Working Paper

Scenarios for Mauritius, 1990-2050

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WP-93-19
April 1993

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ABSTRACT

This Working Paper constitutes Chapter 16 of the book manuscript, *Understanding Population-Development-Environment Interactions: A Case Study on Mauritius*. The Mauritius case study was carried out by IIASA in scientific collaboration with the University of Mauritius and funded by the United Nations Population Fund (UNFPA).

The paper presents and discusses findings from the interdisciplinary computer model simulating alternative future population-development-environment interactions for the period 1990 to 2050. It serves to answer some of the main questions raised by the project, such as "what is the effect of population growth and education on development and the environment of Mauritius".

In a first section, some general elements which should be kept in mind when doing scenario experiments are discussed, relating to hard-wired and soft links in the PDE-Mauritius model. Next, alternative "unadjusted" future scenarios are constructed and compared in order to identify the partial impact of various population, economic, and environmental assumptions.

A subsequent section demonstrates how those unadjusted scenarios are transformed into consistent multi-component scenarios, labelled as "adjusted scenarios". Those scenarios present consistent development alternatives and hence offer answers to the relevant questions under various development paths.

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SCENARIOS FOR MAURITIUS, 1990-2050[1]

Einar Holm, Christopher Prinz, Anne Babette Wils

1. INTRODUCTION

Chapter 16--together with Chapter 17--serves to answer some of the main questions raised by the project: What is the effect of population growth and education on development? Can economic development occur without population control? What is the effect of population on environment? The answers to most of our questions relate to the very specific situation of Mauritius and its population, economy and environment, but are generalized whenever possible.

To answer those questions our PDE-Mauritius model is used to calculate alternative future paths in the population, development, and environment components, and the interactions between those components. The time horizon chosen in this application of PDE-Mauritius is 60 years from the starting year 1990. For each segment (population, economy, environment) two basic alternatives, one optimistic and one pessimistic, have been defined. These are combined in various forms.

Other time horizons and alternatives could have been chosen. We chose a 60-year time horizon, approximately the life span of one person, to the rounded year 2050. It is a sufficiently large time horizon to see the long term effects of the scenario assumptions. Longer time horizons with this model become too speculative. With the two extreme alternatives, we seek to see extreme effects. Calibration of the scenarios often leads to middle solutions.

Section 2 discusses the basic scenario definitions and some general, but also very important elements of the model one has to keep in mind when doing scenario experiments.

Section 3 presents alternative scenarios for the population module combining demographic variables with education and labor force participation. Two reasons justify the separate discussion of the population: first, in the discussion of population and environment it is important to understand the dynamics of population growth, population inertia, possible effects of education campaigns and of female labor force participation. Second, the population module was designed to be used either independently or in combination with the full PDE-Mauritius model.

In Section 4 we combine the two basic population scenarios with two economic and two environmental scenarios, hence--by cross-classification--resulting in eight different combinations. Results of those "unadjusted scenarios" are discussed in detail as they give the partial impact of different assumptions.

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[1]Chapter 16 in the forthcoming book, *Understanding Population-Development-Environment Interactions: A Case Study on Mauritius,* edited by Wolfgang Lutz.

In Section 5, those eight unadjusted combinations are modified into a form that makes them consistent multi-component scenarios. That is, assumptions in different modules should fit well together in order to present consistent development alternatives. These scenarios are referred to as "adjusted scenarios".

2. BASIC SCENARIO DEFINITIONS, -LINKS AND -CONSTRAINTS

The definitions of the scenarios are motivated by the desire for a specific answer to a specific question. The answer to such a specific question is, however, partly dependent on all other specific assumptions for the scenario. The answer is always a conditional one. Since the model is an interdependent system, a specific change related to a specific question might also change several other indicators.

In a scenario experiment we often want to see results for several different output indicators as a consequence of a certain combination of input variables. It is possible to monitor hundreds of indicators during the performance on the system. In the first scenarios we will concentrate on just a few output parameters. Among these are total population, GNP/capita, employment, agricultural land use and water balance.

2.1. Scenario Definitions

As indicated above, we first define two extreme scenarios within each of the three areas: population, economy, and environment.

I. Population

A. *Modern* population
Fertility declines, life expectancy increases, education increases and female labor force participation increase continues, and approaches European levels within two decades.

B. *Traditional* population
Fertility, education and female labor force participation return to 1983 levels in the 1990s; life expectancy remains constant.

II. Economy

A. *Boom* economy
The present rapid increase in exports and labor productivity continues. There is a 5% annual GNP growth until 2020 and then slower, 2%, annual GNP growth until 2050.

B. *Crisis* economy
A major world crisis at the end of the century causes the Lomé Convention to be discontinued, thus causing a rapid decline in export of sugar and textiles. Due to the general crisis, they cannot be substituted by other exports. GNP declines by 30% in the first ten years of crisis and then remains stagnant. Labor productivity does not increase.

III. Environment

A. *Garden* island policy
Environmental management policies include building reservoirs and pollution treatment plants to ensure water quantity and quality on the island. Fertilizer use is no longer increased or perhaps decreased, although improved sugar types and other measurements insure a stable sugar yield per acre.

B. *Laissez-faire* policy
No environmental management policies are implemented. Reservoir capacity and water treatment capacity remain at 1990 levels. Fertilizer use is further increased with higher yielding sugar types and yield per acre increases 2% annually.

It must be said that within the ranges of the existing world these scenarios are a narrow band. From Mauritius' present condition, it is hard to imagine some of the changes that would lead to certain world extremes in demographic and economic indicators.

2.2. Links and Constraints, Adjusted and Unadjusted Scenarios

As discussed in Chapter 11 on the basic PDE approach, we consider two kinds of interrelationships between the different segments of the model, hard-wired and soft. The hard-wired links are fixed, taking the same kind of effect in every scenario, regardless of the choice of input data and parameter values. These are links between elements in the system about which there exists a broad consensus in the scientific community. The soft links are the scenario variables and requests to the user that certain combinations of scenario results, which are inconsistent, impossible or at least undesirable, demand some kind of countermeasure. The model supplies the diagnosis, but the cure is left to the user since not only one but several different cures with different side effects are possible.

Combining a certain scenario from one module with scenarios from the other modules, and then comparing the outcome of the combinations is a quasi controlled experiment. These are the unadjusted scenarios, which combine the above scenario specifications without change. If systematic changes are done in only one variable, or domain, the partial impact of that factor would become isolated. There are some problems with this idea that have to be considered when interpreting the result of the experiment.

In a dynamic system the factorization of variables does not work consistently if there is feedback to the variable from the rest of the system. If there are feedbacks, the model itself contradicts the assumption of independence implicitly assumed in the experimental set up. The quasi controlled experiment cannot be performed without cutting off the feedback link. This means that the result of the experiment is no longer a result of the specified model but a result of a different model with different behavior.

A view of the model reveals that of the three domains of the model only population, as a whole, qualifies as being independent of the development in the other domains in the sense that there are no hard-wired causal links implemented from economy or environment into population. This, of course, is not the assumption of the final scenarios that are later presented. The final scenarios replace the lacking hard-wired relations with soft relations based on the results of the unadjusted scenarios of the quasi controlled experiment and calibration. In addition to the advantage of being directly usable as an independent experimental factor, the isolation of the population module means that it can be easily used alone, apart from the rest of the model. Thus, population scenarios are discussed separately in the next section of this chapter.

The most important difference between the two economic scenarios is the assumptions about export demand. Because of the fact that it is exogenous, export can certainly be treated as an experimental factor. Labor supply and productivity, however, are definitely and directly affected by the assumptions and developments in the population module. The economy is further affected by population through the cost of education, the amount and education of labor supply. It is affected by environment through available land and water. Thus, based on the discussion above, it is impossible to isolate economy as an independent factor and investigate its partial impact on environment. This indicates that what is kept independent in economy is only export demand, not production, employment, GNP, or other variables.

Environment, as such, can hardly be used as an independent experimental factor since the ingoing impacts are much stronger than the outgoing ones. The volume and composition of production creates demand for land and water. However, if this creates a land use conflict and/or a water deficit, then they also feed back as constraints on certain types of production. Water supply is affected by regular investments in storage capacity, combined with somewhat reduced use of fertilizers in the *garden* alternative. This might influence water balance and land use in comparison to the direct influence of the totally different production volumes that result from the two export scenarios.

In the adjusted scenarios, the user is deliberately required to follow several steps when producing scenarios in the model. The first step is the initial specification of scenario input data and parameters and an execution of the model. On rare occasions this directly produces acceptable, seemingly consistent and useful results. If not, the next step is to check the output, especially the prepared balances and choose appropriate corrections.

There are three main soft constraints which must be balanced:

Labor: The model economy is not affected by a labor shortage or surplus in a hard-wired way. However, if a shortage of workers is the result of particular scenario specifications, then this result must be seen as impossible. Something must be done. A number of solutions are possible, and the user will decide which one to use. A surplus of workers, or unemployment, is not, as we observe daily, an impossible result, but it is undesirable. Therefore, it might be instructive and in most cases desirable to try to eliminate it.

Government budget: The model calculates the government budget according to the specified tax rates and per capita expenditure levels. It disregards imbalances. In most cases, either a budget surplus or a deficit results from the initial scenario, and the user must decide which of the various policy options to use to decrease it.

Water: A water deficit is incompatible with a scenario which demonstrates a sustainable development path, although the model calculates the scenario as if enough water were available. Again, there are a number of options open to the user to eliminate the imbalance---contracting the economy, building reservoirs, investing in pollution treatment facilities--and part of the experiment is to decide which option to use.

The comparisons of the eight unadjusted scenarios in Section 4 are based only on the first step, without further calibration. This means that an observed difference between any two scenarios in an output indicator like GNP/capita might be biased. If, for example, labor demand is greater than labor supply in one of the scenarios but not in the other, then there is actually an overestimated production in the unadjusted scenario. If, on the other hand, the scenarios were fully calibrated e.g. by reducing production to ease the labor shortage, then this would seriously disturb the quasi controlled experimental set up. Calibration essentially means changing parameters until the results are consistent. In that process the scenario changes character and might diverge heavily from what was initially stipulated. Thereafter, the output differences are no longer a specific effect of the experimental factor.

Before introducing some of these multi-sectoral scenarios, however, the outcomes of some reasonable scenarios defined for the population module will be studied.

3. FUTURE POPULATION TRENDS

A main concern of the project is the interplay between population and the environment. The environment, without influence from human activity, is relatively stable over a long period of time--that is, the same annual cycles, the same soil type, the same coral reefs, etc. The environment of Mauritius, by itself, would remain in more or less the same state as it was described in Section 2. Not so the human population. It is an element of faster change, both with regard to its size, and to its composition--it too, is subject to lagged changes; a fertility decline in 1990 only really affects population size in one generation's time. It is therefore useful to look at the dynamics of population change by themselves, how changes in fertility, mortality, education and such would affect the future of the population, before turning to interactions with the environment and the economy.

3.1. Alternative Scenario Assumptions

The alternative future scenarios for the Mauritian population are based on 1990 input data discussed extensively in Chapter 12. Unlike most other population projection models, this model requires assumptions not only on fertility, mortality and migration, but also on rates of progression in educational status and rates of changing labor force participation. Each of those five variables can be specified status-specific, i.e. for each educational and labor force group separately. Such status-specific data are used for fertility, and migration, but are not available for mortality. Assumptions for population scenarios are listed in Table 1, which gives total fertility rates (TFR) by education, life expectancies at birth (the inverse of mortality levels) by sex, the total number of net immigrants, school enrollment rates by age, and female labor force participation rates at age 35-39 by education.

Table 1. Assumptions for the population module.

