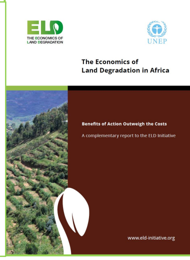
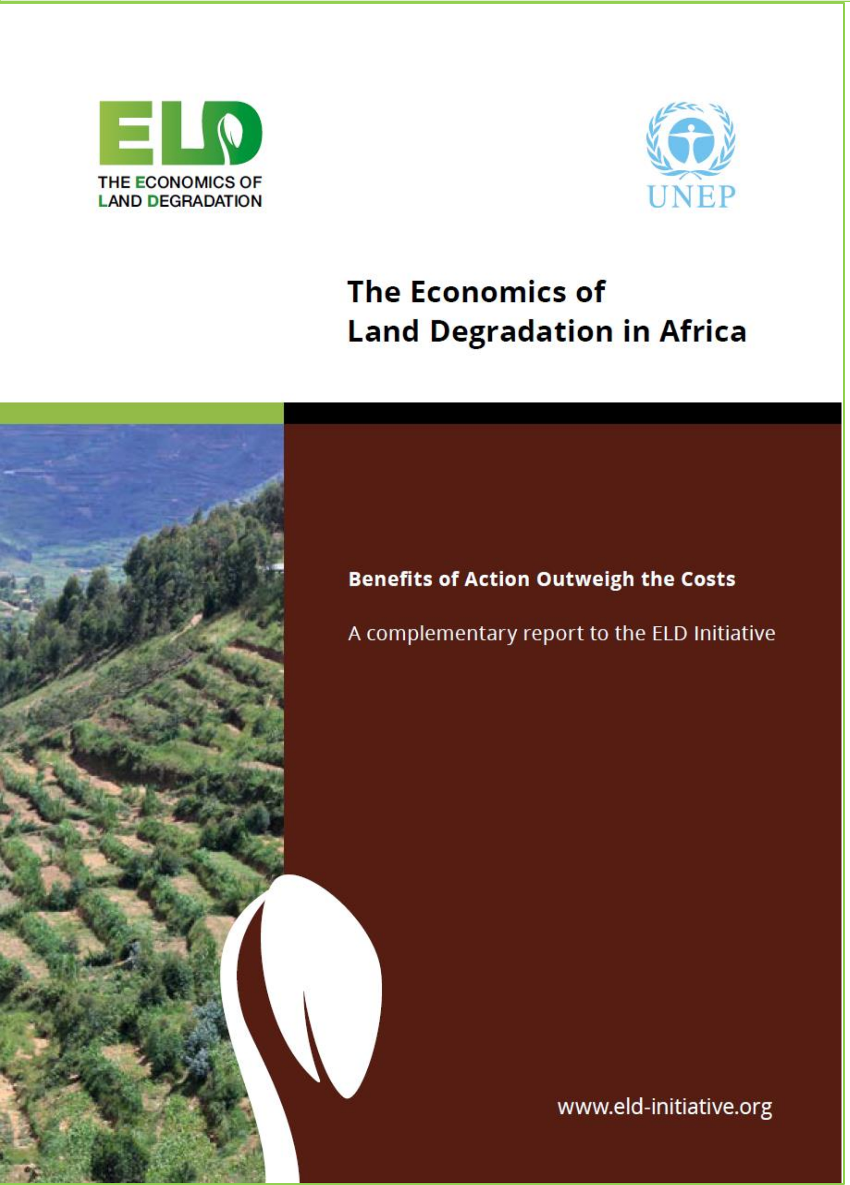
THE ECONOMICS OF LAND DEGRADATION IN AFRICA:
Benefits of Action Outweigh Costs





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AMCEN Side EVENT: LAND SOLUTIONS

Cairo, April 17, 2016

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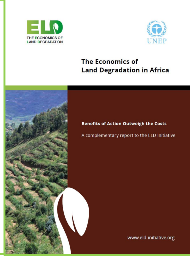

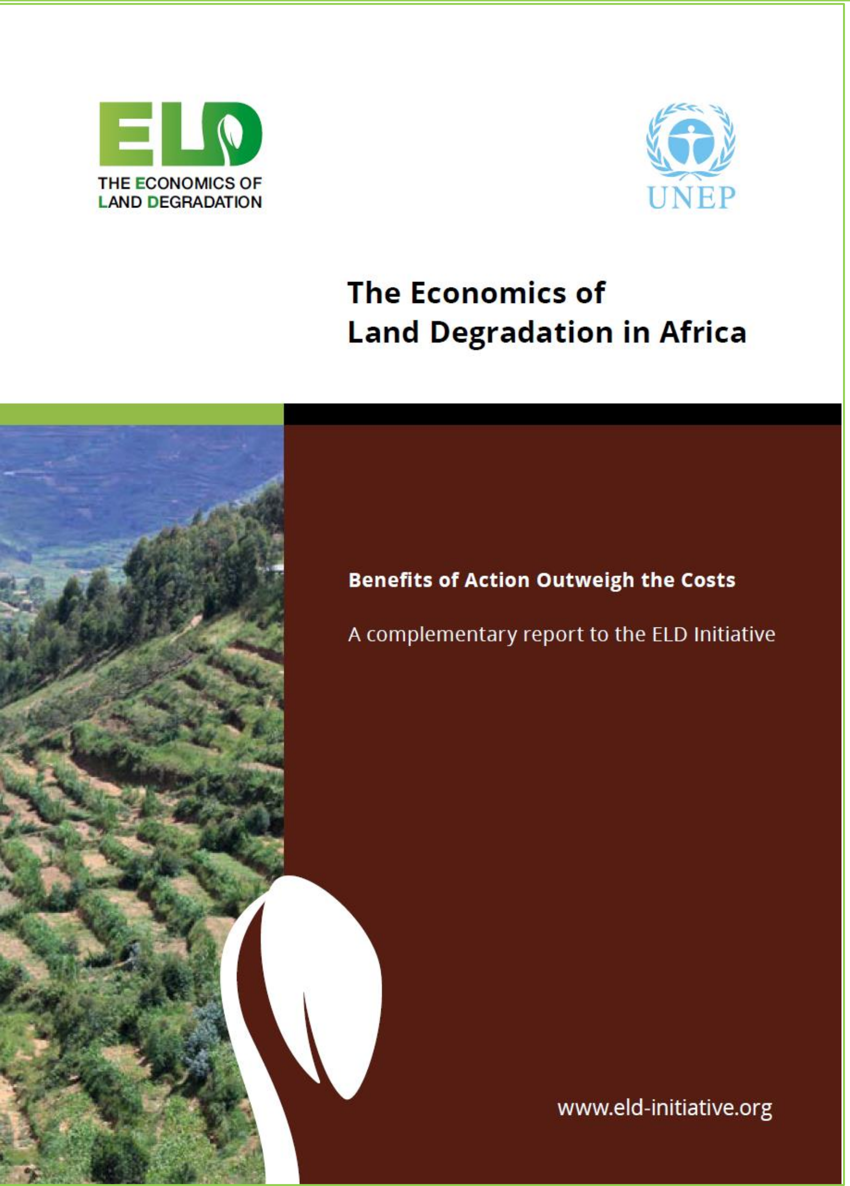

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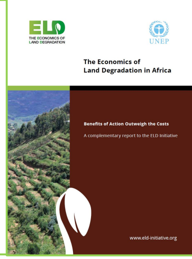
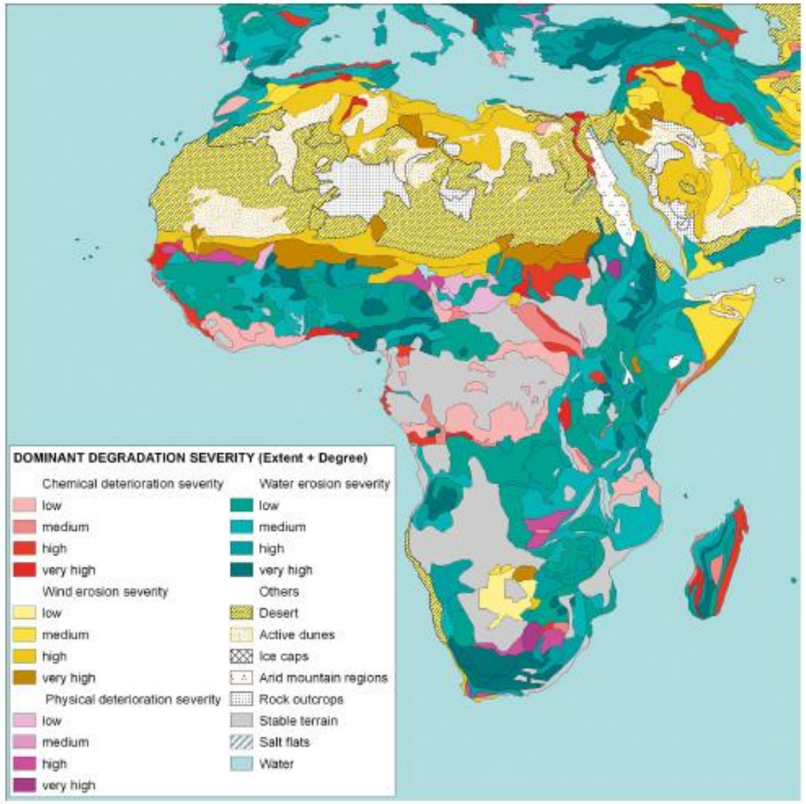
Chapter 1: Overview & stocktaking of land degradation in general and in africa

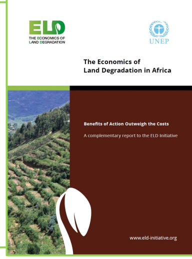


- The chapter covers an assessment of land degradation in Africa, undertaken as part of the ELD initiative
- It is based on comprehensive and credible data sets on the status and trends of global land degradation and
- It maps regional hotspots as the basis to evaluate the economic impact of soil nutrient depletion in cereal croplands and to inform its scenario development to 2030.
- It sates generating national and regional (Africa) estimates of the economic value of soil nutrient depletion due to erosion and its effect on cereal production as general objective.

