**Simulating the Effects of Environmental Policy Change**
**Via Gains in the Efficiency of Natural Resource Use**

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Over the past few months, the team convened by USAID/AFR-SD on CBNRM (Community based natural resource management) in Africa[1] has been addressing a number of issues, including the overall magnitude and significance of economic and environmental trends, the nature and evolution of the CBNRM experience, its expansion and its impact on the environment and political processes.

Recent work on economic and environmental trends in Africa[2] highlights key trends. The review of the CBNRM literature done by the author, and the USAID-sponsored NRM-Tracker also provide information on specific cases, and on political, economic, social and biophysical factors at work in CBNRM experiments. This knowledge is synthesized in the various logical relationships portrayed through the *NetWeaver*- and *Stella*-based models developed by the team.

Although the quest for better environmental policies and natural resource use is universal, little or no information is available on what such changes might imply, or on the scale of change needed for significant progress. For example, if an African country were to raise efficiency in the use of its renewable resources by the equivalent of 25 or 50 or 100 percent overall; what would this mean in terms of trends of natural capital use? What would be the impact of doubling the current area in managed forests by substituting managed forest areas for natural forest and woodland areas? Conversely, what change in resource use efficiency would it take to stabilize typical trends in the mining of renewable resources, for an "acceptable" level of depletion of non renewable resources?

To provide illustrative answers, the author has developed a simple spreadsheet-based model of a "typical" African economy. **'Jump' directly to the model** Env_Econ_Model.xls

The economy is very simply specified, by main sector of activity, with population, resource endowments and returns to resources combined with labor and other inputs. Depending on the assumptions made on gains in the efficiency of resource use, a range of net domestic resource gains is attained. These gains are then expressed as trends in income per capita, or of a reduction in the rate of loss of natural capital (for a fixed, given level of per capita consumption). In effect, the model is mostly driven by the hypotheses that:

- Environmental policies and practices change in response to pressure (both endogenous and exogenous);
- Environment-related policy reforms, including wide CBNRM application, induce significant changes in the allocation of factors and resources, and a higher level of efficiency in the use of certain types of natural resources, within a span of five years;
- Such changes have a positive impact which can be measured as higher returns to the combination of labor, capital and natural resources. This higher return can also induce domestic resource savings because of lower food or energy imports requirements (holding total or per capita consumption constant);
- The impact on the rate of depletion natural capital, for a given level of annual consumption, can be estimated.

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[1] Paul Bartel, Mike McGahuey, AFR-SD; Henri Josserand, ARD, Inc.; Kathy Parker, Max McFadden, the Heron Group; Mike Saunders, Bruce Miller, Pennsylvania State University; John Woodwell, University of Maryland.
[2] Economic and Environmental Trends in Sub-Saharan Africa, EPIQ Report for USAID, June 1999.

Constructing the simulation models involves the following steps:

1. Specifying a basic input-output or mass-balance model highlighting sectors which are sensitive to environmental policy change, and where gains in resource efficiency can be measured in terms of domestic resource savings by main type of tradables (in this case, food, energy products);
2. Specifying basic parameters and assumptions for each main type of economic and environmental country profile, consistent with the range of African economy situations;
3. Choosing several levels of discrete change in the effectiveness of NR management practices (e.g. 25, 50, 100%);
4. Assuming a set of economic outcomes for each discrete level of change in the efficiency of allocation and use of natural resources;
5. Expressing the outcomes in terms of changes in per capita income over time, given the nature of each typical country profile;
6. For the resulting rates of efficiency in resource use and per capita consumption, estimating the impact of the gains in domestic resource savings on the annual change in the country's stock of natural capital.

The basic model is specified along the following general lines:

All prototype countries are first assumed to have a certain population size at t=0, growing at 2.6% p.a., the average for sub-Saharan Africa. Another set of runs is done with population growth at 2% p.a., equivalent to the rate of economic growth. GDP per capita at t=0 is set at $580, a value within the range prevailing among African nations.