Variable	1990 value	Target value *traditional*	Target value *medium*	Target value *modern*
Total fertility rate by education of mother:				
primary	2.5	3.3	2.3	1.7
secondary	1.9	2.5	1.7	1.4
tertiary	1.6	2.1	1.5	1.3
Life expectancy at birth by sex:				
female	73	73	80	85
male	65	65	72	80
Annual number of net migrants:				
total	-500	0 or -3,000	0	0 or 5,000
Percentage enrolled in school by age:				
age 10-14	80	80	80	90
age 15-19	36	36	45	60
age 20-24	3	3	7	12
Female labor force participation rate at age 35-39 by education:				
primary	40	26	50	65
secondary	60	50	70	85
tertiary	95	95	95	95

In 1990, the total fertility rate (TFR) was 2.3 children; 2.54 among primary, 1.93 among secondary and 1.61 among tertiary educated women. Net migration to and from Mauritius was close to zero: a net of 500 people left their country, roughly as many men as women. The most recent Mauritian life table calculated for the period 1988-90 gave a life expectancy at birth of 73 years for women and 65 years for men. Labor force participation of women at the age of 35 to 39 in 1990 (the age at which women return to work after childbearing, if they do, and at which maximum activity rates were observed) was 46%; 40% among primary, 60% among secondary and 95% among tertiary educated women. Differences in school enrollment ratios by sex had virtually disappeared. At age 10-14 school enrollment was around 80%, at age 15-19, 36%, and at age 20-24 about 3%.

The *traditional* population scenario assumes constant mortality and school enrollment, an increase in fertility, and a decline in female economic activity, reflecting social stagnation or a more traditional society. The *modern* population scenario, on the other hand, assumes strong increases in life expectancy, school enrollment and female economic activity, and a further decline in fertility, reflecting rapid social development to a modern European society. The *medium* population scenario assumes changes somewhere in between *traditional* and *modern*, with more moderate changes in the same direction as *modern*. In all three scenarios net migration was assumed to be zero. In order to investigate the role of migration for population development, the *traditional* population was alternatively combined with emigration (-3,000 people annually), expressing the belief that the higher population caused by high fertility may favor emigration, while the *modern* population was alternatively combined with immigration (5,000 people annually), considering the possibility that declining population size resulting from low fertility may demand and attract immigration of labor.

For more extensive assumptions and results concerning fertility, mortality and migration the reader is referred to Prinz (1991). In this chapter, an emphasis will be placed on the interplay between fertility, mortality and migration on the one hand, and economic activity and education on the other hand.

3.2. Selected Results

Some major population developments are presented in Table 2. Despite the low level of fertility assumed in some of the scenarios, the Mauritian population increases until 2030, even in the case of low fertility and zero net migration (*modern* population). This is entirely due to the young age structure, and is a prime example for the momentum of population growth. Figure 1 shows an increase in total population size by around 25% by 2030 for the *modern* population scenario, while an additional influx of 5000 people annually results in an increase of almost 50% by 2040. However, even with immigration, negative population growth is observed in the long run. In *traditional* with emigration, projected population growth is very similar to the growth observed under the *modern* with immigration until 2030, while growth continues almost linearly in the long run; to almost 1.7 million people by 2050. Under the *traditional* scenario the Mauritian population even doubles, i.e. reaches 2 million, by the year 2060.

The total labor force increases between 30% (*traditional* with emigration) and 60% (*modern* with immigration) by the year 2020 (see Table 2). Comparing the two *modern* scenarios shows that, in the long run, 5000 immigrants annually keep total labor force stable, while without immigration the labor force shrinks very rapidly. Another interesting observation: although there is a difference in total population size of around 200,000 people, *traditional* with emigration and *modern* with immigration give almost the same size of the labor force by the year 2050, because of the high labor force participation rates of women under *modern* population assumptions.

Typically for a country which just completed the demographic transition, Mauritius will experience population aging during the coming decades. While the proportion of the population aged 60 years and over does not quite double under *traditional* assumptions, it triples or even quadruples under *medium* and *modern* assumptions, respectively (see Table 2). Aging is the result of low mortality as well as low fertility. Strong population aging seems indicated, since a long term return to a fertility level as high as assumed under *traditional* (overall TFR equal to about 3 children per woman) has so far never been experienced by any country that has completed the demographic transition.

Depending on fertility assumptions, the proportion of children declines significantly; even under *traditional* assumptions the proportion is always below the 38% observed in 1990, but under *modern* assumptions this proportion is cut in half.

Table 2. Projected population developments by scenario, 1990-2050.

Year	Population size (1000)	Labor force (1000)	Proportion aged 0-19 (in %)	Proportion aged 60+ (in %)	Socio-demo. dependency ratio
1990	1022	419	38	8	175
traditional population:					
2020	1463	600	35	13	158
2050	1895	758	36	14	164
medium population:					
2020	1304	600	26	17	129
2050	1271	547	23	26	149
modern population:					
2020	1251	613	24	18	118
2050	1147	505	17	35	142
traditional population with emigration:					
2020	1377	551	35	13	163
2050	1676	654	36	14	168
modern population with immigration:					
2020	1395	684	24	17	113
2050	1471	677	18	33	133

The development of the socio-demographic dependency ratio (SDDR), a dependency ratio considering economic activity, productivity, and age of dependents (see Chapter 12 for more details), is surprisingly robust with diverging scenario assumptions. As shown in Figure 2, it never again reaches a level as high as the 175 dependents per 100 actives observed in 1990. The SDDR strongly declines during the next three decades under *medium* and *modern* population assumptions, by 29 and 35 per cent respectively, and even under *traditional* assumptions, it would still decline by 17% by the turn of the century. After a clearly diverging development between 2010 and 2040, the socio-demographic dependency ratio converges to a level around 140-160 by the year 2050. Assumptions on migration affect the dependency ratio to a smaller extent than they affect the size of the total population and the labor force.

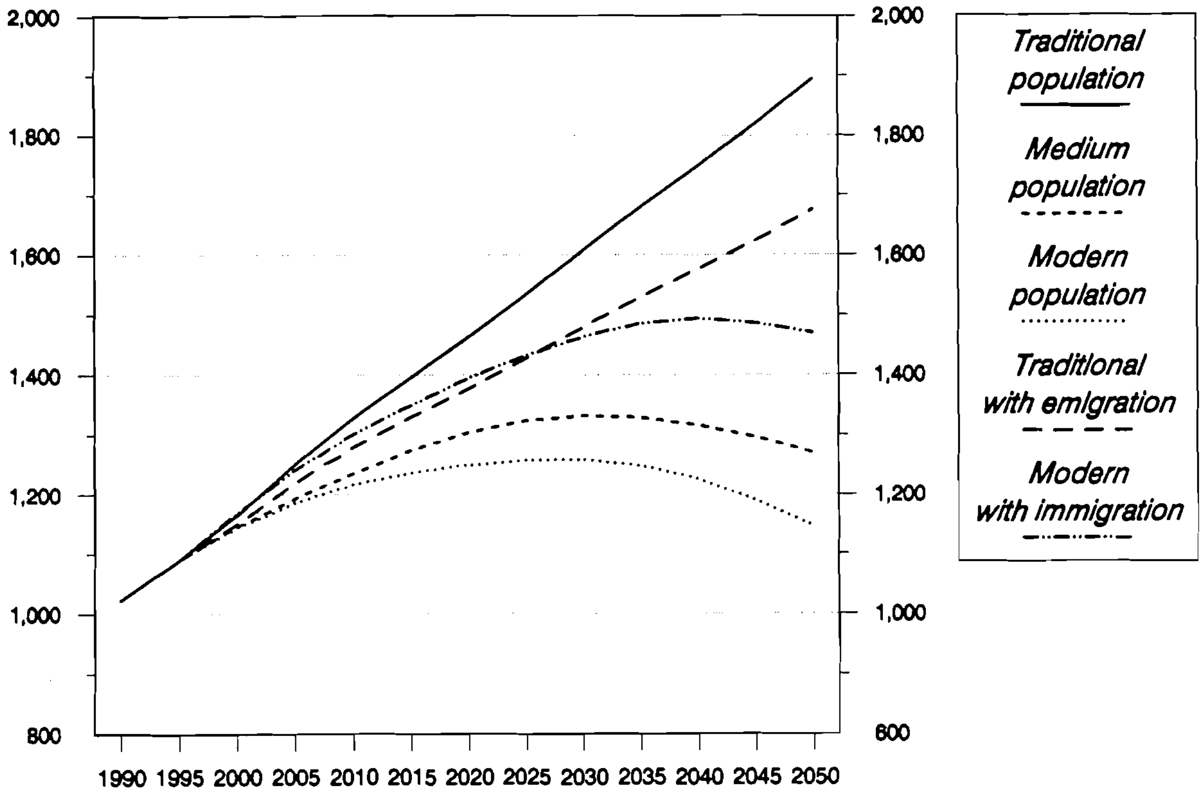

Figure 1. Projected population size by scenario, 1990 to 2050.

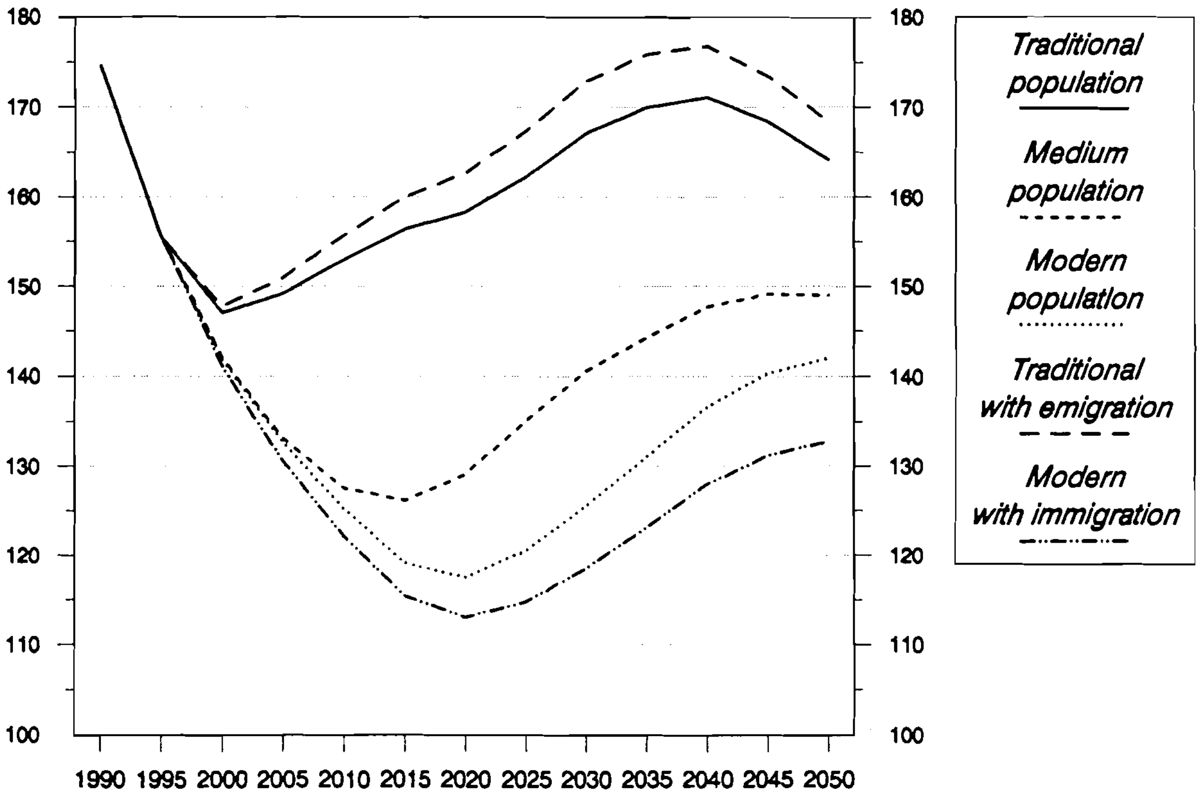

Figure 2. Projected socio-demographic dependency ratio, 1990 to 2050.

If lower SDDRs have a positive influence on the economy as indicated in some of the literature, then further economic development is favored during the coming decades simply by changes in the socio-demographic composition of the population.

