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Big Data Climate Challenge – Climate Summit 2014

Project title

Development under Climate Change (DUCC): An Application to South Africa

Executive summary

UNU-WIDER, in collaboration with external partners, has progressively developed an analytical framework called Systematic Analysis of Climate Resilient Development (SACRED) that integrates comprehensive biophysical and economic analysis. This framework traces the implications of changes in climate outcomes through a series of important impact channels including production of hydropower, agricultural yield, water supply/demand balance, and costs of maintaining infrastructure and other installed capital. These impacts then serve as inputs into an economywide model of the country in question in order to consider economic impacts and policy options. One of the unique aspects of the SACRED framework is explicit treatment of the considerable uncertainties associated with projections of climate change at the country and regional levels. The SACRED framework incorporates distributions of climate outcomes allowing evaluation of robust adaptation strategies. Focusing on distributions of climate outcomes represents an inherent step into big data.

Variants of the SACRED framework have been applied to eight developing countries. Here, we focus on recent analysis for South Africa. We conduct analysis of 367 future climates that represent the best available estimate of the distribution of potential climate outcomes in South Africa by 2050. All subsequent biophysical and economic analysis steps occurred at the level of South Africa's 19 water management areas or a finer level of disaggregation, including (notably) the economywide analysis. All modelling was also run dynamically to 2050. Overall, the study distils results from an extraordinary volume of data and represents one of the most detailed analyses of climate change impacts and adaptations options ever undertaken for a developing country.

The total impact of climate change on the level of real GDP by 2050 is found to range between negative 3.8% and positive 0.3%, with the very large majority of climate futures resulting in negative GDP impacts. The median result shows that by 2050, South Africa's real GDP level will be about 1.5% lower than in the baseline scenario. The net present value of the potential impact on GDP by 2050 is highly variable, ranging from losses of ZAR 930 billion to gains of ZAR 310 billion (real 2007 South African Rand). The median loss in net present value is approximately ZAR 259 billion which, at more than 10% of 2007 GDP, is sizeable. Importantly, results in the water sector suggest that climate change will have a limited impact on water supply in most regions, largely as a result of the high level of development and integration of South African water supply infrastructure. Finally, there are numerous cases where the impacts, particularly on dry land agriculture in vulnerable regions, become large and highly variable across climate futures. The potential for strong impacts on agriculture are cause for concern given the concentration of poor households whose livelihoods depend on agriculture.

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Project background and context

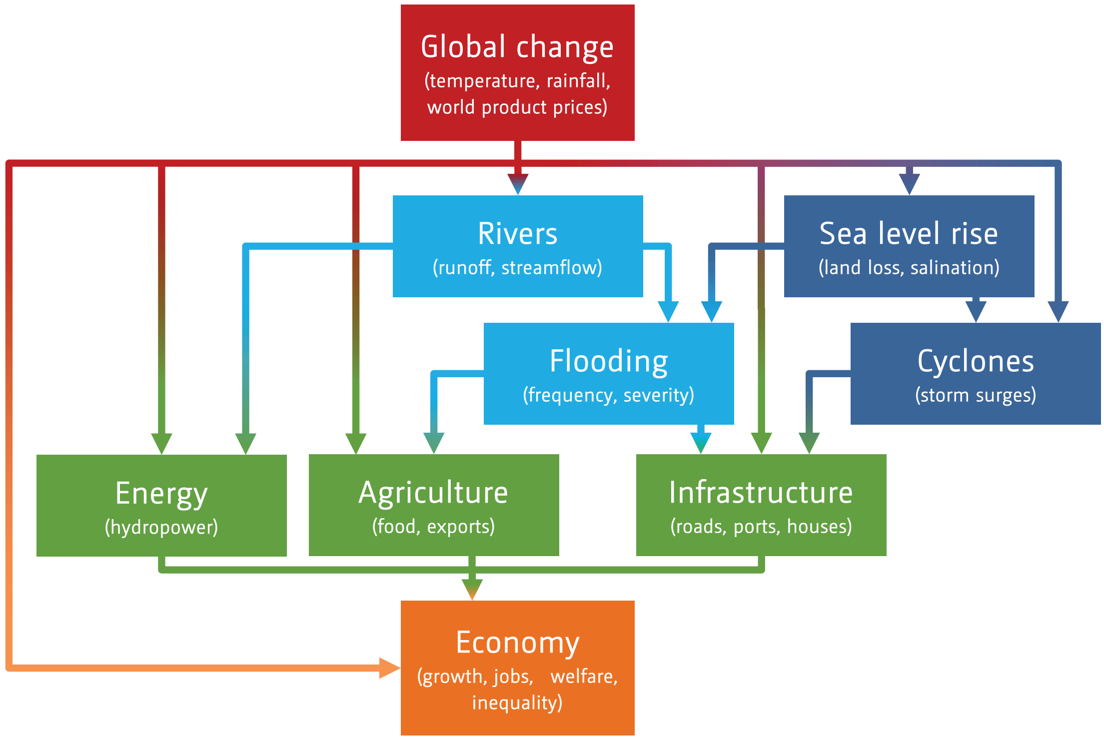
The 'Development under Climate Change' (DUCC) project began implementation in 2010. At that time, there were remarkably few researchers and government officials in developing countries who had considered in detail the interactions between climate policies and development policies. In the view of UNU-WIDER, the lack of broad based understanding of climate change and climate change issues in the large majority of developing countries was deeply problematic. This view was strongly reinforced by the reality that climate change is likely to remain a serious issue for decades to come if not indefinitely. One of the difficulties in assisting policy-makers in developing countries address the uncertainties of climate change is to translate scientific and biophysical processes into economic outcomes, which can then be addressed through policy. Understanding the impacts of climate change and its links to development policy therefore requires a range of methodologies and a multidisciplinary team.