The structure of each economy is expressed in the simplest terms: a stock of natural capital, and three main sectors: food, energy and manufacturing/services. Resources are originally allocated among sectors on the basis of relative factor and product prices, consistent with ex-ante economic and environmental policies; that is, before the policy changes and CBNRM have fully taken effect. Natural capital includes both non renewable (geological) and renewable (biological) resources. Labor, capital and renewable resources are combined to generate a certain level of domestic product and consumption in food, energy, manufactured goods and services. The remainder of labor, capital and natural resources are allocated to the export sector.

Total consumption is increased by recourse to the trade sector. In the simplest of cases, the current level of domestic production and consumption is maintained by: (a) using renewable resources beyond a sustainable level (given current technology) and (b) mining part of the non renewable natural capital (e.g. iron ore, oil, gold, diamonds). For the desired total level of per capital consumption, export earnings from the depletion of non renewable resources finance imports complementing the output of the three domestic sectors. Import substitution is possible, but only to a point, beyond which the allocation of resources to domestic production is punishingly inefficient. Conversely, for a given level of total consumption, more efficient domestic production allows for a decrease in export requirements, and thus, in the mining of natural capital. It is assumed that any additional increases to output and consumption from other transfers such as Official Development Assistance (ODA) are constant and given, and are not taken into account here.

Obviously, at a constant level of technology and of efficiency in resource allocation and use, the model is unsustainable. All countries, especially with fast-growing populations, can only maintain per capita consumption by continuing to mine natural capital, presumably up to or near the point where it is entirely used up.

Assumptions about the domestic and trade sectors, and the size of the stock of natural capital define the number of years before total collapse. Since both geological and biological capital are being mined, tradeoffs are possible: for example, if the country pushes the use of renewable capital beyond a critical level of diminishing returns, higher import requirements can be met (for a while) out of increased exports of non renewable capital. Also note that some renewable resources, exploited beyond the maximum sustainable yield, may be treated very much like geological ones (harvested up to complete collapse and depletion); marine fisheries off the coast of some west African countries may be an example. Finally, all countries are price-takers from a mercifully stable world market for tradables, although the impact of a major devaluation could easily be integrated into the model.

The model is just about as simple as they come, and does not have prescriptive value. However, the relative size of the resource-based economic activities is such that the impact of large changes in the efficiency of resource use can be simulated and provide insights into the orders of magnitude involved.

The model also tries to reflect the reality that energy production in Africa is relatively low (6.2% of world production). Continent-wide, production outpaces consumption, but that is only because consumption is very low (2.6% of world consumption), and because a lot of that production is from a few countries with relatively large liquid and gaseous fuels production, such as Nigeria, Algeria, Lybia, Angola. Most of the officially recorded energy consumption is accounted for by the industrial and transportation sectors, which use up about two-thirds of available energy resources. Agriculture and residential use make up about 5% of total consumption. However, in non oil-producing countries, traditional sources of energy such as fuelwood and charcoal provide a very large share of total domestic energy consumption, ranging from 91% in Ethiopia, to well over half in Kenya, Côte d'Ivoire and Senegal.

The model is also based on the fact that a typical land use pattern for an African country is such that 6.5% of total land area is cropland, permanent pasture accounts for 30%, forest and woodland for 24%, and "other" for 39.5%. The four country cases show a range of values around these averages. Finally, the declining productivity of agricultural and rangelands is included in the modeled through a yield reduction factor, which can be offset by conservation measures.

Because of its simplicity, the model assumes no flexibility in the structure of the economy; that is, the relative shares of the labor force in each main sector do not change in response to a change in returns to labor by sector. Finally, the assumption of economic growth can be taken into account, although it is arbitrarily set at the same level for all sectors in this illustration.

