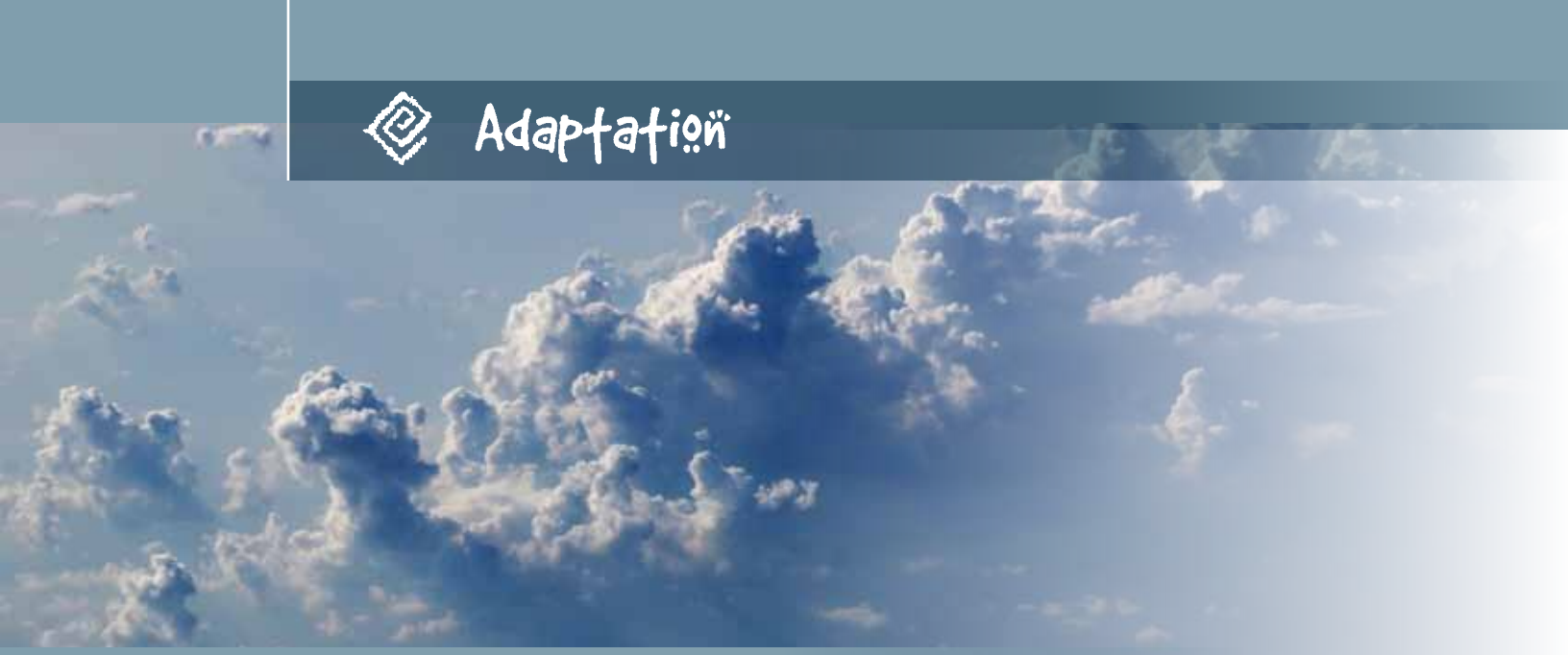

CCAA PERSPECTIVES

Managing uncertainty in adaptation

Guy Jobbins
Senior Program Officer, Climate Change Adaptation in Africa program

Introduction

This paper discusses some of the uncertainties that arise in complex, multidisciplinary research, and how these uncertainties are understood and dealt with by researchers and decision-makers. It draws on the experience of the Climate Change Adaptation in Africa (CCAA) program, which supports 46 participatory action research and capacity development projects in 33 countries oriented towards changes in adaptation practice and policy. Based on the experiences of these projects, this paper highlights some limitations on the use of research results in sound climate change adaptation decision-making in Africa, and questions how future research and programming can be oriented to address these constraints.