Consequently, the project explicitly opted for a broad approach to policy engagement and research uptake. The project has sought not just to contribute to improved policy-making today but also to contribute to the development of a firm basis for improved policy-making into the future. As such, the project engaged in multi-disciplinary research, vigorous dissemination, innovative training using distance techniques, curriculum development, joint research and training including transfer of tools, and engagement with decision-makers both within and outside of governments.

Methods

To meet these goals, UNU-WIDER, in collaboration with external partners, has progressively developed an analytical framework called Systematic Analysis of Climate Resilient Development (SACRED) that integrates comprehensive biophysical and economic analysis. The impacts and adaptations side of the SACRED framework is illustrated in Figure 1.

Figure 1
Systematic Analysis for Climate Resilient Development (SACRED) framework



Source: UNU-WIDER

The framework begins with global climate change as regionally projected for a particular country. Climate change manifests itself as change in expected levels for temperature, precipitation, barometric pressure, humidity and other weather outcomes. However, with this information alone, it is not credible to assess the potential impacts of climate change on many variables of interest such as economic growth, development prospects, and the material well-being of the population. The SACRED framework links climate outcomes to economic outcomes by quantifying the implications of changes in climate outcomes through a series of important impact channels including production of hydropower, agricultural yield, water supply/demand balance, and costs of maintaining infrastructure and other installed capital. These impacts then serve as inputs into an economywide model of the country in question. The economywide models employed respect macroeconomic identities, meaning that all simulated futures are economically coherent, and account for multiple simultaneous impacts. For example, higher levels of rainfall may be favourable for hydropower generation and agricultural production but unfavourable for road infrastructure due to washouts or widespread flooding.

Variants of the SACRED framework have been applied to Ethiopia, Ghana, Malawi, Mozambique, South Africa, Tanzania, Vietnam and Zambia. Here, we focus on results for South Africa as the most recent and advanced application of the framework. The South Africa study also formed an integral part of the Long Term Adaptation Scenarios (LTAS) framework developed by the South African government and partners in order to begin integrating climate change adaptation responses cross-sectorally and in the context of development aspirations. The study represents the first attempt at an integrated approach to assessing the potential impacts of climate change on the national economy of South Africa looking out to 2050.