## COUNTRY A

In country A, the proportion of total land suitable for agriculture is relatively small, and only a sixth of agricultural land is allocated to cash crops. There are extensive areas of low-productivity rangeland and forest/woodland. Most of the population is in the rural sector, involved in a combination of agriculture, livestock raising and traditional energy production. The country sets a relatively high goal of maintaining income per capita at the t=0 level of $580. It is met by drawing heavily on the limited geological resources available for export. The effects of various discrete changes in the efficiency of resource use are estimated as scenarios for two main cases: economic stagnation, and slow growth (2%p.a.).

1. <u>If the economy stagnates (economic growth =0% p.a.)</u>

Population grows at 2.6% per annum. To sustain per capita consumption near this level, the country needs to adopt at least Scenario 3 or 4. Scenario 3 requires a 50% increase in the efficiency of use of all natural resources, full conservation of agricultural and rangelands. Scenario 4 requires a 100% increase in the efficiency of use of all natural resources, and doubling the size of managed forests from the area at t=0. Even so, the initial gains in income per capita are slowly eroded by population growth. After about ten years, unless there is a sharp increase in the mining of geological resources, per capita income starts to fall rather sharply.

If Country A tries to hold to the goal of maintaining per capita constant at $580/yr, there is an initial reduction in the rate of mining of geological capital, which greatly increases the lifetime of known reserves. However, the population effect strikes again, so that even after 15 years of careful resource management, the $580/capita/yr goal can only be maintained by a rapid increase in the mining of geological resources.

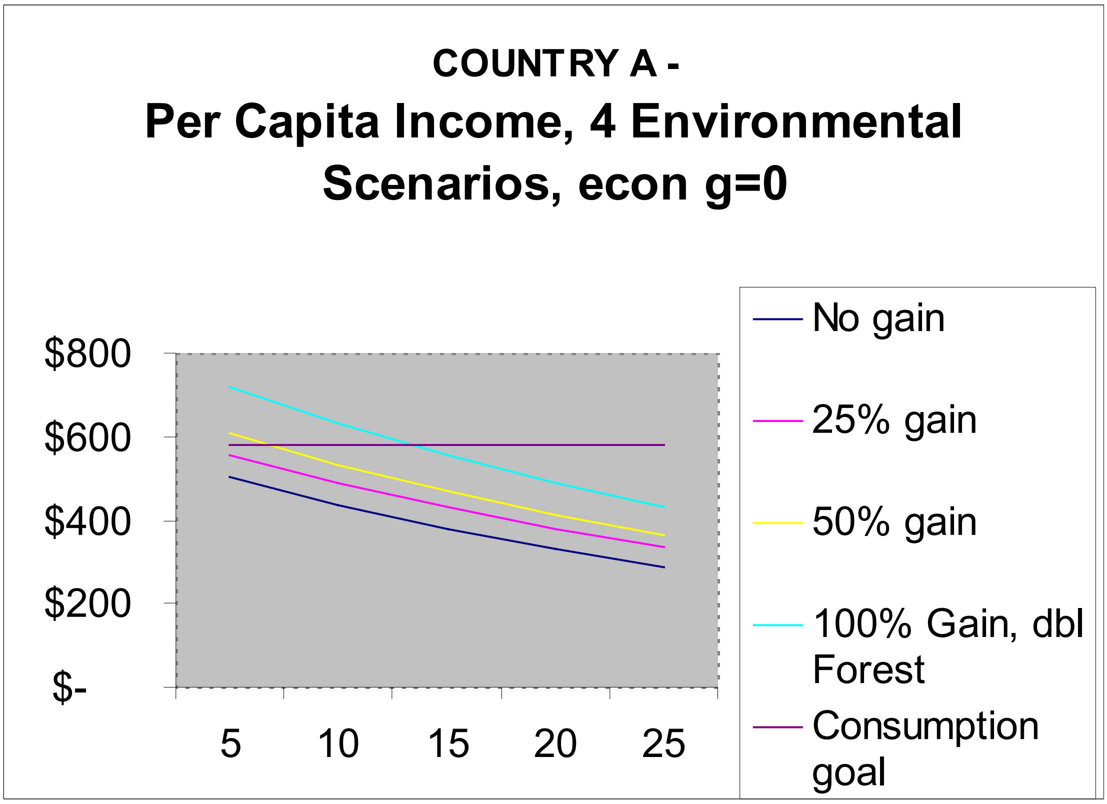
With anything less than the drastic changes in the efficiency of resource use implied by Scenario 4, the situation deteriorates even further and very quickly. Under Scenario 1, for example, the path of per capita consumption falls immediately and ends at about half of the original value after 25 years, if the rate of geological resources depletion is held constant.

