons are made on a cell by cell basis.



- Pushing the fourth button  will display the differences between the two maps selected in the first and the second list box by means of a matrix-like numerical overview.

The Kappa statistic is a measure of the resemblance of both maps compared, globally or per land-use.

ANALYSE															
File Options Help															
RISE 0		RISE 40		1 2 12			agriculture								
The number of cells changed from (row) to (column) :															
	natur	agric	indus	trade	touri	rural	urban	fores	fores mangr	sea beach	coral	termi	infra		
natural ve	1585	236	19	4	9	0	142	30	0	0	20	0	0	0	0
agricultur	5	3186	0	15	0	67	7	4	0	0	0	0	0	0	0
industry a	0	0	71	1	0	0	0	0	0	0	0	0	0	0	0
trade and	2	1	0	157	0	0	0	0	0	0	0	0	0	0	0
tourism	18	0	0	0	53	0	0	0	0	0	2	0	0	0	0
rural resi	37	0	1	2	0	1425	6	2	0	0	2	0	0	0	0
urban resi	1	0	0	10	0	0	193	0	0	0	0	0	0	0	0
forest	11	95	0	0	0	0	0	883	0	0	0	0	0	0	0
forest res	0	0	0	0	0	0	0	0	1250	0	0	0	0	0	0
mangroves	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0
sea	0	0	0	0	0	0	0	0	0	12807	0	0	0	0	0
beach	0	0	0	0	0	0	0	0	0	0	1	18	0	0	0
coral reef	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0
terminals,	0	0	0	0	0	0	0	0	0	2	0	0	72	0	0
infrastruc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
The number of function cells changed : 583															
The total number of cells changed : 752															
The number of cells on map 1 (RISE 0) :															
	2045	3284	72	160	73	1475	204	989	1250	18	12807	19	19	74	17
The number of cells on map 2 (RISE 40) :															
	1659	3518	91	189	62	1492	348	919	1250	18	12834	18	19	72	17
The individual Kappa statistics :															
	0.84	0.93	0.87	0.90	0.78	0.96	0.70	0.92	1.00	1.00	1.00	0.97	1.00	0.99	1.00
The overall Kappa statistic : 0.95															

## 8. Policy exercises with SIMLUCIA

Now that the general functionality of **SIMLUCIA** has been covered, this chapter will briefly describe how to run simulations with **SIMLUCIA** and how to use it for Decision and Policy support. We will treat three rather theoretical exercises that get progressively more complex and require a better understanding of **SIMLUCIA**.

### 8.1 *Introduction*

Policy making and more generally Decision making is a stepwise process. In order to come to a decision, the steps are run through sequentially in one or more iteration. Depending on the author or the literature that is consulted, the process is a subdivided in more or less phases (or steps) and different names are given to each phase. Some agreement seems to exist about the following three major phases, and their contents:

- the *identification phase*, the purpose of this phase is to better discern the real problem which requires a decision to be taken. This is an analytical phase during which the real origin of a problem is the topic of research, before suggestions to solve the problem are made.
- the *development phase*, this is the phase during which a more or less large number of alternative solutions for the problems are developed.
- the *selection phase*, is finally the phase during which the ‘least unfavourable’ solution among all alternative solutions is searched for and selected for implementation.

Although the three phases have been described in a sequential order, it should be stated clearly that decision making is very often a cyclical process, during which some if not all of the phases are run through a number of times. The purpose of these cycles is clearly: (1) to get an in depth understanding of the real problems; (2) to generate more and better solutions, and (3) to decide upon an intervention or a combination of interventions that will solve the problem, at least in part.

Full fetched Decision Support Systems (DSS) will support the decision maker in each of the three phases mentioned. However many so-called Decision Support Systems will focus on one or two of the phases only. For example quantitative models are used to generate alternative solutions during the development phase, while multi-criteria analysis is used to select among alternative solutions in the selection phase.

This version of **SIMLUCIA** provides support for both the first and the second phase. **SIMLUCIA** will help the user to get a better understanding of the origin of problems as they exist in St. Lucia or as they might pop-up in a more or less distant future and it will support the user in the design and evaluation of alternative solution to cope with these problems. The selection phase is less well supported in **SIMLUCIA**, since there is less functionality built-in to compare and rank alternative solutions, other than what is available in **ANALYSE**, Microsoft Excel or **IDRISI**.

In the three exercises we will study the effects of external factors and policy interventions. The exercises have been kept rather simple. Their purpose is mainly to make you acquainted with **SIMLUCIA** to the point that you will be able to run your own exercises. First we will show how to study the effects of external factors. Next we will see how interventions of the type ‘policy interventions’ can be tested with the system.

If you intend to use **SIMLUCIA** for planning or policy making, you should remember that you are working with a model and that this particular model is a strong simplification of reality (see chapters 2 and 3). More, **SIMLUCIA** is an instrument intended for scientific analysis, hence, you have full access to nearly all of its parameter and variables. Whenever you change parameters or variables beyond their validity interval, the model might generate results that are merely nonsense. In conclusion, use the model in a responsible manner and with particular care !

All the exercises in this chapter will be done with the simulation files named *LucNoCh.SIM* and *LucRise.SIM*. In the chapters 4 and 5 we have explained how to Start **SIMLUCIA**, how to Open a simulation and how to Run, Reset and Exit a simulation exercise. We assume that you know all this at this point. Begin each of the exercises described underneath by starting **SIMLUCIA**.

## 8.2 **Exercise a: Working with scenarios**

The effectiveness of planning can be strongly influenced by physical, economic and social factors external to the system. They are usually beyond the control of the planner or policy maker. His intervention is limited to the early detection of possible dangers caused by these factors and the design and implementation of counter measures. In order to select appropriate and robust measures, he will introduce external factors as *scenarios* in the system and study the behaviour of the system and its response to these new conditions.

In **SIMLUCIA** Change in temperature and Change of the sea level are external factors, because it is very unlikely that local decision makers can directly influence these.

**Aim:** In this exercise we want to examine the effects of temperature rise and sea level rise on the loss of land and its further consequences on the tourism sector.

**Screen arrangement:** We will arrange the screen layout in such a manner that the input and output windows of the model which are most relevant to this exercise are on the display. This does not mean that the other windows are irrelevant. Because **SIMLUCIA** is a highly integrated model, most state variables will undergo some changes as a result of the exercise. Hence, feel free to dig deeper into the model to discover other effects of the scenarios that we will simulate.

- First open the simulation file called *LucNoCh.SIM*;
- Minimize the Micro-scale dynamics window;
- In the Macro-scale dynamics window, click the MBB called ‘*Climate*’. The Climate window will open. Move it to the left (top) side of the display;
- In the Macro-scale dynamics window, click the MBB called ‘*Land use*’. Move the Land use Dialog window to the right (top) side of the screen;
- In the Macro-scale dynamics window, click the MBB called ‘*Labour*’. In the Economic Sub-system dialog window, click the edit field in the column ‘Tourism’ and the row ‘Labour’. As a result a new dialog window will open named Jobs:

Tourism. Move this window to the right side of the screen, position it below the Land use dialog window, and click the check box left of the text Jobs. As a result a graph will open named 'Jobs: Tourism';

- now minimize the Macro-scale dynamics window;



It is good practice to manage your windows very carefully. This will keep you from being distracted. Keep only the windows opened that are of direct interest to you. All windows and dialogs that are open are updated by the program, even if they are hidden by other windows. This takes execution time and memory space, and thus will slow down the program.

As a result of the above actions, your Application window should look more or less like this:

The screenshot shows the SimLucia application window. At the top is a menu bar (File, Edit, View, Maps, Rules, Simulation, Options, Window, Help) and a toolbar with buttons for Step, Run, Stop, and Reset, along with a counter set to 0. Below the toolbar are three main panels:

- Climate Panel:** A flow diagram with a green background. It includes boxes for Time (0.00), Temperature (0.00), Sea Level (0.00), Beach Loss (1.00), Storm Damage (0.00), and Precipitation (0.00). Arrows indicate relationships between these variables. On the right, there are boxes for Industry, Tourism, and Agriculture, all showing 0.00, with a note for 'External Demand'.
- Land use Panel:** A table showing 'Initial land use' and 'Current land use' for various categories. The values are identical for all categories, indicating no change.
- Jobs: Tourism Panel:** A window with a graph (Y-axis from 4000 to 7000) and a toolbar. The 'Jobs' checkbox is checked, and the values are: Jobs = 5617.38, Jobs per million \$ = 36.15, and Labour costs = 155.40.