An advantage of working in South Africa is the ability to incorporate local modelling frameworks into the analysis. These local models have been used, validated and improved over extended time periods. In addition, researchers, technical staff within government and many policymakers are familiar with the inner workings of these models and comfortable with the results produced. For runoff, a variant of the WRSM2000 catchment model (popularly known as the Pitman model) was employed. This model was linked to the WRYM model of the Department of Water Affairs for analysis of water resources. South African irrigation demand and dryland crop yields were also employed. For infrastructure, a recently developed infrastructure planning model was calibrated to South African data (Chinowsky et al. 2013). The main economic analysis was conducted on the basis of an economywide model that has been employed in the National Treasury for more than a decade (Thurlow 2004). Climate change scenarios were developed using the Integrated Global Systems Model (IGSM) of Sokolov et al. (2009) combined with regionalization techniques developed by Schlosser et al. (2012). These forecasts were cross checked against results from downscaled climate models for South Africa (Hewitson and Crane 2006).

Data used

One of the unique aspects of the SACRED framework is explicit treatment of the considerable uncertainties associated with projections of climate change at the country and regional level. In many developing countries, policy recommendations have been proposed on the basis of a distinctly limited number of future climate scenarios. For specific countries and regions, this is potentially highly problematic. To give one simplified example, it may be unwise to invest in countering decreased precipitation based on a handful of scenarios that indicate drying if, in fact, increased precipitation is equally likely. For Malawi, Mozambique, South Africa, and Zambia, the SACRED framework analysis employed distributions of climate outcomes allowing evaluation of robust adaptation strategies including insights into the sequencing of adaptation policies.

Focusing on distributions of climate outcomes represents an inherent step into big data. The methodology of Schlosser et al. (2012) generates 6800 fully detailed future climates per emissions scenario. These climates are designed to represent the range of possible climate outcomes for South Africa by 2050. Complete biophysical and economic analysis of 6800 future climates is impractical. Arndt et al. (2014) developed an informed sample selection technique based on numerical integration theory to select a sub-sample of 367 climates that represent the complete distribution. All subsequent biophysical and economic analysis steps occurred at the level of South Africa's 19 water management areas or a finer level of disaggregation. This included the economywide analysis, which represents a very rare if not unprecedented level of disaggregation for an economywide analysis of a developing country. All modelling was also run dynamically to 2050. Overall, the study distils results from an extraordinary volume of data.

Results

The study considers outcomes to about 2050 and focuses on the potential impacts of climate change on the water supply sector, dry-land agriculture, hydropower, roads infrastructure costs and sea level rise. It represents one of the most detailed analyses of climate change impacts and adaptations options ever undertaken for a developing country.

The study considers two future global emissions scenarios: an Unconstrained Emission Scenario (UCE) where global policies to reduce emissions fail to materialize and a Level 1 Stabilization Scenario (L1S) where aggressive emissions reduction policies are pursued. For reasons of space, we focus here on the UCE climate scenarios. For the UCE scenario, 367 possible climate futures were extracted from the Integrated Global System Model (IGSM) developed at the Massachusetts Institute of Technology. The 367 climates contain both 'wetter' and 'drier' futures. As noted, the South African climate futures developed specifically for LTAS fall within the ranges of the sets of climate outcomes considered.

Results in the water sector suggest that climate change will have a limited impact on water supply, largely as a result of resilience due to the high level of development and integration of South African water supply infrastructure. This resilience was developed in response to a history of variable rainfall, typical of a subtropical semi-arid region. In particular, the impacts on the main urban and industrial centres in Gauteng appear to be minimal and could even be positive due to the integrated nature of the Vaal system, the planned development of the Lesotho Highland Water Supply System and the fact that many of the global climate scenarios show potential wetting over the Eastern half of the country including Lesotho and the Upper Vaal, which are sources for the country's largest rivers.

In contrast, the results show all models predicting a reduction in stream-flow in the Western Cape including the Berg River catchment. The potential for constrained supply in the future may imply reallocation of water from agriculture to urban and industrial demand for Cape Town, because the Western Cape is not integrated into the national water system due to geography. The greatest negative impact on future water supply is in the Gouritz Water Management Area (WMA) where urban and bulk water supply are dependent on smaller and less integrated local resources and the climate models predict likely future drying.

Impacts on irrigation demand vary across the country, with increases in some areas, notably the East coast and KwaZulu Natal, potentially being offset by increases in precipitation. Overall, the median impact on irrigation demand is around +5%. This is not considered to be significant as there is potential that these increases can be addressed through improved irrigation practices and the development of new crop varieties, recalling the 2050 time frame.