Soil degradation severity, by type extent, and degree
(Source: ISRIC, 1990)

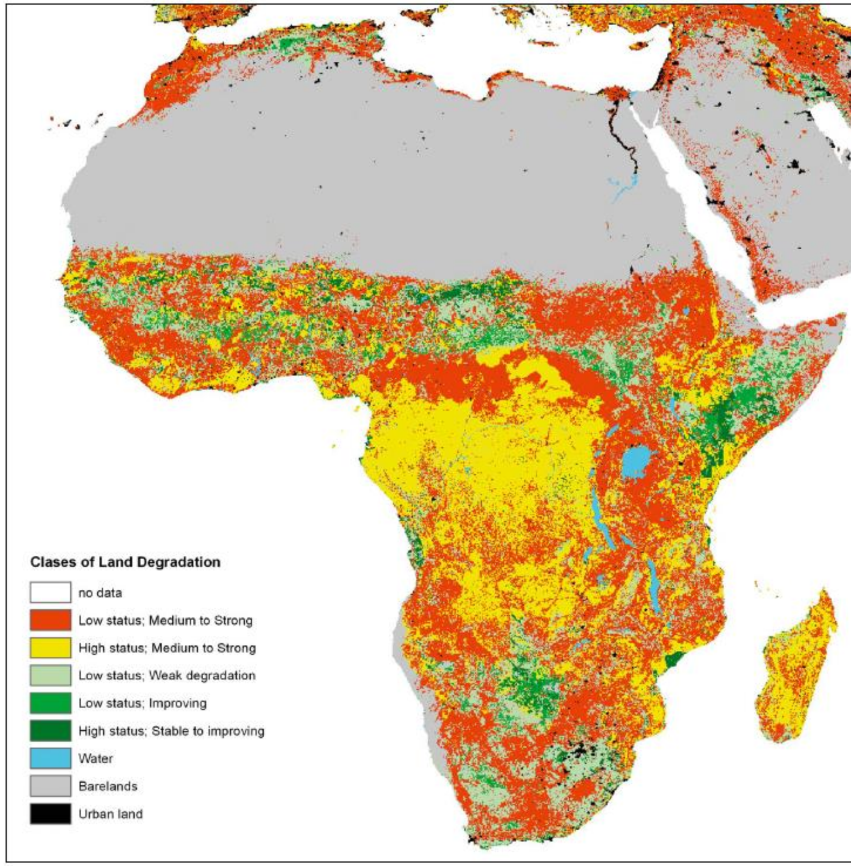


Chapters 2-4: Background

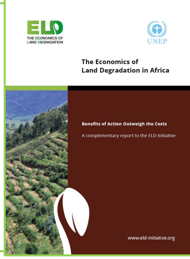


- Land degradation is one of the world's greatest environmental challenges; global soil loss ≈75 billion ton/year (Eswaran et al., 2001)
- Processes exacerbating land degradation include:
  - **soil degradation** that encompasses the deterioration in the physical, biological or economic properties of soils, and the loss of natural vegetation through deforestation (Pagiola 1999).
  - processes contributing to soil degradation include soil erosion, soil nutrient depletion, soil pollution, salinization, and decline in soil structure
- **Nutrient depletion** refers to the net loss of plant nutrients from the soil or production system due to a negative balance between nutrient inputs and outputs.
- Major channels of nutrient depletion are removal through soil erosion, harvest, leaching, and denitrification (Lal, 1994; Pieri, 1995; Enters, 1998).

GLADIS map of land degradation
(Source: Nachtergaele, et al., 2011b)

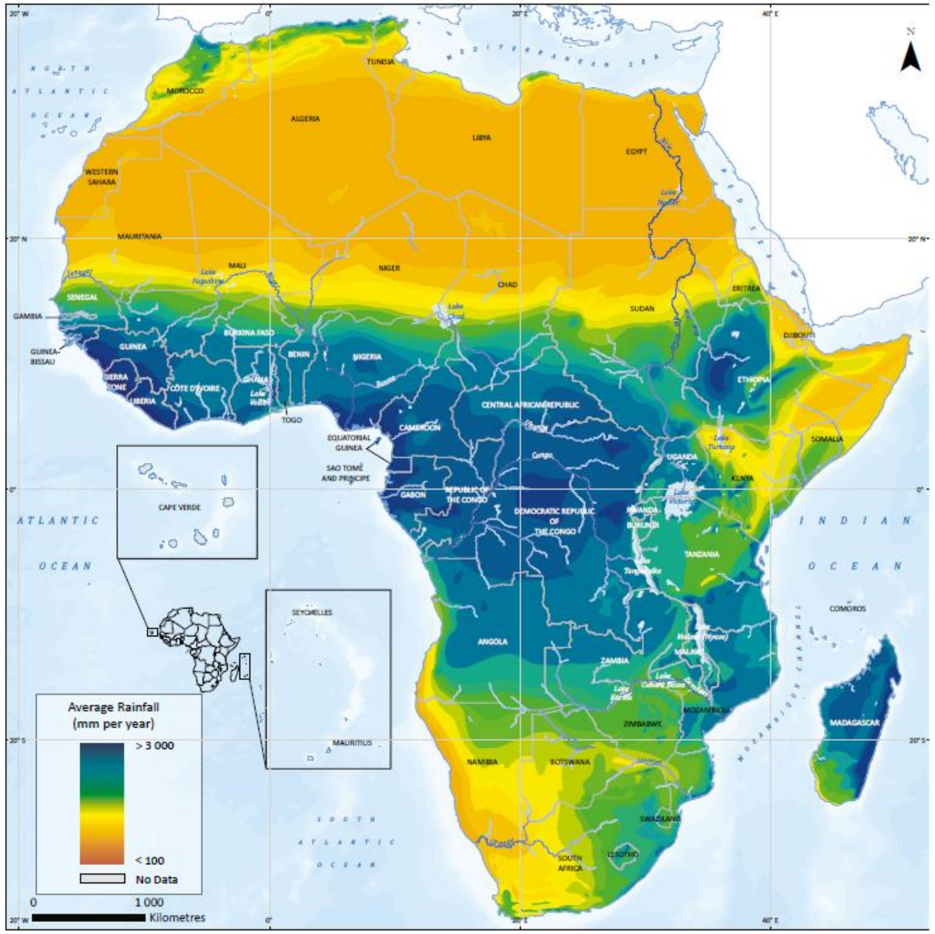


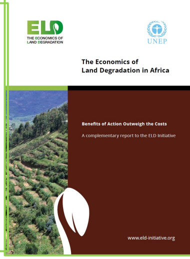
CHAPTERS 2-4: BACKGROUND…



- Over a period of 40 years, erosion has removed nearly one-third of the world's arable land from production (Fischer, et al., 2011).
- Additionally, desertification threatens over 41 % of the Earth's land area (MEA, 2005; Solh, 2009).
- Reviews of global land degradation affirm that Africa is particularly vulnerable to soil erosion and no doubt, the most severely affected region (Lal, R, 1995; Nellemann, et al., 2009; Obalum, et al., 2012).
  - LD affected ≈ 2/3 of Africa's productive land area (UNCCDE, 2013)
  - Up to 25 % of the global food production may be lost during the 21st century because of the combined effect of land degradation, climate change, water scarcity, and invasive pests (UNEP, 2009).

Average rainfall distribution
(Source: UNEP, 2013)



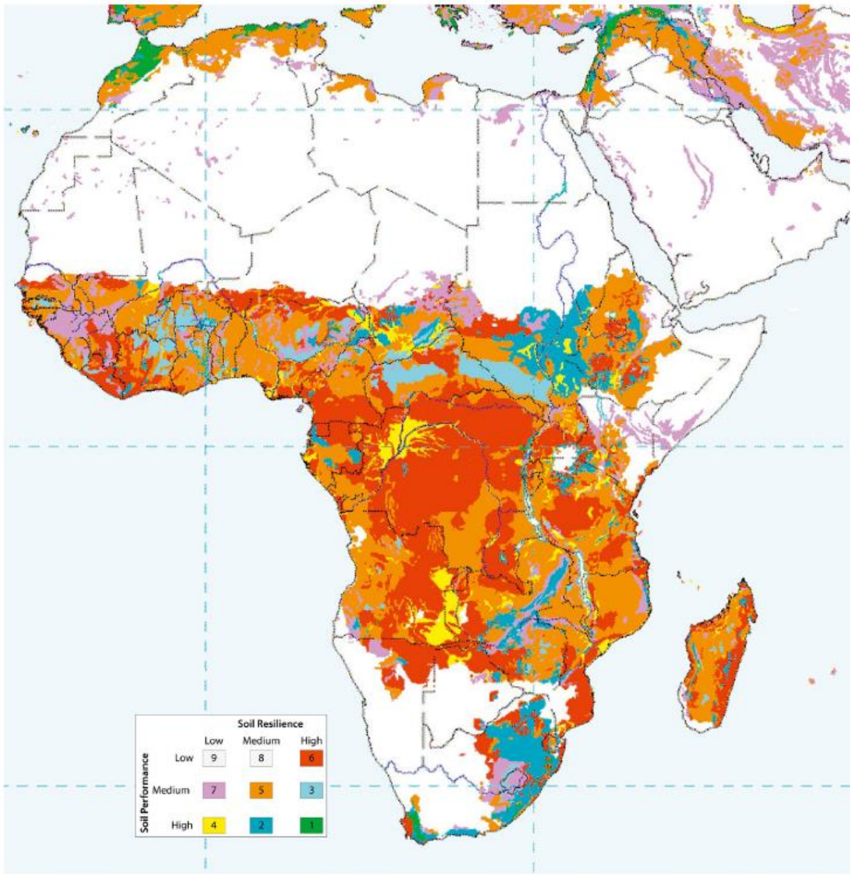


CHAPTERS 2-4: BACKGROUND…

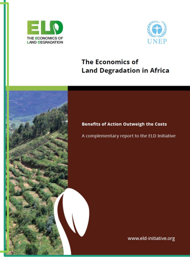
- Concerns of increasing food insecurity are the highest for sub-Saharan Africa where per capita food production has been declining by at least 3 % per year since 1990 (Alexandratos & Bruinsma, 2012; McKenzie & Williams, 2015).
- Yield decline in Africa due to past soil erosion may range from 2 to 40 % (Eswaran, et al., 2001).
- Lal et al (2004) reported the value of annual production losses from declines in agronomic productivity in Africa due to water-induced soil erosion at USD 15 million.
- In Sub Saharan Africa, soil nutrient depletion accounts for about 7 % of the sub-continental Agricultural GDP or close to USD 3.9 billion (Drechsel & Gyiele, 1999) and there was substantial variation by country.
- Nkonya et al. (2013) noted the lack of consensus on the magnitude and severity of land degradation plus its effects in the Eastern Africa region or in sub-Saharan Africa (SSA) all together.
- However, in Eastern Africa the resource loss due to land degradation is believed to be huge (Kirui and Mirzabaev, 2014).