2. If the economy grows at an overall 2% p.a.

A 25% increase in the efficiency of NRM will sustain per capita income only for a few years. It takes a 50% increase in efficiency of use of all natural resources to keep per capita income over the goal of $580, at least for 12 years or so after the effects of policy change. After that, the effects of population growth start cutting into per capita income again. The most favorable case is Scenario 4: 100% increase in resource use efficiency, combined with 2% economic growth per year. Even so, income per capita decreases somewhat, suggesting that even quantum changes in environmental policy coupled with modest economic growth can be eroded by population growth in the long run.

**COUNTRY A**

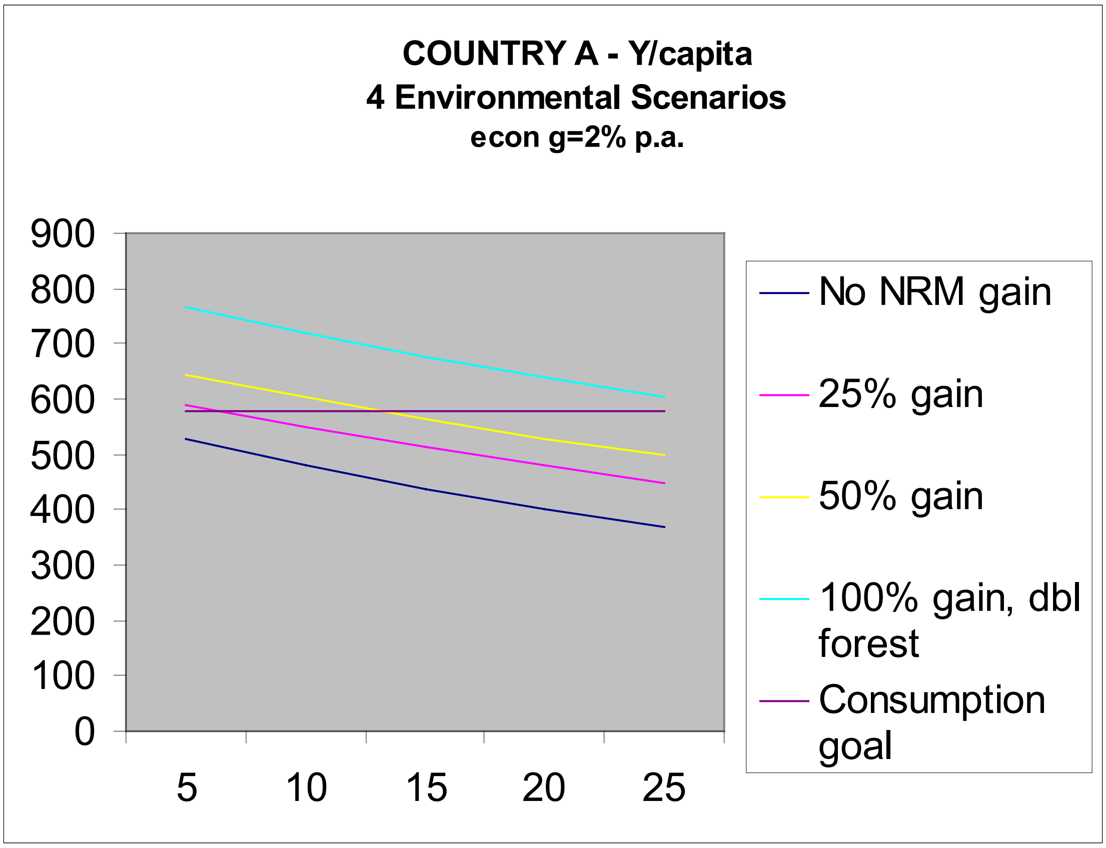
| **Situation after years of NRM change:** | **5** | **10** | **15** | **20** | **25** |
|---|---|---|---|---|---|
| **Scenario 1: No gain in NRM efficiency, no conservation, no forest expansion** | | | | | |
| A) Consumption constant ($580), Mining rate varies | | | | | |
| Rate mining exhaust. Resources (%/yr) | 6.5 | | | | |
| No. years to exhaustion | 10.4 | depleted | depleted | depleted | depleted |
| B) Consumption varies, Mining rate constant (2.5%/yr) | | | | | |
| Path of consumption/capita | $ 503 | $ 436 | $ 379 | $ 329 | $ 286 |
| Path of consumption with 2% economic growth | 528 | 481 | 439 | 402 | 368 |
| **Scenario 2: 25% gain in NRM efficiency,full conservation (stop erosion), no forest expansion** | | | | | |
| A) Consumption constant ($580), Mining rate varies | | | | | |
| Rate mining exhaust. Resources (%/yr) | | | | | |
| No. years to exhaustion | | | | | depleted |