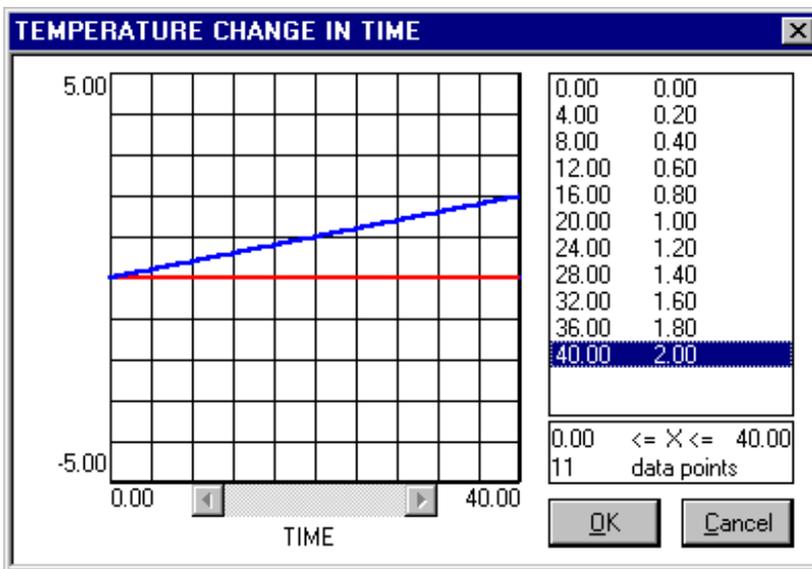
At the bottom of the SimLucia window, there are buttons for 'Macro-scal...' and 'Micro-scale...', and a status bar with 'For Help, press F1' and a 'NUM' button.

**What-if? simulation:** We will compare two scenarios: the first with no climate change, the second with a temperature rise of 2°C and sea level rise of 0.8 foot in 40 years (between 1990 and 2030). The first scenario is a so-called 'business as usual' scenario which we will use to establish a reference state, the second is a scenario which is within the limits of scenarios presented recently (see for example: Maul, 1993)

Press the Run button in the toolbar to start the simulation. In the Climate window, none of the values will change (as we assume no climate change in this first run). In the Land use window you will see how the number of cells for each land use are changing. These changes are due to the population dynamics and the external demand for goods produced by the different economic sectors. Notice for instance how natural vegetation and forest

is gradually losing cells as the simulation proceeds. Notice also that the tourism sector is expanding and new cells are taken in by tourism activity. This growth is also visible in the Jobs: Tourism dialog and graph.

When the simulation comes to a halt (after 40 years), push the Reset button. Then click the Restore button in the title bar of the (minimized) Micro-scale dynamics window. As a result the window will open. Run the simulation again and see how the land use is changing. Remember that these changes are simply due to the demographic pressure and expansion of the economic sectors. Notice for instance the fast expansion of the industrial area near Vieux Fort and Hewanorra airport and the urbanization of the southern tip of the island. Remember that this is the business as usual situation. The model is showing us what is likely to happen if things are evolving purely driven by the internal dynamics of the system (and based on the hypotheses built into the model). If planners or policy makers are not happy with this evolution they will have to decide on the right counter measures to stop unwanted impacts. That is how scenarios are used in policy making.



Now we will run our second scenario. First minimize the Micro-scale dynamics window again. Then select the Climate window and click in the edit field named 'Temperature' a temperature which gradually changes to a maximum of 2°C in 40 years. When finished the Temperature Change window should more or less look like this.

Now select the edit field Sea Level and click-in a sea level rise which gradually changes to a maximum of 0.8 foot in 40 years

Then run this new scenario for the full 40 years. In the Climate window, you can see in the different edit fields how the changes in temperature and sea level rise will result in a rising storm frequency and precipitation and how this will affect (percent increase or decrease) in the demand for Tourism, and goods in the Agriculture and Industry sectors. Notice the difference (in comparison with the previous scenario) in the evolution of the Jobs in the Tourism sector. Notice also in the Land use window the differences in the number of cells that are taken in by Tourism as well as the amount of land that is lost to the sea. If your scenario settings are similar to ours, the island will have lost 10 cells to the sea (read the line sea with the value 0 in the column Initial land use and 10 in the column Current land use).

If you run the simulation again with the Micro-scale dynamics window opened, you will notice which coastal cells are lost to the sea (for example part of the causeway linking Pigeon Island to the mainland will be lost to the sea). In the next exercise we will show how maps can be compared more easily.

From this exercise we can conclude that climate change would have a considerable effect on the Tourism sector. The effects in terms of land loss are rather limited. We would

like to repeat however that the results are influenced to a degree by the assumptions built into the model. Certainly the time series entered for the external demand of each sector (among which the Tourism sector) will have considerable effects on the employment in the sectors.

Also, we would like to remind you of the remark which we made about the representation of the relief in this model (see Section 3.2). Due to the grid representation of the relief, the typical narrow beaches of St. Lucia are not very well represented. They tend to get disregarded because they hardly ever cover more than half of the surface of a cell (250 by 250 meter) and their elevation above sea level is usually overestimated (because a cell has an average elevation value). Since the calculation of sea level rise and loss of land is directly related to the elevation of coastal cells, one should be careful in interpreting the amount of land that is really at risk. Also, and even more important, is the remark that **SIMLUCIA** does comprise models that take into consideration the effects of waves, currents and wind on the erosion of beaches. On field trips to St. Lucia, we have witnessed the effects on the beaches of storms in combination with seasonal current regimes: during the winter season, beaches erode strongly, while in the summer season, beaches are naturally replenished. In order to study these effects, **SIMLUCIA** would have to be further developed and appropriate models of the kind should be included.

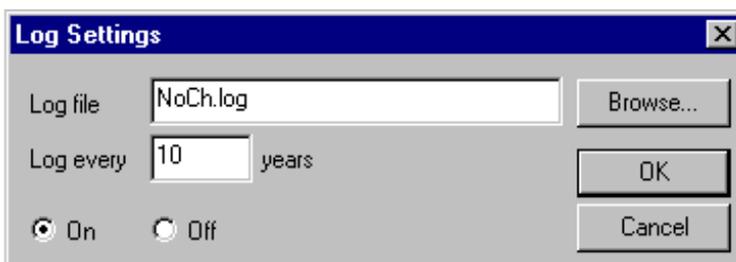
### 8.3 *Exercise b: Working with ANALYSE and MS Excel*

In the chapters 4-7 we have explained that results produced with **SIMLUCIA** can be further analysed by means of the programs **ANALYSE** and Microsoft Excel. The purpose of this exercise is to practice this procedure.

**Aim:** the aim of this exercise is to re-run the simulations of exercise a, but to store the results of the simulations on file, in order to allow for the further analysis of the results by means of **ANALYSE** and Microsoft Excel. In order to be able to produce and store Excel files, it is required that you have Excel installed on your PC.

**Screen arrangement:** The screen arrangement is not different from the one explained in exercise a. Hence, make sure that your screen is organised as explained in Section 8.2.

**What-if? simulation:** Again we will compare two simulation runs: the No-change scenario and the Rise scenario. Once your screen arrangement is ready to start the No-(climate) change run, select from the Options menu the command Log... As a result the Log settings dialog will open. The dialog allows you to define a so-called log-file in which the Micro-scale dynamics maps produced by a simulation can be stored. This file is always and immediately saved on your hard disk. Hence, there is no need for you to save it manually.



First click the On radio-button, next define the name of the log file in the Log file edit field (for instance NoCh.LOG) and finally fill in the (simulation) interval for which you want a map to be added to the log file (for instance every 10 years).

Next, we will link **SIMLUCIA** to Microsoft Excel and enable the transfer of simulation data to Excel. To that end, select the Link to Excel... command from the Options menu. As a result the default Excel file LUCIA.XLS will open. This workbook file is now ready to receive data from the simulation. Click in the **SIMLUCIA** application window to bring it back to the foreground of your screen.