These are important questions, because in African societies there are a large number of development challenges, and limited resources to meet them. Climate change is an additional stress on development, and one which could have negative effects on development strategies and decisions that do not account for it appropriately. It is therefore important to ensure that development decisions account for the potential impacts of climate change. It is equally important that initiatives focusing on adaptation to climate change do not waste resources, and do not exacerbate development challenges, poverty, or climate vulnerabilities through poor decisions.

To that end, the role of researchers is to reduce uncertainties regarding climate impacts and consequences of adaptations wherever possible, and to clarify and communicate the remaining uncertainties appropriately in their results and recommendations. However, the ability of decision-makers and their institutions to exercise sound judgment in the use of such results is at least as important as the ability of researchers to produce them. Yet, as this paper describes, there are challenges with both sides of this equation. Researchers struggle to manage uncertainties in complex multidisciplinary research and communicate them appropriately, and decision-makers and institutions may not be equipped to account for scientific uncertainties appropriately in decision-making.

IDRC CRDI

DFID Department for International Development

Jobbins, Guy, 2011. Managing uncertainty in adaptation. International Development Research Centre, Ottawa, Canada. Climate Change Adaptation in Africa Perspectives series.

Acknowledgements

The author would like to thank Fatima Denton, Simon Carter, John Stone, Michele Leone, Jabavu Nkomo and Nathalie Beaulieu for their insightful comments on drafts of this paper.

Please send enquiries and comments to ccaa@idrc.ca

About CCAA

The Climate Change Adaptation in Africa (CCAA) program was launched in 2006 and is jointly funded by Canada's International Development Research Centre (IDRC) and the United Kingdom's Department for International Development (DFID). It is hosted and managed by IDRC from headquarters in Ottawa and three regional offices in Africa.

Web site: www.idrc.ca/ccaa

About IDRC

IDRC is a Canadian Crown corporation that works in close collaboration with researchers from the developing world in their search for the means to build healthier, more equitable, and more prosperous societies.

www.idrc.ca

About DFID

DFID is the part of the UK government that manages Britain's aid to poor countries and works to get rid of extreme poverty.

www.dfid.gov.uk

About CCAA Perspectives

CCAA Perspectives papers are authored by members of the Program Management Unit of the Climate Change Adaptation in Africa program. They draw on insights derived from oversight of research supported by the program, and the professional experience of individual authors. The series includes a mix of short, topical papers which are reviewed by colleagues at the International Development Research Centre, and longer working papers which are reviewed internally and externally.

CCAA Perspectives can be accessed in electronic format at www.idrc.ca/ccaa. Hard copies are available upon request.

The problems of uncertainty in adaptation research

Uncertainty does not simply refer to the distribution of points around a mean, which can be treated with statistical methods to evaluate confidence. Nor, as argued by Frank Knight (Knight 1921), is uncertainty equivalent to risk, which can be measured and quantified. Rather, uncertainty is the cumulative effect of errors, approximations, assumptions and ignorance that can overwhelm the validity of research results. Although there are numerous ways of classifying and discussing uncertainty (Metz et al. 2007), here I will use a simple taxonomy of three broad sources that are roughly parallel to Donald Rumsfeld's notorious typology[1]: statistical uncertainty, corresponding to errors in measuring "known knowns"; process uncertainty, largely related to "known unknowns" about how variables in a system interact; and ignorance, which equates to "unknown unknowns".

Data – or statistical - uncertainty arises from poor historical records, poor experimental design, miscalibration of parameters, interpolating data from different sources, human error, and other such sources. It is a common problem, for example, when trying to predict the impacts of sea level rise in coastal areas without precise topographical surveys. If available map data is based on a 90-meter grid, then assessments of a 1-meter sea level rise have to be treated with caution, because 1 meter is much less than the resolution of the base map. The resulting assessment can be useful as a rough approximation in the absence of better information, but it remains a rough approximation. The availability and reliability of data in much of Africa remains an ongoing challenge: census data cannot always be taken at face value, the quantity and quality of meteorological data is patchy across much of the continent, and high resolution digital maps are often either unavailable or beyond the budgets of researchers. The paucity of basic data is one reason for programs such as ClimDev, which has the laudable goal of improving the provision and use of climate information across Africa. Most CCAA projects have not had the development of basic data as a primary objective, but rather as a secondary objective to feed their goals in innovative applied research. However, as we shall see later, several research teams have found that a key benefit of their projects to local stakeholders has been to provide them with such data.