Table 3 gives more information on characteristics of the Mauritian labor force. Among men, the share of the adult population in the labor force declines at a rate that depends on the speed of aging, i.e. as people get older, a higher proportion is found older than retirement age. For example, the proportion of the population in the labor force declines from 81% in 1990 to 60% by 2050 under *modern* or strong aging assumptions. Under the same scenario, the percentage of women in the labor force will increase significantly due to increasing labor force participation rates: from 35% in 1990 to 44% by 2020. Due to the increase in the proportion of elderly it declines again somewhat thereafter. The share of the female labor force in the total labor force increases from 30% in 1990 to between 32% and 44% by 2050 depending on social development.

Table 3. Labor force characteristics 1990-2050, by sex and scenario.

Year	Adults in labor force (in %)		Total labor force (1000)		Primary educated (in %)		Secondary educated (in %)		Tertiary educated (in %)	
	f	m	f	m	f	m	f	m	f	m
1990	35	81	126	290	58	53	40	45	2	2
traditional population:										
2020	35	78	195	404	20	32	73	64	7	4
2050	34	77	245	510	15	29	77	67	8	4
medium population:										
2020	41	75	221	383	24	33	65	60	11	7
2050	38	68	213	338	21	30	61	59	18	11
modern population:										
2020	44	74	232	373	20	30	65	60	15	10
2050	43	60	222	287	13	19	62	63	25	18

The educational distribution of the labor force and of the population as a whole is in a state of transition. While even in 1990 a majority of the labor force only had primary education, this proportion declines rapidly to about one-fourth or even one-fifth among the female and about one-third among the male population by 2020 (see Table 3). The lower proportion of primary educated among working women results from higher labor force participation rates among secondary and tertiary educated women, as compared to primary educated women. Interestingly, especially among women there is little difference between *traditional* and *modern* as regards the proportion of primary educated among the labor force. This is due to the combined effect of increasing labor force participation rates and increased educational attainment. In the total population, the percentage with only primary education is around one-third and is slightly higher among women than among men by 2050 (only one-fourth in the case of *modern* population development).

Most striking is the projected increase in the number and proportion of tertiary educated people. Taking both sexes together, the proportion of the tertiary educated increases to around 13% of the labor force by 2050 in *medium* development, and even up to 21% under *modern* assumptions (see Table 3). Among the total population the respective figures are 8% and 14%. This huge increase would give tremendous room for changes in the structure of the Mauritian economy. Under *traditional* assumptions the increase in the proportion tertiary educated is small.

Whether alternative past and future developments of the socio-demographic dependency ratio hinder or favor economic development is tested by the full population-development-environment model. A general conclusion is difficult since the relation depends on the economic strategy adopted. The full model is also able to monitor the effects of alternative population developments on the environment, again mainly via economic development.

4. UNADJUSTED SCENARIOS

Now is the time to add the environment and the economy to the population scenarios. The idea in this section is to set up a laboratory experiment, in which the two extreme scenarios for the population, the economy and the environment each are set up together in eight combinations and computer runs are made without adjustments. The outcome is a set of scenarios most of which are as yet imbalanced--a great water or labor shortage; a large government budget deficit. The scenarios point out some immediate impossible developments--e.g. no great economic growth on Mauritius without investments in water management--but they are also instructive because they provide an initial feeling for the model and what it can tell us, and because the eight scenarios can be compared to each other as quasi controlled experiments--which is no longer possible once the scenarios have been through the organic process of user-driven calibration and adjustment.

4.1. Alternative Scenario Assumptions

The main question of this section is: What is the partial impact of different population developments on income per capita, employment, water balance, compared to the effect of different export developments and different water treatment policies? Table 4 gives a detailed description of the definition of the scenario assumptions for each of the three areas: population, economy, and environment.

Table 4. Assumptions for two scenarios in each of the three modules.

Population	***traditional***	***modern***
Fertility	3.0 children per woman by 2000.	1.5 children per woman by 2010.
Mortality	Constant.	Male/female life expectancy 80/85 by 2030.
Net migration	Zero.	Zero.
Education	Transition rates constant.	European rates by 2010 (see Section 3).
Female economic activity	Return to 1983 activity rates.	European rates by 2010 (see Section 3).
Economy	***crisis***	***boom***
Exports: Sugar	50% reduction in 2000, then constant.	No change.
Textiles	Decrease by 35% 2000-2010, and further 15% by 2050.	Increase to 2x 1990 level in 2005, then constant.
Other EPZ manufactures	No change.	Linear increase to 25x 1990 level in 2050.
Tourism	No change.	Increase to 2x 1990 level in 2005, then constant.
Sales-, transportation-, business services	No change.	Linear increase to 25x 1990 level in 2050.
Labor productivity from technological change	No change.	1% annual increase 1990-2020; 0.5% annual increase 2020-2050.
Land productivity: Urban	No change.	Linear increase to 2x 1990 level in 2030, then constant.
Environment	***laissez-faire***	***garden***
Land productivity: Sugar cane	0.5% annually until 2050.	No change.
Other agriculture	1.5% annually until 2050.	1.5% annually until 2050.
Water investments: Storage	No investments.	Increase to 2x 1990 storage capacity by 2050.
Primary treatment	No new investments.	Double 1990 capacity by 1995.
Secondary treatment	No investments.	6 mln m^3 capacity by 2000 for manufacturing wastes.

The population scenarios are described in detail in Section 3 above. The economic *crisis* scenario assumes a discontinuation of the Lomé convention in 2000, which results in a drastic decrease in sugar and textile exports. The other potential export sectors are too weak to compensate for these losses, and stay constant. Or, alternatively, the world market in general does not demand as much as before due to a global economic crisis.

In contrast, in the economic *boom* scenario, the Lomé convention is continued. The present sources of wealth--sugar, textile and tourism--remain constant or grow slightly, but are overtaken by the much more dynamic, future oriented other EPZ and service export sectors. GNP growth is about 5% annually until 2020 and 2% annually until 2050. The introduction of new technologies increases labor productivity 1% annually above and beyond the labor productivity increases from better education. Higher urban land competition in this expanding economy causes land rents to increase, which imposes higher urban land productivity.

The main feature of the *garden* policy scenario is the investments in water resources. Storage and treatment capacity are increased considerably, which adds 50% to the present net water flow. Fertilizer use is not increased further causing a stagnation in sugar cane land yields. Other agriculture yields continue to increase 1.5% per hectare annually.

In the *laissez-faire* policy scenario no care is taken of water: there are no investments in water management. Higher fertilizer use combined with better seeds leads to 0.5% annual increase in sugar yields per hectare. Other agriculture yields increase as above.

4.2. Selected Results

Table 5 summarizes the outcome of our alternative model runs for the period 1990 to 2050, for the years 2020 and 2050 for some selected indicators from the eight scenarios. Also, 1990 starting values of the indicators are listed.

Table 5. Selected results for eight unadjusted scenarios, 2020 and 2050.

Economy:		crisis				boom				Observed
Environment:		laissez-faire		garden		laissez-faire		garden		in 1990
Population:		trad.	modern	trad.	modern	trad.	modern	trad.	modern	
Pop.size	2020	1.46	1.25	1.46	1.25	1.46	1.25	1.46	1.25	1.02
(mill.)	2050	1.90	1.12	1.90	1.12	1.90	1.12	1.90	1.12	
GNP	2020	19.5	19.0	19.4	18.9	87.0	84.2	85.5	84.9	22.1
(bill.Rs.)	2050	19.1	16.1	18.9	16.5	122.8	114.1	121.1	116.9	
GNP/cap.	2020	13.3	15.3	13.2	15.2	59.4	67.6	58.4	68.2	21.7
(1000 Rs.)	2050	10.1	14.4	10.0	14.8	64.8	102.0	63.9	104.5	
Govt.Bal.	2020	-1.0	-1.0	-6.0	-5.0	+10.0	+10.0	+5.0	+5.0	0.0
(bill.Rs.)	2050	-2.5	-1.0	-7.5	-5.5	+15.0	+15.0	+9.0	+10.0	
Labor	2020	51	60	51	60	-26	-10	-23	-10	4
Bal.(%)	2050	62	67	62	64	-15	-15	-13	-18	
Water	2020	14	18	43	46	-19	-10	13	16	1
Bal.(%)	2050	10	25	49	58	-55	-44	8	17	
Sugar	2020	394	393	455	454	397	423	416	420	746
land(km²)	2050	326	316	441	433	*	*	*	*	
Exports	2020	15	15	15	15	90	89	88	88	19
(bill.Rs.)	2050	14	14	14	14	143	141	140	140	

* land use did not converge.

4.2.1. Impact on Income

In the *traditional/crisis/laissez-faire* unadjusted scenario, income per capita decreases from 21,700 Rs. in 1990 to 10,000 Rs. in 2050. If, however, fertility continues to decrease as proposed in the *modern* scenario, income per capita decreases less and stays at 14,400 Rs. in 2050. Advance investments in water reservoirs and water treatment have a marginal impact on the income development path in this situation.

The *boom* scenarios, however, trigger entirely different economic developments. With or without water investments, income per capita increases to almost 65,000 Rs. in 2050 with the high, traditional population, i.e. 1.9 million people. With a lower *modern* population increase, income per capita increases much more, to over 100,000 Rs. in 2050. This implies a fivefold (real) increase from 1990, but is still roughly one-third the present European and North American level.

Income per capita in 2050 induced by two different population developments is 40% to 50% lower in the *traditional* population scenarios than in the *modern* population scenarios. Total population size is 70% larger in the high population scenario. By definition, the export generated income is the same in each comparison with low and high population within the same economic scenario, but total GNP is higher with a larger population because of higher endogenous demand.

The difference in income levels created by the different export scenarios are still much larger than the differences created by the different population developments. In all scenario combinations, the Mauritians earn 5 to 10 times as much in the year 2050 with the export *boom* assumptions as compared to export *crisis* assumptions. One could argue that the export scenarios have been arbitrarily chosen to be more extreme than the two population scenarios. On the other hand, ranges in rates of economic growth and economic wealth are much greater over time or cross-sectionally in the globe--of the order of a couple of magnitudes--than population growth differences which stay within the same order of magnitude, so the extremes are closer together.

4.2.2. Impact on Employment

The income results, of course, only reflect the impact of the hard-wired assumptions and interdependencies built into the model without further adoptions. Looking at labor Table 5 and Figure 3 reveal that the export *boom* scenario combinations are not entirely possible as they are specified. They create a labor shortage of 13%-18% in the year 2050 with both *traditional* and *modern* populations.

This means that there is labor available for only 82% to 87% of the total demand. Actual production and GNP would--without any countermeasures--decrease proportionally. Several countermeasures would be possible. There is substantial room for increasing education expenditures, since the governmental budget is heavily overbalanced in all four export *boom* scenarios (see Table 5). Labor immigration, especially in the low population alternatives, is obvious. The labor participation rates can be increased in the *traditional* population alternatives. Eventually most of the labor deficit can be relieved this way. If not, production will not be able to match labor demand and incomes must decrease proportionally.