Now start the simulation. The dialogs will be updated and, hidden from the user, maps are written to the log file NoCh.LOG (at every 10th simulation step) and to the workbook LUCIA.XLS (at every simulation step). When your simulation comes to a halt (at simulation step 40) select the workbook and save it as NoCh.XLS.

At this point we will not further discuss the results of the simulation as they are not different (except for some effects due to the probabilistic variables) from what has been said in exercise a. We will immediately continue the exercise with the second simulation. However, do not change the Temperature rise and Sea level Rise by hand, rather select from the File Menu the command Open Simulation to open the simulation file named Rise.SIM. This file is identical to the NoCh.SIM except for the fact that a climate change scenario (2°C Temperature rise and 0.8 foot Sea level rise in 40 years) is pre-defined.

When Rise.SIM is opened, the old simulation will close automatically. None of its output is saved, except for the NoCh.LOG. A dialog will open asking you whether you want to save the simulation results. If you answer yes, the Save as dialog will open. Answer No.

Once Rise.SIM is opened, make certain that the maps produced by the Rise scenario are written to the LOG file named Rise.LOG for every 10<sup>th</sup> iteration. Also, select Link to Excel again in order to open a new (empty) workbook LUCIA.XLS to receive the results of the Rise scenario.

Then, start the simulation and run it for 40 years and save LUCIA.XLS with the new name RISE.XLS.

**Comparison of simulation results:** We will compare the results of both simulations: to compare maps, we will use the application **ANALYSE**, and to compare numerical results, we will use Microsoft Excel..

Open **ANALYSE** (consult Chapter 7 for more details). If you installed **SIMLUCIA** as explained, it should be located in the same Program Group. Next, select from its File menu the Open... command to open the file named NoCh.LOG. As soon as the program has opened the file, it will display the first map of the file. Maximize the window to increase the map to the maximum size possible (on your monitor).

Next select again from the File menu the Open... command. Now open the file named Rise.LOG. **ANALYSE** will ask you whether you want to close the current (= NoCh.LOG) log file(s). Answer No to this question and select Rise.LOG in the Open dialog. From this moment on, **ANALYSE** is ready to show you any of the maps stored in both log files and to perform a comparison between any two maps. Let us compare the end states of both simulations. To that end select in the first list box (from the left) the map NOCH40 and in the second list box the map RISE40. Then press the comparison  button. **ANALYSE** will now show the results of a cell by cell comparison between the two maps and for each land use. In the third list box you can select the land use for which you want to see the comparison.

Pick Sea from the list of land uses. In green you see which cells are taken in by the sea in both simulations and in blue you see the 10 cells that are lost to the sea due to sea level rise.

Now pick Tourism from the list of land uses. Again in green you see cells that are taken in by tourism in both simulations, in red the cells which land use has changed due to sea level rise and in blue cells that are taken in by tourism in the Rise scenario, but not in the No change scenario. To understand better the overall changes that have taken place in the vicinity of some of the red or blue cells, it is interesting to look at the original maps that are being compared by pressing the buttons  or . There is an interesting case of coastal retreat to be seen in the Rodney Bay area. Some cells are lost to the sea, the beach has moved inland, and some tourism cells have been abandoned. Of course, the simulations are showing what would happen in the absence of beach protection by public or private authorities. Also, land loss and beach loss in our simulation depend largely on the elevation map, which has only one elevation reading per cell (250 by 250 m).

The numerical results of both simulations can be compared and further analysed by means of Microsoft Excel. Excel is a very elaborate package with almost unlimited capabilities. One way of comparing two simulation runs is to open both .XLS files that have been generated and stored (in our case NoCh.XLS and Rise.XLS) and to create a new (a third) Workbook in which the comparisons (differences) are calculated. Excel will also allow to make graphs of the simulation results. However, it is beyond the scope of this chapter to explain the functionality of Excel.

We would like to conclude this exercise with the remark that **SIMLUCIA** also supports the Export of its maps to IDRISI (as .IMG files). In IDRISI they can be further compared, analysed and manipulated. This too is beyond the scope of this chapter.

#### 8.4 *Exercise c: Working with policy interventions*

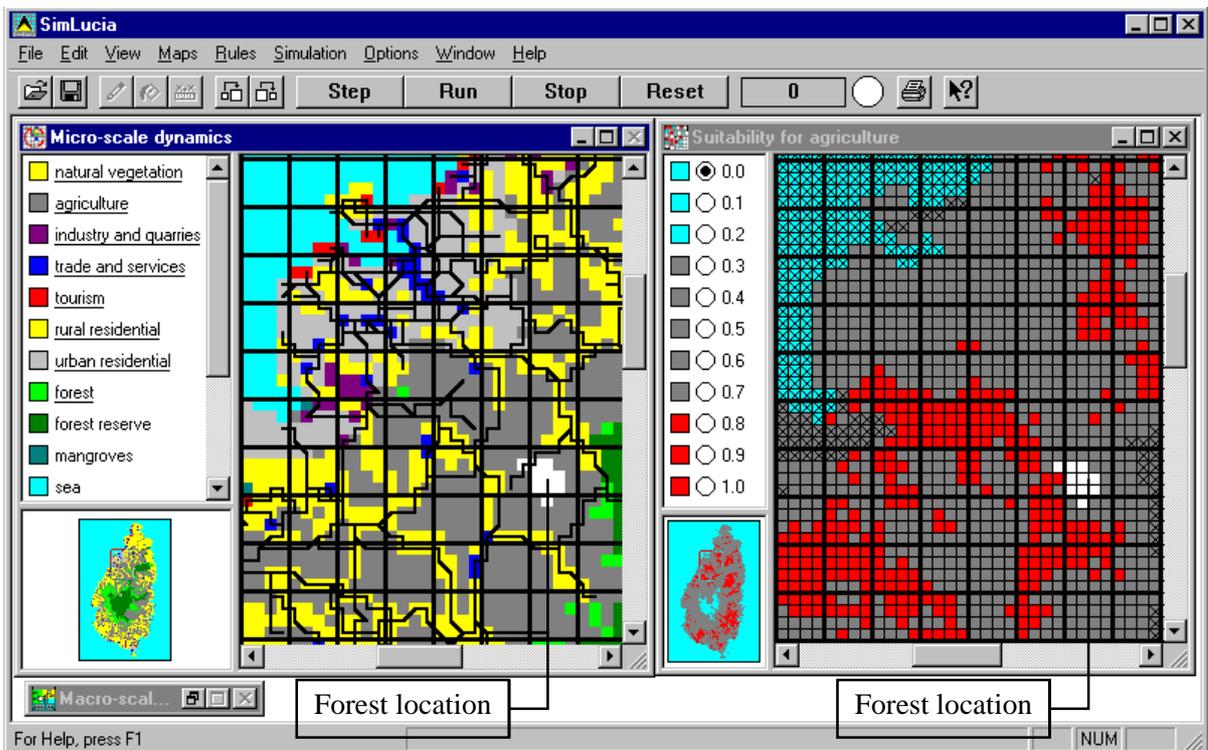
In the previous exercises we worked with scenarios, which we defined as hypotheses related to external factors not under the control of the decision maker. Other parameters in **SIMLUCIA** can be controlled by planners and decision makers. To mention are the demographic parameters that define the long term trends in birth, death and the migration rates. Decision makers can influence these parameters at the least in part through information campaigns, education, and/or health programmes. The same is true for the economic parameters. For example, a directed promotion campaign abroad for a product produced in St. Lucia (say tropical flowers) could boost the exports of the Agriculture sector. Finally decision makers can restrict the spatial expansion of particular sectors in specific parts of the island through zoning regulations. We define this type of interventions as *policy interventions*. The next exercise will demonstrate how **SIMLUCIA** can be used as an instrument for land use planning, possibly watershed management. We will show how a zoning regulation can be introduced in the simulation and how the effects of such regulation can be analysed. It is an exercise that will reveal the real dynamic capacity of **SIMLUCIA**.

**Aim:** The particular aim of the exercise is to protect a remnant of forest which is located South of Forestière and North of Floissac on the lower slopes of Piton Flore and drained by a tributary of the Cul de Sac River. On the Land Use and Vegetation map in the Atlas of St. Lucia the forest is marked as Secondary Natural Forest (= Land that was cleared for agriculture or forest products and has since reverted to forest). On the **SIMLUCIA**

Land use map, the forest consists of 10 cells (= 62.5 ha) located around cell [row = 67, column = 66].