Process uncertainty arises from incomplete understanding - or simplifications - as to how variables interact in a dynamic system, leading to systematic errors in results. This is perhaps the largest source of uncertainty in most of CCAA's research projects, which attempt to understand complex problems such as food security, or how to reduce climate change impacts on human health. In many research projects it is not always clear what all the pertinent variables even are at the beginning of the research process, let alone how they might be isolated and experimentally controlled. For example, in a project run by the Moroccan Institut National de la Recherche Agronomique[2], it became clear in the course of the research that the communities in the two study sites contrasted markedly in their willingness and capacity to engage in adaptation efforts. Amongst the factors that might account for this difference between the two communities, the research team noted geographic determinants such as access to urban markets and public services, social aspects such as cultural values, and socioecological issues such as per capita water supplies[3]. Clearly, these possible causal factors imply different kinds of solutions, but it remains unclear which factors, or which combination of factors, were most significant, and further phases of research would be necessary to investigate further and draw firmer conclusions.

In many research projects it is not always clear what all the pertinent variables even are at the beginning of the research process, let alone how they might be isolated and experimentally controlled.

Such initial phases of new research are important in terms of exploring the issues and identifying areas for further enquiry. Exploratory phases of research can produce

1 "There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we now know we don't know. But there are also unknown unknowns. These are things we do not know we don't know." – Donald Rumsfeld, 2002 press conference. Despite some mockery at the time, Rumsfeld was providing a valid typology for uncertainty. To that list, for pleasing symmetry, could be added "unknown knowns", knowledge we do not know that we possess, such as biases and prejudices.

2 Moroccan Coastal Management : Building Capacity to Adapt to Climate Change

3 Counter-intuitively, it was the community with scarcer water resources that was less interested in adaptation.

useable policy recommendations, but there are often higher levels of uncertainty regarding the costs and benefits of decision-makers adopting such recommendations. Hence the desirability of multiphase research projects, where initial exploratory work iteratively refocuses and refines both the variables of research and the knowledge of those variables.

The ability to communicate uncertainties surrounding recommendations to decision-makers relies on the ability of the research team to manage uncertainties internally, which is particularly difficult across research disciplines.

The third source of uncertainty, ignorance, arises from unknown processes or mechanisms – the "unknown unknowns" of Rumsfeld's phrase. These can arise from limitations of current human knowledge or from deeper ontological problems about things that cannot be known (Bhaskar 2010). Models cannot contain all possible variables and all possible interactions, and as the global climate, economy, human technology and so on evolve, emergent phenomena are likely to arise that we have no reasonable way of anticipating. The further into the future one looks, the more this type of uncertainty becomes pertinent. Researchers are largely constrained to extrapolating existing trends into the future, but what trends in 1960 would have indicated the significance to African development of the internet or HIV/AIDS in 2010?

The response by many CCAA projects to this type of uncertainty has been to address drivers of vulnerability and build adaptive capacity in the communities with which they work. Vulnerability can be considered as a function of stresses and shocks, sensitivity to those stresses and shocks, and the capacity to adapt to them. When specific shocks and stresses can be anticipated, specific adaptations can be developed in response. In other cases, the ability to withstand unanticipated shocks and stresses can be enhanced by reducing sensitivity[4] to them by reducing fundamental drivers of vulnerability, such as poverty. The community's capacity to adapt to environmental, economic and social changes can be strengthened also, so that they are better prepared to respond appropriately to future conditions.

For example, a CCAA project in Benin[5] has worked with farmers, researchers, NGOs and government officials. Amongst its activities it has developed field schools and experimental trials of agricultural techniques, enhanced access to climate information, enabled the broadcast of severe weather warnings on community radio, and improved food security. These actions include specific adaptations to specific climate hazards, such as increased flooding, but also include activities strengthening adaptive capacity, such as agricultural experimentation, and addressing drivers of vulnerability, such as improving food security. The project therefore includes different types of adaptation activities, some focussing on climate vulnerabilities specifically, and others addressing the general robustness of the community to shocks and stresses.

