Natural Resources, Environment, and Sustainable Growth in Mozambique

APPENDICES

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Warning

We present in this appendix the details of the methodology and the data used. Our objective is to be transparent so that anyone can criticize the work. The calculations will then be improved with feedbacks from the workshop. At this stage, we use existing databases. Of course some of the data are rough. Later on, these could be refined. It can also be an objective during the seminar: an identification of what key data are missing.

Appendix 1

Theoretical Framework

- **General presentation of the framework**

An economic transcription of the Brundtland Commission's classic definition of sustainable development is that "each generation should bequeath to its successor at least as large a productive base as it inherited from its predecessor" (Dasgupta and Mäler, 2001). An economy's productive base has to be understood in a broad sense that considers not only produced capital. We expand our productive base to several forms of capital: human (education level, knowledge, health, etc.), social (institutions, level of trust, etc.) and natural (mineral resources, soil resources, forests, halieutic resources, etc.).[1] A development path is sustainable as long as the society's productive base does not shrink. This paper assesses the change in the productive base of a particular economy, that of Mozambique, through the calculation of a macroeconomic sustainability indicator: the genuine saving.

Our departure point is the World Bank publication *Where is the wealth of nations?* (2006). It is an impressive study, built on several years of effort. David Pearce, among others, laid the theoretical foundations (Pearce and Atkinson, 1993). Kirk Hamilton and his team at the World Bank continued the work and made major improvements over the last ten years. *Where is the wealth of nations?* presents natural capital (and total wealth) estimates and calculates genuine saving for 210 countries. Many assumptions and simplifications had to be made and the work is still in progress. It nevertheless delivers interesting insights on the composition of wealth, and an assessment of the sustainability of these countries' growth paths.

There has been much theoretical debate on natural capital valuation and genuine saving calculations (see for example Atkinson and Hamilton (2007) for a review of progress achieved). Yet apart from the World Bank's impressive work, there have not been many detailed empirical applications.[2] For Africa, again except for the World Bank's work, there has not been any attempt at valuating the natural capital and genuine saving of any country, even though natural capital is very often an essential part of their total wealth. Moreover, poor populations, especially in rural areas, are highly dependent on their natural assets for their subsistence. The assessment of natural capital trends is thus of crucial importance in the actual pro-poor growth strategies context advocated by international organizations.

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1 Institutions are not always considered as a capital. Dasgupta for example considers them as a social infrastructure guiding the allocation of resources.

2 See for example Lin and Hope (2004) for Taiwan, and Brown (2005) for Australia, or Alisjahbana (2003) for Indonesia.

- **More formal presentation of the framework**

As noted above, sustainability is achieved if the current generation leaves the next one with the capacity to enjoy the same or a better quality of life. Pezzey (1989) gives a more formal formulation in economic terms: a development path is sustainable if utility does not decline at any point along the growth path. Let us define intertemporal welfare W through:

$$W(t)= \int_t^{\infty} u(c(s))e^{-\delta(s-t)}ds$$

where *u* is a utility function, *t* is time, *c* is a vector including marketed goods consumption flow, but also non-marketed goods or services consumption such as ecosystem services, and *δ* is the discount rate. The intertemporal welfare of a generation is thus determined not only by its utility from current consumption but also by the care it has for future generations. Considering our sustainable development definition, we can derive the following sustainability criterion:

$$\frac{dW(t)}{dt} \geq 0 \qquad \forall t \in [0,+\infty[$$

The consumption path is determined by the economy's productive assets: produced capital K (buildings, machines, roads, etc.), human capital H (education, health, etc.), social capital S (mainly formal and informal institutions) and natural capital N (exhaustible and renewable natural resources, ecological services). The output generated by this productive base is allocated between consumption and investment in the different capital stocks. We suppose that the allocation rule used for the share between consumption and investment is autonomous, which means that W is not an explicit function of time (Arrow et al., 2007).
Thus, we have:

$$W(t) = W[K(t), N(t), S(t), H(t)]$$

and $$\frac{dW(t)}{dt} = \sum_1^n \frac{\partial W}{\partial K_i}\frac{dK_i}{dt}$$

where $\frac{\partial W}{\partial K_i}$ is the marginal increase in intertemporal welfare from one increase unit of the capital stock. [3] It can thus be interpreted as the shadow price of the capital stock. $\frac{dK_i}{dt}$ represents the stock variation. In the case of autonomous allocation rules, Hamilton and Hartwick (2005) show that the value of the heterogeneous set of assets which constitute total

[3] See: Hamilton and Hartwick (2005) and Arrow (2003) for a rigorous demonstration of the results.

wealth is equal to the present value of future consumption, that is, intertemporal welfare. Thus, we have:

$$W(\mathrm{t}) = \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{p_i} \mathrm{K_i}(t)$$

where p_i is the shadow price of capital stock i ($\frac{\partial W}{\partial K_i}$ in previous equation).

Our sustainability criterion becomes:

$$\frac{dW}{dt} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{p_i} \frac{\mathrm{dKi}}{\mathrm{dt}} = G \geq 0 \qquad \forall t \in [0, \infty[$$

which means that the growth path is sustainable as long as the total wealth, that is, the sum of the value of the different capital stocks, does not decline at any point in time. G is called 'genuine saving'.[4] It is now a well-known macroeconomic sustainability indicator, mainly used and developed by the World Bank. Hamilton and Clemens (1999) demonstrate for optimal economies that a negative genuine saving implies an unsustainable development path. Dasgupta and Mäler (2000) extend this rule to non-optimal economies. Hamilton and Withagen (2004) show that a sufficient condition to maintain a constant consumption level is to have G=0. This is an extended version of the Hartwick rule (Hartwick, 1977). The meaning of a positive genuine saving is not straightforward. G>0 implies an increasing welfare provided that the growth rate of G does not exceed the interest rate (Dasgupta, 2001).

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[4] Genuine saving is also called genuine investment or inclusive investment in several other papers.

Appendix 2

Detailed Methodology and Data Used

Step 1 - Measuring the wealth of Mozambique

A. Measuring the value of natural capital stock for Mozambique

General introduction

The value of a capital is the present value of the stream of benefits from its future use. This definition is extended to natural capital. Natural capital includes exhaustible resources, renewable resources (forests, land resources) and environmental services produced by ecosystems (water filtration, waste assimilation, etc.). Most of the time, renewable resources are multifunctional: they provide goods as well as environmental services. The whole ecosystem can then be considered as a capital. Market prices for natural assets are often missing. As a consequence, the different resources are valued as the present value of resource rents during the asset's lifetime:

$$V = \sum_{i=t}^{T} \frac{\left(p_i q_i - C(q_i)\right)}{(1+r)^i} \qquad (2)$$

where p_i is the price at time i, q_i is the production, C the production cost and r the discount rate. For each natural resource, we apply the following assumptions:

- a constant rental rate over time[5]
- a 25-year accounting period (2005-2030)
- the value of the resource at the end of the discounting period is zero
- a 4% discount rate.[6]

One important point is that we assume a competitive economy so that rents reflect the 'contribution of nature' (if we disregard externalities) and are used to value flows from natural capital stocks. However, especially in a country such as Mozambique, prices are highly distorted and rents also reflect market power effects. The methodology we use for natural capital calculation is very similar to that of the World Bank (2006). We improve on it in several respects. First, we use local prices instead of world prices, which makes sense as most goods are consumed locally and are not exported. Second, whereas rental rates in the World

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[5] Rental rate = economic rent / output *100

[6] This choice is critical to the calculation. The discount rate can be broken down with the following formula: $\delta = r + \sigma.\mu$ with r the pure rate of time preference, σ the elasticity of marginal utility with respect to consumption, and μ the consumption growth rate. Reasonable orders of magnitude are: r=0.1% σ=1, μ=4%. See Stern (2007) for more details.

Bank study are crude, whenever possible we use local production cost studies to estimate rental rates. This reflects local production conditions more accurately. Finally, because some of the data are not reliable (for wood production for example), we use better data, according to local experts, whenever possible. Finally, we add halieutic resources.

This work is of course not exhaustive. We do not value every natural resource and ecological service, and have to be cautious not to double-count some services. One important point is that we do not really value ecosystems as separate assets. For example, we may think that mangroves are not valued. But the two main services they produce, wood for the local population and a habitat for fish nurseries, are valued through wood resources and fisheries. We therefore compile our results by categories of service produced and not by ecosystems.

Another point is that the rents calculated are the sum of different environmental services. For example, cropland rent is not only the service produced by the soil ecosystem; it also includes externalities from the forest cover in the upper watershed which regulates water and sediment flows. As a consequence, these kinds of services are counted through the cropland value and not in the forest value. Moreover, these rents also often include services from public infrastructures, social rules, etc.

In the following paragraphs we describe the methodology more specifically for each type of resource.

Cropland

The main crops in Mozambique are: maize, cassava, mapira, different kinds of beans, peanuts, rice, cotton, cashew nuts, potatoes, tobacco. We consider only crops covering more than 60000 hectares over the country. We assess rental rates on the basis of various production cost studies and local market prices (Gergely, 2005) (FAO producer prices). Total rent in 2005 for each crop is estimated with the following formula:

Total rent (crop i) = mean yield (crop i)*local market price*rental rate*crop i area

To project those rents in the future, we use current production trends (over the last five years) for each of these crops. In order to assess the sustainability of current cultivation practices, the World Bank (World Bank, 2006) posits constant production between 2025 and 2030. We use the same assumption although results are not very sensitive to it. A disputable point is the way to include unused lands. Uncultivated lands do not have a price at present, but do have an option value as they could be used in the future. They are in a way included in our accounting as we consider a growth of the production (resulting from productivity growth and cropland extension). Those lands which will be cultivated in the future thus have a value equal to the rent they will produce. However, it would be necessary to introduce an adjustment cost, the cost to transform the unused lands into croplands.

Details on the data used

We considered only crops covering more than 60000 hectares.

crop	2005 area (Ha)	Yield (tons/Ha)	Producer price ($/tonne)	Rental rate (%)	Production growth rate
maize	1 749 534	1 004	153	34	0,0186
cassava	1 038 851	7 341	113	9	0,1603
sorgho/mapira	364 370	637	146	30	0,0616
beans (all types)	659 151	500	441	30	
peanuts (tous types)	433 092	341	475	30	-0,0206
pumpkin	103 413	1831	164	30	0,0193
rice	278 368	902	296	36	-0,0177
cashew	54 616	1193	238	---	0,0289
potatoes	78 938	13 046	352	---	0,0043
tobacco	85 234	1 388	1671	---	0,0444
sesame	65 027	661	129	30	0,0954

Table 1 : data used for cropland valuation

Crop areas	TIA 2005
Yields	FAOSTAT
Prices	FAOSTAT / SIMA
Rental rates	(Gergely, 2005) (Arlindo, 2007) (Coughlin, 2006) (Benfica, 2005) (Uaeine, 2005)
Production growth trend	FAOSTAT

Table 2 : data sources for cropland valuation

Pastureland

Pasturelands in Mozambique are used mainly for cattle grazing. Cattle meat, goat meat and milk constitute the main output from pastureland. As we found no comprehensive data on production costs, we use the rental rate from the World Bank (2006), which assumes that return to pastureland is 45% of the output value. Future rent projections are forecast using current production volume trends.