**Screen Arrangement:** In this exercise we will work with the maps of the Micro-scale models. If your PC is equipped with a low resolution monitor, you will have to keep the maps sufficiently small (or zoom out) to see them simultaneously on your screen. As part of the exercise, we will edit maps. Please keep in mind that **SIMLUCIA** is not equipped with a so-called Undo edit function. This means that corrections made to maps are definite. You can press the Reset button to reverse all the corrections made since the simulation was opened. Be careful when you save the simulation not to overwrite original maps with copies that have been edited by you (read the instructions in Chapters 3-6).

- Start **SIMLUCIA** and Open the simulation file named '*NoCh.SIM*'. Close the Macro-scale dynamics window.
- Select from the Maps menu the Suitability map for Agriculture.
- Zoom in on both maps to the point that the cells are sufficiently big to allow you to click-in new values.
- Position the maps in such a manner that the area around the cell with the co-ordinates [row = 67, column = 66] is handy. In order to find cell [row = 67, column = 66] you can select from the view menu the command Goto... and fill in the co-ordinates.
- In order to focus your attention on the area where we will intervene, it helps to show the Major Grid on top of both maps. To that end, select Grid... from the Options menu and draw a Major Grid every 4 cells.
- Finally, make the Micro-scale dynamics window active (by clicking it) and select from the View menu the command Network in order to draw the road system on the map.
- Your screen should now look more or less like this:



**What-if? simulation:** For the sake of the exercise we assume that we have the power to impose zoning plans. With **SIMLUCIA**, we want to find out why the particular forest area is threatened, what type of land use is likely to replace the forest, when will this happen and how rigorous should the zoning regulation be that is to prevent the forest from vanishing.

- First, run the simulation and watch carefully what is happening to the forested area. Mark when forest cells disappear. What is replacing the forest? Reset and re-run the simulation if everything goes too fast for you. In the end you should have concluded that the forest entirely disappears and that it is replaced by agriculture. The first forest cell disappears around the third year, and the last is gone after about 35 years. All cells are taken in by agriculture. Notice that the first cells disappear near the road, where the Accessibility is highest. Check the latter by selecting the Network map from the Maps menu and Accessibility for Agriculture from the View menu. Clearly, the increasing demand for agricultural products, due to both the growing local population and the export markets is putting a lot of pressure on the land. Agriculture is gradually taking in more land all over the island and also in our forest area. This you can check by running the simulation again while you zoom in on other locations. If you want to know how many cells are taken in by agriculture, you can double-click the left mouse button in the Micro-scale dynamics window to open an overview window showing the number of cells of each kind at each simulation step. Notice also the fact that while the forest disappears, the rural residential area just West of the forest expands, and that the expansion of Castries to the South adds to the general pressure on the land in this part of the island.
- Next, we will try to stop the farmers from entering our forest by imposing a zoning regulation. This can be done by means of the suitability map. As explained in Chapter 4, a suitability map is the expression of the capacity to support a particular land use. On your screen you have opened the suitability map for agriculture. Hence, for each cell you can read how well suited it is for agriculture. In the Suitability calculation (See Chapter 3 and Annex D) we have considered a number of factors, including actual use, land capability, slopes, elevation, rainfall, etc. But suitability also involves institutional aspects, such as zoning plans. Hence, the planner can in an artificial manner lower the (physical) suitability to represent institutional regulations.
- Read from the Suitability map the suitability value for the forest cells. To that end move the cursor over the cells. Do not click the mouse, if not, new values will be entered in the cells.

	Pot.	Infl.	Suit.	Access.
natural vegetation			0.60	
agriculture	2.14	4.06	0.60	0.88
industry and quarries	0.00	0.00	0.40	0.53
trade and services	10.70	98.75	0.30	0.36
tourism	0.00	0.00	0.40	0.22
rural residential	54.16	128.75	0.50	0.84
urban residential	10.42	51.12	0.30	0.68
forest			0.80	

Another way of knowing the accessibility values is by clicking the right mouse button on a forest cell in the Micro-scale dynamics window. A window will pop-up which shows all the information that is available for this particular cell, among which the Suit(ability) for Agriculture. You will read that the suitability value for the forest cells is 0.7 on a (0.0 - 1.0)-scale.

- The policy maker could lower this suitability value by introducing zoning regulations. Entering a value of 0.0 would mean a very strict regulation, which would definitely and absolutely protect the forest from intrusion by agriculture, but which would be

very expensive and difficult to enforce. The least costly and simplest to enforce would be a policy intervention which will reduce the suitability from 0.7 to 0.6.

- Try out the latter. To that end, reset the simulation and click a suitability value of 0.6 in all (10) or some of the forest cells. Then run the simulation again. Are the cells still taken in by agriculture? Keep on lowering the suitability value till the complete forest area can withstand the pressure from agriculture for the full 40 years. Notice, that the policy maker could reduce the cost of his intervention by fine-tuning the timing of his interventions. To that end he has to lower the suitability of a cell only the year before it is threatened by agriculture. Thus the surveillance and other costs could be reduced.
- Now that you have been able to stop agriculture from taking in our forest, it is interesting to know where farmers will have found an alternative area to expand their activities. To that end, use the technique explained in the previous exercises. Run a simulation without policy intervention and the one where the forested area remains untouched by agriculture. Put the results on .LOG files and compare them by means of **ANALYSE**. Notice that the policy intervention has consequences for the location of agriculture, but that other activities, due to their links with agriculture, have been affected as well. Possibly the policy intervention has effects that are even worse than losing the 10 forest cells, and possibly the policy maker has to decide on additional measures to control agriculture, or any other activity for that matter. It is up to you to try this out from here.

Many more exercises of the kind explained could be tried out with **SIMLUCIA**. We could have studied what effects the construction of new roads has on the location of specific land uses, we could have experimented with measures to stop the expansion of Castries to the North, or to the South. We could have tried how to divert some of the growth of Castries to the Vieux Fort area, etc. We hope however that these 3 exercises have made you acquainted with **SIMLUCIA** to the point that you can start experimenting on your own.

Remember that the prime role of **SIMLUCIA** is to give you a better insight in the linked non-linear dynamics of socio-economic systems and the consequences of growth on a limited resource such as land. Further to show you how these dynamics could be affected by climate change. **SIMLUCIA** will **not** predict the exact future of St. Lucia. It is much too simple a model to do so. The best it can do is to calculate and visualise what sort of alternative futures are possible and what the role of different social, economic and spatial actors is in all this. As such it is a formal discussion platform: it will calculate effects in a consistent and consequent manner. Thus, it should assist in awareness building and education generally and it should support policy makers and analysts in making better informed decisions in particular.

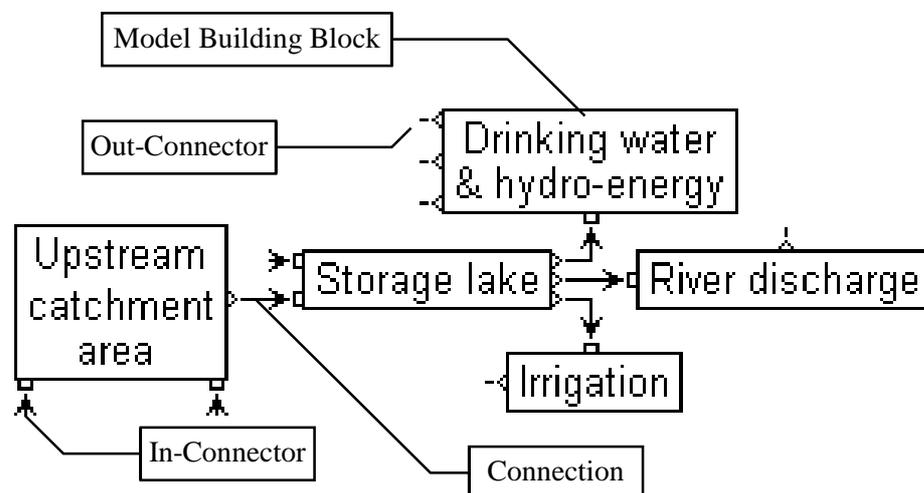
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## ANNEX A: GEONAMICA<sup>®</sup> Simulation Environment