Process uncertainty and ignorance are often grouped together and referred to as 'systematic uncertainty', i.e. they are based on theoretical and conceptual shortcomings leading to systematic errors. One ideal goal of researchers is to reduce systematic uncertainties to statistical uncertainties, meaning that all variables and processes are completely understood and the only sources of uncertainty would be due to errors in measurement and so on. Another ideal is to reduce statistical uncertainties towards zero by improving methods and tools for data collection. Although science is always advancing and scientists will and should always focus on these goals, both goals are ultimately unachievable in practice.

Reducing uncertainty where possible, and learning to live with that which remains, can be a more pragmatic, immediate approach for providing information and recommendations to decision-makers, as we shall see later. However, the ability to communicate uncertainties surrounding recommendations to decision-makers relies on the ability of the research team to manage uncertainties internally, which is particularly difficult across research disciplines. This raises the challenge of managing multidisciplinary research projects.

4 This is frequently framed as increasing resilience, rather than reducing sensitivity.
5 Strengthening the Capacity to Adapt to Climate Change in Rural Benin led by Initiatives pour un développement intégré durable.

The exercise of clarifying uncertainties is a fundamental step in managing and living with uncertainties, and also requires expert judgement from researchers.

The challenges of multidisciplinary research

In order to identify, screen and propose appropriate recommendations for the complex problems found in applied settings, adaptation researchers need to deal with a further challenge of methodological complexity – multidisciplinary research[6]. For example, a CCAA project in South Africa[7] supporting equitable water-use policies in the face of climate change is drawing on expertise in regional climate modeling, economic modeling, regional hydrologic modeling, and taking into account policies, plans and technological options for increasing water supply and reducing water demand. These provide information/inputs that feed into dynamic programming models, yielding results with important implications for policy, climate and water demand scenarios. These disciplinary components are each accompanied by different methods, and different sources and means of dealing with uncertainty. Understanding how these issues are dealt with in the different disciplines is crucial in developing and assessing results and, therefore, potential recommendations and adaptation options.

Traditionally, responsible researchers present their findings couched in terms of the uncertainty surrounding its conclusions, or otherwise are challenged to do so by others in their field. However, in multidisciplinary environments, researchers - particularly project leaders - can find themselves using inputs from research areas with which they are unfamiliar, making it difficult to apply the same judgement as they would do in their own fields of expertise. In such projects, the traditional system of managing uncertainty can break down due to a number of factors, including:

- Lack of understanding and/or critical scrutiny on methods and results in one discipline from team members in other disciplines
- Cultural unwillingness of researchers to engage in critical debate in areas outside their own field of expertise
- Lack of consultation with disciplinary experts in developing the initial research proposal
- Poor project management and leadership

These factors can all influence the results arising from the individual working groups or disciplines of a multidisciplinary research project. However, when attempting to produce overall, project-level conclusions and recommendations based on the integration of results from the different disciplines and working groups, an additional set of emergent issues face multidisciplinary research, including:

- Adoption of datasets or results from another discipline without accounting or appreciation for underlying error or uncertainties
- Limited time for interaction between working groups, particularly when operating in complex multi-institution or multi-country projects
- Lack of formal tools, methodologies or guidelines when integrating results from different disciplines
- A tendency for a group to converge on a particular view and become over confident in it
- Lack of knowledge as to how different kinds of uncertainty from different methods can synergise

Being able to interpret, interpolate and integrate data and results from different fields is a non-trivial and sophisticated task, crucial to generating sound results, that requires systematic treatment[8]. This issue is inevitably compounded in climate change adaptation research in Africa, where one is attempting to make adaptation recommendations whilst confronted by all of the uncertainty issues discussed above. Taken collectively, these issues imply that results from multidisciplinary adaptation research projects should initially be treated with caution, especially where adequate methods and rigour have not been applied to the managing multidisciplinary integration.

6 There are clear and important distinctions between multidisciplinary, interdisciplinary and transdisciplinary research, but they are not dealt with in this paper. In this context, multidisciplinary is used to refer to any type of methodological interactions between research disciplines.
7 Managing Climate Risk to Agriculture and Water Resources in South Africa led by University of the Free State.