Details on the data used

Wool and sheep production were very small. So we considered only beef and milk productions.

Output	Price ($/tonne)	2005 production (tons)	Rental rate (%)	Total rent production growth trend (%)
Cattle meat	4 052	38 100	45	0
Sheep meat	6 931	768		
Milk	518	68 765		

Table 3 : data used for pastureland valuation

Prices	FAOSTAT
2005 production	FAOSTAT
Rental rate	World Bank (2005)
Production growth trend	FAOSTAT

Table 4 : data sources for cropland valuation

Timber resources

Timber wealth is calculated as the net present value of rents from wood production. We distinguish industrial roundwood from fuelwood production. We do not use FAO data (from the FAOSTAT database or the Forest Resource Assessment 2005), which are not always consistent. For legal logging, we use data from DNTF. We assume that illegal logging is 40% of legal logging (MacKenzy, 2006). This figure is of course very difficult to assess and this study provides an indication only. The sustainability of wood production is introduced through the lifetime of the resource. We evaluate the time to exhaustion with current production trends, annual regeneration, and total wood stock (from (Wisdom, 2008) and the last National forest inventory). Rental rates are assumed to be 40% for industrial roundwood (Bila, 2003) and 50% for fuelwood production.

<u>Details on the data used</u>

2005 productions	MacKenzy 2006 DNTF – USAID/CTA Wisdom Report
Prices	WWF 2006 USAID-CTA FAO
Rental rates	USAID-CTA Timber World Bank (2005)
Production growth rate	FAOSTAT

Table 5 : data sources for timber resources valuation

Cost Component (us$/m3)	Sawn Timber for Export	Log Export

Felling and extraction cost to loading point[a]	25	25
Royalty	31	123
Reforestation Levy (15%)	5	18
Transportation (350 km one way to port or mill)[a]	60	60
Logging overheads [b, c]	10	10
Sawing costs to green sawn [a, b]	52	
Sawing overhead [d]	5	
Transport to port	10	
Total Costs	198	236
Profit margin	22	114
Selling Price [e]	220	350

[a] Assumed to include depreciation [b] Based on TECHNOSERVE analysis "Overview of the Mozambique Timber Industry" May 2003 [c] Includes concession cost amortization, management, marketing [d] Includes management and marketing

[e] Based on 0.4 m^3 (40 percent conversion rate) of Umbilla sold at US$550 per m^3

Table 6 : cost comparison of log and sawn timber

Log production (m3)						
Province	2000	2001	2002	2003	2004	2005
Maputo	685	1.082	495	30	123	36
Gaza	300	878	4,704	3,76	3,068	1,273
Inhambane	3,147	7,083	9,372	3,952	3,084	2,089
Sofala	39,289	28,372	26,214	18,768	30,24	22,387
Manica	12,201	15,719	20,442	13,536	15,099	13,784
Tete	1,26	660	1,145	3,097	2,77	8,608
Zambézia	28	26,622	33,2	25,395	23,932	25,084
Nampula	10,68	13,266	15,714	9,869	10,985	7,851
C. Delgado	21,44	27,683	51,456	34,376	63,062	21,167
Niassa	359	839	472	342	348	348
	117,361	122,204	163,214	113,125	152,711	102,627
Sawn timber (m3)						
Province	2000	2001	2002	2003	2004	2005
Maputo	4,993	14,674	9,238	19,151	4,443	11,607
Gaza	84	311	848	1,03	1,196	461
Inhambane	217	1,1	511	353	498	750
Sofala	1,283	3,926	2,636	4,968	5,997	4,091
Manica	591	1,133	1,607	2,006	1,328	3,117
Tete	100	560	336	500	1,79	278
Zambézia	2,469	2,336	3,215	4,206	4,941	3,458
Nampula	987	1,291	639	1,186	1,316	1,055
C. Delgado	3,147	1,418	5,161	11,403	6,514	7,362
Niassa	797	393	111	364	98	155
Total	14,668	27,142	24,302	45,167	28,121	32,334

Table 7 : log production and sawn timber (from USAID-CTA/DNTF)

Non timber forest resources (NTFR)

There are very few quantitative studies on NTFR in Mozambique. Most surveys are qualitative and do not give any value to products extracted from the forest. We used two studies giving some values for NTFR: Suich (2006) in Bazaruto, Vilanculos and Chirendzene districts and Lizon (2002) in the Gilé district (Zambeze province). These studies consider direct values only: fruits, wild animals, honey, raffia and bark… They do not estimate the time spent to collect these products so that it is not possible to estimate production cost. Thus, we use a 50% rental rate, based on figures from other southern African countries (Schakleton 2002). We do not add indirect values (such as watershed protection for example) because it is already included in cropland (or other type of activities) downstream value (if we consider the environmental service 'protection against erosion')[7].

To extrapolate from household surveys at the country scale is a difficult and dangerous task as we have only data from four sites, all in the central part of Mozambique. We use the average of NTFR value consumed per household in the two studies presented above, excluding woodfuel value which is already considered in the timber resources part of forest capital. This is of course a strong assumption as forests (and the way to use them) are very diverse. We use rural population as a proxy for the number of households using NTFR, and we extrapolate thanks to the last National forest inventory which gives an interesting qualitative assessment of the importance of NTFR at the national level. More details are given in the appendix. Finally, it is impossible to have an idea of the sustainability of NTFR harvesting as we have no idea of the evolution in time of the stocks. As a consequence, we assume constant volumes harvested. But there are some observations suggesting that techniques used on the exploitation of NTFR are not sustainable: "Game and freshwater fish have suffered substantial decreases over the last decade, and people have often longer distances to travel to collect mushrooms or caterpillars" (Lizon 2002).

[7] On this point, we disagree with the World Bank methodology which leads in our sense to double counting.

Details on the data used

	Lizon	WWF 2006			Average
$/household		*Bazaruto*	*Chirindzene*	*Vilanculos*	
Food	58	27	20	0	30
Medicinal plants	---	---	---	---	---
Material and construction wood	11	46	172	91	65
Wood fuel	44	126	170	132	123

Table 8: summary of the value of the main NTFR
[adapted from (Lizon, 2002) and (WWF, 2006) to fit our framewok]

	North	**Centre**	**South**
Food	21%	38%	52%
Fodder	2%	1%	4%
Medicinal plants	29%	20%	32%
fuel	19%	18%	1%
Construction wood and utensils	25%	21%	8%

Table 9 : % use of NTFR [adapted from the national forest inventory]

province	Pop (2007)	Household size (2002)	position	Rural population	Rural household
niassa	1178117	5,29	north	789338	149213
cabo delgado	1632809	4,34	north	1093982	252070
nampula	4076642	4,44	north	2731350	615169
zambezia	3892854	4,81	centre	2608212	542248
tete	1832339	5,08	centre	1227667	241667
manica	1418927	5,73	centre	950681	165913
safala	1654163	5,9	centre	1108289	187846
inhambane	1267035	5,25	south	848913	161698
gaza	1219013	5,73	south	816739	142537
maputo	1259713	5,46	south	844008	154580
maputo city	1099102	4,97	south	0	0

	centre	north	south
Food	30	17	41
Construction wood	85	101	32

Table 10 : value of the two main NTFR for the different regions ($/rural household)
[These values were extrapolated from the value of NTFR from the different studies we had, all in the central regions of Mozambique to the other regions through the national forest inventory]

Protected areas

In (World Bank 2006), protected areas are valued at the lower of per-hectare returns to pastureland and cropland – a quasi opportunity cost. This is of course a minimum value but not the complete value of protected areas. Instead, we propose below several elements to estimate the net present value of the network of protected areas. This is a preliminary calculation which would need further investigations. Our estimate is based on (IUCN, 2008) for the benefits of the network and on (WWF, 2008) for the costs. (IUCN, 2008) give some elements on the main benefits from the main protected areas: ecotourism benefits: net revenues from the tourism industry account for 45 MUS$ (11.5 MHa are concerned by this number); 'existence value' of the parks through environmental NGO investments which reflect the willingness to pay of people in rich countries to protect biodiversity. There are no estimates of indirect benefits at this stage. (WWF 2008) give some elements on the operating costs of the parks which are around 5.3 $/ha/year. However, this figure is based on three national parks only (Bazaruto, Qirimbas and Limpopo) and do not reflect the diversity of protected areas in Mozambique. The network of protected areas is indeed very heterogeneous with important differences between national parks, reserves and coutadas (hunting reserves). To derive the net present value of the protected areas network, we assume that:

- The opportunity cost of the network is supposed very low (mostly because of the quantity of land available). This assumption is disputable as there are many conflicts at the borders of these protected areas.
- The return on capital invested is 15%
- The growth rate of the rent is 5% per year (it is the one used in the IUCN report, and it is quite conservative considering the projections for tourism of the Ministry for Tourism)

A critical element is the management cost. As a result, we did a sensitivity analysis on this parameter in our calculation presented on table 2. We took an average value between 3 and 4$/ha/year in our estimations.

Cost ($/Ha/year)	Net present value of PA network ($/per capita)
1	56
2	46
3	36
4	26
5	16
6	7

Table 11 : sensitivity of the net present value of the PA Network to the average operating cost of PA

Most of our assumptions on the different parameters are quite conservative. Our calculation is thus more a low value of the network of protected areas. It should however be a more precise estimate than World Bank previous calculations. Although it gives an idea of the contribution of protected areas to natural capital, the calculations remain quite rough, and there is a need for further investigations.

Marine fish resources

We value here only marine fisheries. We distinguish artisanal, semi-artisanal and industrial fisheries. We used data from (Wilson 2008) which are based on data from IIP and IDPPE. We adjust upward artisanal fisheries captures as official statistics do no cover the whole coastal area (more precisely, we add 40000 tons to captures recorded). We have also reliable data on the value of fishes harvested. The difficult task is to have an idea of rental rates. (Wilson 2008) gives some very interesting elements on the evolution of the fisheries rent in industrial fisheries. It shows that rents vary a lot, one reason being that fishing boats are particularly dependant on fuel costs. We used a 10% rental rate for industrial fisheries and 5% rent for artisanal, but these have to be considered cautiously as they are very volatile. Indeed, even if artisanal fisheries are not very dependent on fuel cost, rents are very low. Another point is the sustainability of actual catches trend. There are not strong evidences of overexploitation of the fish resources. As a consequence, it seems reasonable to assume that catches could remain constant along the discounting period. Another problematic issue is the introduction of illegal fishing. We have no estimates of its intensity at this stage.