Inherent land quality

(Source: USDA, 2003)



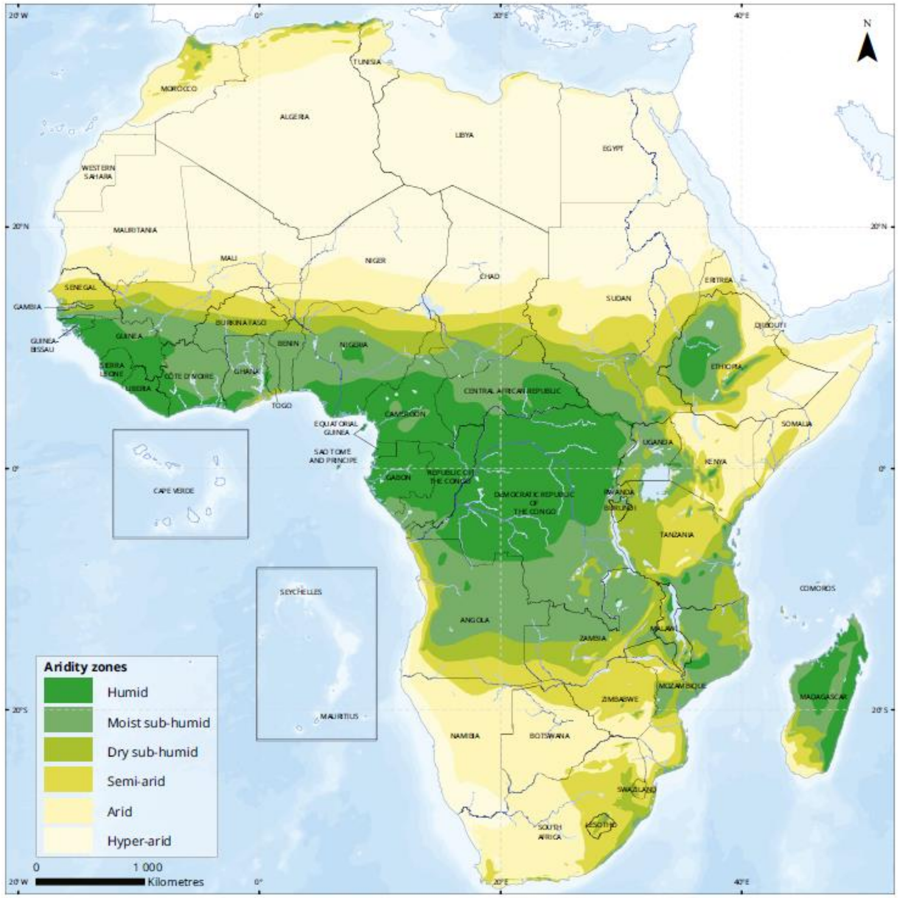
CHAPTERS 2-4: BACKGROUND…

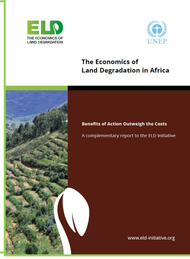


- This indicates that the validly, accuracy and comparability of current estimates of land degradation is in doubt. This is partly because:
  - Most estimates are at least a decade old and may no longer be accurate.
  - Large variation in estimates themselves makes it difficult to identify the scope of the problem.
  - Furthermore, results of studies are not comparable due to differences in methodology.
  - Hardly any studies review continental scale costs of inaction, the costs of action, and the benefits of taking action against nutrient depletion induced by economic and biophysical factors in a way to allow cost benefit analysis of alternative land management practices that tackle soil erosion.

The drylands of Africa

(Source: World Meteorological Organization (WMO), United Nations Environment Programme (UNEP), Climate Change 2001: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), cited in (UNCCD and CFC, 2009))