8 Methods and tools for managing multidisciplinary integration have been developed, but are not necessarily systematically applied across research projects. See, e.g. Miller et al. 2008.

These issues are highly problematic, and ultimately come down to the expert judgement and assessment of the researchers. As the IPCC uncertainty guidelines (IPCC 2004) make clear, researchers need to not only make expert judgements when integrating results from different disciplines, they also need to clarify the types and levels of uncertainty surrounding final assessments and recommendations. The exercise of clarifying uncertainties is a fundamental step in managing and living with uncertainties, and also requires expert judgement from researchers. Developing and documenting methods and approaches used and decisions made in such judgements is crucial, providing a paper-trail useful for in-house quality control, revising results as further data comes in, and for justifying and communicating recommendations and uncertainties to decision-makers.

The use of scientific information in decision-making processes

The immediate objective of most CCAA research projects is to inform adaptation decisions. This might include influencing the policy of a health ministry on how and where to deploy malaria prophylaxis, or convincing local farmers to adopt new irrigation techniques. Although it is not always well recognised by researchers, scientific results are only one element that feed in to decision-making processes, and not even the most important element in many cases. Decisions are dependent upon individuals, processes and institutions, as well as the wider policy environment, available resources, and the legacy and framework of previous decisions. This is to say that decision-making is inherently political, and rarely follows a sequential, linear approach of enquiry, analysis, choices and decisions. Inevitably, decision-makers' perceptions of uncertainty affect how they weight information in reaching decisions.

Adaptive, or experimental, management is one widely-adopted approach to managing large amounts of uncertainty, with cycles of problem identification, research, analysis, implementation and evaluation. It is an incremental approach to adaptation (and other complex policy problems) that emphasises action whilst uncertainties are reduced through further research. This philosophy of "learning by doing" has been central to CCAA's approach to building the adaptive capacity of researchers, decision-makers and vulnerable communities.

Some studies from the developed world have found that strong institutions with processes for reviewing and refining policies in the light of new information are adequately prepared for adaptation to climate change decision-making, meaning that they have appropriate tools and internal feedback mechanisms for adaptive management (Klein & Nicholls 1999). In such environments one might expect a premium to be placed on scientific information with low uncertainties, but also an ability and willingness to cope with larger uncertainties - at least in the short to medium term and for potentially large impacts. However, other studies suggest that even in strong institutions in developed countries, decision-makers are frequently unequipped to understand, or reluctant to tolerate, complex information regarding uncertainties, preferring straightforward information that can be used as inputs in decisions, or that they may use scientific uncertainty as a reason to delay difficult political decisions, or that they may not regard scientific uncertainty as a significant issue at all (Moser 2005). Such factors seem to intensify as stakes increase, and ample studies have demonstrated that individuals deal with risk and uncertainty irrationally (E.g., Slovic 1987).

Whilst African decision-makers may have similar attitudes towards scientific uncertainty, the experiences of CCAA suggest that the conditions under which they work are qualitatively different, in that strong institutions are less common than they are in developed countries. This is to say that organisations are likely to have fewer resources; institutional arrangements for dealing with complex policy problems may be weak; adaptive management processes are unlikely to be in place; legal frameworks may be insufficient for taking action; and both formal and informal institutions may have challenges with leadership, accountability, and building constituencies for meaningful and appropriate adaptation. In large areas of Africa, communities tend not to rely on public services and institutions at all, either because of problems in access or shortfalls of institutional resources. Particularly in those political systems where decision-making processes are lengthy and based on patronage – which can be just as true with respect to community level institutions as it can of the state - vulnerable people are required to be self-reliant.

Unsurprisingly, in cases where institutional capacities are weak, the uncertainties around scientific results may not be seen as the most significant limitations on developing and implementing adaptation decisions.

The experience of CCAA projects so far has been that institutional weaknesses for adaptation are more significant limitations than issues with scientific uncertainty surrounding adaptation options.