Details on the data used

	production 2005	2005 value
Industrial and semi-industrial production	tons	US$ 1000
lobster	1	11
crab	158	474
deep water shrimp	1774	8870
fish	660	1650
shallow water shrimp	8520	68160
nephrops	149	1490
cephalopods	165	413
kapenta	12991	15589
bycatch	1830	915
tuna	5396	10792
Artisanal production		
crab	273	816
fish	84674	211685
shallow water shrimp	2977	14887
cephalopods	406	1016
sharks	1510	3775
lobster	20	223
others	7888	3944

[source : (Wilson, 2008)]

	Rental rate (%)
Industrial fisheries	10%
Semi-industrial fisheries	
Artisanal fisheries	5%

	Production (tons)
Tons added to official artisanal production	40 000
Artisanal productions :	
- IIP not adjusted	57 748
- PESPA (2008)	118 300
- WWF	around 100 000
=> Adjusted production considered	**97 748**

Table 12 : Hypothesis to adjust the artisanal production which is not fully covered by the national statistics

Comment on fish stock depletion

We focus on the Sofala bank as it is the only one with sufficiently good data. Several bioeconomic models have been developed. These do not indicate a decrease of the biomass stock, which is what we try to assess here in terms of natural capital depletion. However, there has been of course during the last 20 years a sharp decrease of the catch per unit effort (CPUE). This decrease is linked to an important increase of the effort, and to some extent to a modification of the Zambezia flow. Moreover, there would be other damages to consider such as by catches and the damages of bottom trawling. We however have no studies on it.

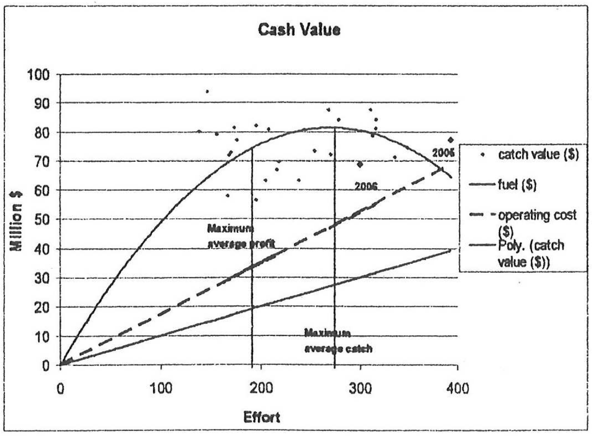

Figure 1: Catch-effort relationship of the Sofala Bank shrimp fishery; values converted into US$ with indication of fuel cost and operating costs (De Sousa, 2005)

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Mineral resources

Bucuane (2007) has conduced interesting and unique work on subsoil assets valuation for Mozambique, following the same methodology developed in World Bank's *Wealth of Nations*: assets values are estimated at the present discounted value of economic profits over the life of the resource. For finite resources such as natural gas, coal and heavy sands considered here[8], the scarcity rent is quite important. Calculations assume constant total rents and optimality of the extraction path in time. In our work we use prices from Bucuane's medium scenario, relatively conservative if we regard long-term structural trends of fossil fuel prices in last IEA (2008) study. More precisely, he uses a method presented in Vincent (1996). He assumes that the unit rent grows at rate g defined by:

$g = \frac{r}{1+(\varepsilon-1)(1+r)^{T}}$ where ε = 1.15 is the curvature of the cost function, assumed to be isoelastic (as in Vincent, 1996). The effective discount rate is then $r^{*} = \frac{r-g}{1+g}$ and the value of the resource stock can be expressed as:

$$Vt = \pi_t * q_t * (1+\frac{1}{r*})(1-\frac{1}{(1+r^{*})^{T}})$$

B. Measuring the value of reproducible (or physical) capital

We use the perpetual inventory method (PIM).which derives capital stocks from the accumulation of investments series. The aggregate capital stock value in period t is given by:

$$K_t = \sum_{i=0}^{19} I_{t-i}(1-\alpha_i)^{i}$$

where I is the value of investment in constant prices (gross capital formation in WDI) and α_i the depreciation rate. We derive depreciation rates over time from (Jones, 2006). As in (World Bank, 2006), we assume that urban land value represent 24% of produced capital (Kunte et al, 1998). Moreover, we are interested in produced capital owned by Mozambicans, and not the stock owned by investors outside the country. In the same way, Mozambican residents own

[8] In the absence of reserves' exploration and estimates, oil is excluded from the mineral assets value.

some reproducible capital outside the country. As in Arrow (2007), our notion of sustainability focuses on the changes in the productive base owned by a given country's residents. We use (Lanea et al, 2006) which constructs net holdings of international assets from balance of payments and other IMF data. We can then calculate the reproducible capital adjusted for international holdings.

C. Measuring the value of intangible (social and human) capital

"The next step is the measurement of total wealth. Measuring total wealth as the sum of its components makes intuitive sense, but this is limited by data and methodological constraints. We have few good tools for valuing human capital, for example, and even fewer for valuing social or institutional capital. The alternative is to rely on economic theory, which defines total wealth as the net present value of future consumption. We therefore measure total wealth by assuming a future consumption stream and calculating the net present value in year 2005. However, some countries have unsustainable levels of consumption, which is signalled by negative net or genuine saving levels. In these cases consumption is decreased by the amount of negative saving in order to arrive at a sustainable level of consumption. Intangible capital is calculated as a residual, the difference between total wealth and the sum of produced and natural capital. Since it includes all assets that are neither natural nor produced, the residual necessarily includes human capital—the sum of knowledge, skills, and know-how possessed by the population. It also includes the institutional infrastructure of the country as well as the social capital—the level of trust among people in a society and their ability to work together toward common goals. Finally, the residual includes net foreign financial assets through the returns generated by these assets. For example, if a country is a debtor, then interest payments on the foreign debt depress consumption, reducing total wealth and therefore the intangible residual" [from (World Bank, 2006)]

Step 2 - Cost of environmental degradation / Genuine saving calculation

A. Natural capital depletion

Mineral and forest resources depletion

The World Bank estimates resource extraction for a range of fossil fuels (oil, natural gas, hard coal and brown coal), minerals (bauxite, copper, iron, lead, nickel, zinc, phosphate, tin, gold and silver), and one renewable resource (forests). Depreciation of these resources is computed as the product of price minus average costs of extraction multiplied by the volume of extraction: $(P-AC)*R$ where P is the resource price, AC is average cost and R is the volume of extraction (in the case of a renewable resource, R represents harvest beyond natural regeneration).

- For exhaustible resources (mainly coal and gaz for Mozambique), we use World Bank calculation (compiled for genuine saving calculation and available on the World Bank Website).

- For forest resources, we consider two different stocks: the roundwood stock (of commercial value) and the woody biomass stock. For each stock, the first step is to assess the evolution of these two different stocks. As previously, we do not use FAO data. Data used and main results are presented on the table below.

		Annual regeneration	Volume harvested
Roundwood stock	National Forest Inventory DNTF	500 000 m3	135 000[9] m3
Woody biomass stock	Wisdom Report	46 921 000 tons	14 003 000 tons

Table 13 : simple balance of the roundwood and fuelwood stocks

[9] Without illegal logging

Through these figures, a depletion of these two stocks at the national scale does not seem obvious. For the roundwood stock (of commercial value), quantities harvested, even if we assume very important rate of illegal logging are far below the annual regeneration rate reported in the last National forest inventory. However, many observers indicate a depletion of the most valuable species. Our roundwood stock mixes every commercial species. But it would be important to refine the picture and differentiate the difference stock of species. Indeed, there may be a depletion of top class species. We would have a degradation of the quality of the forest. For the woody biomass stock, a major work has been made through the Wisdom report. At the national level, the potential biomass productivity remains higher than actual use, so that the balance is positive and the stock should not be decreasing. However, in some provinces (Maputo for example), the balance is negative so that the stock is decreasing.

Province	total Woody biomass stock	total non industrial increment	available increment physically accessible	residential and commercial consumption	local balance	commercial balance "liberal"	commercial balance "conservative"
	000 t	000 t	000 t	000 t	000 t	000 t	000 t
Niassa	308,447	10,607	6,977	749	6,228	3,757	3,600
Cabo Delgado	178,505	6,502	4,851	1,079	3,772	2,087	1,935
Nampula	169,033	6,868	5,885	2,755	3,131	2,226	2,095
Zambesia	248,529	9,745	7,862	2,526	5,336	3,988	3,635
Tete	169,455	6,876	4,188	1,114	3,074	1,921	1,425
Manica	144,755	5,843	4,594	937	3,657	1,997	1,885
Sofala	126,496	4,866	3,753	1,184	2,569	973	889
Inhambane	125,461	5,127	4,294	890	3,405	2,326	1,697
Gaza	112,708	4,345	3,382	863	2,519	977	821
Maputo	31,464	1,267	1,124	924	201	-204	-263
Maputo Capital	238	11	11	982	-971	-971	-971
Mozambique	**1,615,091**	**62,055**	**46,921**	**14,003**	**32,921**	**19,077**	**16,748**

Table 14 : main results of the Wisdom report

The balances of the stocks estimated above are preliminary and there is a need to assess the evolution of these stocks more precisely, especially for the valuable roundwood stock, including deforestation figures, wildfires and sensitivity analysis on the illegal logging.

<u>Preliminary calculation of deforestation cost (to further investigate)</u>

We focused previously on the stock of roundwood or woody biomass and we try to assess the evolution of these stocks mainly because of logging. We did not focus so much on deforestation. As we said before, Mozambique is loosing every year 219000 hectares of 'forests' (which can be very diverse). We present below some preliminary reflections. To estimate the loss of this 'forest capital', we need to estimate the net present value of one hectare of 'average forest' before and after deforestation. We introduce the following assumptions:

- yearly deforested area: 219000 hectares
- 80% of the 'deforested area' are forests and closed woody vegetation; 20% are woodlands and open woody vegetation
- 68%[10] of the land cover is cleared to shifting agriculture with some tree standing and 32% to field crops with very little vegetation

Land cover	Potential sustainable annual roundwood harvest (m3/ha/year)	Potential sustainable annual woody biomass harvest (t/ha/year)
Forests and closed woody vegetation	0.025[11]	0.8
Open woody vegetation		0.7
Shifting cultivation with forest	0	0.7
Crop fields	0	0.3

Table 15 : main hypothesis used for the loss of forest capital calculation
[Mainly from the DNTF-Wisdom report]

- rental rate for roundwood production: 40% ; for woody biomass production: 50%
- average price of roundwood: 300$ per m^3 (weighed price by the different classes) / average price of woody biomass: 50$ per ton
- 4% discount rate

Type of values	Before deforestation ($/ha)	After deforestation ($/ha)
Direct use value (sustainable management)	60	0
Fuelwood (sustainable management)	310	230
NTFR and indirect use value (watershed benefits, flood mitigation…)[12]	50	20
Option value (bioprospecting) and Existence value	Not considered	
Total value (direct + fuelwood only)	420	250

Table 16 : average scenario of forest values

[10] This figure, reflects more the situation in the Manica province, (with tobacco cultivation), might be too much for other provinces.
[11] Average estimate for Miombo forests
[12] This item is particularly difficult to assess, we take conservative values (adapted from (Pearce, 2001)). Moreover, it is very difficult differentiate the value between the different land cover types, from closed forests to crop fields with some trees standing. We take indicative values of 50$ and 20$ before and after deforestation, but these figures should be further investigated

The difference of the "forest capital" before and after deforestation is thus 170 $/ha. In the end, the deforestation cost (or loss of forest capital) equals this value multiplied by the deforested area 219000 ha, thus around 35 MUS$. The calculation is very rough and would need to be more precise into the differentiation of the forest area lost and to what kind of land cover and use it is converted. The cost should however remain quite low, partly because of the low roundwood productivity of the Mozambican forests. However, we considered only certain direct use value of the forest and no option values or indirect use values. Our estimate is thus a low estimate.