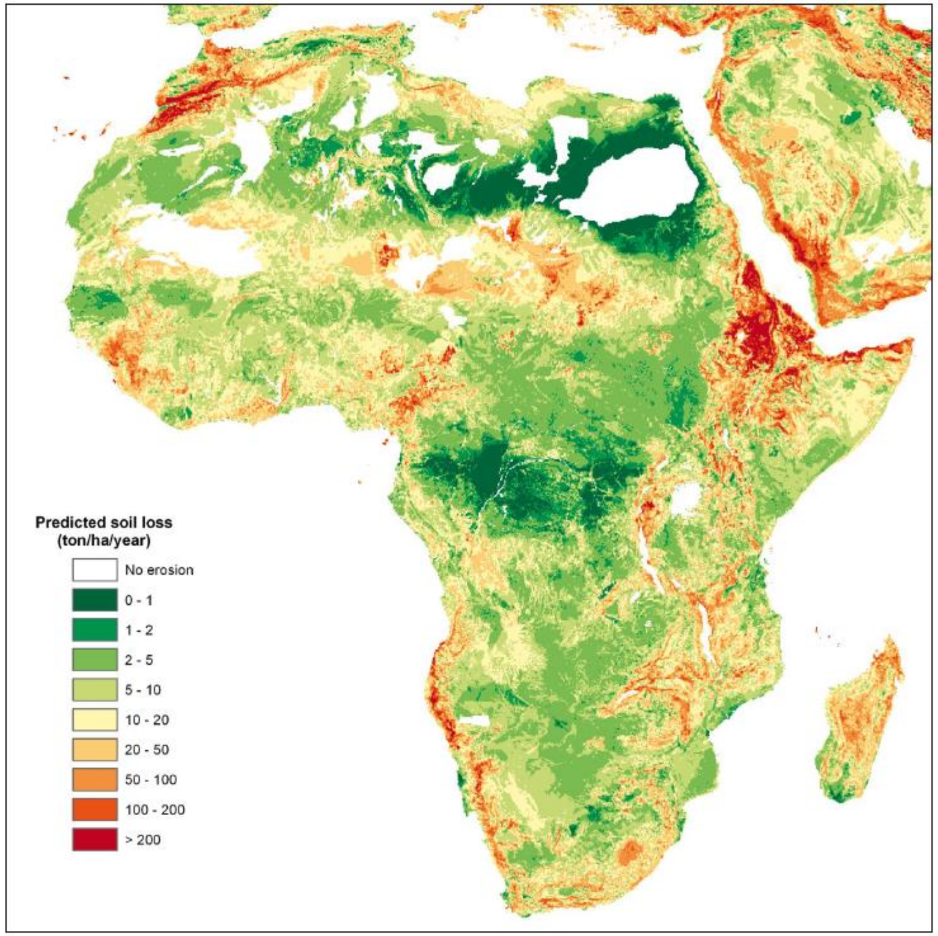


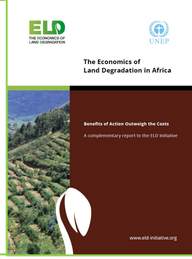


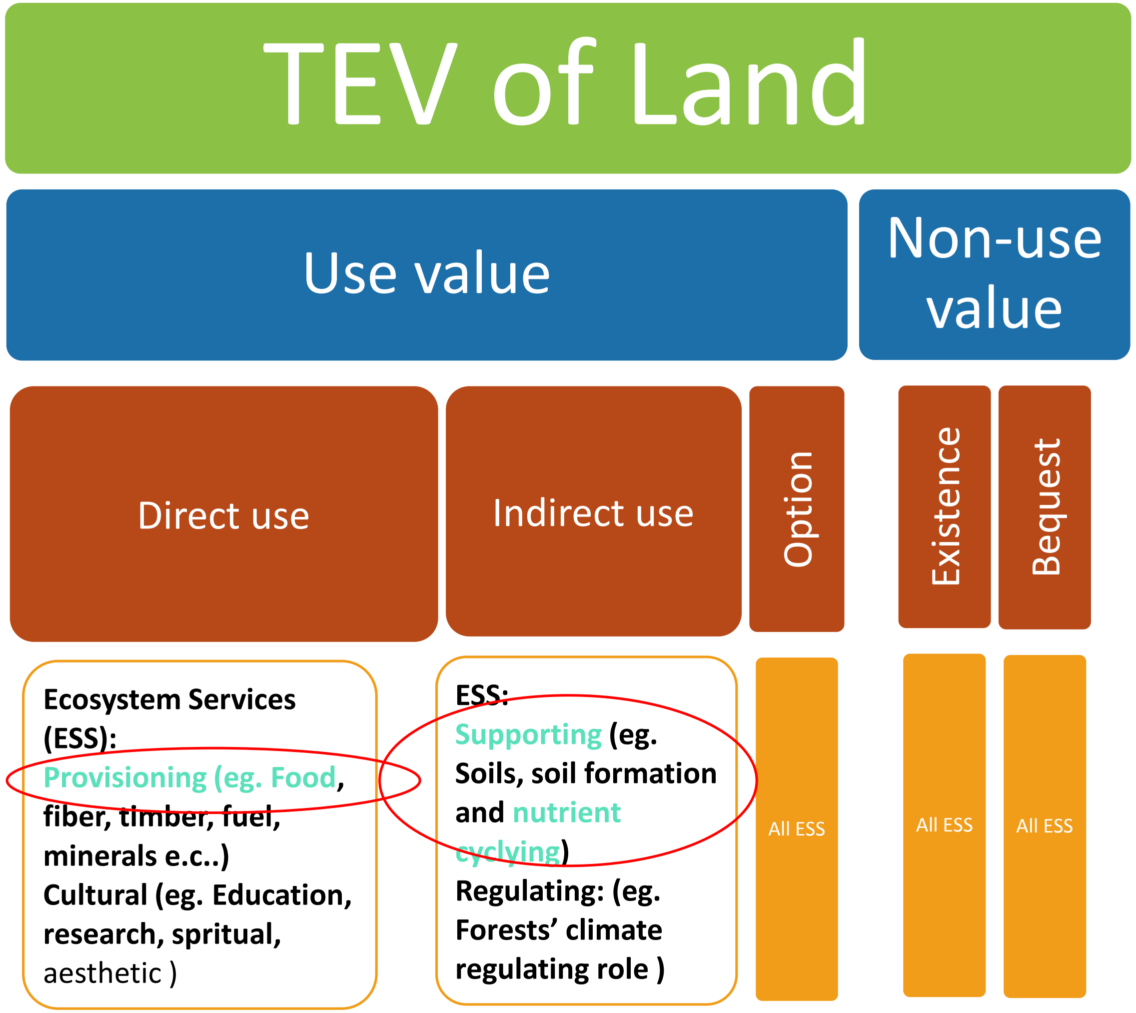
Chapters 2-4: Specific objectives

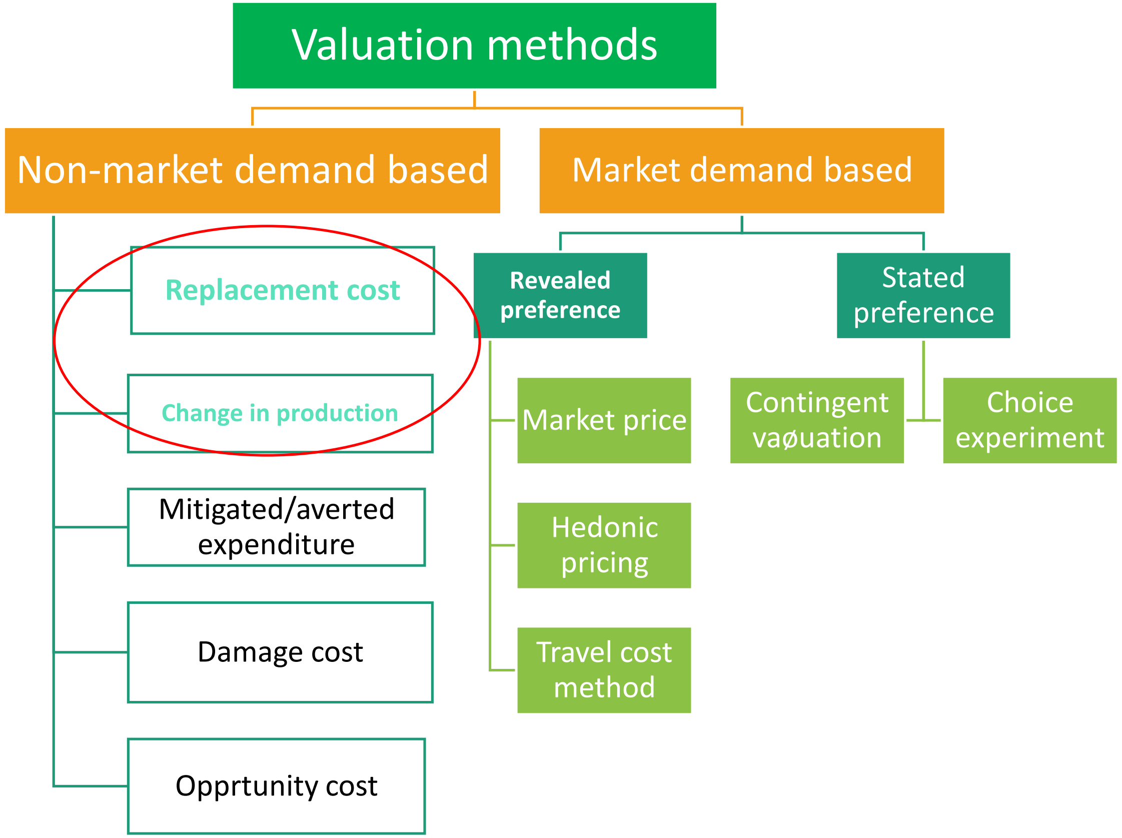
1. Develop a model of land degradation (measured in terms of soil nutrient loss in African cultivated lands) as a function of biophysical and economic factors based on data from 2002–2004 as base years (Chapter 2)
2. Estimate crop productivity loss as a function of land degradation (erosion induced soil nutrient depletion) and factor inputs (Chapter 2)
3. Estimate the cost of intervention: (biological and mechanical), including the initial cost of capital and operational costs (Chapter 3)
4. Recommend concrete policy actions based on cost benefit analysis (Chapter 4 & 5)

GLADIS map of predicted soil loss in ton/ha/year
(Source: Nachtergaele, et al., 2011b)

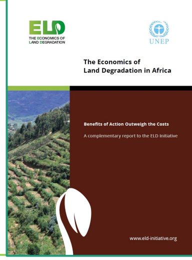





TEV of Land
Use value
Non-use value
Direct use
Indirect use
Option
Existence
Bequest
Ecosystem Services (ESS):
Provisioning (eg. Food, fiber, timber, fuel, minerals e.c..)
Cultural (eg. Education, research, spritual, aesthetic)
ESS:
Supporting (eg. Soils, soil formation and nutrient cyclying)
Regulating: (eg. Forests' climate regulating role)
All ESS
All ESS
All ESS


Valuation methods
Non-market demand based
Market demand based
Replacement cost
Change in production
Mitigated/averted expenditure
Damage cost
Opprtunity cost
Revealed preference
Stated preference
Market price
Hedonic pricing
Travel cost method
Contingent vaøuation
Choice experiment

Chapters 2-4: Methods-*Conceptual framework & data*



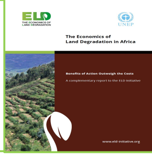
- **Soil nutrient balance (NB)** is a common indicator used to assess changes in soil fertility of agricultural ecosystems (Lesschen et al., 2006).

- Stoorvogel and Smaling (1990) and Stoorvogel et al. (1993) estimated national level balances of NPK nutrients (**Nitrogen, Phosphorous (P_2O_5), and Potassium (K_2O)**) for 37 SSA countries

- Henao and Baanante (1999) and Henao and Baanante (2006) reported negative annual average **NPK balances for 49 African countries** for the cropping seasons of 1993-1995 and 2002-2004 respectively.

- These national scale studies of NPK balances **do not provide direct entry point for intervention and are not very meaningful for policy makers**; and there is a need to link these results with other applications and data to optimize its use (Lessechen et al. , 2007).

Chapter 2-4: Methods-*TEV & Valuation*



1. Modeling

1.1. Biophysical Modelling of Supporting Ecosystem Service: Soil Nutrient Balance in Croplands (Lesschen et al., 2007)

1.2. Econometric Modeling of Loss of Supporting Ecosystem Service (Nutrient depletion[1]) as a function of:

$$NPK_{it} = \alpha_0 + \alpha_1 X_{1it} + \alpha_2 NPK_{it-n} + \alpha_3 X_{2it} + u_{it} \qquad (1)$$

1.3. Econometric Modeling Provisioning Ecosystem Service (Crop Yield/ha)[9] as a function of:

$$Y_{it} = \beta_0 + \beta_1 TNPK_{it} + FI_{it} + \varepsilon_{it} \qquad (2)$$

Estimated nutrient depletion [10]

Factor inputs(Land size [11]; Labor [12]; Fertilizer [13])

2. Estimation, valuation

2.1: Estimation: Agricultural ecosystem service trade index:

$$AESSTI_{it} = \frac{L_{it}(\beta_1 TNPK_{it})}{L_{it}(NPK_{it})} \qquad (3)$$

2.2. Valuation

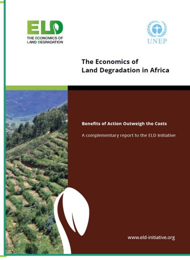
2.3. Cost of action against LD induced by

Erosion: cost of SLM technologies[16]

Poverty: Poverty gap filling income[17]

3. Cost benefit analysis[18]

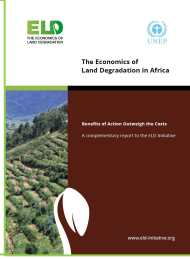
Note	Data	Description	Year	Source
16	**Cost of SLM**	**Establishment and maintenance costs of physical and biological structures for soil and water conservation (Cost Transfer functions)**		**WACOT**
17	Resource for poverty reduction	The amount of money required to lift the people living below the poverty line to a level of income equal to the poverty line.		This study
		Population	2010-12 (V)	FAOSTAT
18	**Cost benefit analysis**	**Discount rate: Real interest rates**	**2010-12**	**W. Bank**



Chapters 2-4: Results: model of nutrient balance

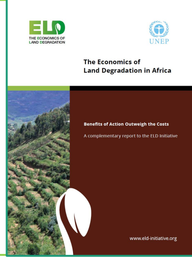
Dependent variable: **Nutrient loss NPK kg/ha/year**	Model Coefficients (*** = significant at P<1%)
Socio-economic factors	
Poverty gap (%)	47.633(14.688)***
GDP per capita (100's of PPP USD)	0.109(0.062)*
Manufacturing sector GDP (Billions of PPP USD)	-0.364(0.084)***
Livestock in 1000s of Tropical Livestock Units (log transformed)	-4.617(1.585)***
Biophysical factors	
Forest cover (% of total land area)	-0.250(0.087)***
Soil erosion (Mg/ha/year) (log transformed)	4.965(1.450)***
Historical nutrient balance in Kg/ha (crop seasons of 1993-95)	0.224(0.061)***
Constant	37.024(12.591)***
F (7. 34) statistics	14.17***
R^2	0.745
Adjusted R^2	0.692
Mean VIF	2.27

Chapters 2-4: Results-Cereal crop production function



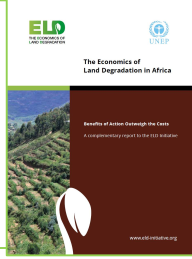
Dependent Variable : **Cereal crop yield (Kg/ha/year)**	Model Coefficients
Land degradation	
Total Nutrient depleted from cereal cropland in NPK Kg/year (log transformed)	-125.40(43.17)***
Factor inputs	
Land (total land area harvested with cereals in millions of ha)	-50.042(26.930)*
Labor in agriculture (log transformed)	246.34(79.72)***
Fertilizer (total NPK fertilizer consumption in 1000s of Mg)	3.616(0.264)***
Constant	1299.34(600.89)**
F (4. 37) statistics	51.93***
R^2	0.849
Adjusted R^2	0.833
Mean VIF	1.70