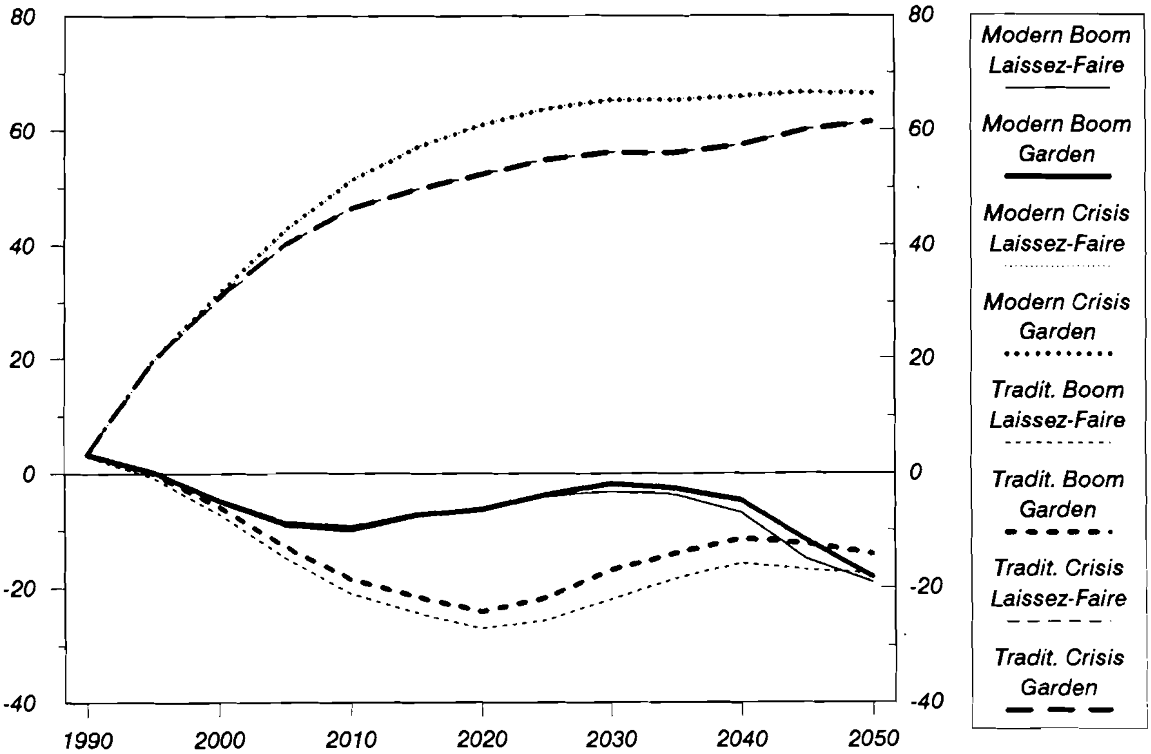

Figure 3. Unemployment (+) and labor shortage (-) in eight unadjusted scenarios.

Such changes alter the assumptions in the experimental set up. They may result in a mixture of the two population scenarios combined with a reduced export scenario. This is done in the next section. The question of population impact on the development of economy and environment is then further elaborated.

The four export *crisis* scenarios give examples of an opposite imbalance with regard to labor. The unemployment rates increase to levels above 60% in all four *crisis* scenarios. The highest unemployment rates are reached with the *modern/crisis* scenarios. This is counter-intuitive: how can a smaller population result in higher unemployment than a larger one with the same GNP development? The smaller, *modern* population is much better educated and therefore more productive. So, for a given output, fewer workers are needed. Moreover, the labor force participation of women is much higher than in the *traditional* alternative. Therefore, the total labor force is only 27% smaller although population is 70% smaller, hence, the paradoxical effect that the "population decline impact" on unemployment is positive.

It is not mandatory to reduce unemployment by reducing labor force participation in order to reach a consistent scenario since the model does not care if a non-working person is classified as unemployed or as not being in the labor force. It is, however, unrealistic not to do so. The discouraged worker impact on participation rates is well established in labor market research. If unemployment is high, then other potential but somewhat less determined workers find no reason even to apply and formally register as members of labor force. This might be introduced as a "soft" change of the participation rates in the scenario.

Another more substantial adaption would be to reduce the education efforts in the *modern/crisis* scenarios. There is simply no need for this education when corresponding demand, production and jobs are not present, and incomes and consumption are very low and directed towards basic needs. Many would object against taxes for education in that situation since it creates more unemployment and less food. As before, those soft changes would also change the interpretation of the experimental results.

The *crisis/garden* scenarios result in 2-5% less unemployment in 2050 than the *crisis/laissez-faire* scenarios. Reservoir construction and lower productivity in sugar agriculture seems to increase employment to some degree in this alternative.

Compared to the shortage of labor in the *crisis* scenarios, the labor shortage in the *boom* scenarios is tremendous. One advantage of the crude experimental set up is that it clearly shows the size order of the impact of export change on employment, without any induced adoptions among individuals, in firms or in governmental policy.

4.2.3. Impact on Land Use

Land use for sugar agriculture, the dominating spatial activity on Mauritius, decreases considerably in all eight scenario combinations. In the *crisis* scenarios, the primary reason is obvious: sugar demand is reduced by 50% in the year 2000 as part of the scenario assumptions. After that, sugar land continues to decrease in the *laissez-faire* scenarios because of assumed continued increases in land productivity. These might be considered somewhat superfluous in a calibrated *crisis* scenario. In the *crisis/garden* scenarios, there are no increases in yield per acre and much more of the sugar land remains used. This builds up to a difference in area used for sugar cane growing in the year 2050 of about 100 km^2. Those developments are hardy affected by the difference between the two population scenarios when combined with an export crisis.

Land use for sugar decreases almost as much in the four *boom* scenarios, but for an entirely different reason since export demand for sugar is now maintained for the whole scenario period. The main reason is that in the *boom* scenarios, land demand for commercial and residential purposes increases continually and rapidly. A built-in rule solves the land use conflict in favor of the urban land use when no explicit policy to maintain agriculture land is stipulated. The reason for the rule is that agriculture cannot compete with the land rents possible from urban activities. These demand much less space per unit of production value. This also means that the volume of sugar production becomes lower than present trade agreements.

4.2.4. Impact on Water Balance

The anthropogenic impact on supply and demand for water interact in a complicated way with natural sources, sinks and discharges in the water system. The resulting net water balance is also affected by the quality level at which the balance is registered. A measured water deficit for high quality water could turn into surplus if the water quality standard is set somewhat lower. The norm for water quality is that set by the present Mauritian government.

In addition, water is indexed to be just about balanced in the starting year 1990. This is because around 1990, Mauritius experienced not only some drought years but also some water surplus years--indicating that water use was hovering just at the maximum reliable level. This might more accurately indicate a situation closer to water deficit than to the calculated figures in the World Bank (1992) Report which states that water demand is 16% of supply on Mauritius. This 16% is based on the total rainfall-minus-evapotranspiration on Mauritius, but as discussed in Chapter 10 on water resources, actual water available for use is much less. Nevertheless, the water balance results to be presented should be regarded as conditional or indexed: if water demand equals water supply in 1990, then a 30% water deficit in 2050 means a 30% deficit relative to the present water balance.

Water demand is affected by consumer demand and the volume of production, especially in sugar agriculture, since this is the dominant user of water--for irrigation, and because of the large biological waste discharge into the water. The irrigation demand for sugar, however, is reduced via a hard-wired link in the model if there is a water shortage. A water deficit in Table 5 and Figure 4 is a deficit following the cancellation of all sugar irrigation (in the model this also has the side effect of reducing sugar land productivity). Water supply is affected by building reservoirs and by water treatment activities.

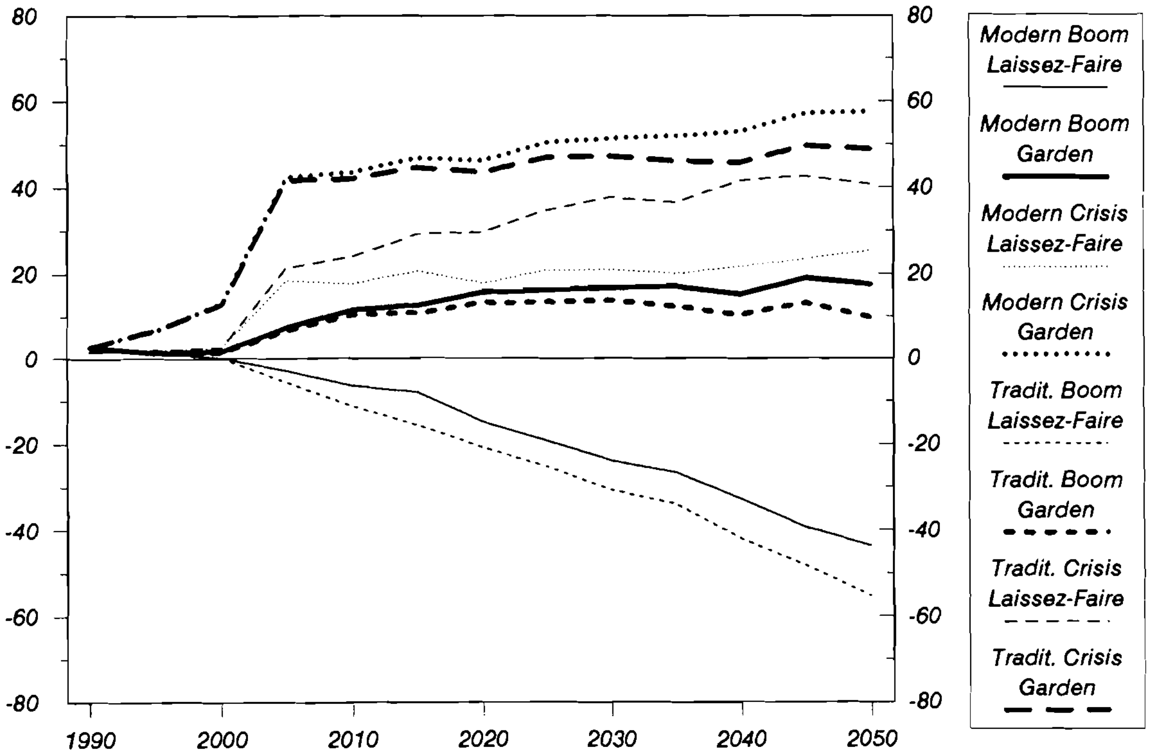

Figure 4. Development of water balance in eight unadjusted scenarios.

Only the two scenarios combining *boom/laissez-faire* create a water deficit. The impact of the *garden* water policy on the *boom* scenarios is substantial. A water deficit of 55% with the *traditional/boom/laissez-faire* changes into a surplus of 8%, and a 44% deficit with a *modern/boom/laissez-faire* scenario turns into a 17% surplus with the *garden* policy. Also in the four *crisis* scenarios, the *garden* policy increases water surplus by some 30%. The differences in water balance induced by different population sizes alone are relatively small compared to the effects of high or low economic growth and water management or not. However, the water model does not account for all the effects the raw sewage disposal--which is directly proportional to population size--80% of which was on-site and untreated in 1990, hence it might affect the groundwater.

The water preservation activities suggested in the *garden* scenarios seem to be sufficient for all the different developments tested. But are they necessary in all those circumstances? There is sufficient water without water reservoir investments in the *crisis* alternatives. With the limited amount of resources available in this case it seems to be somewhat luxurious to invest in water facilities that are not needed until a much better economic development is achieved.

5. ADJUSTED SCENARIOS

From the previous discussion of the eight unadjusted combinations it is obvious that several of the combinations are largely impossible, and that all of them need further adjustments in order to become consistent. In this section the scenarios are merged and changed parts of the original differentiating scenario assumptions are maintained. The original experiment is intended to isolate the partial impact of population development, export demand change and water investments. The lesson to learn is, what adaptations are unavoidable, which scenarios become similar, what parts remain as interesting possible differences between the scenarios, and finally, the content of remaining different alternatives for the development of the island. It is only the fully calibrated scenarios, which present at least possible, if not likely, future paths that can answer the questions set out at the beginning of the chapter in specific and the project in general. Below, the four *crisis* scenarios are adjusted first, and then the *boom* scenarios.

As explained in Section 2 of this chapter, there are three criteria for a consistent scenario:

1) the water balance is positive;
2) the labor balance is positive; desirably only slightly positive, representing the small unemployment necessary for the smooth running of an economy;
3) the government budget balance is zero.

5.1. The Crisis Scenarios: Population and Environment in Poverty

The first of the scenarios is the combination of *traditional/crisis/laissez-faire.* This is a worst case scenario--by 2050 the population is 1.9 million and growing at a rate of 1% annually. There is practically no economic growth so that income per capita is almost exactly directly related to extra population. The budget deficit is almost half of the expenditures, and unemployment is a roaring 62%. And everything is getting worse each year as the population grows (see Table 6).