Decision-makers in developing countries are often working in constrained situations with limited opportunities to take action, and frequently lack basic information. To such actors, results and recommendations from complex research are likely to be judged not in terms of their uncertainties, but in terms of their practicalities. Recognising this, a number of CCAA projects have focused on strengthening institutional capacity for adaptation, for example by creating multi-stakeholder platforms for information sharing and decision-making. A CCAA coastal adaptation project in Morocco[9] has used exactly this approach to compensate for the lack of a legal and institutional framework for integrated coastal zone management by bringing together stakeholders from different government departments, NGOs and citizen's groups. Similar approaches have been used in coastal adaptation projects in Egypt[10] and Cape Verde[11], and by a regional fisheries project in West Africa[12], and in projects on, for example, agricultural and health adaptation. Outcomes of these attempts have varied, their sustainability remains to be seen, and there are questions about the extent to which such informal institutional arrangements can substitute for formal organisations and institutions. Nonetheless, the collective experience of these projects has been that convening stakeholder forums and providing even the most indicative information can catalyse adaptive capacity by raising awareness, focusing attention on the problem, building relationships between stakeholders, and generating experience in selecting and evaluating adaptation options.

Fundamentally, adaptation will be a long term, iterative process rather than a series of one-shot solutions. CCAA researchers have made valuable contributions to institutional strengthening of the communities and government departments which are partners in their projects, but these are initial steps in a long process. The experience of CCAA projects so far has been that institutional weaknesses for adaptation are more significant limitations than issues with scientific uncertainty surrounding adaptation options. In that context decision-makers may be more willing to rely on indicative information, and less concerned by high levels of uncertainty in recommendations from adaptation research. It is also possible that in some cases decision-makers are eager to take action on adaptation due to external factors such as political or institutional pressure, and are less concerned with taking appropriate action than appearing to act.

The appropriate and wise use of information is, ultimately, a key component of an institution's competence, and understanding and managing the uncertainty of information is a precursor to its wise use. Through mentoring and training workshops, the CCAA program has provided capacity building to researchers on how to influence decision-making. Such efforts can be strengthened by helping researchers appropriately communicate uncertainties in research results and recommendations to decision-makers. There is also a need for researchers to better understand how their clients use and value different kinds of information, and how their perceptions of risk and uncertainty influence their decisions, which implies innovative research activities. Also, to build long term adaptive capacity, programs need to strengthen decision-makers' capabilities for understanding and handling uncertainties.

Expanding research in adaptation decision-making

This does not mean that scientists should not be concerned with reducing scientific uncertainties – of course they should. Scientific uncertainties will decline over time as methods and observations improve and consensus grows, even though they never will be eradicated absolutely. However, there is also a need for researchers to rigorously manage uncertainties in multidisciplinary research, and to grapple fundamentally with the information needs of decision-makers, and their capacity to understand and account for uncertainties in decision-making. As other authors have argued, scientists frame issues around

9 Moroccan Coastal Management: Building Capacity to Adapt to Climate Change led by École Nationale Forestière d'Ingénieurs.
10 Adaptation to the Impacts of Sea Level Rise in the Nile Delta Coastal Zone led by the National Water Research Center and the Center for Development Services.
11 CapaSIDS : Capacity Building and Knowledge on Sustainable Responses to Climate Change in Small Island States led by Instituto De Engenharia Mecanica.
12 Adapting Fishing Policy to Climate Change with the Aid of Scientific and Endogenous Knowledge led by Environmental Development Action in the Third World (ENDA).

Decision theory and informatics research approaches can help researchers support decision-making in complex environments, using uncertain information.

expertise and scientific knowledge, whilst decision-makers frame issues around societal goals and values (Morss et al. 2005). This is not to say that decision-makers do not rely on evidence in their work, but rather that researchers tend to focus on what can be known, whilst decision-makers focus on what must be done.

These issues imply that there are opportunities for adaptation research in Africa to draw on fields dealing with the use of information in decision-making, particularly informatics (or information sciences) and decision theory. Specific research questions of value to adaptation science might be how research results and related uncertainties are communicated and presented, how different kinds of information are valued and utilised by different stakeholders, how preferences and values affect decision-making, and how to develop tools and methods to support decision-making capacity. These research questions can help guide the development of tools to support decision-making where "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz & Ravetz 1991). This is a perspective which recognises that in decision-making environments faced with high uncertainty, high stakes, and with different priorities, costs, benefits and values in play, social and political processes can subsume even the best data and analyses, and that researchers need to be equipped with tools to at least understand these issues better (Moss 2007).