How to improve this very rough calculation?

We present below several elements which could improve significantly the calculation:

- A more precise description of the type of forests lost: the AIFM (Integrated Assessment of Mozambican forests) work gives some interesting elements on the land cover at different scale (1:1000000 for the whole country, 1:250000 for the Manica and Maputo provinces). To have land use *changes*, we need land cover data at several points over time to compare. Although several land cover data exist in Mozambique, these cannot be compared to one another. A specific work has been developed on the Manica province to study land cover changes (at the nominal scale of 1:250000) for the period 1990-2004, but not for other provinces. The applied methodology can however not be applied at the 1:1000000 scale. It can be an interesting tool to have an idea of the deforestation pattern
- When we know what type of forest has been lost, it is then possible to know the potential of wood (or other resources) production lost. Several sources could be used as the Wisdom report for woody biomass productivity (for each type of land cover) or the national forest inventory for commercial roundwood productivity (for the different forest types)
- We should also introduce here (or in the appreciation of cropland capital) the value of the alternative land use. As said before, it is site specific but maybe it is possible to draw the main outlines. For example, in the Manica province, it has bee estimated that 7.5% of deforested dense forests were converted to permanent agriculture (mainly tobacco), and 26% for open forests. The rest of deforestation was caused mainly by shifting agriculture which degrades the forests severely

It would be interesting to mix the different sources presented above with a more qualitative expertise to qualify more precisely the actual deforestation pattern for the whole country. It would then be possible to have a more precise idea of the 'forest capital' lost, and to what other type of capital it is converted. There is a need here for further investigation.

Comments on data availability and quality

As we said previously, data regarding forest degradation and deforestation are quite rough. It is important to note that many observers indicate an overall degradation of the quality of the forest, with harvests of valuable species above the regeneration. We had only aggregate data for all species so that we could not differentiate for each species. But the degradation of forest quality could be important. Another issue is that the depletion appears to be quite low at the national scale. But of course, locally, there can be overexploitation of the resource. Finally, it is very difficult to assess the evolution of the different wood stocks. Indeed, the roundwood stock evolution results not only from logging (legal and illegal) but also slash and burn and wild fires. Particularly on the latter, we have very few information.

Other documents important regarding the forest resource

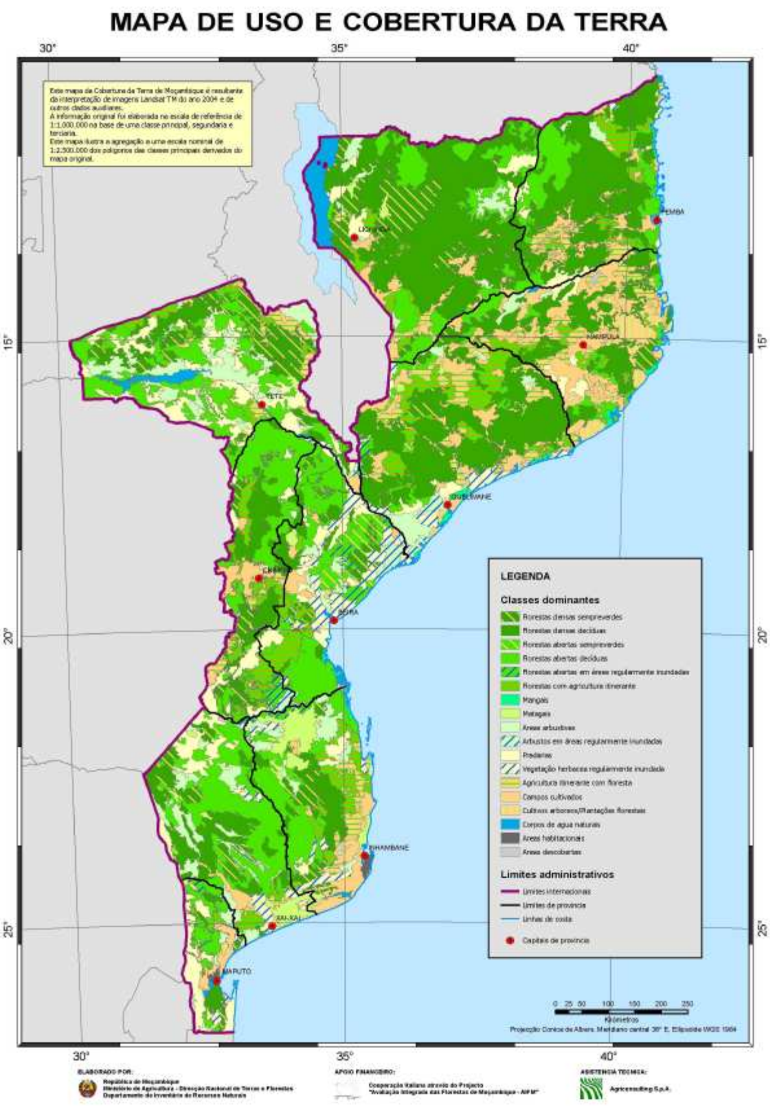


Tabela 12. Valores médios por ha e totais de volume e número de árvores por tipo de vegetação para todo o país

Tipo de vegetação	Número médio de árvores por ha	Volume total médio (m^3/ha)	Área (1000 ha)	Número total de árvores (milhões)	Volume total (1000 m^3)
Florestas densas	111.3	40.2	22727	2530	913
Florestas abertas	89.7	32.2	16390	1470	528
Sub-total florestas	102.2	36.8	39118	4000	1440
Arbustos/matagais	72.5	18.8	8800	638	165
Florestas/agricultura itinerante	72.2	20.6	6751	488	139
Total o médias para florestas e outras formações lenhosas	**93.7**	**31.9**	**54668**	**5125**	**1745**

Tabela 17. Volume comercial médio e volume comercial disponível, por hectare, para os diferentes estratos

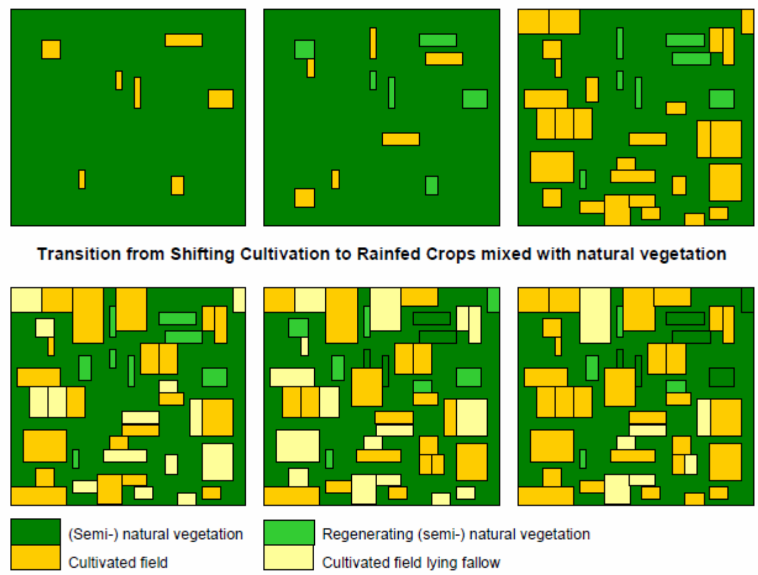
Estrato	Volume comercial total (todas árvores de espécies comerciais com DAP > 10 cm) (m^3/ha)	Volume comercial disponível (todas árvores de espécies comerciais com DAP > diâmetro mínimo de corte) (m^3/ha)
Florestas densas	12.88	4.83
Florestas abertas	9.16	4.17
Arbustos/matagais	5.66	1.96
Florestas/agricultura itinerante	5.77	1.97

Tabela 32. Estimativas de taxa de desflorestação por província

Província	Área de florestas e outras formações lenhosas estimadas para 1990 (1000 ha)	Área de florestas e outras formações lenhosas estimadas para 2002 (1000 ha)	Mudança anual de florestas e outras formações lenhosas (1000 ha)	Mudança anual de área de florestas (1000 ha)	Taxa anual de desflorestação 1990-2002 (%)
Cabo Delgado	5322	4989	28	25	0.54
Gaza	5182	5027	13	13	0.33
Inhambane	4585	4424	13	11	0.52
Manica	4340	4005	28	23	0.75
Maputo	1280	1078	17	16	1.67
Nampula	3958	3509	37	33	1.18
Niassa	9635	9379	21	21	0.22
Sofala	4430	4161	22	20	0.63
Tete	7376	7025	29	27	0.64
Zambezia	5819	5356	39	31	0.71
Total	**51926**	**48952**	**248**	**219**	**0.58**

Table 17 : deforestation rate at the provincial level

Figure 20. Transition from Shifting cultivation to Rainfed crops



Agricultural land capital variation (only cropland)

Soil erosion and degradation reduce soil fertility and thereby future agricultural productivity. We consider only on-site costs and cropland soils. Off-site costs are too difficult to assess and are often already included in standard national accounting as they affect marketed assets. We do not have any information on pastureland degradation. Various authors try to include soil depletion in natural resource accounting (Adger, 1992; Crowards, 1994; Hrubovcak et al., 2000). Soil is usually introduced as an homogeneous production factor modelled through one stock variable such as soil depth or a soil quality index. However, soil is a very complex and heterogeneous ecosystem and it is an over-simplification to describe a soil through only one proxy. A vector of variables would be more appropriate (Ekbom, 2007). However, abundant data are required, and are not available on a national scale. That is why we consider soil resources as a nutrient stock. Soil depletion, as other natural resources, can thus be valued as net nutrient depletion multiplied by the price of lost nutrients. However, obtaining an idea of soil nutrient depletion on a national scale is a very ambitious and uncertain task. Extrapolations from field plot data to watersheds or regions are highly complicated. And soil nutrient budgets are often based on models which have important caveats: they do not model non-linear processes of soil degradation, and results are highly sensitive to soil erosion rates (erosion being one of the main exporters of nutrients outside the field).

To give an overview of soil degradation, we add below the results from the GLASOD (Global Assessment of human induced soil degradation) survey.