Table 6. Scenario results for *traditional/crisis/laissez-faire*, unadjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.46	19.5	13.5	-1.0	+14%	51%
2050	1.90	19.1	10.1	-2.5	+10%	62%

This is similar to the bad situation of Mauritius thirty years ago when it was still a poor, mono-crop island with high population growth, except that by 2050 it would be worse: four times as many people. Although for Mauritius in 1990 this scenario looks unlikely, for a large number of developing countries it is a reality.

In order to calibrate the scenario the budget has to be balanced. This can be done either by raising taxes or by lowering expenditure. In many countries in this situation, social services deteriorate and this is the choice made in this scenario. Government services per capita are reduced 1% annually. This balances the budget, but it leads to an even lower GNP because the multiplier function of government expenditure is reduced. The new results are shown in Table 7.

Table 7. Scenario results for *traditional/crisis/laissez-faire*, adjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.46	18.8	12.9	0.0	+13%	53%
2050	1.90	15.7	8.3	0.0	+12%	69%

Unemployment is unrealistically high. The lack of possibilities would certainly discourage people from being in the labor force. Female labor force participation, which is already low in this scenario (see Section 3) would decrease even further, men would retire earlier. However, including such changes decreases the rate of unemployment only marginally. This is because the bulk of the labor force, young and middle-aged men, is not affected. This group, despite discouragement, would probably remain looking for work in order to survive. They would begin doing informal jobs--street vendors and such --which are not caught in the model. They would also probably be willing to work for lower wages, accept fewer working hours--the typical underemployment situation of many poor countries. To bring unemployment down to a more likely (but arbitrary) 15%, labor productivity has to be decreased by about 1% annually from 1990 to 2030. The total underemployment in this situation is about one-third in 2050. This means the economy would probably be a little better than these results indicate, but not much.

What would be a way out of the misery, which is getting worse with each increment in population size?

5.1.1. Alternative Exports

Increase exports. But part of this scenario is precisely what would happen if Mauritius does not succeed in increasing exports. The sugar exports drop because the Lomé sugar convention is not extended, and the textile industry moves on to different, cheaper countries. So these options are out. But there are the beaches of Mauritius. A doubling of tourist revenues by 2005 and constant thereafter would bring per capita income to 10,400 Rs. per capita up from 8,300 Rs. But by then, Mauritius' capacity would be reached, and no further improvements would be possible because the beach resources on Mauritius are limited and fixed.

Perhaps marine resources in Mauritius' vast territorial waters could be exploited. It is thinkable that they would add substantially to income even at a sustainable fishing level. Unfortunately, very little is known about these resources at the moment, and they could not be included in the model.

5.1.2. Food Self-Sufficiency

Substitute imports. In its early history, Mauritius was self-sufficient in food for some time (with a population of a few thousand people), but it since has a long tradition of food imports. Today, Mauritius produces about one-third of the food its population consumes, and in the original *crisis* scenarios, continues to do so. Food self-sufficiency does not necessarily have high priority in an open export-oriented economy, but it might be a good strategy of sustainable development and resilience to international crises.

Even under *crisis* scenario assumptions, regarding the question of food self-sufficiency which could be achieved with economic benefit, there is the question of attitudes and the willingness of people to change preferred eating habits. The decrease in (unmeasured) consumer utility should be offset against the (measured) higher GNP. However, some increase of the currently low proportions of domestically produced food would be a good strategy.

To explore the alleviating effects of food substitution, the *traditional/crisis/laissez-faire* scenario is further adjusted. Mauritius is assumed to react by becoming 85% food self-sufficient by the year 2010. In the past, such a quick substitution of food crops for sugar crops was achieved during World War II. Scenario assumptions are changed so that food import is phased out and replaced by domestic agricultural production. This new production obviously demands an increase in the proportion of land to be used for agriculture. In the *crisis* scenario, this land is available because of freed sugar land and the land productivity increases in other agriculture. Moreover, the small economy has led to a very significant water surplus. Domestic food production is not only desirable; it is also possible. Unit domestic food demand is increased by 75% quinquennially from 2000 to 2010, and imports are reduced by 50% in the period 2000-2005. The effects of this scenario are shown in Table 8.

Table 8. Effects of a food self-sufficiency policy under the traditional/crisis/laissez-faire scenario.

Year		Agriculture production	Land use agriculture	GNP per capita	Labor balance	Budget balance	Water balance
1990		1.0	130	21,000	5%	0.0	0%
2050	no policy	1.0	51	8,300	69%	0.0	12%
	agriculture policy	3.0	150	11,800	56%	1.0	0%

Under this scenario, Mauritius is better off in opting for food self-sufficiency. An increase of employment through more labor-intensive agriculture decreases unemployment significantly. GNP and income per capita are 40% higher than in the original scenario, offering some respite from poverty. However, the limits of water availability are reached already by 2010. After that year, no further increases in food production are possible. Subsequently, every extra mouth to feed means that all get less food. This water balance includes the higher evapotranspiration from more food crops. Of course, more efficient irrigation methods could be used and the sea could be harvested. But all this must be seen in the context of the scenario: Mauritius is poor in this future, and limited in its technical and creative resources. Therefore, although food import substitution offers respite--which is temporary on an island where the population continues to grow and water and land do not.

5.1.3. Small and Modern Population

Reduce population growth. The combination of a *modern/crisis/laissez-faire* scenario shows the result (see Table 9). Population size is only 1.12 million in 2050. Exports are at the same low level. Total GNP is even lower than in the previous scenario because there is less income produced by the domestic market and activities because there are fewer people. Income per capita is 40% higher than with the large population. The paradoxically high unemployment with the small population is the result of higher productivity due to higher education and higher female labor force participation rates.

Table 9. Selected results of the *modern/crisis/laissez-faire*, unadjusted scenario.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	19.0	15.3	-1.0	+18%	60%
2050	1.12	16.1	14.4	-1.0	+25%	67%

First, the budget must be balanced. In compliance with the modern society, services are not decreased but taxes are raised slightly, 1% annually through the period. Moreover, one could argue that with the enormous unemployment, the high education efforts of this scenario are superfluous, and unrealistic. Also, the female participation rates would be lower than anticipated. The scenario is adjusted. Education transition rates and the labor force participation rates of women stay at the 1990 level. The results show that although the general level of education is considerably reduced, there is little effect (see Table 10). The main reason for this is that lower education is associated with higher fertility, which ultimately means a larger population and labor force. Employment is increased from 158,000--after tax increase--to 236,000 through lower productivity; but the labor force is increased from 482,000--after the female labor force participation rate has been reduced--to 500,000 through higher population in 2050.

Table 10. Selected results of the *modern/crisis/laissez-faire* scenario, adjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.28	18.4	14.4	0.0	+18%	53%
2050	1.24	15.2	12.3	0.0	+24%	53%

5.1.4. ...and Food Self-Sufficiency

To further improve the situation, food imports are substituted by domestic food production, as in the scenario with the *traditional* population. In this case, the higher GNP leads to a budget surplus which is corrected by lowering taxes again to the original rates. The results below are with the original modern labor force participation rates and education (see Table 11).

Income per capita in 2050 is 85% greater than in the original *modern/crisis/laissez-faire* scenario, and is even increasing slightly in 2050 because the population is shrinking. The water balance is zero and constant, as above, from 2010, because food production (irrigation) and industrial production are constant, but in contrast to the above scenario, per capita consumption is not declining. The unemployment effect of food self-sufficiency is the same order of magnitude as the lower female labor force participation and education effects just above.

Table 11. Selected results of the *modern/crisis/laissez-faire*, adjusted, with food self-sufficiency.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	30.3	24.3	+1.0	0%	38%
2050	1.12	25.5	22.8	0.0	0%	50%

Combining the semi-traditional population above in the first adjustment with food self-sufficiency results in even higher income per capita, and also lower unemployment. Employment is increased from 158,000 to 254,000 by turning to domestic agriculture; and from 254,000 to 369,000 through lower productivity.

5.1.5. Environmental Concern Necessary?

The two initial *crisis/garden* scenarios show that there is a large budget deficit because the investments in water cost a lot, and at the same time there is an enormous water surplus. In the case of calibration, the scenario would obviously move towards the situation of *crisis/laissez-faire.*

There is however, a case where a garden policy in the crisis would be desirable although it would be (domestically) unaffordable: in the scenario with traditional, growing population and food self-sufficiency. Here, an increase in water storage capacity after 2010 leads to a proportional increase in the ability to produce food. This is a clear case where international development aid is useful--at least in the short run--if the country uses the temporary respite from decreasing per capita food production to curb its population growth. Otherwise, it will run into a ceiling again soon, except at a higher level of population size and food production. This discussion may not be relevant for Mauritius anymore, but it is applicable to many small developing countries.

5.2. The Boom Scenarios: Population and Environment in Prosperity

Scenarios which are probably more relevant to Mauritius are those which foresee a continuation of economic growth as the island experienced it in the past decade. In the years 1985-1990, GNP grew at a rate of around 6.5% annually. In the *boom* scenarios, GNP is projected to continue growth at an annual rate of 5% until 2020, and then to slow to a "normal" 2% annually from 2020-2050. The growth is led by an expansion of new export sectors--new manufactures in the EPZ sector, and an increase of sales-, transportation-, and business services.

The usual scenario for development is decreasing population growth, increasing education, and increasing economic growth. Traditionally there is no explicit care for the environment: Nature is regarded as the unending supplier of resources. Such philosophy is reflected in the *modern/boom/laissez-faire* scenario. The unadjusted results for this scenario are given in Table 12.

Table 12. Selected results of the *modern/boom/laissez-faire* scenario, unadjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	84.2	67.6	+10.0	-10%	-10%
2050	1.12	114.1	102.0	+15.0	-44%	-15%

Economic growth is good--by 2020 the income per capita is three times the 1990 level, and by 2050 it is almost five times the 1990 level. But there is an enormous water shortage, and also a significant labor shortage. On the other hand, there is a huge government budget surplus. This is an impossible situation. In 1990 water is exactly balanced. From this starting position, growth in any sector (since all sectors require water) can only be achieved through either reduction of activity in another sector or investments in water management. Both options are discussed.

5.2.1. Reduction of Agriculture

The largest user of water in Mauritius in 1990 is agriculture. Through irrigation, evapotranspiration, and required dilution flow for the biological sugar milling wastes, it consumes more than half of the water required on the island. In the above scenario, by 2050, through the higher income and therefore higher demand, the non-sugar agriculture is the second largest user of water. To achieve industrial and commercial growth, sugar production and domestic demand for other agricultural products are reduced. Sugar exports are reduced gradually from 4500 mln Rs. in 1990 to 640 in 2050, and domestic demand for other agriculture is kept roughly equal. This alleviates the water shortage to only -29% in 2050.

GNP is hardly affected. In 1990 sugar exports were 4,500 mln Rs. or 23% of total exports. By 2050, urban exports in this scenario have increased to more than 144,000 mln Rs. so it does not matter much whether sugar is exported at a level of 4,500 mln Rs. (3% of total exports in 2050) or 640 (0.5% of total exports). Sugar does not make very much difference in income. To reduce the still enormous water shortage urban exports have to be reduced.

5.2.2. Reduction of the New Export Sectors

The 25-fold growth of the new, dynamic export sectors--non-textile EPZ manufactures and sales-, transportation-, and business services--is reduced over the projection period to tenfold. Textiles and tourism growth remain as in the original scenario. At the same time, the government budget must be balanced. With the high surplus, taxes can be reduced. All indirect taxes and import duties are reduced 2% annually until 2020 and 1% annually until 2050. The results are shown in Table 13.

Table 13. Selected results of the *modern/boom/laissez-faire* scenario, adjusted to reduced boom 1.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	45.8	37.0	0.0	0%	37%
2050	1.12	56.9	50.9	0.0	0%	39%

Unemployment is very high, and the GNP per capita is reduced by 50% compared to the unadjusted scenario. This is the effect of the water constraint without *garden* policy.

