Supporting Online Information for

Climate change risks for African agriculture

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This PDF file includes

Table S1: 'Line of sight' from the key statement about African food security in the IPCC Synthesis Report (SYR) to underlying chapters and summaries

<table>
<tr><td>SYR</td><td colspan="5">"By 2020, in some countries, yields from rain-fed agriculture could be reduced by up to 50%.", preceding the main point in the associated paragraph: "Agricultural production, including access to food, in many African countries is projected to be severely compromised. This would further adversely affect food security and exacerbate malnutrition."</td></tr>
<tr><td rowspan="6">based on</td><td>WGII SPM</td><td colspan="4">"In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020", at the end of a paragraph on food security in Africa: "Agricultural production, including access to food, in many African countries and regions is projected to be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020". The WGII SPM conclusion is linked to sections 9.2, 9.4 and 9.6 which integrate present sensitivity, projected effects and interactions with non climate stressors to provide the basis for the conclusion.</td></tr>
<tr><td rowspan="5">referring to</td><td>WG II 9.4.4</td><td colspan="3">"In other countries, additional risks that could be exacerbated by climate change include greater erosion, deficiencies in yields from rain-fed agriculture of up to 50% during the 2000-2020 period, and reductions in crop growth period (Agoumi, 2003)." (1, page 448). The paragraph in which this text occurs describes a range of risks additional to those discussed in preceding paragraphs, including declines in net crop revenue and loss of national agricultural production in Egypt. In each case the "deficiencies in yields form rain-fed agriculture of up to 50% during the 2000-2020 period", are described as a climate change impact in Agoumi 2003 (2, page 5)</td></tr>
<tr><td rowspan="4">referring to</td><td>Agoumi 2003</td><td colspan="2">"Studies on the future of vital agriculture in the region have shown the following risks, which are linked to climate change: […] deficient yields from rain-based agriculture of up to 50 per cent during the 2000–2020 period", which in turn is based on <i>Initial National Communications to the UNFCCC</i> by three countries (Algeria, Morocco, and Tunisia)[1]:</td></tr>
<tr><td rowspan="3">referring to</td><td>Morocco 2001</td><td>Morocco projects cereal production to experience up to 50% reductions due to climate change: "The study of CC impacts on agriculture (dominated by cereal cultivation) in 2020 unfolds the following results: A decrease in cereal yields by 50% in dry years and 10% in normal years." (3, page 11)</td></tr>
<tr><td>Tunisia 2001</td><td>Tunisia does not assess any impact on agriculture: "As for the vulnerability, apart from the impact of Sea Level Rise, no study has been conducted, to this date, on the vulnerability of forests and continental agriculture to Climate Change, and on the identification of adaptation measures." (4, page 25)</td></tr>
<tr><td>Algeria 2001</td><td>Algeria applies assumptions on technological and management improvements that lead to considerable yield increases in 2020. Climate change impacts are projected to reduce cereal yields by 0.1 to 13.9% in 2020 (5, page 95, table 47).</td></tr>
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[1] Initial National Communications to the UNFCCC from Algeria, Morocco, and Tunisia, presented at COP-7 in October 2001. These communications are available at the Web site of the United Nations Framework Convention on Climate Change (UNFCCC).

Table S2: Recent studies about quantitative climate change impacts on African agriculture (published after IPCC AR4 WGII literature cut-off deadline, April 21, 2006)

Reference	Method	Reference area	Time horizon	Resolution	Max damage [%]	Min damage / max benefit [%]
Cline 2007 (6)	Ricardian	Africa	2080s	countries	-100	64
Benhin 2008 (7)[2]	Ricardian	South Africa	2050 2100	-/-	-27.74 -89.39	-1.15 -8.82
Liu et al. 2008 (8)	process-based model (GEPIC)	SSA	2030s	grid (30‘ lon / lat)	<-50	>+50
Liu et al. 2008 (8)	process-based model (GEPIC)	SSA	2030s	countries	<-20	>+20
Lobell et al. 2008 (9)	statistics	SSA	2030s	sub-regions	-40	+30
Paeth et al. 2008 (10)	statistics	Benin	2020s	Benin	-17	-9.1
Seo et Mendelsohn 2008 (11)	econometric, livestock sector	Africa	2020 / 2050 / 2100	-/-	-25	+168
Walker & Schulze 2008 (12)	process-based model (CERES)	South Africa	stylized scenarios (2070-2100)	catchments	-28	+33.8
Müller et al. 2009 (13)	process-based model (LPJmL)	SSA & North Africa/Middle East		regions	-12.9	+17.3
Nelson et al. 2009 (14)	process-based model (DSSAT)	SSA & North Africa / Middle East		regions	-84.2	+61.8
Seo et al. 2009 (15)	Ricardian	Africa	2100	Agro-Ecological Zones	-62	+135
Thornton et al. 2009 (16)	process-based model (DSSAT)	East Africa	2050	sub-regions	-15	-1
Thornton et al. 2009 (16)	process-based model (DSSAT)	East Africa	2050	grid (10’ lon/lat)	<-20	>+20
Thornton et al. 2010 (17)	process-based model (DSSAT)		2050	random selection of highly impacted grid pixels (10’ lon/lat)	-65	-35
Schlenker et Lobell 2010 (18)	statistics	SSA	2046-2065	-/-	-37	12
Schlenker et Lobell 2010 (18)	statistics	SSA	2046-2065	Maize in SSA countries	-57	-7
Tan et al. 2010 (19)	process-based	Bawku savanna zone in NE Ghana,	Time series but only 2100 is discussed	-/-	-41	52