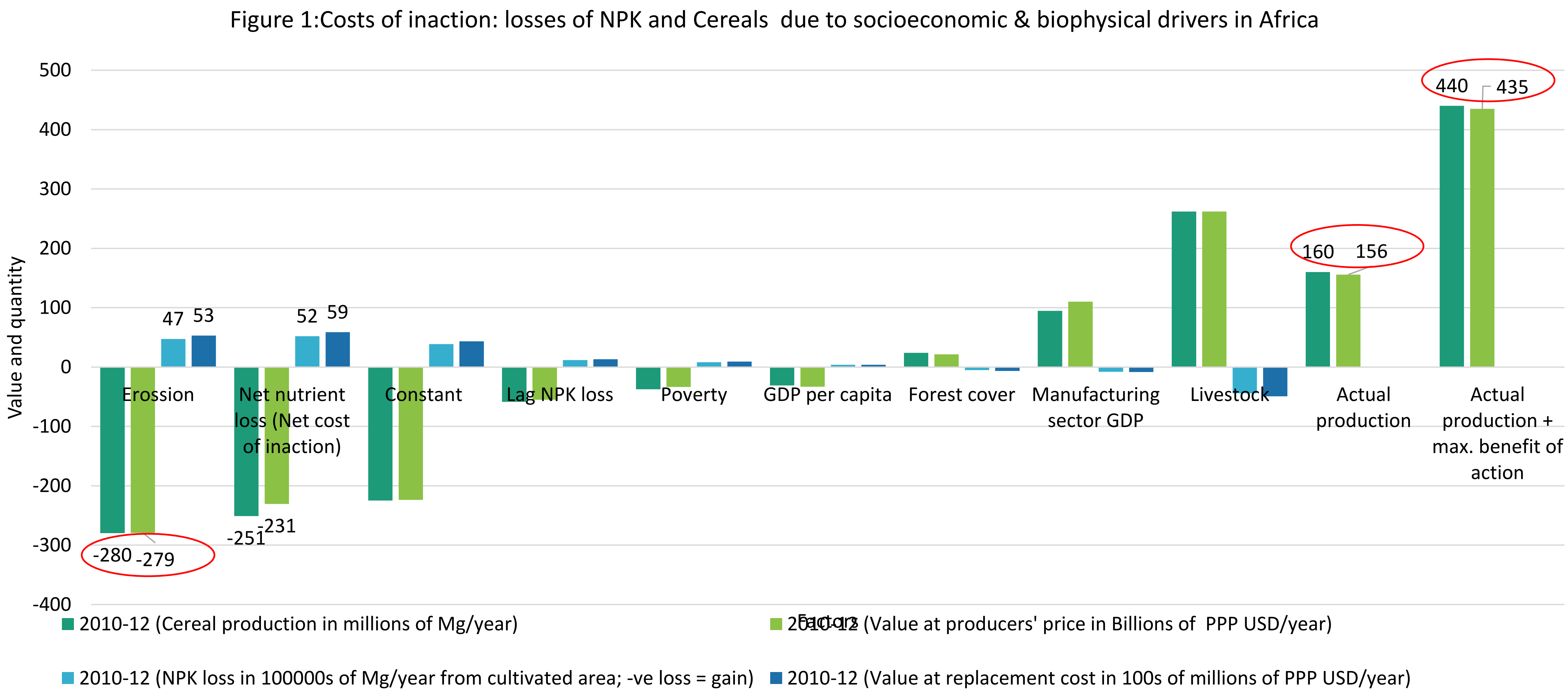
Chapters 2-4: Results-Average Ecosystem Service Trade-off Index (AESSTI)



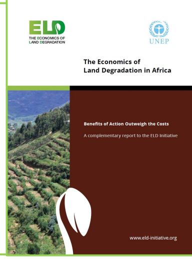
Country	AESSTI =(Crop loss in Kg / 1 Kg NPK loss)		Country	AESSTI =(Crop loss in Kg / 1 Kg NPK loss)		Country	AESSTI =(Crop loss in Kg / 1 Kg NPK loss)	
	2002-04	2010-12		2002-04	2010-12		2002-04	2010-12
Djibouti	15.26	16.11	Rwanda	26.10	35.98	Sierra Leone	38.96	44.31
Gabon	26.56	25.54	Angola	37.14	36.06	Benin	45.72	45.38
Congo	26.61	27.24	Chad	35.42	37.85	Uganda	36.73	45.55
Lesotho	29.83	27.98	Eritrea	36.90	38.24	Guinea	39.97	45.84
Liberia	27.24	28.38	Cameroon	45.67	39.16	Tunisia	43.94	46.50
Namibia	28.58	29.07	Mozambique	43.96	39.46	Burkina Faso	43.61	49.32
Botswana	30.68	29.48	Zambia	43.43	40.24	Senegal	44.47	50.70
Burundi	26.45	30.52	Mali	35.05	40.32	Ethiopia	41.11	51.34
DR Congo	30.99	30.87	Zimbabwe	43.66	41.48	UR Tanzania	37.25	51.55
CA Republic	33.54	30.96	Ghana	38.63	41.76	Sudan	58.17	56.46
Mauritania	31.78	31.04	Swaziland	33.36	42.02	Nigeria	40.08	58.55
Madagascar	32.40	31.92	Niger	38.99	42.14	Morocco	60.71	66.14
Togo	36.65	32.76	Kenya	37.55	42.24	South Africa	116.82	77.54
Malawi	31.41	35.87	Côte D'Ivoire	40.10	42.35	Egypt	118.86	352.66
Average ESSTI for Africa							43.04	48.29

Chapters 2-4: Results-Base periods costs of inaction (2010-12)





Chapters 2-4: Results-Future costs of inaction (2016-30)



PV of *costs of inaction against erosion induced LD*

Erosion class	Mean cultivated land area in Millions of ha/year	Mean NPK loss in 1000s of Mg/year	Value at Replacement cost in Billions of PPP USD (constant 2011 $) PV	Annuity	Mean crop loss in Millions of Mg/year	PVC inaction in Billions of PPP USD
ER1	0.704 (0.753	24.221 (27.629)	0.205 (0.226)	0.025 (0.029)	0.952 (1.170)	9.130 (12.590)
ER2	1.190 (0.595)	46.107 (24.264)	0.375 (0.185)	0.043 (0.021)	1.702 (0.981)	12.465 (7.176)
ER3	1.952 (1.755)	82.755 (73.539)	0.670 (0.643)	0.089 (0.075)	4.118 (4.630)	32.229 (35.591)
ER4	4.900 (5.723)	229.984 (269.672)	5.444 (10.489)	0.247 (0.258)	11.948 (15.863)	301.634 (654.065)
ER5	3.976 (3.529)	195.854 (173.318)	2.246 (2.082)	0.217 (0.172)	15.330 (17.466)	212.593 (378.904)
ER1-ER5	2.487 (3.339)	112.818 (160.197)	1.724 (4.846)	0.121 (0.162)	6.607 (11.539)	109.185 (335.371)
Africa	105	4738	72	5.09	280	4585

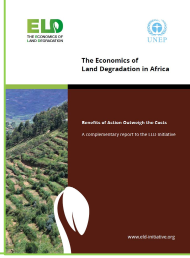
(4.6 trillion PPP USD = 286 Billion PPP USD/year = 12.3% GDP)

PV *costs of inaction against poverty induced LD*

Poverty class	Mean cultivated land area in Millions of ha/year	Mean NPK loss in 1000s of Mg/year	Value at Replacement cost in Billions of PPP USD (constant 2011 $) PV	Annuity	Mean crop loss in Millions of Mg/year	PVC inaction in Billions of PPP USD
PGI1	2.151 (2.702)	2.616 (6.256)	0.024 (0.050)	0.003 (0.006)	0.165 (0.352)	1.410 (2.768)
PGI2	3.403 (3.535)	18.050 (17.951)	0.180 (0.202)	0.020 (0.022)	0.834 (0.865)	6.596 (7.454)
PGI3	1.891 (1.668)	14.688 (12.367)	0.126 (0.101)	0.014 (0.012)	0.630 (0.543)	4.401 (3.292)
PGI4	3.511 (6.548)	45.256 (85.845)	1.555 (3.477)	0.042 (0.063)	2.460 (5.094)	86.484 (207.573)
PGI5	1.330 (0.783)	27.829 (18.114)	0.153 (0.075)	0.029 (0.024)	0.973 (0.613)	3.501 (2.128)
PGI1-PGI5	2.487 (3.339)	19.251 (35.263)	0.324 (1.323)	0.019 (0.030)	0.891 (1.996)	15.840 (78.280)
Africa	105	808	13.6	0.81	**37.4**	**665**

(665 Billion PPP USD = 27.6 Billion PPP USD/year = 1.75% GDP)

Chapters 2-4: Results-NPV of taking action (2016-30)

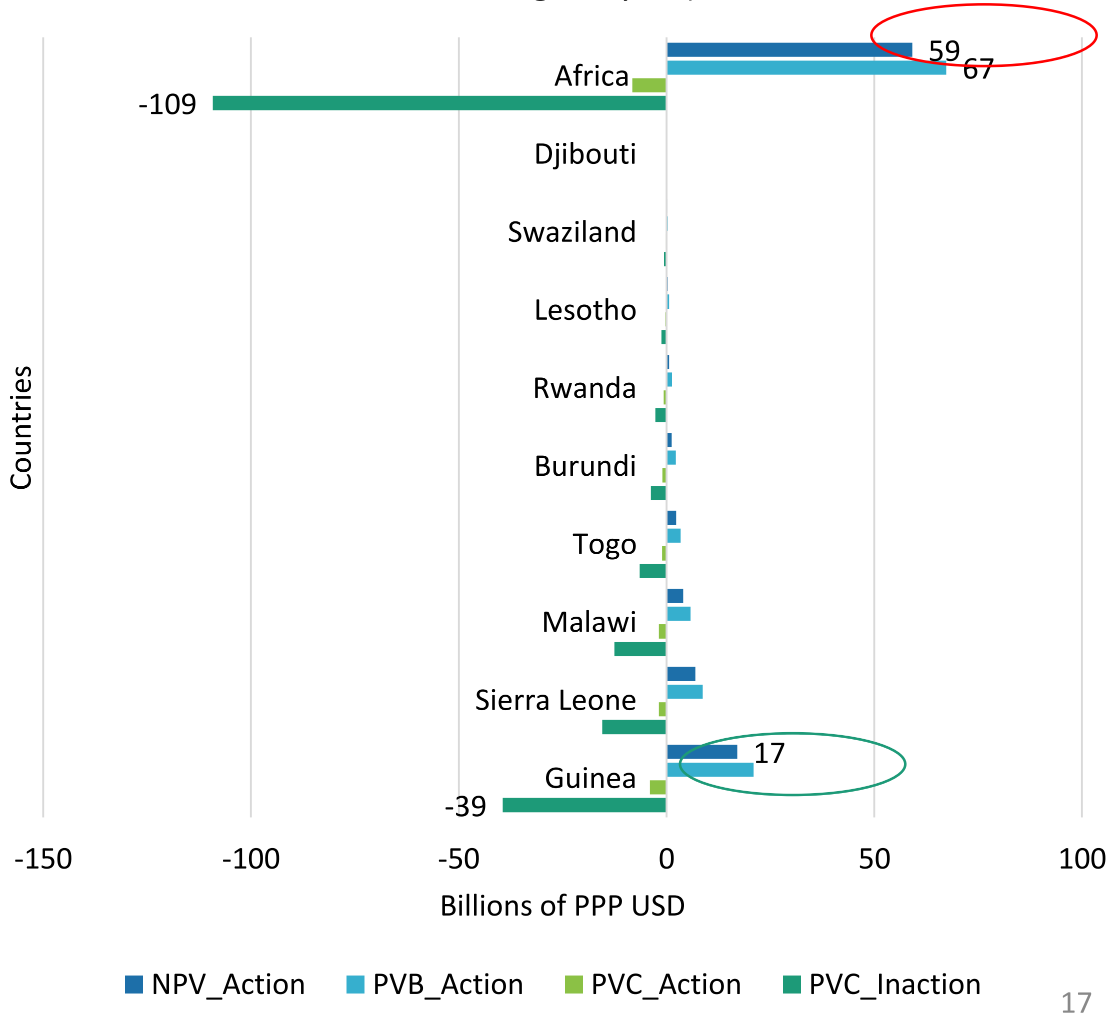


NPV of action against *erosion induced LD*

Quantiles	Benefits of action in Billions of PPP USD				NPV	BCR	BCR2
	PV	Annuity	Annuity as % of 2010-12 average				
			GDP	Agri GDP			
Average	67.333 (224.855)	3.854 (8.105)	6.46 (12.06)	22.46 (31.86)	59.135 (199.407)	6.58 (13.92)	0.62
Total Africa	2827	161.8	6.46	22.5	2483	6.58	0.62