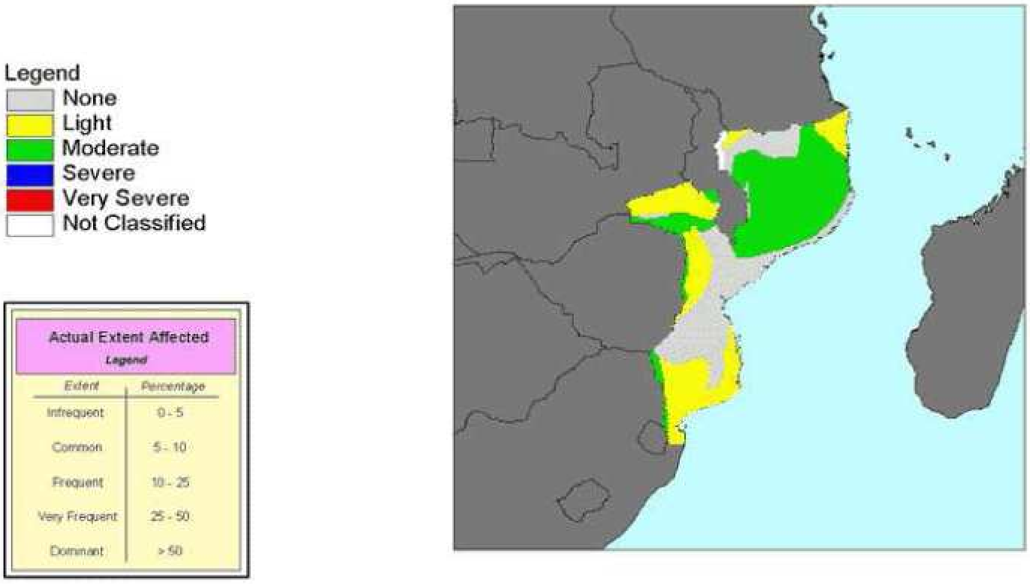
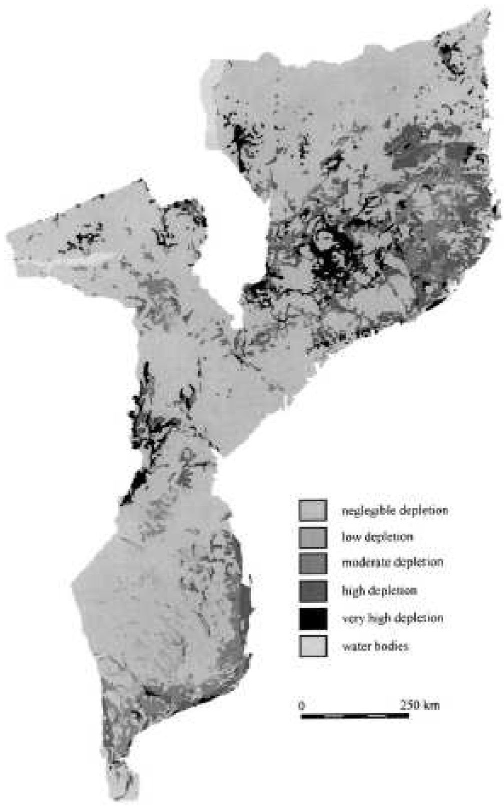


Figure 1 : GLASOD figures on soil degradation in Mozambique

There exist three studies of nutrient depletion at the national scale: (Folmer, 1997), (Drechsel and Gyiele, 1998), (Henao and Baanante, 2002-2004). We use the results from (Folmer, 1998) which is a study for Mozambique only compared to the others which are at the scale of the whole African level. The figures below give an overview of the results.



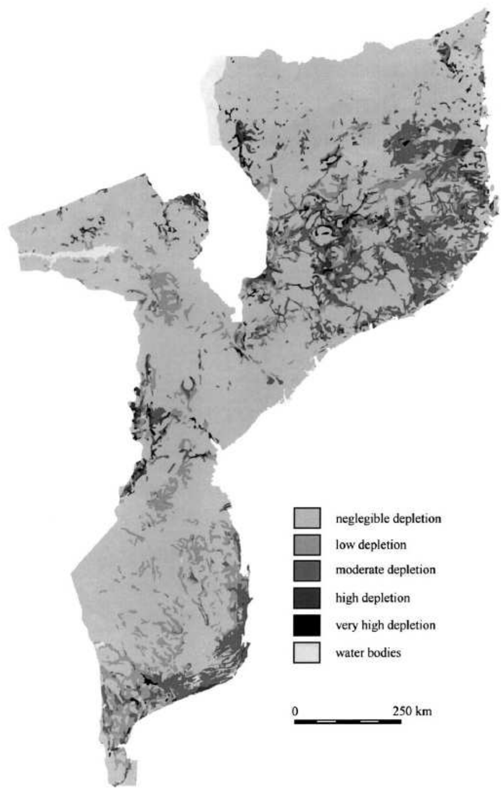


Figure 2 : Folmer's results for cultivated fields (left) and at the land use system (right)

N (kg/ha)	P (kg/ha)	K (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	NPK (kg/ha)	Fertilizers (kg/ha)	Cost[13] ($/ ha)
33	6,4	25	15	30	77	172	72

Table 18 : nutrient balance for cultivated fields and associated cost

[We assume a 0.42$/kg fertilizer price]

There are some limitations to use this type of studies, for several reasons:

- most of the nutrient depletion are on a yearly basis, although there may not be any depletion of the nutrient stocks at a larger time scale (thus if we include fallows and rotations), and only for cultivated fields (ignoring fallows)
- Chemical fertilizers may not be the cheapest substitute to soil nutrients. Moreover, these are not available everywhere in the country. It would be more appropriate to find organic substitutes. Or the cheapest substitute may be the opening of a new field as good land is not a scarce resource in Mozambique

As a consequence, we decided not to consider nutrient depletion on non permanent fields (because we can assume that fallows compensate the loss of nutrients during the cultivated years). We considered only the permanent crop area, which is fairly low in Mozambique, around 235000 ha. In the end, this gives an annual cost around 17 MUS$.

Details on the calculation

The coefficients used to convert the nutrient content of the soil into forms in which they exist in fertilizers (N, P_2O_5, K_20) are:

$$\text{Kg P/ha} * 2.29 = \text{kg } P_2O_5\text{/ha}$$

$$\text{Kg K/ha} * 1.2 = \text{kg } K_2O \text{ /ha}$$

"The assumption here is that the form of NPK in the eroded soil is the same as in the compound fertilizer. It is further assumed that the NPK lost is, in the conventional fertilizer

13 More details are given in appendix on the calculations

standards, in the form of 15-15-15 that is to say, a bag of fertilizer contains 15% N,15%K, and 15% K. A 50 kg bag of fertilizer then contains 7.5 kg of N, 7.5 kg of P and 7.5 kg of K with a total amount of nutrients in the bag o f 22.5 kg NPK. This can be used as a conversion factor: 22.5kg NPK / 50 kg fertilizer yields .45 kg NPK / kg fertilizer. So the total amount of nutrients lost per hectare has a corresponding amount of Z kg of fertilizer “lost” per hectare, which can be found using this conversion factor. One ton per hectare of soil lost has a corresponding Z lost kg of fertilizer (or more precisely, nutrient-lost-equivalent kg of fertilizer).” [From the Country Environmental Analysis in Ghana]

B. Pollution damages on health

The methodology used here relies on the methodology developed by Bjorn Larsen (independent consultant) in several Country Environmental Analysis (Ghana and Senegal for African context). This methodology is particularly adapted and well thought to countries with poor data. The underlying principles remain the same for each pollution. We have the following steps:

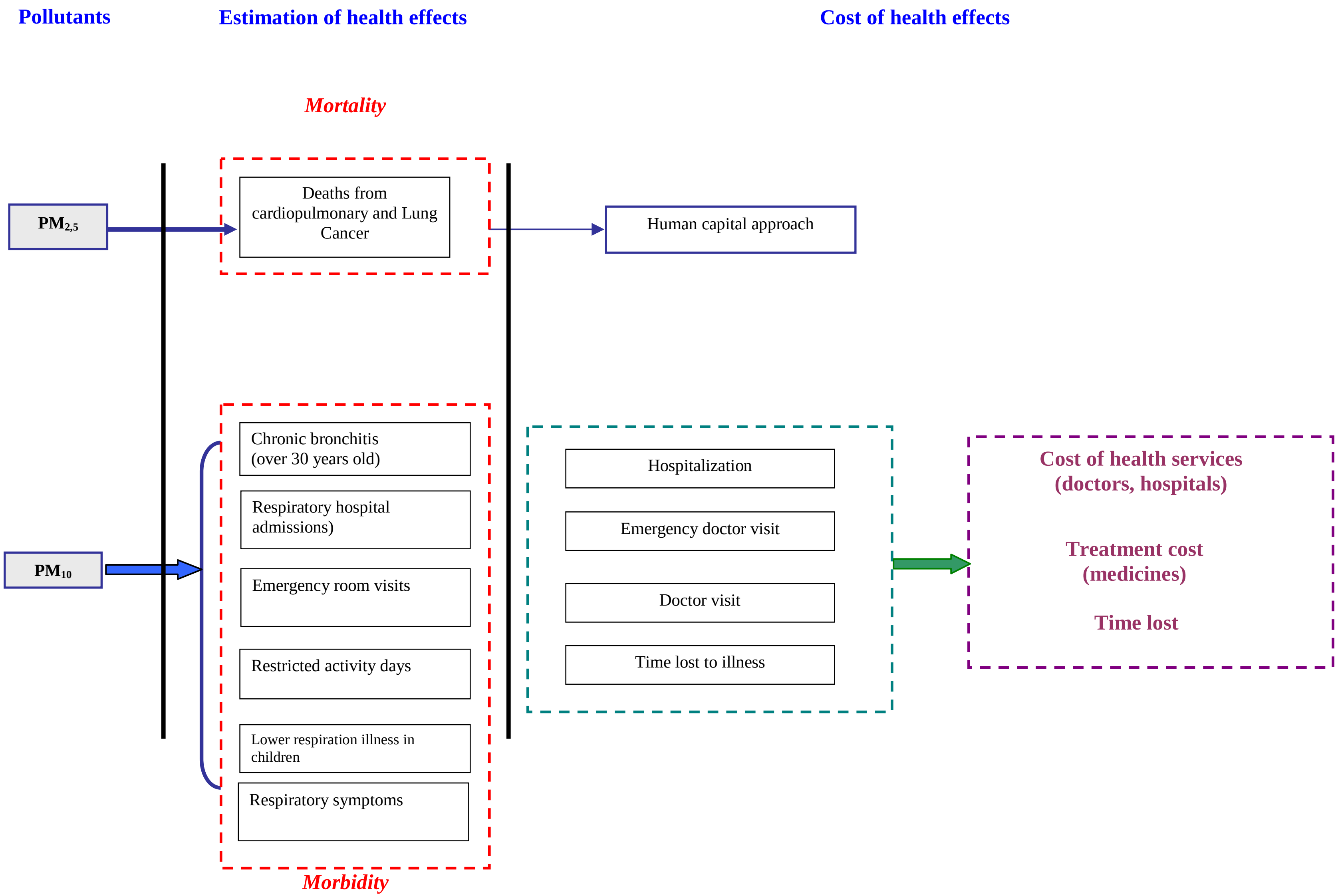
(a) We assess the impact of the pollution on health (in terms of increased mortality or morbidity)