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[2] Already assessed in the AR4 WGII report as ref. (*7*)

Table S3: Recent qualitative impact assessments of climate change on African agriculture (published after IPCC AR4 WGII literature cut-off deadline, April 21, 2006)

Reference	Method	Reference area	Time horizon	Statement
Burke et al. 2009 (20)	analysis of GCM projections	Africa	2025 / 2050 / 2075	“If breeding efforts cannot sustain yield for maize for these hottest climates in the face of warming temperatures, switches to potentially more heat-and drought tolerant crops, such as sorghum and millet, could be necessary.” “With maize, for example, 28% of the population of Africa lives in countries where less than half of the area will have an analog in the current climate of locations in their own country.”
Funk et al. 2008 (21)	empirical relationships, analysis of GCM projections	Eastern & Southern Africa	21st century	“These anthropogenic drought tendencies may be indicative of other ‘Indian Rim’ and South American countries as well, because similar precipitation reformulations also suggest 21st century main season declines (40), with the result that main growing season droughts may disproportionately affect tropical and subtropical countries. Global assessments of anthropogenic precipitation (13) and yield (18) changes may be underestimating these drought signals.”
Jones and Thornton 2009 (22)	analysis of GCM projections	Africa	2050	“Under even a moderate GHG-emission scenario for the coming decades, there are likely to be substantial shifts in the patterns of African cropping and livestock keeping to the middle of the century.” “Climate change impacts in some of the marginal cropping lands of Africa are likely to be severe, and poverty rates in these areas are already high. Results of this analysis suggest further that the poor in the more remote transition zones are likely to be disproportionately affected.”
Li et al. 2009 (23)	drought risk assessment, analysis of GCM projections	global	2050 / 2100	“Among the regions, Africa is ranked as the highest, with a baseline drought risk index value of 95.77 which increases to 205.46 in 2100 projections. Correspondingly, the rates of yield reduction related to drought disaster for major crops will increase significantly with future climate change, by >50% in 2050 and almost 90% in 2100 for the major crops.”
Battisti and Naylor 2009 (24)	historical analogues, analysis of GCM projections	global	2050	“If growing season temperatures by the end of the 21st century remain chronically high and greatly exceed the hottest temperature on record throughout much of the world, not just for these three examples, then global food security will be severely jeopardized unless large adaptation investments are made. Climate model projections from the IPCC 2007 assessment suggest that this outcome is indeed very likely (Fig. 3). Figure 3A shows that, as early as 2050, the median projected summer temperature is expected to be higher than any year on record in most tropical areas. By the end of the century, it is very likely (greater than 90% chance) that a large proportion of tropical and subtropical Asia and Africa will experience unprecedented seasonal average temperature [..]”
Blignaut et al. 2009 (25)	statistical analysis	South Africa	historic	“A 1% decline in rainfall is likely to lead to a decline in maize production of 1.16% and a decline in wheat production of 0.5%. Such a decline in rainfall is also likely to lead to a decline in net income in the most productive provinces.”

Text S1: Sources of uncertainty in recent assessments of climate change risks for African agriculture

The published impact assessments employ various methods, input data, and assumptions to project climate change impacts. For a better understanding of the different levels of uncertainty, we give a short overview of the different sources of uncertainty, comprising the level of aggregation, input data used (i.e. climate projections), other system dynamics considered (e.g., CO_2 fertilization, adaptation).