5.2.3. Replacing Textile and Sugar Exports with Service Exports

Is this the highest possible GNP while maintaining the water constraints? Or, is there ? "optimum" export strategy? Is it possible with less textile--which is a water polluting industry--and a little more of other, cleaner sectors to become wealthier?

Sales-, transportation-, and business services return to the original scenario: 25-fold increase. Other EPZ manufactured exports are maintained at the low tenfold increase. Textile is removed almost completely by 2050. With the higher GNP, government services are increased 1% annually (see Table 14).

Table 14. Selected results of the *modern/boom/laissez-faire* scenario, adjusted to reduced boom 2.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	72.8	58.5	0.0	0%	14%
2050	1.12	109.5	97.9	0.0	0%	0%

Through this change, income per capita can be doubled. There is almost no more unemployment. The choice of urban sectors to be promoted is extremely important. The polluting textile industry--or analogously, any other polluting industry--severely constrains growth in a situation where the ceiling of limited resources is reached. A service-oriented economy, both in exports and in higher government services, allows considerable growth even without investments in water management.

In summary, compared to the unadjusted scenario, the following reductions have been made: 1) unit domestic agricultural food demand, 2) sugar exports, 3) indirect taxes and import duties, 4) textile exports, and 5) to a lesser extent, non-textile EPZ manufactures. Government expenditures are increased. Through these changes, almost the same GNP per capita can be achieved as in the original unadjusted scenario. Most importantly, this higher income can be achieved in harmony with the environmental framework.

5.2.4. Garden Policy

Is higher growth possible with water management? Or, conversely, is the lack of water management in the scenario above a constraint on development?

Rather than the *laissez-faire* policy, the government invests in water management. The surface water storage capacities are doubled by 2050; the capacity for primary treatment are doubled and secondary treatment of industrial wastes is introduced in the 1990s. The original, unadjusted scenario results for *modern/boom/garden* are shown in Table 15.

Table 15. Selected results of the *modern/boom/garden* scenario, unadjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	84.9	68.2	+5.0	16%	-10%
2050	1.12	116.9	104.5	+10.0	17%	-18%

In order to make the scenario comparable to the adjusted *modern/boom1/laissez-faire* scenario above, exactly the same changes are made from this unadjusted scenario. This results in a lower GNP than this last scenario, because part of the income generated by exports is invested in water management (which does not add to GNP in this model--no positive accounting for pollution abatement). To balance the budget, taxes are reduced only 1% annually from 2005. The results are shown in Table 16.

Table 16. Selected results of the *modern/boom/garden* scenario, first adjustment.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	67.1	53.9	0.0	47%	21%
2050	1.12	98.7	88.3	0.0	64%	9%

Water surplus is 64% by 2050. What shall the water be used for? To keep (i.e. reinstall) the traditional exports, sugar and textiles? Reintroducing sugar and textile export scenarios as above increases income per capita to 93,000 Rs., and reduces the water balance to +38%. There is a much bigger demand for workers. Reintroducing non-textile EPZ in the original 25-fold increase increases GNP to 105,000 Rs., reduces the water surplus to only 30%. With this scenario, there is a shortage of workers again.

Would the water surplus be "used up" when exports for sales-, transportation-, and business services are increased 35-fold? A paradoxical result occurs with this change. The higher urban growth reduces sugar land availability by 150 km^2 which reduces water demand for irrigation. The net effect is that higher growth is achieved with the same water balance. When manufactures are introduced, the result is an increase in urban land at the cost of sugar land, and the increase in water demand in the former sector is almost canceled out by a decrease in the latter. A continued restructuring of the economy along these lines to take full advantage of the water would require also high increases in land productivity and labor productivity--that is, development in all aspects, not just environmental policy.

Analogous to the discussion above with the *laissez-faire* policy, more growth can be achieved by replacing the textile industry with less polluting, or more productive industries. A scenario with a 95-fold increase in exports of sales-, transportation-, and business services and a 95-fold increase in other EPZ manufactures just uses up the water surplus. Land productivity increases are 3% annually throughout the projection period. To balance the labor force, considerable labor productivity increases are needed--4% annually from 2015-2050 from technology alone. The high growth rates allow the government to be more generous; the budget in this scenario is balanced when e.g. services are increased 2% annually and taxes are first increased 2% annually to pay for initial water treatment installments (until 2000), and thereafter decreased by about 2-3% annually. The new results are shown in Table 17.

Table 17. Selected results of the *modern/boom/garden* scenario, adjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	90.6	72.7	0.0	35%	6%
2050	1.12	332.3	297.0	0.0	7%	3%

This is the average West European level of per capita income in 1990.

In short, investing in mater management allows income to continue to increase quickly well into the next century. In the scenario without water management, income lags only 33% behind the scenario with water management in 2020, but by 2050 it was only one-third of the income in the *garden* scenario. It should be noted that the land- and labor productivity increases are quite large.

5.2.5. Is a Boom Possible with a Growing, Traditional Population?

In turn, *traditional/boom/laissez-faire* and *traditional/boom/garden* are discussed. The results of the unadjusted former scenario are given in Table 18.

Table 18. Selected results for the *traditional/boom/laissez-faire* scenario, unadjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.46	87.0	59.4	+10.0	-19%	-26%
2050	1.90	122.8	64.8	+15.0	-55%	-15%

There is a big water and labor shortage, and a big government surplus. Following the same strategy as above--reduction in less productive sectors, and concentration on service exports--textiles and sugar are reduced to almost zero with a tenfold increase in EPZ-other and sales services, and 20-fold increase in transportation-, and business services. This is a slightly larger reduction in service export growth than in the *modern/boom/laissez-faire* adjusted scenario above. The other reductions are the same as in this scenario (see Table 19).

Table 19. Selected results for the *traditional/boom/laissez-faire* scenario, first adjustment.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.46	58.4	39.9	0.0	0%	18%
2050	1.90	78.5	41.4	0.0	8%	34%

Water is now balanced. The income per capita under lower exports because of water constraints is cut by 50% again. Note that the growing population does not allow GNP to grow as much as in the *modern/boom/laissez-faire* above because of the water requirements per capita, and that higher population exactly "eats up" any increase in total GNP: the GNP per capita remains constant from 2000 to 2050.

5.2.6. ... and with a Garden Policy?

The results for the unadjusted *traditional/boom/garden* scenario are given in Table 20. This scenario can be improved by switching to service exports.

Table 20. Selected results for the *traditional/boom/garden* scenario, unadjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.46	85.5	58.4	+5.0	13%	-23%
2050	1.90	121.1	63.9	+9.0	8%	-13%

Sugar exports are reduced from 4,500 million Rs. annually to 640 million Rs. and domestic food demand is reduced to 20% of original values. Textiles are reduced from 7,400 million Rs. in 1990 to 500 million Rs. in 2050. Other EPZ exports are increased 65-fold, and sales-, transportation-, and business services are increased 77-fold. The extra government income is used to increase services 2% annually. Taxes are also raised 2% annually until 2000 to pay for the water treatment installments, and then reduced 2% annually. Labor productivity increases 1% annually until 2010 and then 3% annually. Land productivity increases 3% annually until 2000 and then 2% annually except for agricultural land. Female labor force participation stays at the 1990 level rather than decreasing. The adjusted results are shown in Table 21.

Table 21. Selected results for the *traditional/boom/garden* scenario, adjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.46	88.7	60.6	0.0	28%	0%
2050	1.90	283.8	149.8	0.0	7%	4%

Again, with the large traditional population, income per capita is half the income with the small modern population.

5.2.7. Is More Growth Possible? The *Dream* Scenario

The per capita income in *modern/boom/garden* adjusted, in 2050, was equal to the average European level today. Some readers might ask: is this the maximum that the model can calculate for Mauritius? Mauritius today, in the middle of rapid change and the recent history of, for example, Japan's change over the last 50 years, raises the speculation that in the next 50 years, Mauritius could attain a level of material wealth greater than the average European level today.

In this *dream* scenario exports are increased beyond the *boom* level: a 130-fold increase in the four new export sectors, and textile and sugar reduced gradually to almost zero by 2050. The numbers at this point are quite speculative and theoretical. The results are given in Table 22. As expected, income goes up when exports are increased, but the two main restraining balances on the island, water and labor, turn negative again.

Table 22. Selected results for the *dream* scenario, unadjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	89.2	71.6	+5.0	35%	-7%
2050	1.12	454.7	406.4	+32.0	-46%	-77%

The development of the water balance is interesting, as Figure 5 shows. Initially, as the industry grows, the water balance becomes positive. This is because the largest consumer of water, irrigation, is drastically diminished as sugar fields make way for industrial parks and residential areas. The lowest consumption of water is attained in 2010. In this year, the water balance is almost 40% positive. It seems like the investments in water management are superfluous and water in Mauritius is more than sufficiently available. Then water requirements overtake water availability suddenly around 2040, although just a few years before there had still been a 25% water surplus. And ten years after the first appearance of a water deficit, there is a 46% water shortage. What happened? This is an example of exactly the type of cumulative effects and crash, that were discussed in Chapter 3 on model reviews.

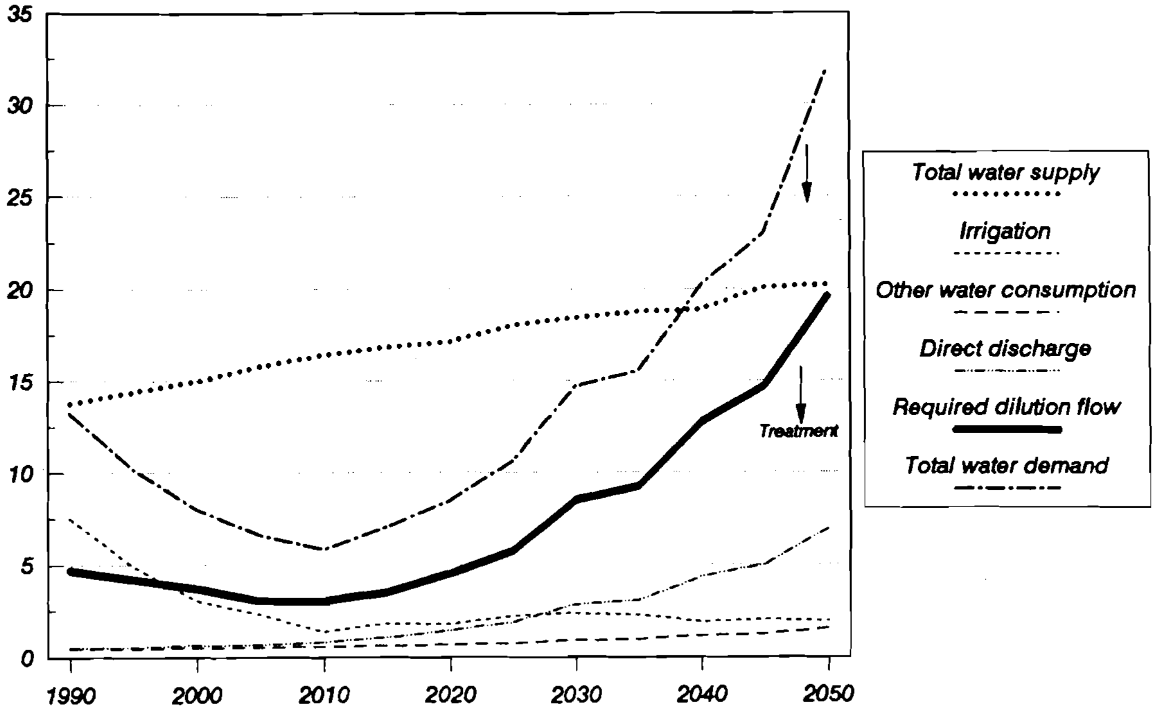

Figure 5. Water demand and supply under *dream* scenario assumptions.

The economic growth is exponential. But so are the pollution side effects in this scenario. As with all things exponential, there comes a point when it explodes, and then the rates of change become suddenly so fast that it no longer seems possible to keep up with them.