(b) Cost of the health effects identified:

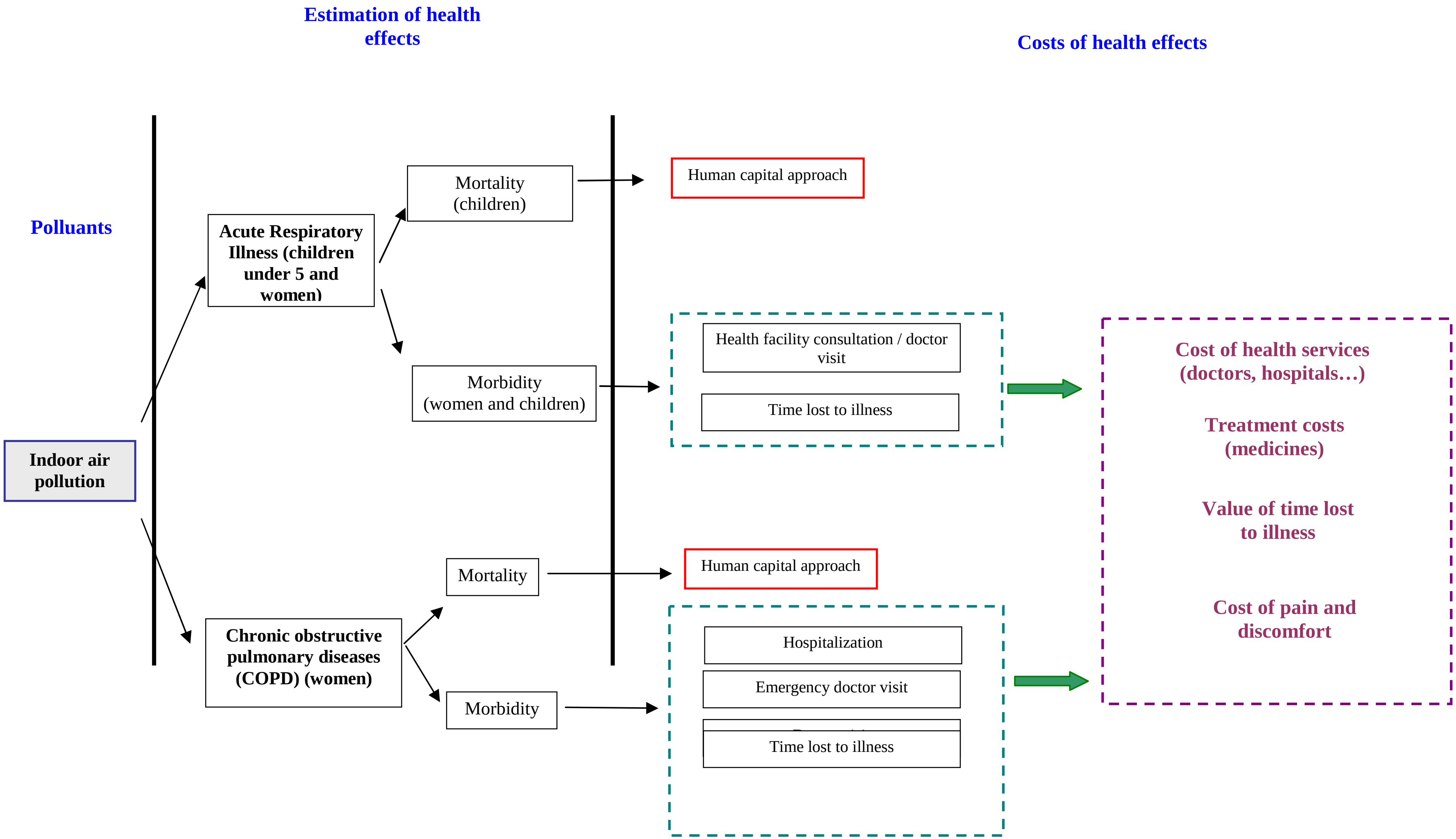
- Cost of mortality: we use the human capital approach to estimate the social cost of these premature deaths. It is based on an individual's economic contribution to society over his or her lifetime. Death involves an economic loss that is approximated by the loss of all that individual's future income
- Cost of morbidity: damages are valued through healthcare expenditures (doctor visits, medicines, hospitalization…), time lost to illness and the cost of pain and discomfort (the proxy applied is valuation of DALYs at GDP per capita)

The main data used are the DHS2003 (Demographic and health survey), the global burden disease 2002 of the WHO, some specific publications for the dose-response coefficients. The cost of health services (consultations, hospitalisation, doctor visit…) and medicines were estimated through interviews with pharmacies, health service providers (clinics, hospitals) and health authorities. Whenever it was possible, we use the cost of private health services which is a better indication of the economic cost of health services than public services as these are often subsidized.

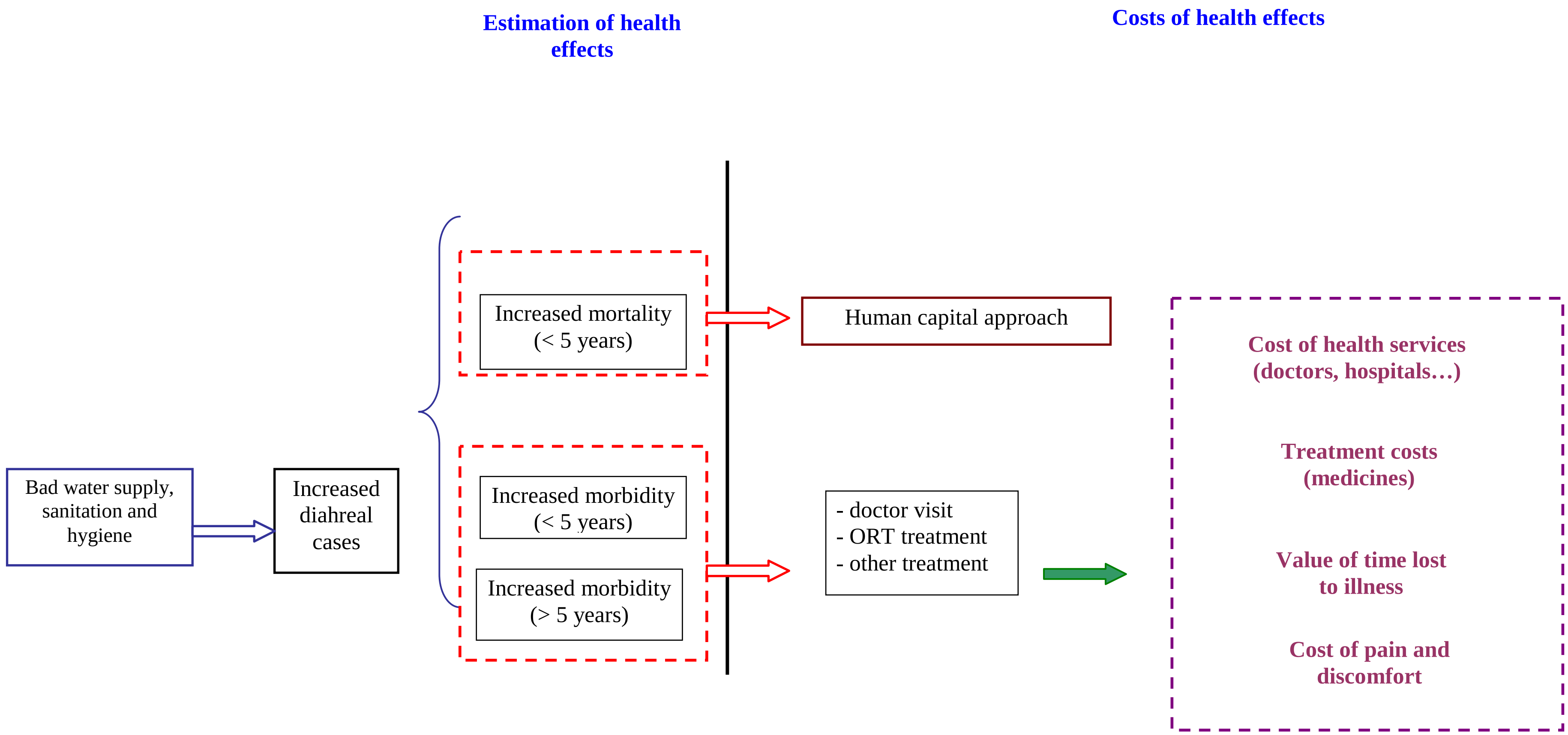
OUTDOOR AIR POLLUTION



INDOOR AIR POLLUTION



***WATER POLLUTION* – UNSAFE WATER SUPPLY? SANITATION AND HYGIENE COST**



Urban outdoor air pollution (from particulate matter)

"There is substantial research evidence from around the world that outdoor urban air pollution has significant negative impacts on public health and results in premature deaths, chronic bronchitis, and respiratory disorders. The air pollutant that has shown the strongest association with these health endpoints is particulate matter (PM)'24, and especially particulates o f less than 10 microns in diameter (PM_{10}) or smaller. Research in the United States in the 1990s and more recently by Pope et a1 (2002) provides strong evidence that it i s even smaller particulates (PM 2.5) that have the largest health effects. The gaseous pollutants (SO2, NOx, CO, and ozone) are generally not thought to be as damaging as particulates. However, SO2 and NOx may have important health consequences because they can react with other substances in the atmosphere to form particulates. The focus o f this section i s the health effects o f fine particulate matter (PM10 and PM2.5). There are three main steps to quantifying the health impacts from air pollution. First, the pollutant needs to be identified and its ambient concentration measured. Second, the number o f people exposed to that pollutant and its concentration needs to be calculated. Third, the health impacts from this exposure should be estimated based on epidemiological assessments. Once the health impacts are quantified, the value o f this damage can be estimated." [From the CEA Ghana]

The table below present the main cities in Mozambique concerned by air outdoor pollution and the $PM_{2,5}$ and PM_{10} concentrations (for 1999). The latter come from a World Bank model based on energy consumptions, some atmospheric factors, population density, and intensity of the economic activity (Ostro, 2004).