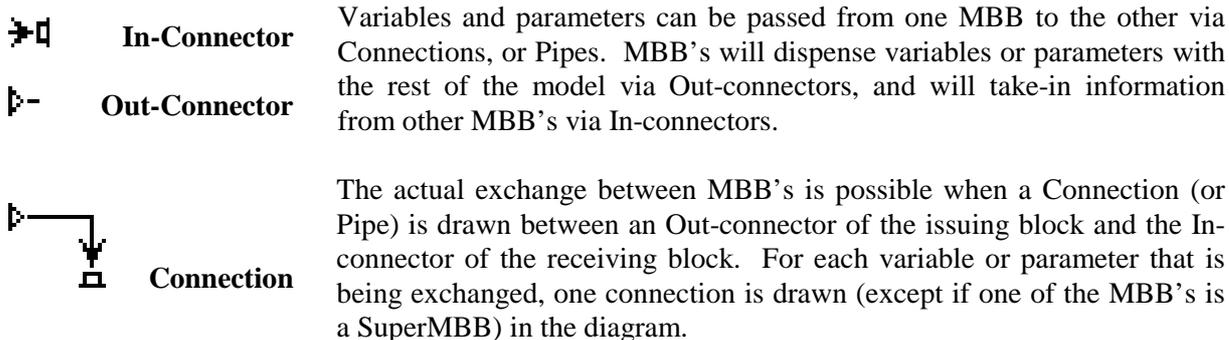
**SIMLUCIA** has been developed by means of the simulation environment **GEONAMICA<sup>®</sup>**. **GEONAMICA** features an Object-Oriented (O-O) simulation language, which enables to build a wide variety of models linking component sub-models at the Macro-scale and the Micro-scale and representing the economic, demographic and natural sub-systems in a network of mutual and reciprocal influence. The simulation objects are the so-called Model Building Blocks MBB's. MBB's are more or less complete models. They vary from simple mathematical operators, such as Multipliers or Adders, to rather sophisticated and nearly complete models consisting of coupled mathematical equations performing a number of sophisticated calculations.

A Model Building Block represents a part of a model: an action or process. Each MBB is represented by means of a unique graphical object that shows how the MBB relates and is connected to other MBB's in the model. From this connection scheme, the MBB knows where it has to get its information from, and where it should send its information to. MBB's may simply represent sources of information (i.e. entered from file or by the user), other will transform information as it passes through them, and still other will simply serve to communicate, in a synthetic manner, the outputs of the model to the user. Despite the fact that all these MBB's play different roles in the model, in Object-Oriented jargon, they are all 'children' of the same 'parent', which is a MBB with the basic capability of exchanging and transforming information.



Next to the *Model Building Blocks*, **GEONAMICA**'s simulation language features a number of additional primitives: *Libraries* where the MBB's are stored and where they are selected from; *In-Connectors* through which MBB's obtain data from other MBB's; *Out-Connectors* through which MBB's send out their information for use in other MBB's; *Connections* that link the MBB's; *Dialogs* through which the MBB's communicate with the user; and a *Documentation page* that contains the technical specifications of the MBB.

*Connectors and Connections.*



A model block has a so-called *In-Side* and an *Out-Side*. The In-Side is where the In-Connectors are placed, the Out-Side is where Out-connectors are placed. The user can decide which of the four edges of the MBB are the In- and Out-Sides. The only limitation is that they should never be on one and the same edge.

Each MBB has a *dialog box* attached to it. This dialog box is the vehicle that permits the interactive exchange of information between the user and the Model Building Block. The MBB will communicate the results (output) of its numerical operations to the user and it will accept the data entered (input) by the user that are required for the execution of the MBB. It concerns data that are internal to the MBB and which it does not get from other MBB's via its In-Connectors.

Model results and model inputs are presented in Edit Fields. The difference between input and output fields is indicated by the colour of the text in the edit field: green for state variables (to be entered as initial values and for the remainder output of the MBB); purple and blue for intermediate variables; black for variables or parameters copied from other MBB's (output of the MBB); and finally red for internal parameters of the MBB (input for the MBB).

Colour of text in the Edit Fields of MBB-Dialog Boxes	Description
RED	<u>Input</u> . Parameter value (can be changed during the entire simulation) or State variable at the initial state.
PURPLE	<u>Input</u> . Variable value. If the edit field is clicked, a dialog will pop-up requesting input necessary for the calculation of the variable
GREEN	<u>Input / Output</u> . State variable which can be changed at the start of the simulation, and which display output for the remainder.
BLUE	<u>Output</u> . Variable value. (read-only)
BLACK	<u>Output</u> . Values copied from other MBB's. (read-only)

Entering data in dialogs is done in a manner which will support and protect the user to a certain extent. Each edit box in a dialog window knows what type of data it is to get from the user: a single number, an array of numbers, or a table (i.e. time series). For each type the appropriate editor is opened when the user clicks in the edit box.

Each MBB has its *Documentation* page in the Documentation system. It is accessible when the dialog window of the MBB is opened (by pressing the F1-key or clicking in the dialog window by means of the Context Sensitive Help cursor). This Documentation page gives technical information about the MBB. It can include the mathematical

expression, scientific references, the specification of the In- and Out-Connectors, the units in which values are displayed, etc.

*Libraries* are repositories of MBB's. The entire definition of the MBB (its C++ code, its graphical representation, its dialog, and its documentation page) are stored in the Library. When a MBB is included in a model, the block itself is not copied to the model, rather a reference to the block in the library is made.

*SuperMBB's* group a number of connected MBB's, thus constitute a sub-model. They are introduced to keep the representation of the model structured and clear.

## ANNEX B: Estimation of the Input-Output Table

### I. Introduction

These notes describe the sequential steps followed in constructing the I-O table for 1990. The numbering of the notes corresponds to the numbers shown on the I-O table. The table has been prepared in June 1996 with data available at that time. The data used is from the following sources:

- ref. 1.** Ministry of Agriculture, Lands, Fisheries and Forestry: Annual Agricultural Statistical Digest 1992 (ADD vol. 10)
- ref. 2.** Government Statistics Department: National Accounts 1977 to 1992.
- ref. 3.** Government Statistics Department: Annual Statistical Digest 1991.
- ref. 4.** Selected Tourism Statistics. (one page).
- ref. 5.** St. Lucia Stay Over Visitors Survey - Summer 1995 (Table: St Lucia Stay Over Visitors Expenditure)

These sources provide essentially all of the data required to construct the I-O table except for the individual inter-industry flows; however, inter-industry row and column totals can be derived from the data. The resulting table is highly constrained by the data, except for the interior of the inter-industry part. Where it is possible to make cross checks by comparing calculated with published values, or by comparing values calculated following two different approaches, the agreement is good: differences are always less than 3.5%. The table is constructed from 1990 data.