As an example of this type of research, CCAA has supported research by the IGAD Climate Predictions and Application Centre which brought together climate modellers and members of the traditional Nganyi weather forecasting community in Kenya[13]. Although initially distrustful of each other and each other's expertise, engagement in the project resulted in the two groups producing integrated seasonal forecasts for dissemination to local farmers. These had the advantage of being tailored to the informational needs and preferences of farmers, and using proven, traditional methods of information dissemination, such as radio broadcasts in local languages and community meetings convened by respected elders, and personal relationships between farmers and traditional forecasters. Methodologically the project is a good example of the approach advocated here, because integration of the two different sources of knowledge dealt explicitly with aspects of uncertainty arising from both scientific and traditional methods. The process of integration even helped with fine tuning the downscaling of climate forecasts based on local knowledge about local features conditioning weather.

Researchers can take such approaches further by developing and applying established techniques for supporting decision-making. Tools such as Bayesian belief networks, fuzzy logic expert systems, and futures scenarios are used in fields as diverse as nuclear power station operations (Kang & Golay 1999), fisheries management (Cheung et al. 2004) and land-use planning (Tress & Tress 2002) to analyse and support decision-making in the face of uncertainty. Futures scenarios are sometimes used as a basis for deliberation and participatory planning, such as in a CCAA project in Cape Verde[14], but otherwise these techniques have not been widely applied in adaptation research in Africa. Donors supporting adaptation need to ensure that researchers are capacitated to not only provide decision-makers with information and recommendations, but also appropriate tools to support decision-making itself.

Decision theory and informatics research approaches can contribute to managing, rather than reducing, uncertainty, and can help researchers understand and support decision-making in complex, uncertain environments, using uncertain information. A significant proportion of this type of research utilises high-tech information and communication software tools which may not always be appropriate for some field settings of adaptation research in Africa. However, the research questions driving the field of informatics and decision theory are highly relevant to the issues faced by developing country institutions responsible for adaptation. Adaptation researchers armed with these questions, and able to develop appropriate research methods and tools, will be better equipped to support adaptation policy making.

13 Integrating Indigenous Knowledge in Climate Risk Management in support of Community Based Adaptation led by the IGAD Climate Predication and Applications Centre (ICPAC).

14 CapaSIDS: Capacity Building and Knowledge on Sustainable Responses to Climate Change in Small Island States led by Instituto De Engenharia Mecanica.

Conclusions

Large scientific uncertainties remain an issue in developing adaptation options in Africa. In addition to the methodological issues that are common elsewhere, in Africa there is also commonly a lack of solid basic information, whether historical climate data or reliable census data. However, experience from CCAA projects indicates that scientific uncertainty is not the principal limitation on effective adaptation in the situations in which they operate. Weak institutional capacity, in particular for making decisions and taking action in the face of complex and uncertain problems, appears currently to be a much greater obstacle. Perfect knowledge is useless without the means of acting on it, whereas even imperfect information is useful to those who must act. As one official in Morocco said to me, "I understand your concern, but my questions are these: is this recommendation the best we have? And is it likely to be worse than doing nothing?"

As one official in Morocco said, "I understand your concern, but my questions are these: is this recommendation the best we have? And is it likely to be worse than doing nothing?"

Researchers should and will continue to focus on gradually reducing uncertainties and expanding the boundaries of knowledge. However, in projects intending to provide recommendations to policy makers, the management of uncertainties in those recommendations needs also to be an area of focus. Project leaders need to tackle issues of managing research projects more systematically, including the development of results and recommendations based on multidisciplinary work and the assessment and management of uncertainty. The skills and expertise to successfully manage multidisciplinary research do not necessarily emerge automatically from being a skilled researcher in a particular field, and donor programs funding research can do more to ensure that resources are available to support researchers and project leaders develop capabilities in these tasks.

Researchers would also benefit from utilising approaches and questions drawing on information sciences in attempting to understand how to communicate results, recommendations and associated uncertainties to decision-makers. Research projects should consider including enquiry on decision-making processes themselves, such as how individuals and institutions cope with uncertainty, and how the use of information can be optimised. Such questions would help researchers produce more useful information, and understand better how to support adaptive decision-making. Strengthening research capacity for producing tools supporting decision-making, such as expert systems and participatory scenario making, should be a priority for both researchers and research donors.