(Africa Level: NPV of taking action ≈2.5 trillion PPP USD = 141 Billion PPP USD/year = 6.5% GDP)

Figure 7b: Erossion Class 1 Countries (Top soil erosion rate < 950 Mg/ha/year)



Chapters 2-4: Results-NPV of taking action (2016-30)…

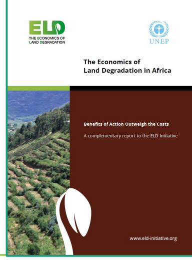


Figure 7b: Erosion Class 2 Countries (Top soil erosion rate between 950 and 1700 Mg/ha/year)

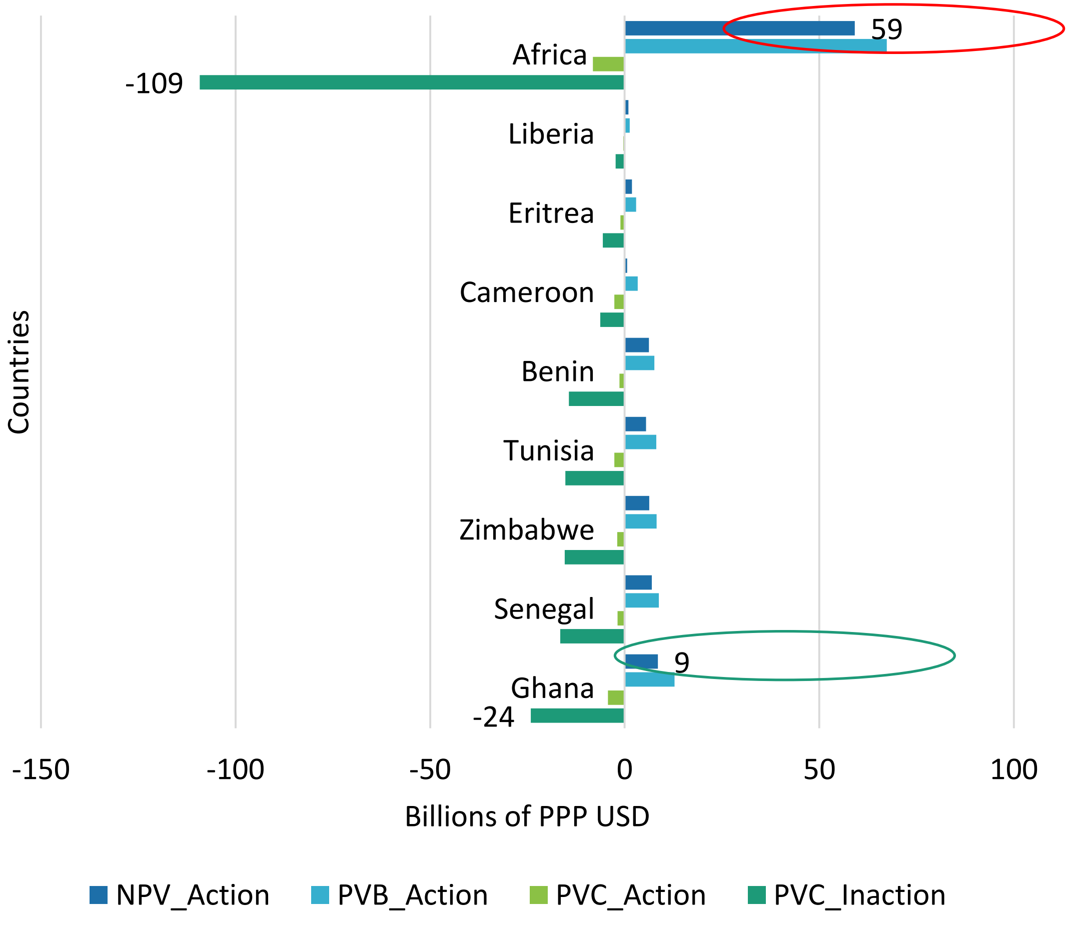
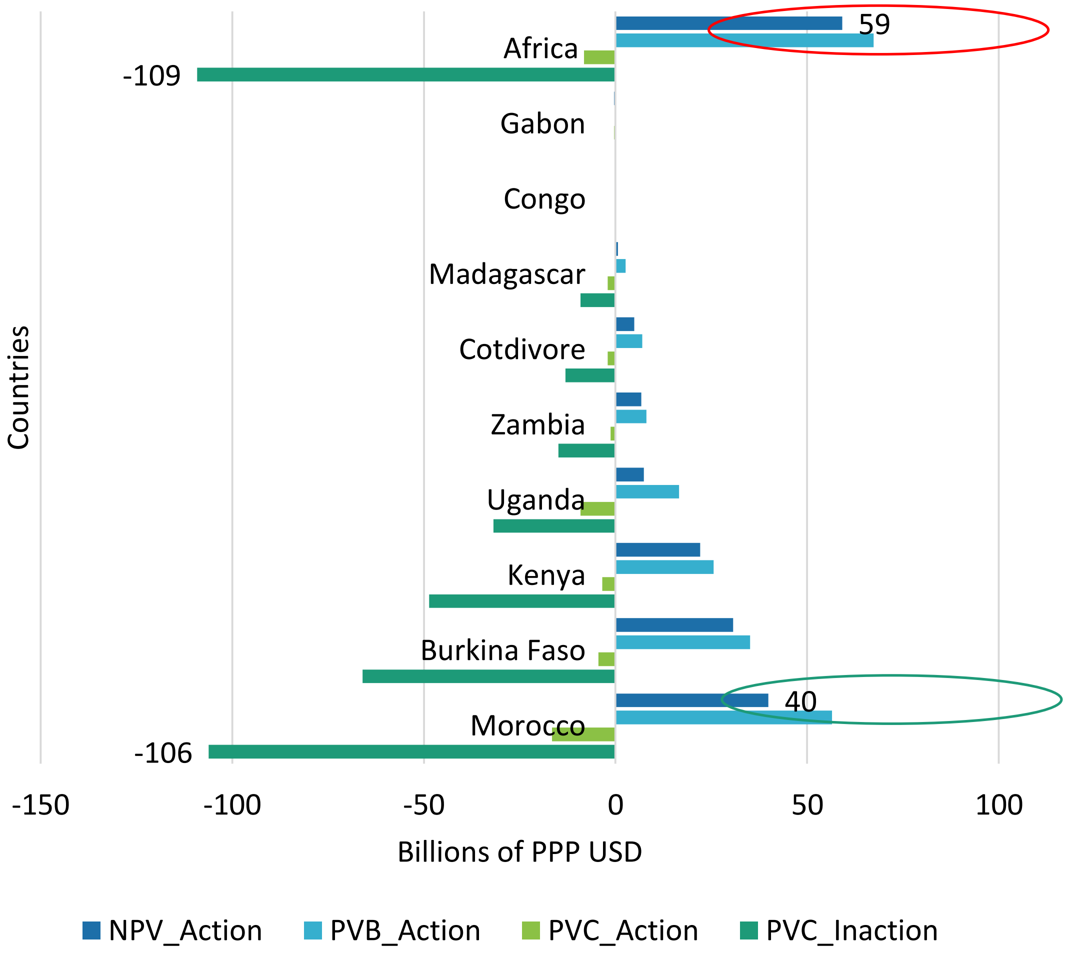


Figure 7a: Erosion Class 3 Countries (Top soil erosion rate between 1700 to 3150 Mg/ha/year)



Chapters 2-4: Results-NPV of taking action (2016-30)…

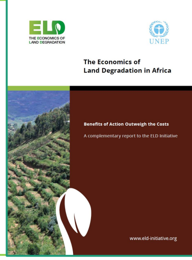


Figure 7d: Erosion Class 4 Countries (Top soil erosion rate between 3150 to 7200 Mg/ha/year)