	a	b	c	d	e	f	g	h	i	j	k	l	m
	AGRIC	INDUST	TRADE	SERVICE	TOURISM	TOTALS	HSEHOLD	CAP.FOR	GOVT	DOM.DEM	EXPORTS	FIN.DEM.	TOTALS
A. AGRICULTURE	5	30	10	2	5.3	52.3				73	194.5	267.5	319.8
(notes)						n1				n18	n15	n14	n7
B. INDUSTRY	20	250	75	30	50.3	425.3				649.5	149.2	798.7	1224
						n1				n18	n16	n14	n7
C. TRADE	5	20	40	50	67.5	182.5				135.4	0	135.4	317.9
						n1				n18	n16	n14	n7
D. SERVICE	6	30	30	20	46	132				370.2	22.3	392.5	524.5
						n1, n10				n18	n16	n14	n7, n9, n13
E. TOURISM	0.2	2.8	0.4	1.3	139.8	144.5				0	415.4	415.4	559.9
						n1, n11				n18	n8	n14	n12
F. TOTALS	36.2	332.8	155.4	103.3	308.9	936.6	748.3	276.6	170.8	1228.1	781.4	2009.5	2946.1
(CORRECTED)	n52	n52	n52	n52	n52		ref.2 p.35	ref.2 p.35	2p.35, n19	n19	n17	n20	
G. DOM. FINAL	124.8	315.2	143.9	227.1	122.2	932.2							
FACTOR INPUTS	n53, n45	n53, n45	n53, n45	n53, n46	n53, n47								
H.													
I. NET INDIRECT	18.7	71.6	18.6	30.7	32.8	172.4							
FINAL FAC. INPUTS	n48	n48	n48	n48	n48								
J. TOTAL DOM. FIN	143.5	386.8	162.5	257.8	155	1105.6							
FACTOR INPUTS	n54, n49	n54, n49	n54, n49	n54, n49	n54, n49	n56							
K. IMPORTS	140.1	504.4	0	163.4	95.6	903.5							902.6
	n40	n41	n42	n43	n44	(calculated)							(ref.2, p.35)
L. TOTAL FINAL	283.6	891.2	162.5	421.2	250.6	2009.2							
FACTOR INPUTS	n55, n50	n55, n50	n55, n50	n55, n50	n55, n50								
M. TOTALS	319.8	1224	317.9	524.5	559.5	2946.1							
	n51	n51	n51	n51	n51								
N. EMPLOYMENT	11666	15174	6720	9958	5603	49121							
		n71, n74		n71, 73, 74	n71, 72, 74								
O. PRODUCTIVITY	123000.7	25490.97	24181.55	25888.73	27663.75								
(n74)													

## II. *Derivation of the Output (or Demand) Side of the Table*

1. Row totals for inter-industry sales are from **ref.2 p.29** but adjusted upward to account for unallocated imputed banking service charge found in the same table: this is allocated in proportion to sector size:

$$r = 881.02 / (881.02 - 52.03) = 1.063$$

$$\text{Agric.} = r (49.15) = 52.3$$

$$\begin{aligned} \text{Industry} &= r (\text{mine \& quar} + \text{mfg} + \text{const} + \text{E\&W} + \text{transp \& comm}) \\ &= r (7.6 + 164.8 + 111.6 + 38.0 + 56.2 + 22.1) = r (400.1) = 425.3 \end{aligned}$$

$$\text{Trade} = r (171.7) = 182.5$$

$$\begin{aligned} \text{Services} &= r (\text{fin.} + \text{RE} + \text{govt} + \text{oth. serv}) \\ &= r (19.5 + 4.5 + 50.9 + 69.3) = r (144.2) = 153.3 \end{aligned}$$

$$\text{Tourism} = r (\text{ho\&re}) = r (115.9) = 123.2$$

Amounts for services and tourism are further adjusted in (10) and (11) below.

2. Imports of agriculture from **ref.1 p.62**.
3. Imports of Industry:  
merchandise debit from ref.3 p.87 less Agric. imports from ref.1 p.62  
 $= 644.5 - 140.1 = 504.4$
4. Imports of Trade: assume none.
5. Imports of Services: from **ref.3 p.87**, debit column:  
shipping + other transp. + other goods, serv, inv.  
 $= 87.9 + 33.6 + 91.9 = 213.4$
6. Imports of Tourism: **ref.3 p.87** : travel (debit) = 45.6
7. Totals: the figures shown in **ref.2 p.28** evidently are total sectoral output *net of imports* (note for example that total output shown for agriculture is less than agricultural exports); i.e. the totals are those required for calculating GDP, rather than true totals. Thus to get actual total sectoral outputs, it is necessary to add imports:

$$\text{Agric: } 179.7 + 140.1 = 319.8$$

$$\begin{aligned} \text{Industry: } &(\text{mine \& quar} + \text{mfg} + \text{const} + \text{E\&W} + \text{transp \& comm}) + \text{imports} \\ &= (12.8 + 237.7 + 172.6 + 61.8 + 160.2 + 75.6) + 504.4 = 1224.0 \end{aligned}$$

$$\text{Trade: } 317.9 + 0 = 317.9$$

$$\begin{aligned} \text{Services: } &(\text{shipping} + \text{other transp.} + \text{other goods, serv, inv.}) + \text{imports} \\ &= 93.9 + 53.7 + 173.9 + 99.0 + 213.4 = 633.9 \text{ (This total is further adjusted in (10) and (11) below).} \end{aligned}$$

Tourism: calculated in (12) below.

8. From **ref.4 "total expenditures"**; assume this entire amount constitutes exports:  
 $= 415.4$
9. Tourism exports as defined by Travel (credit) in **ref.3 p.87** = 326.6 compared with amount shown in (8) above.  $326 / 415.4 = 78.6\%$ . Compare this ratio with that in **ref.5** which shows hotel and meals & drinks expenditures at  $72.5\% + 6.3\% = 78.8\%$ . Thus the Horeca sector seems to account for this proportion of tourism. Therefore adjust other

sectors so that in total they lose an amount equal to 21.2% of Tourism exports. For want of data, assume all of this is reallocated from Total. Output of Services as calculated in (7) above:  $633.9 - 0.212 (415.4) = 633.9 - 88.1 = 545.8$ ; this figure is further adjusted in (13) below. The 88.1 reallocated from Services is already included in Tourism exports as defined in **ref.4**.

10. Since some of the Services sector is reallocated to Tourism, adjust the inter-industry totals from (1) accordingly by an amount calculated from the proportional decrease of services:  $(545.8 / 633.9) (153.3) = 132.0$

11. Increase the Tourism inter-industry total by the amount transferred from Services:  
 $123.2 + (153.3 - 132.0) = 144.5$

12. Tourism Total = inter-industry total + exports + 144.5 + 415.4 = 559.9

13. Services Total Output is adjusted downward by the amount of inter-industry sales transferred to tourism in (11):  $545.8 - (153.3 - 132.0) = 524.5$

14. Sectoral Final Demand (col. l) = sectoral Total Output (col. m) less sectoral total of Inter-industry sales (col. f).

15. Agric. exports from **ref.1 p.5**.

16. Other exports:

Industry: merchandise credit (from **ref.3 p.87**) less Agric. exports (15).  
 $= 343.7 - 194.5 = 149.2$

Trade: assume exports = 0.

Services: from the *credit* column of **ref.3 p.87**, (ship + other transp + other goods, serv, inv) less transfer to Tourism from (9) above  
 $= (0.1 + 35.4 + 74.9) - 88.1 = 22.3$

17. **CROSS CHECK**: the total of the exports column (k) is 781.4 compared with the published total in **ref.2 p.35** of 778.2, a difference of 0.411%.

18. Domestic demand (col j) = Final Demand (col l) less Exports (col k).

19. **CROSS CHECK**: compare calculated total domestic demand of 1228.1 with published totals from **ref.2 p.35**: (households + cap. form. + govt.) =  $(748.3 + 276.6 + 170.8) = 1195.7$ ; the difference is 2.71%

20. **CROSS CHECK**: Calculate GDP at market prices as total output less total imports (from **ref.2 p.35**) =  $2009.5 - 902.6 = 1106.9$ ; compare with published figure of 1071.3 (**ref.2 p.35**). The difference is 3.32%.

### **III. Derivation of the Input (or Supply) Side of the Table**

Note: 

- numbers 21 - 39 are not used
- results of operations 40 - 52 are shown in the table below

40. Imports of Agric from **ref.1 p.62**.

41.Imports of Industry: merchandise debit (from **ref.3 p.87**) less Agric imports (40)  
 $= 644.5 - 140.1 = 504.4$

42.Imports of Trade: assume none.

43.Imports of Services: from **ref.3 p.87**, *debit* col., (shipping + oth. transp. + oth. g,s,i) less reallocation to Tourism  
 $= (87.9 + 33.6 + 91.9) - 40 = 173.4.$

Note that the amount reallocated to Tourism is arbitrary because of lack of data. But the total reallocation on the input side carried out in (43) and (46), and implicitly in (48), is approximately equal to the reallocation on the output side in (9, 10, 11 and 13).