The first level of uncertainty in climate change impact assessments is inherent in the range of climate change projections, which are used as input for climate change impact assessments. Projections of climate change as provided by climate models are driven by emission scenarios. Emission scenarios are plausible future projections of energy demand and supply. These may include assumptions about technological progress (26) as well as other socio-economic factors, which are all inherently uncertain. Guided by the IPCC process, a broad range of possible emission scenarios has been implemented by a number of climate models, which also differ significantly in their projected patterns and magnitude of changing temperature and rainfall (27, 28). Nearly always, only a small selection of available climate change projections is used in impact assessments, and only occasionally the uncertainty inherent in different climate change projections is addressed explicitly (13). Most of the time, between two and five climate realizations are analyzed in parallel, or stylized scenarios are being employed (12). Climate scenarios are usually computed and provided at much coarser scales than typical operational scales of crop models. Most model applications need to downscale climate projections, adding a new dimension of uncertainty (e.g. 29). Consequently, most projections of climate change impacts on African agriculture exclude important aspects of climate change such as e.g. changes in short-term weather variability.

Impact models used to assess the effects of climate change on African agriculture employ a variety of methods that differ in their suitability for climate change impact projections. Statistical methods, both used in bio-physical as well as econometric analyses are generally unsuitable for extrapolation to novel conditions. Climate change is projected to move weather patterns out of the range of observed variability (20), limiting the applicability of statistical methods. Econometric models are strongly limited by data availability, as they derive statistical relationships between farmers' incomes, production systems and environmental conditions (15). Statistical models that describe agricultural productivity as a function of weather conditions often have little explanatory power (9). Process-based models are often limited by the lack of site-specific parameterization of management options and varieties (13, 14) and the risk of over-tuning (30).

The level of aggregation is another reason for differences in reported impact ranges. For specific locations and crops, impacts are reported to range between severe damages and significant increases: Some regions in Africa are likely to undergo changes to more severe conditions (drier, hotter) (21), while others may experience improved cropping conditions (wetter, warmer in temperature-limited highlands). Crops also respond differently depending on their sensitivity to changing heat, water stress, and possible CO_2 fertilization. Wheat, for example, has a low temperature optimum and is projected to experience strong yield reductions in Africa, while millet, with its higher temperature optimum, is projected to mainly benefit from climate change (8, 14). The complexity of different cropping systems, crop types, and crop varieties is often poorly represented in impact models, although there are attempts to link crop variety parameters to environmental conditions, assuming an adaptation of crop varieties to climate change (31). Due to the heterogeneous spatial patterns of climate change and the complexity of cropping systems, reported climate change impacts tend to be more moderate if reported at higher aggregation levels, as positive and negative responses to climate change may cancel out. This has been demonstrated by e.g. Liu et al. 2008 (8) and Thornton et al. 2010 (17), who provide results at grid cell level as well as national summaries.

Uncertainties from climate forcings and impact models are compounded by system dynamics other than climate change and the assumptions that are being made about them. One of the most crucial aspects is the direct impact of enhanced atmospheric CO_2 on plant growth, which should principally be capable of increasing crop yields considerably due to two processes: i) enhanced carbon assimilation rates, and ii) improved water-use efficiency (32). There is some experimental evidence for “CO_2 fertilization” in various crops such as wheat and cotton (33), but the validity of these findings for larger regions and entire cropping systems is uncertain. First of all, increased carbon assimilation rates can only be converted into productive plant tissue or the only economically relevant part, the harvested storage organs, if sufficient nutrients are available to sustain the additional growth. Where growth is already constrained by nutrient limitations, additional growth will be very limited (33). On top of that, there are indications that key factors of quality of agricultural products may decrease under increased CO_2, e.g., by reduced protein content (34). Some crops grown under elevated CO_2 have been found to be more susceptible to insects and pests (35, 36) or display reduced ability to assimilate nitrogen (37).

Other examples of non-climatic drivers of change include the development of management schemes, technological progress, land-use change, or soil degradation. For some of these non-climatic drivers of change, adaptation may be assumed to occur easily (e.g., by adjustment of cropping periods with changing climate), others are unlikely to happen without major adaptation efforts (24). For a more detailed discussion of non-climatic drivers of changes in agricultural productivity see Chalinor et al. 2007 (30).

Text S2: Additional explanations to the figure in the main text

The reference Ben08 (7) had already been assessed for the AR4 WGII report as (38); Seo08 refer to the livestock sector only; Tho10 report pixel-based results only for a random selection of strongly impacted pixels; Sch10 show country data only for maize; Wal08 employ stylized scenarios that are representative for the climate in 2070-2100; Tan10 refer to NE Ghana only.

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