| B) Consumption varies, Mining rate constant (2.5%/yr) | | | | | |
| Path of consumption/capita | $ 558 | $ 491 | $ 432 | $ 380 | $ 334 |
| Path of consumption with 2% economic growth | 590 | 549 | 512 | 479 | 448 |
| **Scenario 3: 50% gain in NRM efficiency, full conservation, no forest expansion** | | | | | |
| A) Consumption constant ($580), Mining rate varies | | | | | |
| Rate mining exhaust. Resources (%/yr) | 1.15 | 5.25 | | | |
| No. years to exhaustion | 82 | 9 | depleted | depleted | depleted |
| B) Consumption varies, Mining rate constant (2.5%/yr) | | | | | |
| Path of consumption/capita | $ 606 | $ 533 | $ 469 | $ 413 | $ 363 |
| Path of consumption with 2% economic growth | 645 | 602 | 564 | 529 | 497 |
| **Scenario 4: 100% gain in NRM efficiency,full conservation, double forest area** | | | | | |
| A) Consumption constant ($580), Mining rate varies | | | | | |
| Rate mining exhaust. Resources (%/yr) | 0.01 | 0.1 | 4.65 | | |
| No. years to exhaustion | >1,000 | >1,000 | 6.5 | | |
| B) Consumption varies, Mining rate constant (2.5%/yr) | | | | | |
| Path of consumption/capita | $ 718 | $ 632 | $ 556 | $ 489 | $ 430 |
| Path of consumption with 2% economic growth | 766 | 719 | 677 | 639 | 604 |


COUNTRY A -
Per Capita Income, 4 Environmental Scenarios, econ g=0
$800
$600
$400
$200
$-
5
10
15
20
25
No gain
25% gain
50% gain
100% Gain, dbl Forest
Consumption goal

**If population growth is limited to 2% p.a**. all outcomes are more favorable, especially if economic growth takes place as well. With 2% economic growth, the lower population growth rate is consistent with an increase in per capita income under Scenarios 3 and 4 for 25 years or more.

