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### **Impacts of climate variability and change on development and water security in Sub-Saharan Africa**

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Climate change is likely to have the most severe impacts on developing countries. Most of the least developed countries already face a climate with unpredictable rainfall and future climate change is likely to increase water stress and make water availability less reliable. The future development of many poor countries depends heavily on water. Water availability is usually related to rainfall and due to significant climate variability in many developing countries water availability is often unpredictable. Both insufficient rainfall (droughts) and too much rainfall (floods) have significant impact on development. In this paper we focus on the impacts of climate variability and water availability on the development of countries in Sub-Saharan Africa. To study the relationship between climate variability and development we used annual data on rainfall and total and agricultural GDP growth rates from 1979 until 2001 for most countries in Sub-Saharan Africa. In addition, we analyzed per capita water storage availability and estimated the investments needed to improve water security of African countries. A panel data regression analyses of the historical data showed that climate variability has a clear impact on GDP growth rates. Most countries outside the central African tropical zone, show the highest total and agricultural GDP growth rates during years with average or slightly above average rainfall. The impact of climate variability on GDP growth however is more pronounced during dry than during wet years. During below average rainfall years growth is severely reduced and generally the dryer the lower the GDP growth rate. All above average rainfall years tend to have relatively similar growth rates. Assuming that future relations between rainfall and GDP growth are similar to historic relations, a vulnerability analyses was done assuming that rainfall would become more variable. In all African regions, except Central Africa, a climate with increased rainfall variability would reduce GDP growth. The Sahel region turned out to be most vulnerable to changes in rainfall variability, a 50% increase in the standard deviation of annual rainfall would reduce GDP growth by 35%. In East Africa and coastal West Africa a 50% higher s.d. of annual rainfall would result in about 20% less growth. In Southern Africa, the impact of increased rainfall variability are relatively small. Future development of African countries is more vulnerable to a drier future climate than to increases in rainfall. A 10% reduction in rainfall could result in 12% lower GDP growth rate in Southern Africa and 43% in the Sahel region. Especially a combination of a drier and more variable climate can have a large impact on GDP growth. Using the output of six different Global Circulation Models (GCM) we analyzed what the impact is of increased greenhouse gas concentrations on changes in average rainfall and inter-annual rainfall variability. Lower rainfall is projected for most Southern African countries while East African countries are likely to see more rainfall. Interannual rainfall variability in African countries is projected to increase by 10 to 40% by the end of the century. GCM outputs indicate that rainfall variability will especially increase in Central and West African countries. Using the projected changes in rainfall and assuming that historic correlations between development and rainfall can be used for the future we made projections of the impact of climate change and GDP growth rates of African countries. Results show that in West and Southern Africa, growth rates will reduce between 10 and 20% by 2050 due to changes rainfall. In Southern Africa the reduction is caused by a drier climate while in West Africa the lower growth rates are due to a more variable rainfall pattern. Developed countries with a high climate variability such as Australia, the US and some European Mediterranean countries have developed large reservoirs to buffer the impacts of variable rainfall. An analyses of water storage capacity of Sub-Saharan countries shows that most countries in Africa have very low storage capacities. The only exceptions are some countries in Southern Africa. Several countries have also seen a reduction in storage capacity per capita during the last decades due to a growing population and a lack of investment in water infrastructure. To achieve water security, we assumed that African countries would need on average 750 m<sup>2</sup> per capita storage based on the current situation in South Africa. For most African countries significant investment would be needed to achieve this minimum storage capacity. For example, if countries would invest 5% of their GDP in water infrastructure it would still take East African countries on average between 40 and 70 years to create enough storage. In West Africa it would take between 20 and 40 years. In conclusion, our results show that climate variability has a significant impact on the development of African countries. If African countries want to achieve steady economic growth it is

necessary that countries become less vulnerable to climate variability. Also without adaptation, future climate change is likely to slow down economic growth of West and Southern African countries. To reduce the impact of climate variability and change on African countries significant investment in water infrastructure is necessary in addition to a range of other non-structural measurers.