Ultimately, the strengthening of institutions for adaptive decision-making should be a goal of CCAA projects and those of similar programs, whether talking about informal community institutions or formal organisations. In developing African societies, where resources are constrained and climate vulnerabilities high, it will be imperative for decision-makers to exercise good judgement in making adaptation decisions to avoid the waste of resources and, worse yet, increasing vulnerabilities. "Learning by doing", through iterative cycles of adaptive management, is a sound approach to these challenges, and should include information flow from researchers to decision-makers and vice versa. Donors can do more to encourage institutions, particularly government organisations, to embrace such approaches and meet researchers mid-way, in part by coupling funding for institutional development with appropriate research grants.

These conclusions imply commitments to adaptation initiatives that go beyond single phase research grants of three years. Donors should be prepared to support projects for several phases, moving from stages of exploratory research to more targeted enquiry producing results with lower uncertainties, whilst strengthening the capacities of both researchers and decision-makers to manage complex and uncertain information in adaptive management processes.

References

Bhaskar, R., 2010. Contexts of interdisciplinarity: interdisciplinarity and climate change. Chapter 1, p 1-24 in Bhaskar et al. (eds), Interdisciplinarity and climate change. Routledge, NY.

Cheung, W.W.L., Pitcher, T.J. & Pauly, D., 2004. A fuzzy logic expert system for estimating the intrinsic extinction vulnerabilities of seamount fishes to fishing. P.33-50 in Morato & Pauly (eds.) Seamounts: Biodiversity and Fisheries. Fisheries Centre Research Reports 12(5): 78pp.

Funtowicz, S.O. and Ravetz, J. R., 1991. "A New Scientific Methodology for Global Environmental Issues." In Ecological Economics: The Science and Management of Sustainability, Robert Costanza, ed. New York: Columbia University Press: 137-152.

Global Climate Observing System (GCOS) overview of ClimDev: http://www.wmo.int/pages/prog/gcos/index.php?name=ClimDevAfrica. Accessed November 11, 2010.

IPCC, 2004. Guidance notes for lead authors of the IPCC Fourth Assessment Report on addressing uncertainties. Available online: http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf. Accessed November 11, 2010.

Kang, C.W. & Golay, M.W., 1999. A Bayesian belief network-based advisory system for operational availability focused diagnosis of complex nuclear power systems. Expert Systems with Applications, 17(1): 21-36.

Klein, R. J. T., and R. J. Nicholls, 1999. Assessment of coastal vulnerability to climate change. Ambio 28 (2): 182-7.

Knight, F.H, 1921. Risk, uncertainty and profit. Boston, MA: Hart, Schaffner & Marx; Houghton Mifflin Co. PDF available online http://www.econlib.org/library/Knight/knRUP.html, retrieved August 18, 2010.

Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., & Meyer, L.A. (eds), 2007. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. Section 2.3.2

Miller, T. R., T. D. Baird, C. M. Littlefield, G. Kofinas, F. Chapin, III, and C. L. Redman. 2008. Epistemological pluralism: reorganizing interdisciplinary research. Ecology and Society 13(2): 46. URL: http://www.ecologyandsociety.org/vol13/iss2/art46/

Morss, R.E., Wilhelmi, O.V., Downtown, M.W., and Gruntfest, E., 2005. Flood risk, uncertainty, and scientific information for decision-making: lessons from an interdisciplinary project. American Meteorological Society, Bulletin of the American Meteorological Society, 86, 1593-1601.

Moser, S. C., 2005. Impact assessments and policy responses to sea-level rise in three US states: An exploration of human-dimension uncertainties. Global Environmental Change, Part A 15 (4): 353-69.

Moss, R. H. 2007. Improving information for managing an uncertain future climate. Global Environmental Change 17 (1): 4-7.

Slovic, P., 1987. Perceptions of risk. Science, 236: 280-285.

Tress, B. & Tress, G., 2002. Scenario visualisation for participatory landscape planning – a case study from Denmark. Landscape and Urban Planning 64(3): 161-178.