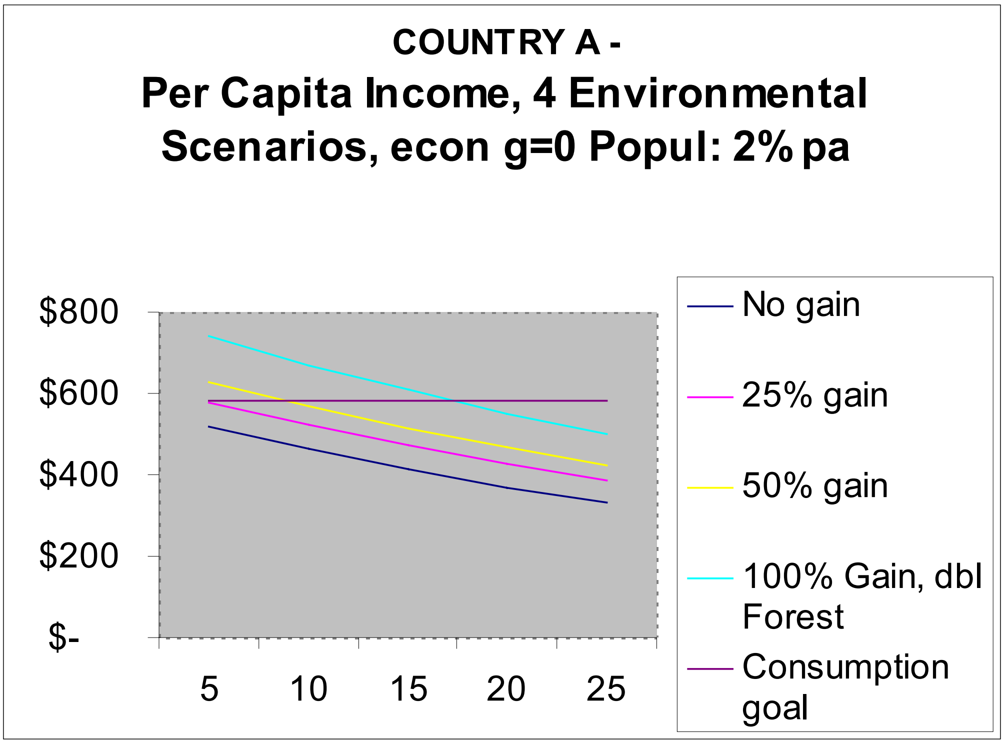
**COUNTRY A - POPULATION GROWTH: 2% pa**

| **Situation after years of NRM change:** | **5** | **10** | **15** | **20** | **25** |
|---|---|---|---|---|---|
| **Scenario 1: No gain in NRM efficiency, no conservation, no forest expansion** | | | | | |
| A) Consumption constant ($580), Mining rate varies | | | | | |
| Rate mining exhaust. Resources (%/yr) | 6.5 | | | | |
| No. years to exhaustion | 10.4 | depleted | depleted | depleted | depleted |
| B) Consumption varies, Mining rate constant (2.5%/yr) | | | | | |
| Path of consumption/capita | $ 518 | $ 463 | $ 414 | $ 370 | $ 331 |
| Path of consumption with 2% economic growth | $ 544 | $ 510 | $ 480 | $ 452 | $ 426 |
| **Scenario 2: 25% gain in NRM efficiency, full conservation (stop erosion), no forest expansion** | | | | | |
| A) Consumption constant ($580), Mining rate varies | | | | | |




| | | | | | |
|---|---|---|---|---|---|
| Rate mining exhaust. Resources (%/yr) | | | | | |
| No. years to exhaustion | | | | | depleted |
| B) Consumption varies, Mining rate constant (2.5%/yr) | | | | | |
| Path of consumption/capita | $ 576 | $ 522 | $ 473 | $ 428 | $ 388 |