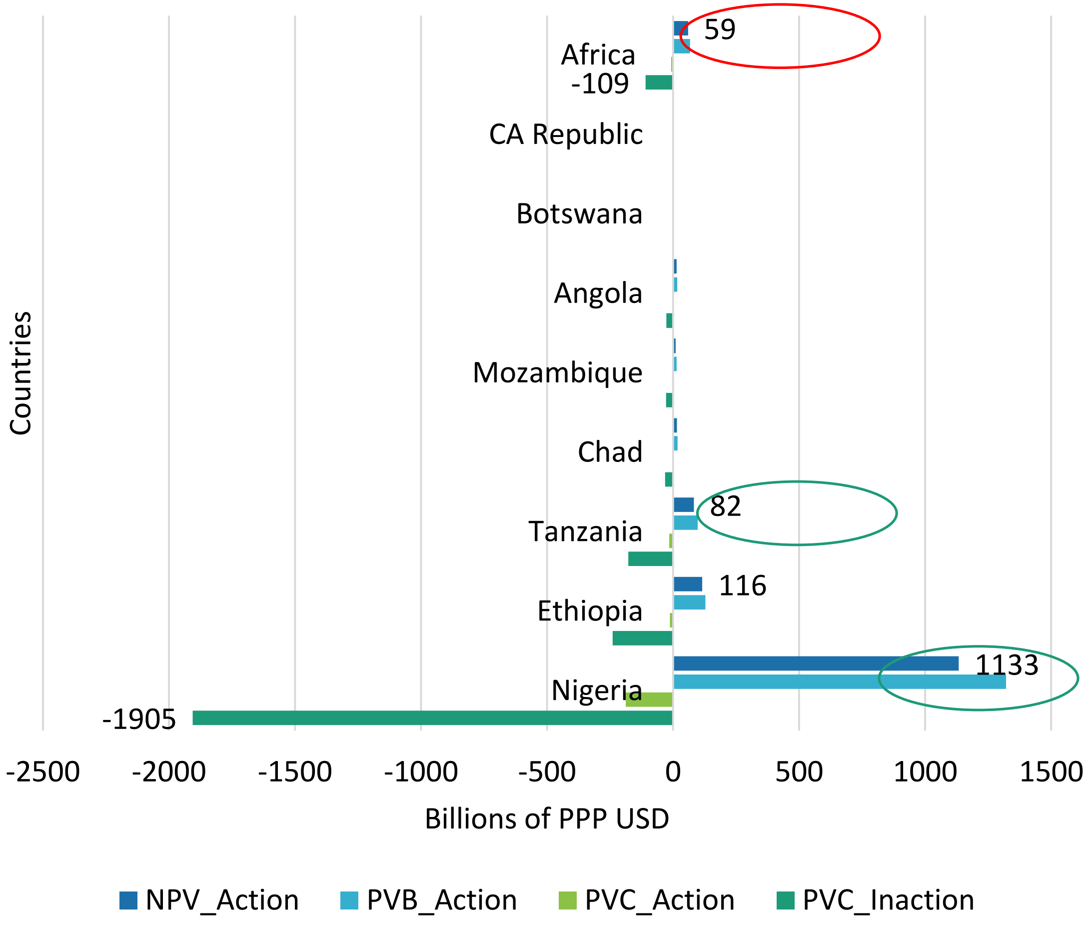
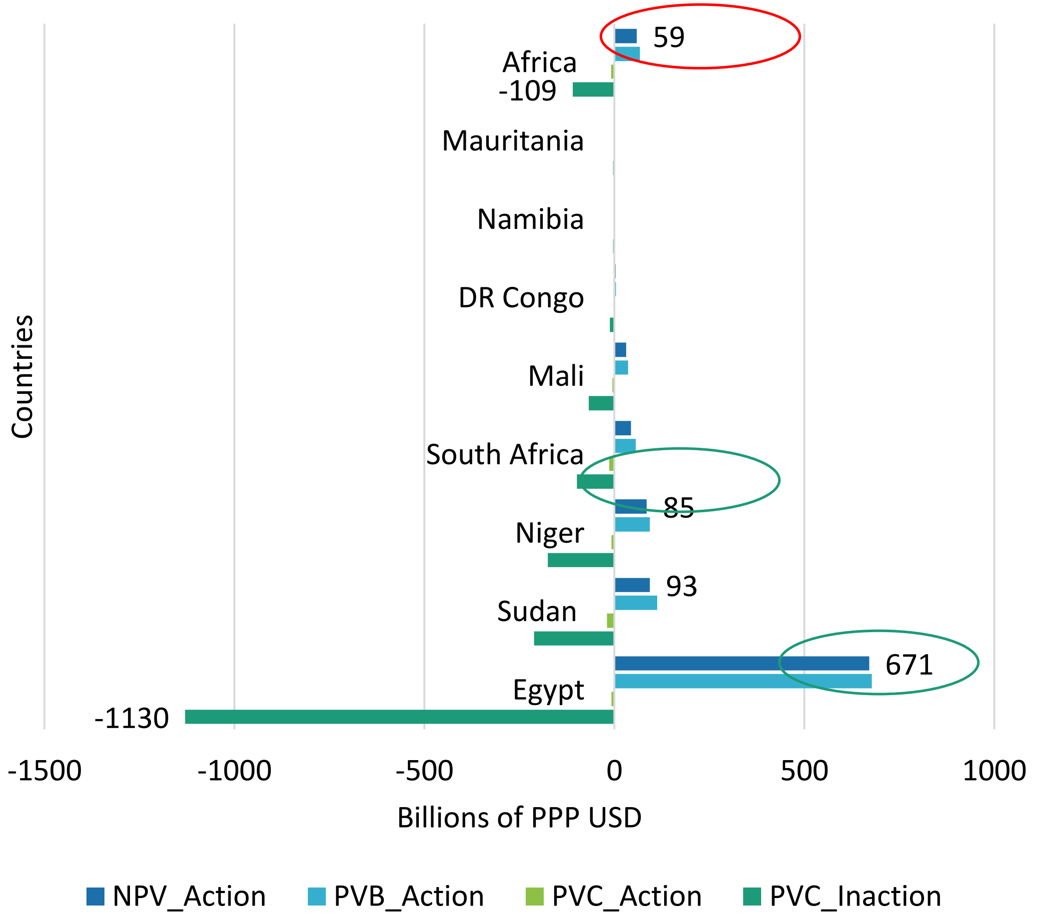
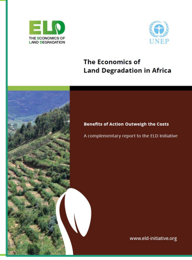


Figure 7e: Erosion Class 5 Countries (Top soil erosion rate > 7200 Mg/ha/year)

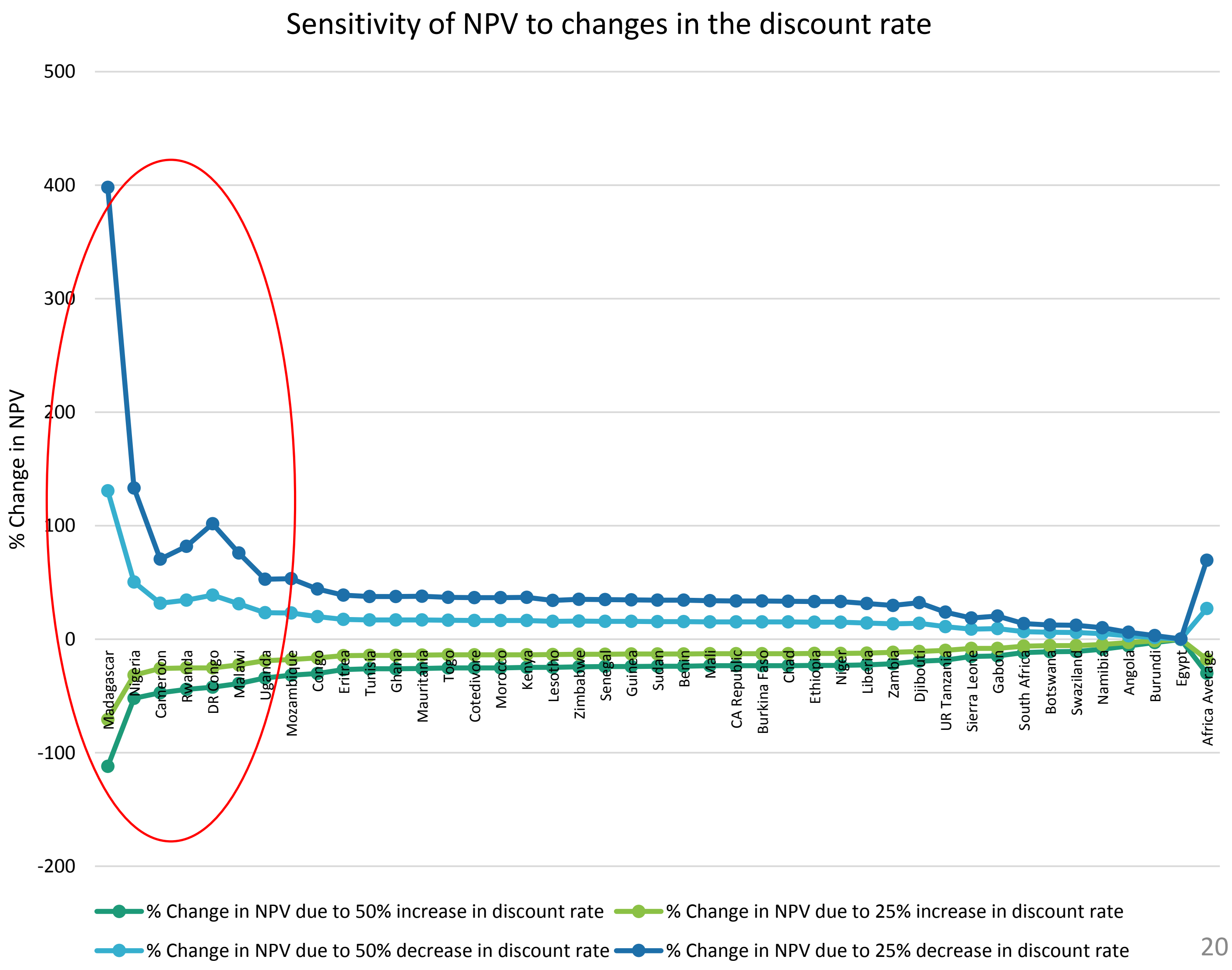


Chapters 2-4: Results-Sensitivity of NPV and BCR to changes in real discount rates by country

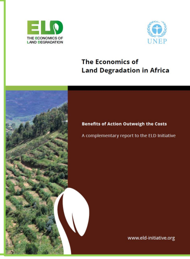


- For a **25 to 50% change in real discount rate**, NPV changes by lesser but opposite proportions for most countries **except Madagascar, Nigeria, DR Congo, Rwanda, Cameroon, Malawi, and Uganda**