The potential impact on dry-land crop yields are mixed with some crops showing an increase in yields, while others show a reduction in potential yields. Of most concern is the likely reduction in the total average annual yields from maize and wheat of around 3.5% and 4.3% respectively for the median impact scenario by 2050. There is, however, a very wide range of potential impacts going from a 25% reduction in the total average annual maize yield to a possible increase of 10% under some very wet scenarios.

The study of potential impacts on roads infrastructure shows significant advantages in implementing adaptation options to the repair and rehabilitation of the existing roads network. Given that the average design life of a major road is 30 years, it is important that adaption measures are implemented sooner rather than later. This is so because the least cost mode for implementing adaptation measures in roads is during initial road construction or major road rehabilitation.

The study of potential economic implications showed significant impacts resulting from additional roads infrastructure costs and variability in dryland agricultural yields, with only limited impacts due to variability in the ability to supply future water demands. The total impact of climate change on the level of real GDP is found to range between -3.8% and 0.3%. For the very large majority of climate futures, the impact on total GDP will be negative. The median result shows that by 2050, South Africa's real GDP level will be about 1.5% lower than in the baseline scenario. This however translates into only a 0.03 percentage point decline in average annual real GDP growth rate.

These aggregate results mask very significant impacts at disaggregated spatial and sectoral levels. There are numerous cases where the impacts, particularly on dry-land agriculture, become large and highly variable across climate futures. The potential for strong impacts on agriculture are cause for concern given the concentration of poor households whose livelihoods depend on agriculture. In addition, while the GDP growth costs are relatively small, climate change typically imposes consistent losses through time, which can be captured through calculation of the net present values of losses (NPV) in GDP to 2050. This NPV is highly variable, ranging from losses of R 930 billion to gains of R 310 billion (real 2007 Rand). The very large majority, 96%, of climates scenarios show overall losses. The median loss in net present value is approximately Rand 259 billion which, at more than 10% of 2007 GDP, is sizeable and should motivate for action in terms of both mitigation and consideration and funding of potential adaptation scenarios.

Employment growth is, both in the economic model used for the analysis and in reality, vastly more sensitive to labour market policies and institutions. Consequently, the potential impacts of climate change, at least at the national scale were found to be overshadowed by these other uncertainties. The modelling does clearly illustrate that a more flexible labour market is likely to provide resilience under future climate and other uncertainties as it allows for the movement of labour and other resources (land, water and capital) between regions and between sectors that are more or less impacted by climate change.

Replicability and scalability

As noted, variants of the SACRED framework have been applied in Ethiopia, Ghana, Malawi, Mozambique, South Africa, Tanzania, Vietnam, and Zambia. As a general rule, the project has relied progressively more on local analysts and locally developed models, with South Africa as the leading example of this trend to date. The framework is flexible enough to be applied in nearly any country though the degree of detail of the analysis will vary with data availability and local capabilities.

In terms of scalability, UNU-WIDER has been working with partners in Africa on energy investment choices. The immense potential for hydropower on the African continent has been a driver of this research. However, hydropower is susceptible to both weather variability and climate change. Consequently, the uncertainty approach that underlies the SACRED analytical framework has valuably transferred over to the analysis of various energy production build plans. UNU-WIDER and partners are in the process of analyzing pan-African energy systems rooted in hydropower and complemented by other renewable sources such as solar and wind power. The costs and economics of these systems can then be prepared to traditional fossil fuel based energy production systems.

Scientific outputs

A listing of the scientific outputs of the project can be found at: http://www.wider.unu.edu/research/current-programme/en_GB/development-under-climate-change_1/. Notable outputs include a special issue of the Review of Development Economics, significant contributions to a forthcoming special issue of the Journal of African Economies, three articles accepted into a forthcoming special issue of Climatic Change, and individual articles related to the SACRED framework or the expansion of activities into the economics of mitigation published in Applied Energy, Climatic Change, Global Environmental Change, Journal of Climate, South African Journal of Economics, and Sustainability Science. Work on mitigation policies and climate change/variability is under consideration as a special section of Applied Energy. The work in South Africa is scheduled to be published as part of the LTAS process.

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