44.Imports of Tourism: travel debit from **ref.3 p.87** plus reallocation from services:  
 $45.6 + 40 = 85.6$

45.Domestic factor inputs from **ref.1 p.5** or **ref.2 p.17** and adjusted in proportion to sector size to exclude imputed banking service charge by the factor  
 $r = 898.92 / (898.92 + 52.0) = 0.9453$

Agric:  $r (130.6) = 123.5$

Industry:  $r (\text{mine \& quar} + \text{mfg} + \text{const} + \text{E\&W} + \text{trnsp \& comm.})$   
 $= r (5.14 + 73.00 + 61.00 + 23.80 + 104.00 + 53.55) = r (320.5) = 303$

Trade:  $r(146.2) = 138.2$

46.Domestic factor inputs (Services): (fin + RE + govt + oth serv) from **ref.2 p.17** less reallocation to Tourism (assumed, but see (43)), and then adjusted by r (see (45)):  
 $= r ((74.37 + 49.18 + 123.0 + 29.7) - 40) = 223.3$

47.Domestic factor inputs (Tourism): Ho & Re. from **ref.2 p.17** plus reallocation from services, then adjusted by r (see (45):  $r (77.4 + 40) = 111.0$

48.Total net indirect taxes and subsidies from **ref.2 p.35** are allocated to sectors in proportion to sectoral Total outputs:  $r = 172.4 / 2946.1 = .05852$

49.Total domestic final factor inputs are calculated as the sum of domestic factor inputs (45, 46, 47)and indirect taxes.

50.Total direct inputs are calculated as the sum of total domestic final inputs (49)and imports.

51.Since total sector inputs for each sector must equal total sector outputs, set input totals (row M) equal to output totals (col. m).

52.Inter-industry totals (row F) are calculated as total inputs (row M) less total final factor inputs (row L). But the total of inter-industry purchases thus calculated is 971.2 compared with the 936.6 total calculated for inter-industry sales in col. f. Since the inter-industry sales are taken from actual data (with adjustments), the purchases figures should be re-scaled so that total inter-industry purchases are equal to total sales. Thus apply a correction factor  $r = (936.6 / 971.2) = 0.9645$  to each inter-industry purchase total to get the final values used in the I - O table. Differences between the preliminary and final figures are shown in the corrections row of the table below.

53. Add the amounts subtracted from the inter-industry totals (shown in the corrections row) to the domestic final factor inputs, since total sectoral inputs must remain unchanged, and the original over-estimation of the inter-industry totals must be due to an underestimation of final factor inputs.
54. Recalculate total domestic final factor inputs: row J = row G + row I.
55. Recalculate final factor inputs: row L = row J + row K
56. **CROSS CHECK:** Total of domestic final factor inputs as calculated here (i.e. including net indirect taxes and subsidies)--1105.6--is an estimate of GDP at market prices. Compare with the published figure of 1071.3 from **ref.2 p.35**. The difference is 3.22%.

#### IV. *Derivation of the Inter-Industry Portion of the Table*

Note: • numbers 57-59 are not used.

60. Au goût, as long as row and column totals of the inter-industry portion are respected.

*Table 1. Preliminary figures for the supply sectors.*

	<b>Agric</b>	<b>Indus</b>	<b>trade</b>	<b>Service</b>	<b>tour</b>
<b>(F) Total inter-industry</b>	37.5	345.0	161.1	107.1	320.5
<b>(G) Domestic factor input</b>	123.5	303.0	138.2	223.3	111.0
<b>(I) Indirect taxes &amp; sub.</b>	18.7	71.6	18.6	30.7	32.8
<b>(J) Total dom. factor inputs</b>	142.2	374.6	156.8	254.0	143.8
<b>(K) Imports</b>	140.1	504.4	0	163.4	95.6
<b>(L) Total direct inputs</b>	282.3	879.0	156.8	417.4	239.4
<b>(M) Total inputs</b>	319.8	1224.0	317.9	524.5	559.5
<b>(FF) Corrected values for row (F)</b>	36.2	332.8	155.4	103.3	308.9
<b>Corrections for row (F)</b>	1.3	12.2	5.7	3.8	11.2

#### V. *Note on Employment and Productivity*

Row J of the input output table shows the total remuneration to domestic factors of production by sector, i.e. total payments (direct and imputed, including all wages, salaries, tips, bonuses, rents, dividends, and undistributed profits) to Labour, Capital, and Land. These earnings may be associated with employment using data from **Table 4.8: Employment by Sex by Industry Groupings - 1991** (loose page in papers sent Guy from St. Lucia).

71. Combine the sectors into the five used in the I-O table as follows:

Agriculture:		11598
Industry: Mining etc.	131	
Manufacturing	6751	
Utilities	575	
Construction	4960	
Transport & Comm.	2669	

		15086
Trade:		6681
Services: Finance	982	
Real Estate	948	
Public Administration	6586	
Other Services	2562	
		11081
Hotels and Restaurants:		4389

72. Estimate Tourism employment as  
 $\text{HoRe} / 0.788$  (see 9 and 43 in I-O Notes):  $4389 / .788 = 5570$

73. Re-calculate Services assuming all employment re-allocated to  
 Tourism came from this sector:  $11081 - (5570 - 4389) = 9900$

74. Allocate the 286 sector “not stated” employees in Table 4.8 in proportion to sectoral employment, and use the domestic factor payments from row J of the I-O table to calculate productivity per employee:

*Table 2. Employment and Productivity*

<b>Sector</b>	<b>Employment</b>	<b>Productivity Per Employee (EC\$)</b>
<b>Agriculture</b>	11666	12300.70
<b>Industry</b>	15174	25490.97
<b>Trade</b>	6720	24181.55
<b>Services</b>	9958	25888.73
<b>Tourism</b>	5603	27663.75

## ANNEX C: Factors and Weights

This annex contains an overview of the factors and weights that have been used in the overlay analysis to produce the set of suitability maps used in SIMLUCIA.

	A	B	C	D	E	F	G	H	I	J
4	<b>Factor 1: Land Use Atlas</b>	<b>factor type</b>	<b>Rating per land use function</b>							
5	<i>map: reluse</i>		<i>Natural</i>	<i>Agriculture</i>	<i>Industry Quarries</i>	<i>Services Trade</i>	<i>Tourism</i>	<i>Rural residential</i>	<i>Urban residential</i>	<i>Forest</i>
6	Sea	1	0	0	0	0	0	0	0	0
7	Primary Forest	2	2	2	1	0	0	0	0	10
8	Secondary Forest	3	4	3	2	1	1	1	0	8
9	Scrub Forest	4	6	4	4	1	1	2	1	6
10	Open Woodlands	5	8	6	4	2	2	2	1	4
11	Grasslands	6	6	7	5	3	3	3	2	2
12	Large-Scale Agriculture	7	6	8	5	4	4	4	3	4
13	Intensive Small Farming	8	5	9	6	7	4	7	5	5
14	Mixed Small Farming	9	4	7	5	5	4	6	4	6
15	Rural Settlement Areas	10	4	6	7	8	6	10	8	4
16	Urban, Commercial, Industrial and	11	2	4	9	10	7	6	10	0
17										
18										
19	<b>Factor 2: Land Use Actual</b>	<b>factor type</b>	<b>Rating per land use function</b>							
20	<i>map: landuse</i>		<i>Natural</i>	<i>Agriculture</i>	<i>Industry Quarries</i>	<i>Services Trade</i>	<i>Tourism</i>	<i>Rural residential</i>	<i>Urban residential</i>	<i>Forest</i>
21	Natural vegetation	1	10	8	4	4	6	6	6	5
22	Agriculture	2	6	10	6	6	6	8	7	4
23	Industry and Quarries	3	8	5	10	8	4	5	7	2
24	Trade and Services	4	8	3	6	10	7	6	9	2
25	Tourism	5	8	5	6	8	10	4	9	2
26	Rural residential	6	6	8	5	7	5	10	8	4
27	Urban residential	7	6	2	8	9	7	6	10	4
28	Forest	8	5	6	5	4	6	7	5	10
29	Forest reserve	9	2	0	0	0	0	0	0	8
30	Mangrove	10	6	3	0	0	0	3	1	4
31	Sea	11	0	0	0	0	0	0	0	0
32	Beach	12	8	3	4	0	9	0	2	2
33	Coral reef	13	0	0	0	0	0	0	0	0
34	Terminals, ports, airports	14	6	0	9	8	8	2	7	4
35	Infrastructure	15	4	0	2	2	2	3	2	6
36										
37										
38	<b>Factor 3: Land Tenure</b>	<b>factor type</b>	<b>Rating per land use function</b>							
39	<i>map: reldis</i>		<i>Natural</i>	<i>Agriculture</i>	<i>Industry Quarries</i>	<i>Services Trade</i>	<i>Tourism</i>	<i>Rural residential</i>	<i>Urban residential</i>	<i>Forest</i>
40	Sea	1	0	0	0	0	0	0	0	0
41	Undivided Government	2	4	4	4	4	4	2	2	6
42	Partly Subdivided Government	3	4	6	5	5	5	4	4	6
43	Fully Subdivided Government	4	6	8	6	6	6	6	6	4
44	Para-statal Land	5	6	8	6	6	6	6	6	4
45	Forest Reserve	6	2	0	0	0	0	0	0	8
46	Undivided Private	7	7	8	6	6	6	6	6	3
47	Partly Subdivided Private	8	7	8	8	8	8	8	8	3
48	Fully Subdivided Private	9	8	8	9	9	9	10	10	2
49	Other	10	5	8	8	8	8	9	9	5
50	Settlements	11	8	4	6	6	6	8	10	2
51										
52										
53										
54	<b>Factor 4: Land Capability</b>	<b>factor type</b>	<b>Rating per land use function</b>							
55	<i>map: reicap</i>		<i>Natural</i>	<i>Agriculture</i>	<i>Industry Quarries</i>	<i>Services Trade</i>	<i>Tourism</i>	<i>Rural residential</i>	<i>Urban residential</i>	<i>Forest</i>
56	Sea	1	0	0	0	0	0	0	0	0
57	Suitable Class I	2	1	10	5	6	6	9	9	1
58	Suitable Class II	3	2	8	6	5	5	8	8	2
59	Suitable Class III	4	3	6	7	4	4	7	7	3
60	Suitable Class IV	5	4	5	7	4	4	6	6	4
61	Not Suitable Class V	6	5	4	6	3	3	5	5	5
62	Not Suitable Class VI	7	6	3	6	2	2	4	4	6
63	Not Suitable Class VII	8	8	2	6	1	1	2	2	8
64	Not Suitable Class VIII	9	10	1	5	1	1	1	1	10
65	Settlement	10	8	4	6	6	6	8	10	2