| | | | | | |
|---|---|---|---|---|---|
| Path of consumption with 2% economic growth | $ 608 | $ 582 | $ 559 | $ 538 | $ 519 |
| **Scenario 3: 50% gain in NRM efficiency,full conservation, no forest expansion** | | | | | |
| A) Consumption constant ($580), Mining rate varies | | | | | |
| Rate mining exhaust. Resources (%/yr) | 1.15 | 5.25 | | | |
| No. years to exhaustion | 82 | 9 | depleted | depleted | depleted |
| B) Consumption varies, Mining rate constant (2.5%/yr) | | | | | |
| Path of consumption/capita | $ 627 | $ 568 | $ 515 | $ 466 | $ 422 |
| Path of consumption with 2% economic growth | $ 664 | $ 639 | $ 615 | $ 594 | $ 575 |
| **Scenario 4: 100% gain in NRM efficiency,full conservation, double forest area** | | | | | |
| A) Consumption constant ($580), Mining rate varies | | | | | |
| Rate mining exhaust. Resources (%/yr) | 0.01 | 0.1 | 4.65 | | |
| No. years to exhaustion | >1,000 | >1,000 | 6.5 | | |
| B) Consumption varies, Mining rate constant (2.5%/yr) | | | | | |
| Path of consumption/capita | $ 740 | $ 670 | $ 607 | $ 550 | $ 498 |
| Path of consumption with 2% economic growth | $ 788 | $ 763 | $ 740 | $ 719 | $ 700 |
| | | | | | |
| Constant consumption per capita | $ 580 | $ 580 | $ 580 | $ 580 | $ 580 |


COUNTRY A -
Per Capita Income, 4 Environmental Scenarios, econ g=0 Popul: 2% pa
$800
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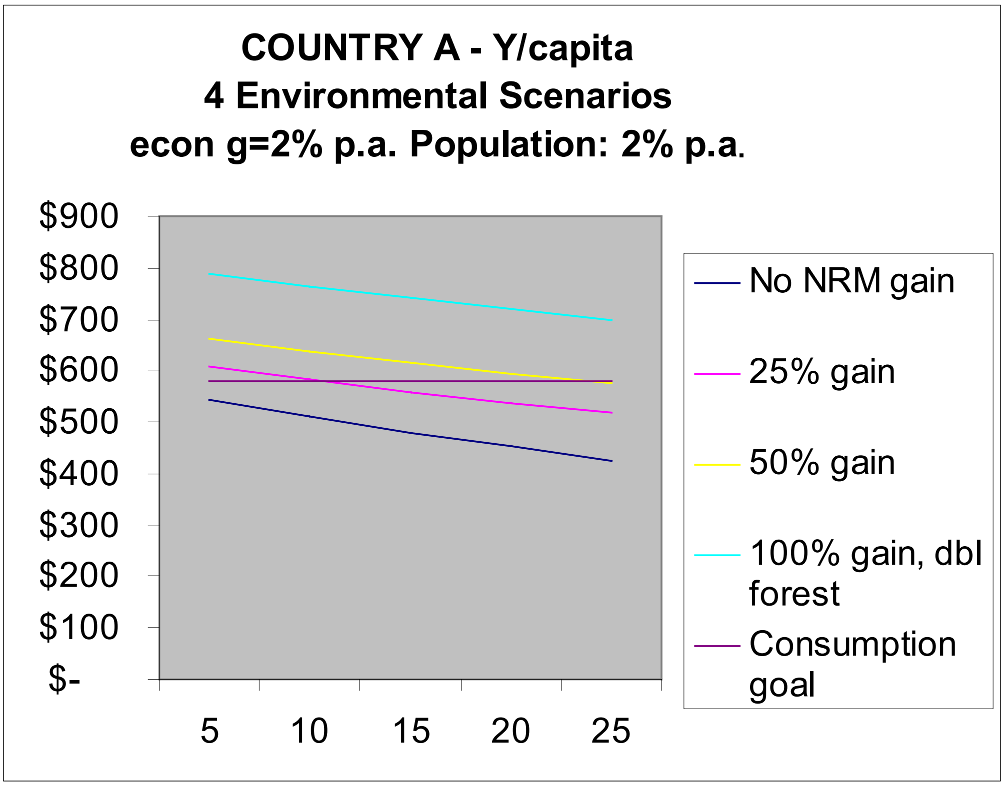
Consumption goal


COUNTRY A - Y/capita
4 Environmental Scenarios
econ g=2% p.a. Population: 2% p.a.
$900
$800
$700
$600
$500
$400
$300
$200
$100
$-
5
10
15
20
25
No NRM gain
25% gain
50% gain
100% gain, dbl forest
Consumption goal