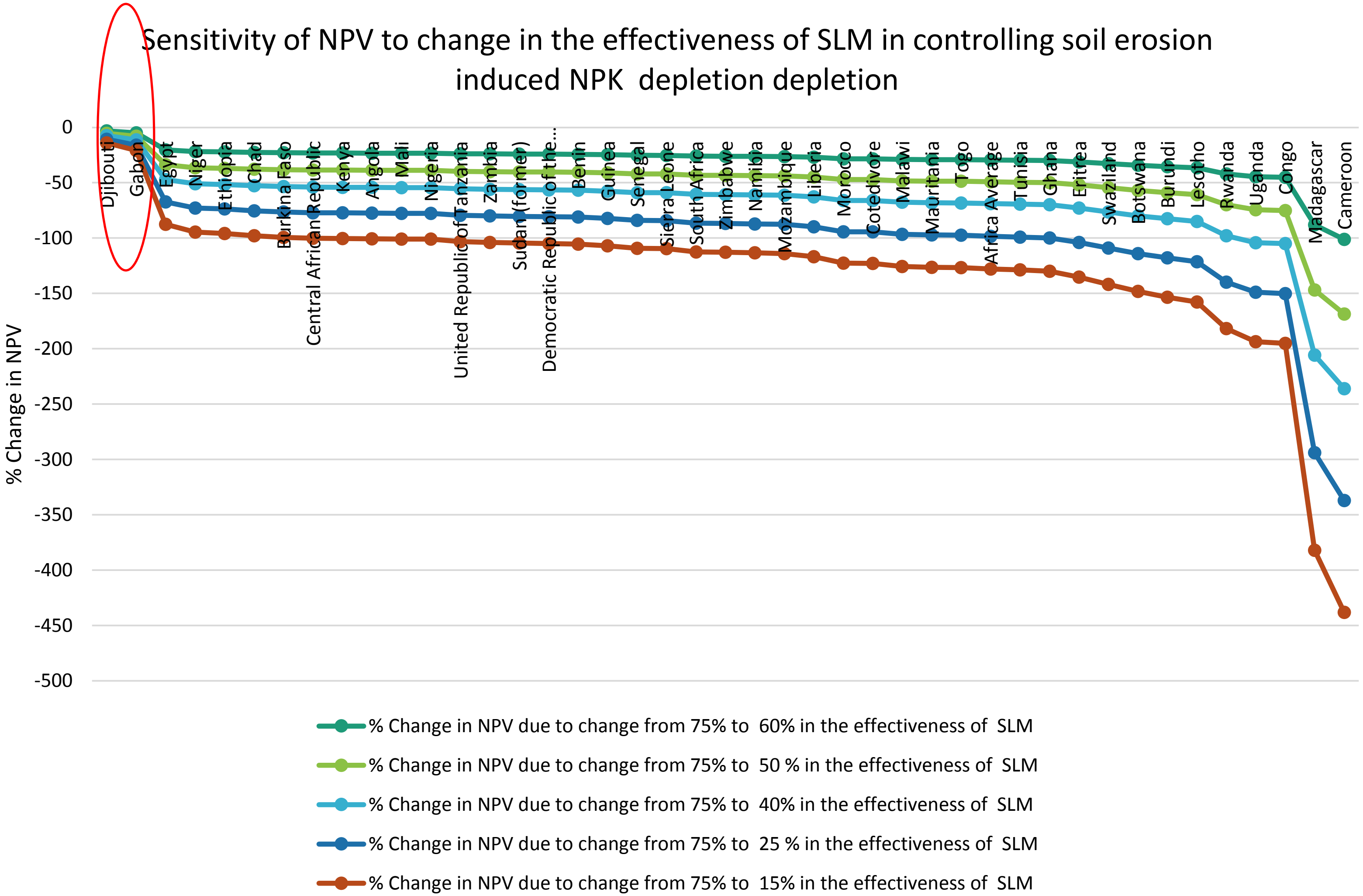
- BCR ≥1 for all countries except countries **(Djibouti, Gabon, and Madagascar)**



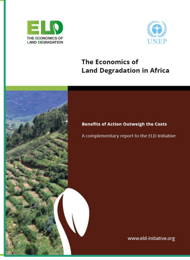
Chapters 2-4: Results: Sensitivity of NPV and BCR to changes in the effectiveness of SLM interventions in controlling soil erosion



- A decrease in the effectiveness of the SLM intervention from the base case 75% to lower rates (60%, 50%, 40%, 25% and 15%) will lead NPVs decline by a proportionally higher rates for all countries except Djibouti and Gabon.
- For a SLM intervention with only 25% effective rate of controlling soil erosion, 30 of the 42 countries will still have BCR ≥ 1.



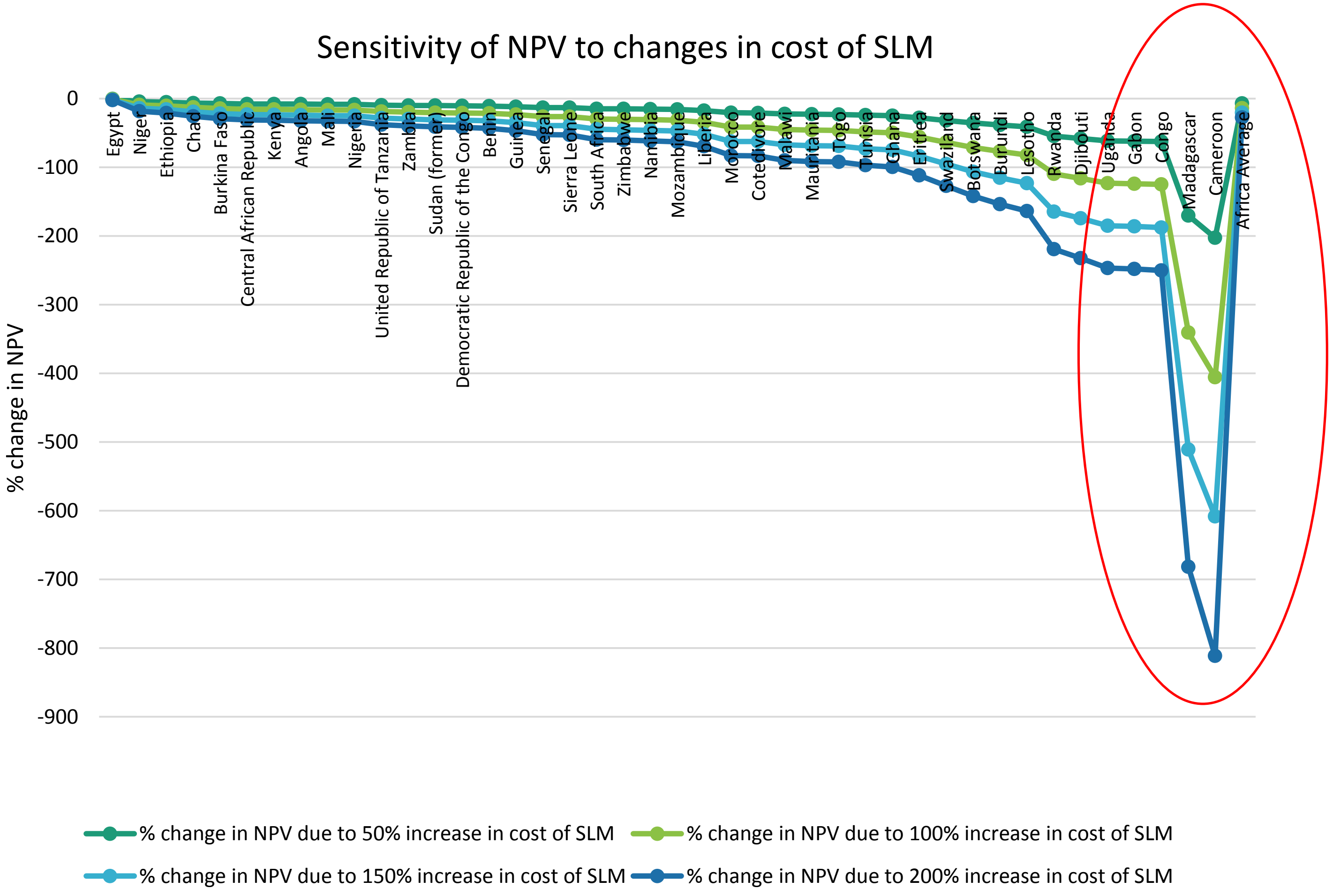
Chapters 2-4: Results: Sensitivity of NPV and BCR to changes in total costs SLM



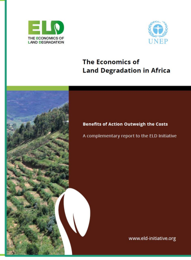
- A 50 to 200% change in the cost of SLM will result in a proportionally lower and opposite change in the NPV for all countries except (Djibouti, Gabon, Cameroon, Madagascar, Congo, Uganda, and Rwanda)

- A 200% increase in the total cost of SLM intervention will result in the sum of all NPVs of the 42 countries to decline by only 27.73%.

- Furthermore, for a 200% increase in costs of SLM, BCR ≥ 1 for all countries except (Djibouti, Gabon, Cameroon, Madagascar, Congo, Uganda, Rwanda, Lesotho, Burundi, and Botswana)



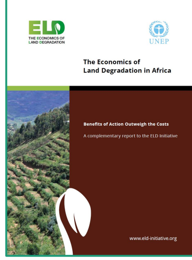
Conclusions



- NPK depletion from croplands in Africa has a positive and statistically significant correlation with poverty and the rate of soil erosion

- In the cropping seasons of 2010-12, from about 105 million hectares of cropland in the 42 African countries there was NPK nutrient:
  - Outflow of ≈ 11 million Mg/year
  - Inflows ≈ 5.8 million Mg/year
  - **Net balance ≈ -5.2 million Mg/year (≈ 50 Kg NPK loss per ha per year)**

- Top soil erosion and poverty induced nutrient depletions contributed:
  - about 43.2% and 7.4% of the outflow (or equivalent to 91.1% and 15.54% of the net loss per year)



Conclusions…

- *Africa is losing about **280 million tons of cereal crops per year** from about 105 million hectares of croplands, which account 45% of the arable land in the continent, due to annual depletion of about 4.7 million tons of NPK nutrient caused by soil erosion.*

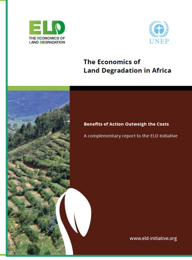
- *The present value of the **cost of inaction** to this loss over the next 15 years (2016-30) is about 4.6 trillion PPP USD with an annuity of 286 billion PPP USD/year (**127 Billion USD/year at 2011 constant dollar**) , which is equivalent to about 12.3% of the GDP of 42 countries in the continent.*

- *However, taking action through investment on sustainable land management will only cost about 344 billion PPP USD over the next 15 years with an annual **cost of action of about 9.4 Billion USD** or 1.15% of the GDP of 42 countries in the continent.*

- *Whereas the **benefits of taking action** is almost 7 times the cost of action. In other words, Africa could generate about 2.83 trillion PPP USD (or about **71.8 Billion USD/year**) if all countries take action against land degradation through investment on sustainable land management interventions.*

- *Hence, the **NPV of taking action** over the next 15 years = 2.48 trillion PPP USD (or **62.4 billion USD/year**).*

Conclusions



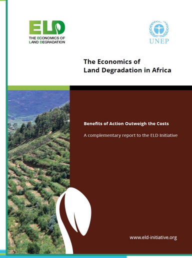
➢ *The sensitivity analysis indicates that at the regional level as well as for most of the countries covered in this study, the NPV of taking action against land degradation remains positive and considerably high to changes:*

- *in discount rates, prices of cereals,*
- *the costs and effectiveness of actions to control soil erosion*

➢ *Thus, in order to achieve a number the future* ***sustainable development goals (SDGs)*** *in the region, taking action against land degradation can optimally be integrated with poverty reduction policy measures and hence harness the benefits of sustainable natural resource management for:*

- *increasing national income,*
- *reducing food insecurity and*
- *reducing poverty in the region.*

Policy Implications



- Policy implications to achieving the SDGs (Goal 15.3, Goals 1 &2, and others)
  - Food security
  - Poverty reduction
  - Employment to rural people
  - Sustainable forest management
  - Livestock sector
  - Food prices
  - Avoiding further land degradation (extensive farming)

THNK YOU!

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