	A	B	C	D	E	F	G	H	I	J
68	Factor 5: Life Zones	factor type	Rating per land use function							
69	map: relzone		Natural	Agriculture	Industry Quarries	Services Trade	Tourism	Rural residential	Urban residential	Forest
70	Sea	1	0	0	0	0	0	0	0	0
71	Tropical dry - very dry forest	2	8	4	8	8	9	4	8	2
72	Tropical dry forest	3	7	6	7	7	8	6	7	3
73	Tropical moist forest	4	6	8	6	6	7	8	6	4
74	Subtropical moist forest	5	5	6	5	5	5	7	5	5
75	Subtropical wet forest	6	4	8	4	4	4	8	4	6
76	Subtropical wet - rain forest	7	2	6	2	2	2	6	2	8
77	Subtropical rain forest	8	0	2	0	0	0	2	0	10
78	Settlement	9	8	4	6	6	6	8	10	2
79										
80										
81	Factor 6: Rainfall	factor type	Rating per land use function							
82	map: rsurface		Natural	Agriculture	Industry Quarries	Services Trade	Tourism	Rural residential	Urban residential	Forest
83	Sea	1	0	0	0	0	0	0	0	0
84	< 1520 mm	2	10	4	9	9	9	8	9	1
85	1520 - 1778 mm	3	9	6	8	8	8	10	8	3
86	1778 - 2032 mm	4	8	8	7	7	7	8	7	5
87	2032 - 2286 mm	5	7	9	6	6	6	7	6	6
88	2286 - 2540 mm	6	6	6	4	4	4	6	4	7
89	2540 - 3045 mm	7	5	4	2	2	2	4	2	8
90	3045 - 3810 mm	8	3	2	1	1	1	2	1	9
91	> 3810 mm	9	1	0	0	0	0	0	0	10
92										
93										
94	Factor 7: Slopes	factor type	Rating per land use function							
95	map: slopec		Natural	Agriculture	Industry Quarries	Services Trade	Tourism	Rural residential	Urban residential	Forest
96	Sea	1	0	0	0	0	0	0	0	0
97	< 2.5 %	2	10	10	10	10	10	10	10	2
98	2.5 - 5.0 %	3	8	8	6	6	7	7	6	4
99	5.0 - 10.0 %	4	6	6	4	4	6	6	4	5
100	10.0 - 17.5 %	5	5	4	2	2	4	4	2	6
101	17.5 - 25.0 %	6	4	2	1	1	2	2	1	8
102	> 25.0 %	7	2	0	0	0	0	0	0	10
103										
104										
105	Factor 8: Land Elevation	factor type	Rating per land use function							
106	map: elevat		Natural	Agriculture	Industry Quarries	Services Trade	Tourism	Rural residential	Urban residential	Forest
107	Sea	1	0	0	0	0	0	0	0	0
108	< 25 feet	2	10	7	8	10	10	8	8	1
109	25 - 50 feet	3	9	8	10	9	9	10	10	2
110	50 - 100 feet	4	8	10	9	8	7	9	9	3
111	100 - 200 feet	5	7	9	7	7	6	8	7	4
112	200 - 400 feet	6	6	8	5	5	4	7	5	5
113	400 - 600 feet	7	5	6	3	4	2	6	3	6
114	600 - 800 feet	8	4	4	1	2	1	4	1	7
115	800 - 1000 feet	9	3	2	0	1	0	2	0	8
116	1000 - 2000 feet	10	2	0	0	0	0	1	0	9
117	> 2000 feet	11	1	0	0	0	0	0	0	10
118										
119										
120	Factor Weights		Weight per land use function							
121			Natural	Agriculture	Industry Quarries	Services Trade	Tourism	Rural residential	Urban residential	Forest
122			N	A	I	S	T	R	U	F
123	w1-land use atlas	1	3	3	1	1	1	2	1	3
124	w2-actual land use	2	3	3	4	3	4	3	4	3
125	w3-land tenure	3	2	2	2	2	2	2	2	2
126	w4-land capability	4	3	4	2	2	2	3	1	3
127	w5-life zones	5	4	3	0	1	1	3	1	4
128	w6-rainfall	6	4	3	0	1	3	3	2	4
129	w7-slopes	7	3	4	3	3	3	4	4	3
130	w8-land elevation	8	2	2	3	3	3	2	3	2

This table is a print-out of the Microsoft Excel Workbook SimLucia.XLS which has two sheets: **sheet 1** consists of the table above and features the factors and weights that have been applied in the overlay analysis to produce the set of suitability maps used in SIMLUCIA. In the left top corner of **sheet 1** you will find a button named 'Make LucMac'. If this button is pressed, the Excel macro stored in **sheet 2** of the Workbook will be executed and produce the IDRISI macro named LucMac.IML. If you run the latter macro in IDRISI, it will generate the set of suitability maps. Thus, with these tools, you can change the factor types and weights and produce your own set of suitability maps

## ANNEX D: Pointer Shapes

Pointer Shape	Description
<i>Standard MS Windows Pointer Shapes</i>	
	Standard Windows© cursor.
	Standard I-beam cursor for editing windows.
	Sizing cursor to change the width of the window. Displayed when the pointer is on top of a vertical window border.
	Sizing cursor to change the height of the window. Displayed when the pointer is on top of a horizontal window border.
	Sizing cursor to change the width and/or the height of the window. Displayed when the pointer is on top of a window corner.
	Sizing cursor to change the width and/or the height of the window. Displayed when the pointer is on top of a window corner.
	Context Sensitive pointer to get on-line help on the command you click on.
<i>Specific SIMLUCIA Pointer Shapes</i>	
	Insert cursor to insert values in an MBB-Dialog edit field by means of the text value and table editor.
	Insert cursor to insert values in an MBB-Dialog edit field by means of the graph editor.
	Insert cursor to insert values in an MBB-Dialog edit field by means of an additional dialog.
	Pen cursor to pick a value from the legend of a map and to enter it in a cell; or to enter ordinal values in the X-Y graph part of the graph editor.
	Bucket cursor to pick a value from the legend of a map and to enter it in a group of contiguous cells.