Say, in this scenario, the Mauritians had 50 year foresight, and began to treat the water already in 1990. With a 7.5% annual increase in tertiary treatment all through the period 1990-2050 in the two growing industrial sectors--EPZ-other and domestic, other manufacturing--water is exactly balanced in 2050. In 2050 the costs for treatment are 60 billion Rs. assuming constant technology and no returns to scale. Since total GNP is 440 billion Rs., the costs of water management are 14% of GNP. With constant tax rates, the total government income is 70 billion Rs., almost all of it used for water management. Labor productivity from technological change needs to increase 1% annually from 1990 to 2015 and 5% annually for the rest of the period. Female labor force participation is increased to almost the level of male labor force participation. The new results are shown in Table 23.

Table 23. Selected results of the *dream* scenario, adjusted.

Year (unit)	Popul. size (mill.)	Total GNP (bill.)	Income/ capita (1000)	Budget balance (bill.)	Water balance (per cent)	Labor balance (per cent)
2020	1.25	87.3	70.0	0.0	38%	12%
2050	1.12	441.8	393.1	0.0	0%	0%

This is called the dream scenario because the input requirements are quite dream-like.

5.2.8. Sugar Policy

Many people dream of this *dream* scenario with unending increases in income. At the same time, for many reasons, Mauritius is reluctant to give up its sugar cane and present policy is explicitly to keep present sugar output, which completely disappeared in the dream scenario. Would it be possible to have both wealth and sugar? This can be tested by activating the sugar policy in the *dream* scenario.

In the PDE-Mauritius model the default choice, in the case of a land conflict, is that the more profitable activity always wins: urban activities take land at the expense of sugar cane. This feature is contrary to current government policy. Choosing the option "sugar policy" in the model takes current government views into account. Now, any demand for sugar will be satisfied first, and the remaining land will be distributed to the remaining economic activities. An indirect impact of this is that industrial production might be constrained at a lower level than is demanded domestically and from abroad, triggering a contraction of the whole economy (see Table 24).

Table 24. Effects of a sugar policy under the *dream* scenario.

Year		Sugar production	Land use for sugar	GNP per capita	Labor balance	Water balance
1990		6.8	734	21,000	4%	0%
2050	no sugar exports	0.3	28	393,000	0%	0%
	with sugar exports	3.8	312	380,000	4%	-9%
	with sugar policy	7.4	591	215,000	46%	0%

There are two alternatives to include sugar in the *dream* scenario. The first has no sugar policy, but does have a continuation of sugar exports. In this case, there will be land conflicts, but with priority to urban land. The second has a sugar policy, which means sugar has priority over urban land in case of a land conflict. Results are given below.

Under the original *dream* scenario, both sugar production and land used for sugar cane growing would decline significantly; all economic balances would develop favorably and GNP per capita would increase 20-fold by 2050 (see also Figure 6). Keeping sugar exports in the scenario, but without including a sugar policy, results in some land conflict. However, because urban land takes priority, the reduction in income is only 3%.

With a sugar policy, the development is quite different. Due to some land productivity increases for sugar, in 2050 somewhat less land is required to produce the same amount of sugar as compared to 1990. Losing in the case of a land conflict, urban activities are reduced drastically and as a consequence, income per capita only increases tenfold until 2050: a 50% reduction compared to the *dream* scenario without a sugar policy. At the same time, tremendous unemployment (almost 50% throughout the period) would occur.

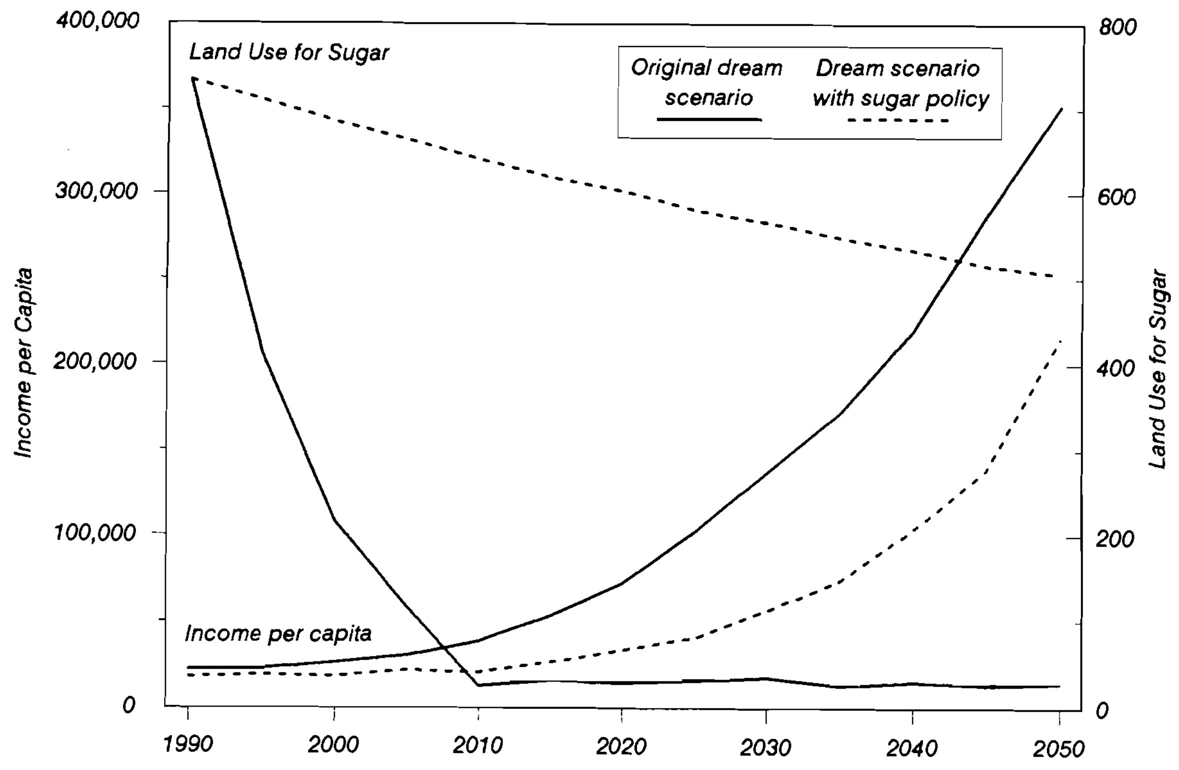

Figure 6. Income per capita and land use for sugar with and without sugar policy.

As one would have expected, in a rapidly growing economy constraints in the form of a sugar or other agricultural policy would hinder rapid development to a certain extent. Giving priority to sugar was reasonable at an earlier stage of development, but may not be beneficial in the future.

6. SUMMARY AND CONCLUSION

Some selected results on income, labor, water and BOD, and some input parameters on land and labor productivity from the most interesting adjusted scenarios are shown in Table 25. The six scenarios selected are:

1. worst case *traditional/crisis/laissez-faire* scenario.
2. *modern/crisis/laissez-faire* scenario with food self-sufficiency which reflects the best scenario in case of an economic crisis.
3. *modern/boom1/laissez-faire* scenario with current export markets which presents a conservative growth estimate if most things remain as they are today.
4. *modern/boom2/laissez-faire* scenario with new service oriented export markets which reflects the best case without any environmental policy.
5. *modern/boom/garden* scenario with new service-oriented export markets deriving full advantage from the water available through the garden policy.
6. *traditional/boom/garden* scenario with new service-oriented export markets as a complement to the previous scenario but with large, traditional population.

Table 25. Some input and output parameters for six selected adjusted scenarios.

		Output values for 2020 and 2050				Model input values: average annual rate of change	
Scenario	Year	Income/ capita (Rupees)	Labor balance (%)	Water balance (%)	BOD in lagoon (kg/m³)	Labor product.	Urban land product.
Current	1990	21,700	4%	0%	0.25	-	-
tradit/ crisis/	2020	12,900	53%	13%	0.19	0	0
l'faire	2050	8,300	69%	12%	0.18	0	0
modern/ crisis/	2020	24,300	38%	0%	0.25	0	0
l'faire	2050	22,800	50%	0%	0.22	0	0
modern/ boom 1/	2020	37,000	37%	0%	0.38	1%	2%
l'faire	2050	50,900	39%	0%	0.41	0.5%	0.3%
modern/ boom 2/	2020	58,500	14%	0%	0.36	1%	2%
l'faire	2050	97,900	0%	0%	0.42	0.5%	0.3%
modern/ boom/	2020	72,700	6%	35%	0.23	1%	3%
garden	2050	297,000	3%	7%	0.38	4%	3%
tradit/ boom/	2020	60,600	0%	28%	0.16	1%	2.5%
garden	2050	149,800	4%	7%	0.42	3%	2%

6.1. Income

Figure 7 shows the GNP per capita developments of the six selected scenarios.

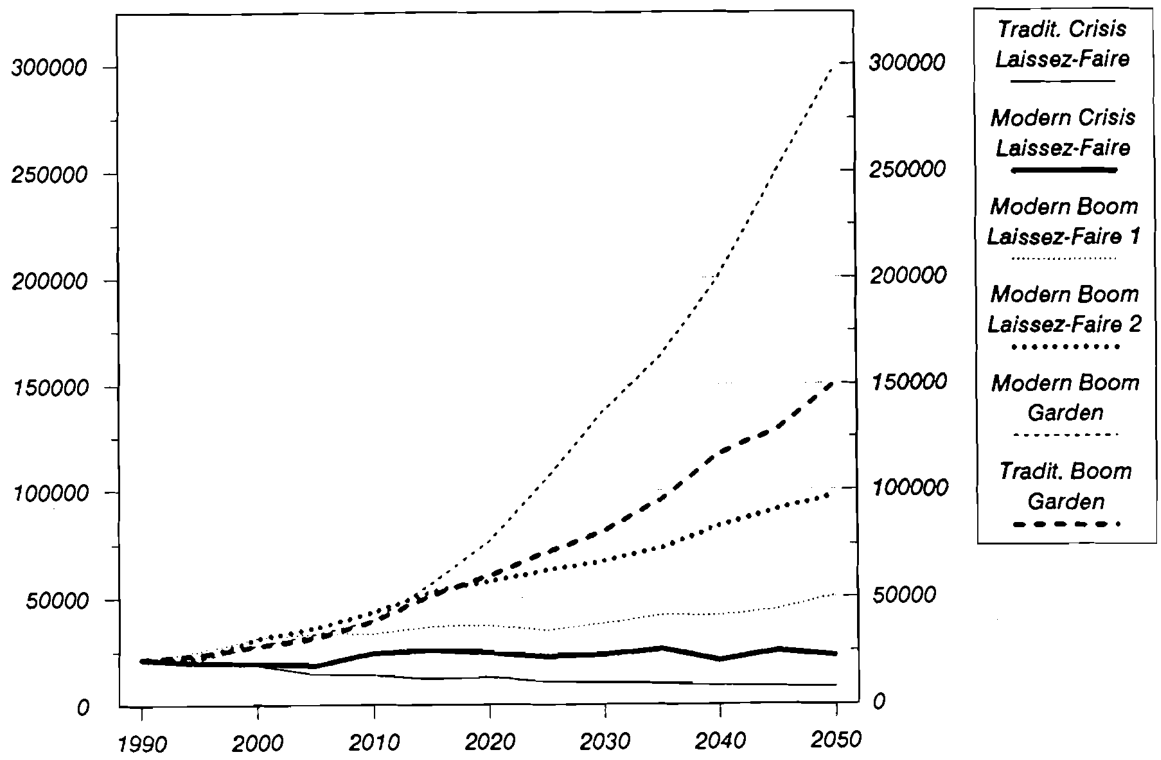

Figure 7. Income per capita development under six adjusted scenarios.

Under the worst case *traditional/crisis/laissez-faire* scenario, income per capita declines linearly down to 8,300 Rupees, as population grows. However, constant GNP per capita is possible. In the scenario with modern population and a food self-sufficiency policy, GNP remains at the 1990 level beyond the crisis (see *modern/crisis/laissez-faire*).