City	Population	Concentration (µg/m3)	
		PM_{10}	$PM_{2.5}$
Beira	696 741	36	18
Maputo	2 867 000	52	26
Nampula	481 294	26	13
Total	4 045 035	46	23

Statistics used for mortality

Urban population (cities with population > 90000)	4 045 035	World Bank
Crude mortality rate per 1000 population	21.35	Word Development Indicators
Cardiopulmonary and lung cancer mortality (% of crude mortality)	15%	(WHO 2002)

Mortality (% change in cardiopulmonary and lung cancer mortality)	0.80%	(Pope et al, 2002)
Share due to pollution (threshold)	0.125	

Dose-response coefficient for $PM_{2,5}$ pollution

Average number of years lost because of outdoor air pollution	10

Statistics used for morbidity

	Dose -Response coefficient (per 1µg/m3 ambient concentration)	**Sources**
Chronic bronchitis in adults (% change in annual incidence)	0.9%	(Ostro, 1994) (Abbey, 1995)
Respiratory hospital admissions (per 100000 population)	1.2	
Emergency room visits (per 100000 population)	24	
Restricted activity days (per 100000 adults)	5750	
Lower respiratory illness in children (per 100000 children)	169	
Respiratory symptoms (per 100000 adults)	18 300	

Dose-response coefficients for PM10

Chronic bronchitis (CB)		
Average duration of illness (years)	17	Shibuya (2001)
% of CB patients being hospitalized per year	1.50%	
Average length of hospitalization	10	
Average number of doctor visits per CB patient per year	1	
% of CB patients with an emergency doctor/hospital hospital outpatient visit per year	15%	Schulman (2001) and Niederman (2001)
Estimated lost work days (including household work days) per year per CB patient	2.6	Estimates
Annual increases in economic cost of health services and value of time	3%	---
Discount rate	3%	---
DALY per 10000 cases	32 536	WHO
Hospital admissions		
Average length of hospitalization (days)	6	Estimates and interviews
Average number of days lost to illness (after hospitalization)	4	Estimates and interviews
DALY per 10000 cases	234	WHO

Emergency room visits		
Average number of days lost to illness	2	Estimates and interviews
DALY per 10000 cases	63	WHO
Restricted activity days		
Average number of days lost to illness (per 10 cases)	2.5	Estimates
DALY per 10000 cases	4	WHO
Lower respiratory illness in children		
Number of doctor visits	1	Estimates
Total time of care giving by adults (days)	1	Estimates
DALY per 10 000 cases	85	WHO
Respiratory symptoms		
DALY per 10000 cases	1	WHO

Indoor air pollution

Statistics used for mortality

ALRI deaths (children under 5)	8 450
COPD deaths (women over 30)	1 230

Source : (WHO, 2007)

Statistics used for morbidity

Population under 5	3 312 000	INSTAT
ARI 2 week prevalence (children under 5) (%)	10%	DHS 2003
female COPD incidence rate (per 100000)	27	WHO 2002

Sources: WHO, DHS2003

% fuelwood exposition	80%	(WHO, 2002)

	low	high
relative risk ratios ARI	1.9	2.7
relative risk ratio COPD	2.3	4.8

Source: (Desai, 2004)

ARI children		Sources
% of ARI cases treated in medical facilities	51%	DHS 2003
DALY per 100000 children	165	WHO
Hours per day of care giving per case of ARI in children	2	Estimation and interviews
ARI adults		
DALY per 100000 women	700	WHO
Hours per day lost to illness per case of ARI	3	Estimation and interviews
Average duration of ARI in days	7	Estimation and interviews
COPD adults		
% of COPD patients being hospitalized per year	1.5%	(Shibuya et al, 2001)

Average lenght of hospitalization (days)	10	
% of COPD patients with an emergency doctor/hospital outpatients visit per year	15%	
Average number of doctor visits per COPD patient per year	1	
Estimated lost workdays (including household work days) per year per COPD patient	2,6	(Schulman et al, 2001) (Niederman, 1999)

Water pollution

under 5 mortality rate 2003 (pour 1000)	178	WDI
diarrheal mortality in children under 5 in AFRO E region (% of total child mortality)	15%	WHO 2002
Diarrheal 2 week prevalence (children under 5) (%)	14%	DHS 2002
% diarrheal cases due to water pollution	90%	WHO 2002

		sources
% of diarrheal cases treated in medical facilities	49%	DHS 2003
DALY for the diarrheal treatment (per 100000)	42	WHO
% of diarrheal cases treated with ORS in children	49%	DHS 2003
% of diarrheal cases treated with ORT in children	70%	DHS 2003
DALY per child treated with ORS or ORT (per 100000)	31	WHO
% of adult cases treated in medical facilities	30%	Combination DHS 2003 + other countries
DALY per adult (per 100000)	130	WHO
Average duration of a diarrheal case (days)	4	Estimates / interviews with health services
Hours per day of care giving per case in children	2	Estimates / interviews with health services
Hours per day lost to illness per diarrheal case	2	Estimates / interviews with health service

<u>Details on treatment and health services costs</u>

We obtained these costs through interviews with the main health service providers (Misau, Maputo clinics (Somershield, Bethesda, 222), Hopital Central de Maputo, Pharmacia InterFrança, Central dos medicamentos e dos equipamentos medicos. We had to deal with several shortcomings:

- Cost of health services (hospitalization, consultation…): we cannot consider prices paid as these are subsidized and do not correspond to the real cost of the service: two approaches are possible: (1) to use prices or costs in private health providers (they are indeed the only one which have accounts sufficiently detailed to derive these costs, which is not the case for public services); (2) to use the fact that the users of the health services contribute to around 20% (through what they pay) to the budget of health centres (for example). It is then possible to derive how much they should pay to pay the real cost. However, this figure is for all illnesses and services. In the end, we used method 1, although it certainly corresponds to an overestimate. It would be important to refine these different costs.
- Cost of medicines: the posology and the treatment used depend on the intensity of the illnesses. diahrrea or ARI (for example) can be very diverse. We chose to consider some form of average form of the different illnesses as we do not have the intensity of the illnesses in the prevalence rates we have. It could be however further refined too.
- there is an important geographical variability and data are very limiting in Mozambique: we took average figures also we are aware of the fact that the variability between provinces is important

We used the quantitative data we found through these interviews with a more qualitative expertise. We did sensitive analysis on the most disputable data such as the costs of health services (see low, medium and high scenario on the table below) and important assumptions such as the discount rate used. The table summarizes the costs we used.

	Low-Medium-High Scenario	Main sources
Cost of hospitalization ($ per day)	33-70-110	Health Country Status Report (based on DHS 2003 and Lindelow)
Cost of doctor visit, consultation or emergency visit ($)	8-16-28	
Value of time loss		75%*average wage
Discount rate (%)	2-3-4	---
Medicine costs growth rate (%)	1-2-3%	---
Diarrheal treatment cost ($) (ORS, ORT or others)	0.7-1-1,2	International experience and Central dos medicamentos e dos equipamentos medicos
ARI treatment cost ($)	3-5-7	

We present on the two tables below a decomposition of the cost: rural/urban and morbidity/mortality.

	Rural	Urban
Outdoor air pollution	---	100%
Indoor air pollution[14]	57%	43%
Water pollution	32%	68%

Table 19 : distinction rural/urban for the different pollution

	Morbidity	Mortality
Outdoor air pollution	53%	47%
Indoor air pollution	34%	66%
Water pollution	30%	70%

Table 20 : distinction morbidity / portality for each of these costs

The Table thereafter presents sensitivity tests on key variables and several scenarios. The results we present in the table above are "base case" scenarios.

Variable tested	Sensitivity of the variable
Hospitalization cost	o
Doctor visit cost	++
Time lost to illness	+
Discount rate for human capital estimates	+++
Growth rate of wages and treatment costs	+++
Average wage	++

Table 21 : sensitivity of the main variables

[14] Only morbidity is considered here

Main references used for the pollution costs

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C. Cost of climatic variability / water shocks (drought and floods mainly)[15]

Impact on Mozambican growth

"Mozambique's economic performance is highly affected by frequent floods and droughts. The correlation between rainfall and overall GDP is strong, and sensitivity of the Mozambique economy to water shocks measured by fluctuations in GDP and growth rates of agricultural and non-agricultural sector products, demonstrates that major floods and droughts have a significant impact on the country's economic performance, reducing GDP growth on average by at least

by 1.1% points annually. Given the low technological level, very limited use of irrigation and underdevelopment of water infrastructure, agricultural production in Mozambique is strongly influenced by weather conditions. The condition of extreme variability will itself affect the performance and the very structure of economies. The expectation of variability and the inpredictability of rainfall and runoff can constrain growth and diversification by encouraging risk averse behavior at all levels of the economy and by discouraging investments in land improvements, advanced technologies or agricultural inputs. An unreliable water supply is a significant disincentive for investments in industry and services, which will slow the diversification of economic activities.

Impacts on the Poor

About 10 million of Mozambique's population live in absolute poverty. Some 70% of the population relies upon subsistence agriculture agriculture for their livelihood which places the majority of the population outside of the monetary economy of the country. About one third of the population is estimated to be chronically food insecure with conditions being particularly fragile in the semi-arid Southern and Central regions of Mozambique which experience frequent droughts. Livelihood options outside agriculture are limited for the great majority of the population. The marketing network is weak and limited by extremely difficult physical access to many areas. All these factors increase vulnerability of the rural economy to the rainfall variability and related water shocks such as droughts and floods."

From Mozambique Country Water Resources Assistance Strategy: Making Water Work for Sustainable Growth and Poverty Reduction (August 2007)

We use the results from a World Bank memorandum: "Role of Water in the Mozambican economy". They estimate an annual cost of water shocks (inundation and drought) through two different methodologies that we develop below.

[15] Warning: this cost should not be confused with the climate change cost, as climate shocks already exist without climate change. These should however be more frequent in the future.

(a) Damage costs of floods and droughts

"Floods and droughts are frequent in Mozambique, appearing with a higher or lower intensity almost each three-four years. A drought shock with severe impacts has occurred seven times over the last 24 years (about once in 3-4 years). Floods have occurred six times over the same period, about once each 4 years. The costs of the flood damage and major drought events estimated above occurred from the exceptionally severe 2000 floods and 1991/1992 droughts. However, it is reasonable to assume that 1 in-3-or-4 year droughts are typically 50 percent as severe as the 1992 drought, and 1-in-4 year floods would be 40 percent as severe as the floods of 2000. That means that, on average, Mozambique experiences floods that cost about US$240 million each 4 years and droughts that cost it about US$45 million every 3-4 years. This translates to a direct long-term fiscal liability of over US$70 million annually. The total costs of water shocks in the period 1980-2003 were about US$1.75 billion." (World Bank, 2007 – Country Water Resources Assistance Strategy).

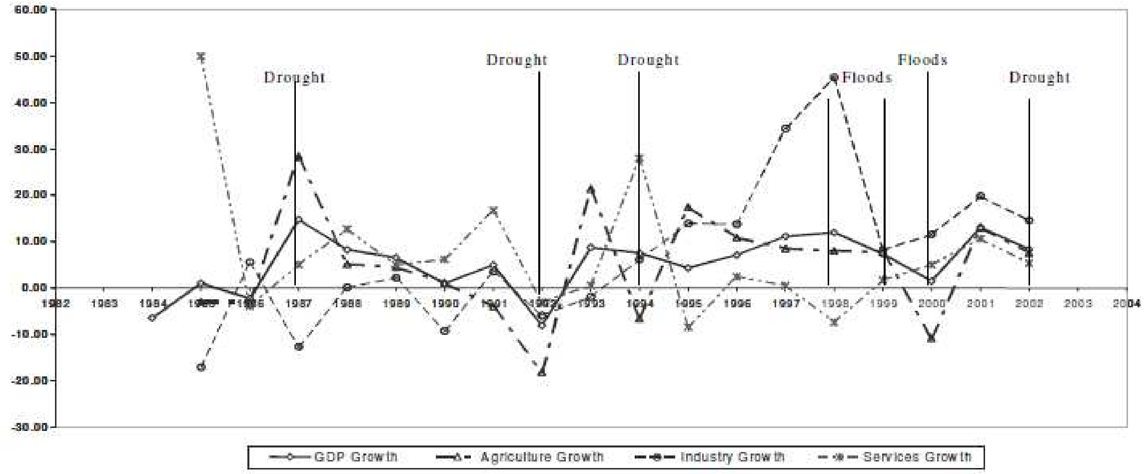
The table below presents the main costs of the 2000 flood to give an idea of the main sectors concerned.

Impacts		Direct	Indirect	Relief	Reconstruction
Social sectors	Food aid			35.5	
	Health	15.7		5.2	25.8
	Education	18.7		0.5	37.3
	Housing	29.1		6	43.6
	Government property	5.2		47.2	116.9
Infrastructure	Water and sanitation	13.4		6.6	13.4
	Energy and telecom	13.6	10.7		15.5
	Roads	47	30	11	87.2
	railways	7.3	10.7		49.2
Productive sectors	Agriculture	57.9	63		57.9
	Livestock	7.9	0.8		7.9
	Fisheries	8.5	6.1		8.5
	Industry	25.7	68		30.8
	Tourism	2	10.5		2.5
	Trade	15.7	15		15.7

Table 22 : World Bank estimates of the 1999/2000 flood disaster in Mozambique (MUS$)

(b) Regression analysis[16]

"A regression analysis undertaken in the recent World Bank study over the period 1981-2004, suggests that in Mozambique GDP growth is cut by 5.6% in average when a major water shock occurs. Assuming the rate of the major disaster occurrence as one in five years, on average GDP growth in Mozambique is reduced by 1.1% annually due to the impacts of water shocks. This estimate translates to a US$711 million loss in total GDP over the last 24 years. The future costs to the national economy, if no measures are taken, will be much higher: assuming a 5% annual GDP growth, by 2030 the total economic costs due to floods and droughts will reach the amount of about US$3 billion."



Mozambique: Real GDP Growth Rates and Rainfall (1988-2002)

[16] M. Benito-Spinetto, P. Moll. CEM Background Paper "Macroeconomic Developments, Economic Growth and Consequences for Poverty". World Bank, Africa Region, PREM 1. December 2004

Year	Type of Event	Details
2002-2003	Drought	43 districts affected in South and Central provinces
2001	Floods	Zambezi river; 115 deaths; 500,000 people affected
2000	Floods	Limpopo, Maputo, Umbeluzi, Incomati Buzi and Save river basins, caused by record rainfall and 3 cyclones; 700 deaths, 2 million people affected
1999	Floods	Floods in Sofala and Inhambane provinces; highest rainfall level in 37 years; EN1 major country highway shut for 2 weeks; 100 deaths; 70,000 people affected
1997	Floods	Floods on Buzi, Pungue and Zambezi rivers; no road traffic to Zimbabwe for 2 weeks, 78 deaths; 300,000 people affected
1996	Floods	Floods on all southern rivers of the country; 200,000 people affected
1994-1995	Drought	1.5 million people affected in South and Central parts of Mozambique. Cholera epidemic.
1991-1992	Drought	Whole country affected. 1.32 million people severely affected. Major crop failure.
1987	Drought	8000 people affected in Inhambane province.
1985	Floods	Floods in Southern provinces; 9 rivers floods; worst flooding in 50 years followed by 4 years of drought; 0.5 million people affected
1983-1984	Drought	Most of country affected. Cholera epidemic and many deaths from drought and war.
1981-1983	Drought	2.46 million people affected in South and Central parts of Mozambique.
1981	Floods	Floods on Limpopo river; 0.5 million people affected
1980	Drought	Southern and Central parts of Mozambique affected

Sources: INAM; Atlas for Disaster Preparedness and Response in the Limpopo Basin, INGC, UEM-Department of Geography and FEWS NET MIND, 2003

Table 23 : water shock events in Mozambique since 1980

Finally, because of climate change which should increase the occurrence of these extreme events, these costs should be more important in the future. Climate shocks have impacts on every type of capitals (we give the details of the main damages for the 2000 flood in the results section).

Limitation of the calculations

The two methods converge to similar results, which indicate that these are quite robust. However, it would be interesting to do econometric calculations with panel data, because a shock at time t have an impact on the economy at time t, but also an impact on the trajectory of the economy, and thus impacts at time t+n. In the end, a shock can have a positive net economic impact if low productive activities are replaced by higher productive activities (Strobl, 2008). It would be an interesting issue to further investigate, data are however very limiting.

D. Cost of climate change

This is a work in progress made through a study on the cost of adaptation to climate change led by Sergio Margulis from the World Bank. We should have in 2009 a precise estimate of the climate change cost for Mozambique. Depending on the data available, the study should assess the impact on several sectors and resources: agriculture, forests, water resources, hydropower, natural disasters, sea level rise, infrastructure and health. Climate change has thus an impact on every type of capital assets. Temporarily, we assume from (Nordhaus and Boyer, 2000) that the cost is 3.5% of GDP.

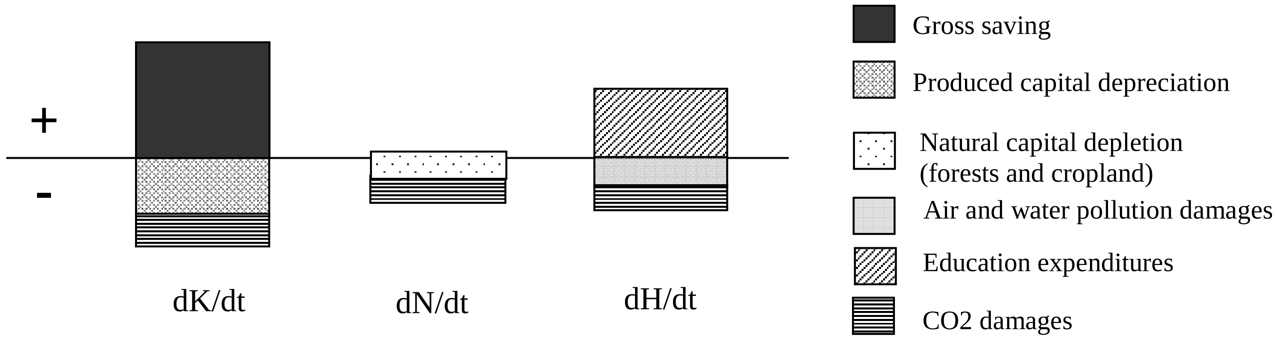
Warning – the cost of climate change and the cost of water shocks should not be confused. The damages from climate change are mainly in the future whereas the costs of water shocks are today.

E. Characterizing the actual Mozambican development path - Genuine saving calculation and update

We now present the methodology to calculate genuine saving. As introduced in section 2, genuine saving (equation (1)) is:

$$G = \frac{dW}{dt} = p_K \frac{dK}{dt} + p_N \frac{dN}{dt} + p_H \frac{dH}{dt}$$

(where K is produced capital, N is natural capital and H is human capital). Figure 1 presents the relationship between our theoretical definition (the variation of each type of capital stock) and the practical calculations (how these variations are assessed). Table 1 presents the main steps and formulae for the practical calculation of genuine saving.



Capital stock	GENUINE SAVING =	**Methodology**	**Formula**
ΔK	+ Gross national saving - physical capital depreciation	National statistics	--- ---
Δ N	- net forest depletion - mineral resource depletion	Net price method Net price method	Forest rent*net forest depletion
	- soil depletion cost	Nutrient lost replacement cost	Nutrient price*net nutrient depletion
Δ H	+ human capital formation	Education expenditures	---
	- water pollution damages	Damage valuation	Morbidity: treatment + time lost value Mortality: human capital approach
	- urban air pollution damages (PM_{10} and $PM_{2,5}$)	Damage valuation	Morbidity: treatment + time lost value Mortality: human capital approach
	- indoor air pollution damages	Damage valuation	Morbidity: treatment + time lost value Mortality: human capital approach
Δ (Kp+Kh+Kn)	- CO_2 damages	Damage valuation	World CO_2 damages (carbon value*global emissions)*(% of the global cost carried by Mozambique)

More details on each of the steps are given below.

Produced capital variation (ΔK)

We extract gross national saving (GNS) from national statistics. GNS represents produced capital investments. Net national saving equals GNS less produced capital depreciation. The latter term is the replacement value of capital assets used in the production process, derived from the World Bank (2006). Net saving is thus a measure of produced capital variation (investments less depreciation).

Gross national saving, education expenditure, consumption of fixed capital, urban particulate matter pollution

For these three elements, we used World Bank data:
http://www.worldbank.org/environmentaleconomics

Natural capital variation (ΔN)

The methodology to estimate forest, exhaustible and soil resources depletion were presented previously. We use here the same results.

Human capital variation (ΔH)

Education expenditure

Investments in human capital are estimated through educational expenditures. This includes both capital expenditures and current expenditures that are usually counted as consumption rather than investment in traditional national accounts. It is certainly not a perfect proxy for human capital formation, as we assume that a one-dollar investment in education produces the same amount of human capital. Thus, we do not consider the efficiency of the investments, nor human capital losses through death or a degradation of the school system.

Pollution damages on health

The methodology to estimate water and air (indoor and outdoor) pollutions was presented previously. We use here the same results. The sound introduction of these pollution costs into the genuine saving framework has however to be further investigated.

CO_2 damages (ΔK+ΔH+ΔN)

We use the methodology developed in (Arrow et al, 2007). Their idea is to index the climate change cost of one particular country on global emissions. Nordhaus and Boyer (2000) estimate that global warming will cost 1.5% of World GDP but 3.5% of the GDP for African countries (we use the most conservative IPCC[17] scenario corresponding to a doubling of CO_2 emissions). We use this approximation for Mozambique. Thus, we can conclude that the climate change cost for Mozambique will represent 0.027% of the world cost. Then, if we consider: carbon emissions in the world from year 2000 to 2005 equal to 6.6 billion tons (WDI, 2005) and a marginal damage cost of 50$ per ton of carbon dioxide (Tol, 2005), we have a global damage of 545 billions dollars for the period 2000-2005 The climatic change cost for Mozambique is then of 41 million dollars. This cost would come in addition to the ones computed in the main report.

[17] Intergovernmental Panel on Climate Change

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