Present levels of GNP per capita are doubled by the year 2050 in the conservative *modern/boom1/laissez-faire* scenario without economic restructuring and without careful water management. This economic performance is considerably surpassed by the *modern/boom2/laissez-faire* which envisions economic restructuring in the sense of promoting service-oriented exports at the expense of sugar and textiles, still without water management. However, much larger economic growth rates are shown in the scenarios with a *garden* policy, i.e. water management, scenarios. In the *modern/boom/garden* scenario, with modern, service export, very high labor and land productivity increases, and the garden policy, GNP per capita in 2050 is 15 times the 1990 level. Combining this best development and environment scenario with the large population--*traditional/boom/garden*--reduces the scenario GNP in 2050 by half. This decrease is more than proportional to population size.

Comparing population, economy and environment settings in the previous analysis, one can conclude that:

- in the case of an economic crisis, low population growth allows a much more favorable per capita income development. This is not only because there are fewer mouths to feed with the same GNP, but also because valuable resources--in Mauritius land and water--can be used for the creation of wealth rather than only to provide subsistence.
- an export demand development that considers the resources and constraints of Mauritius allows the GNP per capita to grow much more than conservative tending of existing export markets which use the scarce resource water heavily and the well-educated labor force sparingly.
- only a far-sighted water policy enables economic growth beyond certain limits. The investments made in the garden policy are a small portion of the gains which can be made in total economic product.

6.2. Employment

In the *crisis* scenarios, unemployment is tremendous and will have several consequences (see the sections above). Unemployment is also high in the *boom1* scenario with moderate growth.

A comparison of the two *modern/boom/laissez-faire* scenarios shows that with the same population development and the same environment policy quite different economic results can be obtained. With a population development such as reflected by modern, which results in higher education and thus higher labor productivity, switching from the current export markets, which still include sugar and textiles, to new service-oriented export markets is essential. Unemployment is high in the conservative *boom1* scenario but would disappear with the new service-oriented markets. The large amount of land taken away from sugar cane can be used for other more productive activities which create more employment.

The population and the economy in the *modern/boom* scenarios with new service-oriented markets adjust harmoniously to each other. While there is a growing demand for export goods, the people entering the labor force are well equipped with more knowledge and skills for a more powerful economy, and women start working more frequently. The investments in education here are considerable, and should not be underestimated: by the year 2050, about 25% of the young people will leave school with some tertiary education, compared to 3% in 1990.

6.3. Land Use

In all scenarios land use for sugar decreases substantially, but for different reasons: in the *crisis* scenarios because of lack of demand for sugar; in the *boom* scenarios because of competition from urban land. Figure 8 presents sugar, urban, and total land use for two extreme scenarios: the worst case *traditional/crisis/laissez-faire* and the best case *modern/boom2/garden.*

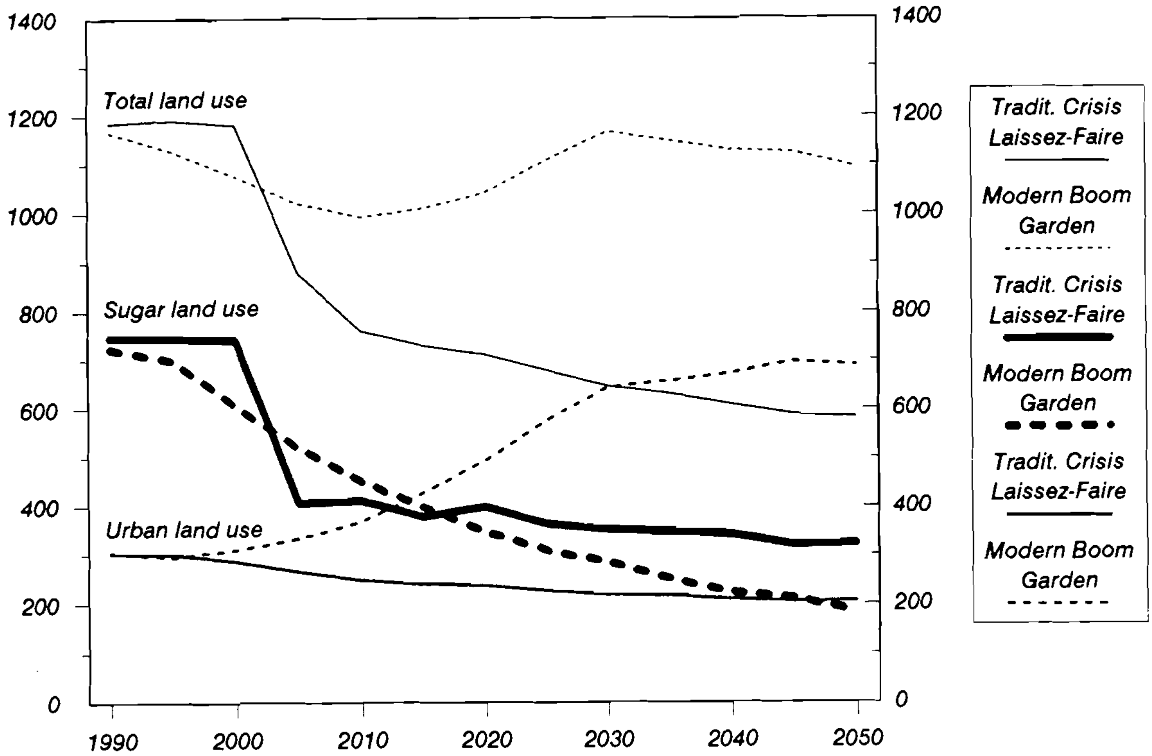

Figure 8. Land use developments under two selected adjusted scenarios.

The sugar land reduction is gradual in the *modern/boom2/garden* scenario, whereas it is abrupt in the *traditional/crisis/laissez-faire* scenario. Urban land use is very different. In the *traditional/crisis/laissez-faire* scenario it even decreases slightly, and much of the former sugar land remains fallow, reverting back to shrub and savannah. This is similar to what can be observed in parts of the north of the island, where some of the former sugar fields are no longer tilled. As a consequence, out of the 1,200 km^2 land used economically today only 50% will be used by 2050. In the best case scenario, land used for urban activities increases more than twofold notwithstanding land productivity increases of 3% annually.

6.4. Water

From a presently balanced situation indexed to 1990, most of the scenarios have been adjusted in a way that water demand virtually equals water supply. In the worst case *traditional/crisis/laissez-faire* scenario, a water surplus is generated after the sudden *crisis* in the year 2000, which remains throughout the rest of the projection period. The surplus comes from lowered economic activity and the lower demand for water. In the best case *crisis* scenario *modern/crisis/laissez-faire* with food self-sufficiency policy, this water surplus is used up through irrigation of locally produced food.

While in the *boom/laissez-faire* scenarios all water is used up every year, in the *boom/garden* scenarios a quite significant water surplus is observed through most of the period. This surplus is because of the prudent government interventions during the next thirty years, aimed at building more treatment facilities and more reservoirs to provide the Mauritian economy and population with sufficient water.

The different developments show that very divergent population and economy paths do not necessarily disturb the environment more or less, but that a lot does depend on the actions that are taken in the environmental policy sphere.

6.5. Lagoon BOD Concentration

So far, only surface water supply and demand and land use for different purposes have been discussed as environmental consequences. Another aspect covered by the model is BOD concentration in the lagoons. Life in the lagoons is important for Mauritius. This is particularly true of the corals, which form a natural defense against ocean surf. The BOD concentration, short for biochemical oxygen demand concentration, measures the amount of organic waste in the lagoon. It measures an important part of the pollution in the lagoon--both in the water and in the sediments: the lower the concentration, the better for the lagoon.

There are remarkable differences in the BOD concentration in the lagoons depending on the scenario. Generally, there are higher concentrations of BOD in economic *boom* scenarios. While under *crisis* assumptions, organic waste concentrations remain below the 1990 value, a booming economy without water treatment policy will approximately double the concentration of BOD in the lagoon (compare the *crisis/laissez-faire* and *boom/laissez-faire* scenarios in Figure 9, which gives the BOD concentration in the lagoon sediments).

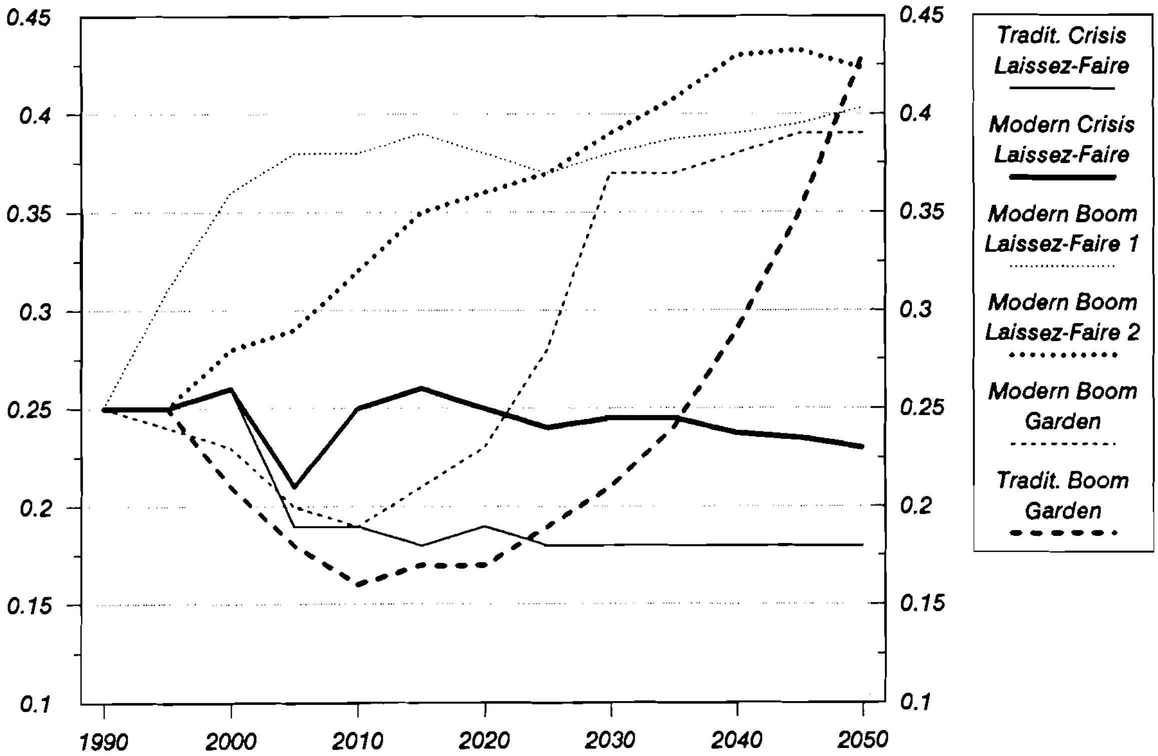

Figure 9. BOD concentration in the lagoon in six selected adjusted scenarios.

With the water management policy adopted in the *garden* scenarios, the concentration of BOD would even decline during the following decades and remain on low levels until 2030, albeit with much higher economic activity as compared to all other scenarios. After around 2030, treatment of waste water can no longer fully keep up with economic activity which grows exponentially. The organic waste concentration starts to exceed the current value and approaches the level reached with *boom/laissez-faire* assumptions.

If there had been more investments in treatment than those we envisaged, rather than alleviating the water balance with reservoirs, it would have been possible to decrease the BOD concentration here also. It would, however, have cost the government on the order of 1,000 mln Rupees extra annually--again 1987 prices and technology--to do so and as a consequence income per capita would have been somewhat lower.

If some types of lagoon life die in certain periods, this loss would be irreparable, even if subsequent cleaning efforts returned the water to a quality that could have sustained that life. Sometimes, a little too late is late enough, but the difference would not be visible from our graphs. If, indeed, such life was killed by high BOD concentrations, then higher investments in treatment would be needed.

In the discussion of population and environment, we can say that it looks as though here, too, population growth and economic growth are possible with care for the environment.

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