EXECUTIVE SUMMARY

Application of ICTs for Climate Change Adaptation in the Water Sector: Developing country experiences and emerging research priorities

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The focus of the reports gathered here is how information and communications technologies (ICTs) can be used to help communities in developing countries facing water stress adapt to climate change. The role and potential of ICTs in helping communities employ innovative approaches to prepare for, respond and adapt to climate change are increasingly being recognised. Within the water sector, ICTs can contribute towards improvements in water resource management techniques; strengthen the voice of the most vulnerable within water governance processes; create greater accountability; provide access to locally relevant information needed to reduce risk and vulnerability; and improve networking and knowledge sharing to disseminate good practices and foster multi-stakeholder partnerships, among others. While drawing on current experiences in the field of water management and sustainability, the perspective of the authors is primarily from the ICT for development (ICT4D) sector. Because of this the reports should be considered exploratory, offering a fresh perspective to the field of water security in vulnerable contexts.

The reports are the result of work commissioned by the International Development Research Centre (IDRC) and the Association for Progressive Communications (APC), which had the key objective of informing the research support agenda of the IDRC in the field of ICTs, climate change and water. The collaboration between the IDRC and APC involved several activities, including regional research in Latin America and the Caribbean (LAC), Africa and Asia, a call for projects working in the field to share their experiences (see the Appendices) and a workshop held in Johannesburg on 7-10 July 2011. Participants at the workshop were from around the world and were invited to discuss the implications of using ICTs to help vulnerable communities facing water stress adapt, and to begin shaping a research agenda in the field.

While water management and sustainability is a specialist concern with its own body of evidence that has emerged over time, the interface of ICTs, climate change and water arguably poses new theoretical challenges and practical gaps. For one, there are not enough projects practically demonstrating the positive potential and innovative impact ICTs can have at the grassroots level in managing water resources. While a number of projects do exist, they are not yet widespread enough to meet the adaptation needs of communities facing water crises given the impact climate change is already having at the local level.

At the same time, the ICT4D sector itself has only recently seen a wider consideration of how cli-

mate change will impact on its work – the interface between ICTs, climate change and water is a complex one, involving new policy dynamics and areas, as well as sciences, that may be unfamiliar to many practitioners. How the sector itself adapts to a relatively new field of enquiry remains to be seen, and part of the purpose of this publication is to catalyse that process.

The timeline of the authoring of these reports is important. For example, the regional studies as well as the project write-ups preceded the Johannesburg workshop, and fed into those discussions. Chapter 4, which discusses an emerging research agenda, drew directly on discussions that were held in the workshop. The conceptual framework, presented in Chapter 2, draws on all of the above, as well as the research and analysis that had already been done in the field of ICTs and climate change adaptation over recent years at the Centre for Development Informatics, University of Manchester. As a result, the conceptual framework offers a more refined theoretical entry point into the subject of ICTs, climate change and water security, while the reports that follow it can be considered as reflecting earlier thinking on the topic. They also consider a range of important issues and observations that are outside of the scope of the theoretical analysis. Similarly, in line with the sequence of project activities, we felt it best to preserve something of the "raw energy" of the research questions that emerged from the earlier workshop discussions in Chapter 4.

In Chapter 2, "The ICTs, Climate Change Adaptation and Water Project Chain: A conceptual tool for practitioners", Angelica Ospina, Richard Heeks and Edith Adera elaborate on a potential methodology for integrating ICTs into the design, operation and evaluation of projects in contexts of water stress. As the authors state, they offer a process-focused approach, which is intended to have practical application and testing in real-life contexts – what the authors call "concrete e-enabled adaptation actions" (Ospina et al., 2012, p. 18).

The authors outline what they call the vulnerability dimensions of water resources, offering a systems perspective that calls for an assessment of the potential of any system – such as a household, a community, a city – to be exposed to external shock, and its ability to cope with the impacts of that shock. Critical dimensions of a system involve livelihoods and finance, food security, health, human settlement and displacement, socio-political issues and water. In this context, water becomes a resource of "transversal importance" (ibid., p. 19), since the availability, scarcity, or other negative impacts of water stress impact on other vulnerability dimensions.

Importantly, the authors argue that adaptation should not be considered as something new: individuals, communities, groups, cities adapt all the time, and it should be considered a constant articulation of change rather than an event (even though climate change could precipitate a single catastrophic event that leads to the sudden need to adapt). While climate change is "challenging the ability of vulnerable populations to withstand, recover from and adjust to change" (ibid., p. 21), the authors argue for adaptation strategies to be wide-ranging in their approach, and to address development priorities holistically rather than with a single, frequently reactive approach that only considers climate-related impacts on communities.

Drawing on prior thinking in the area, the authors categorise adaptation priorities for water into five areas: supply, demand, availability, management and governance. It is here that the potential for ICTs to impact on water security is located, in particular in the ability of technology to catalyse "adaptive actions" of a community or group in a vulnerable context. (Conceptually, the authors make a distinction between the adaptive capacity of a community – the potential for adaptation – and what actually occurs, i.e. the adaptive actions). However, they stress that while ICTs can enhance the adaptation capacities of communities, how they are "adopted, used, sustained or scaled" can also, when ill considered, result in "maladaptive practices and enhanced vulnerabilities" (ibid., p. 28).

One of the key considerations of the model developed is that project processes respond to local realities, and that mechanisms are in place to ensure that it remains responsive to local needs. As the authors put it, "These considerations are key in order to ensure solid linkages between the use of ICTs, and the water adaptation needs that the projects are ultimately trying to tackle" (ibid., p. 27). Drawing on the ICT4D Value Chain, the Sustainable Livelihoods Approach, and the concept of digital capital, the model outlines the symbiotic relationship between institutional frameworks and specific resources at the local level – whether social, human or financial capital – that are needed for the implementation of a project. As the authors point out, the model is not an ICT-centric approach,

even while it attempts to interface the potential of ICTs with local adaptation needs:

> The effective implementation and use of ICTs for adaptation is based on the recognition that the presence of digital capital within vulnerable livelihoods cannot be automatically equated with the contribution of these tools to adaptation. Instead, the analysis of ICTs' role and potential in regards to the adaptation of water resources should be conducted systemically, taking into account the presence of other livelihood determinants (e.g. enabling institutions, structures and assets in the climate change and ICT fields), as well as the influence of both enablers and constraints in the process of ICT implementation (ibid., p. 28).

The authors outline implications for practitioners in the different stages of project implementation, laying the ground for the testing of the model's conceptual linkages on the ground. As they put it, the "model suggests that ICT tools have the potential to strengthen the capacity of developing countries to withstand, recover from and adapt to the water-related challenges posed by climate change" (ibid.). However, it is its attention to local-level differentials that is critical to the model:

> The conceptual model presented suggests that the availability and even use of ICTs within a given context cannot be automatically equated with a contribution of these tools to climate change adaptation. Instead, a more holistic and systematic approach has to be taken in order to integrate their role, maximise their potential and evaluate their impacts within water adaptation processes (ibid., p. 29).

In their LAC regional analysis, Gilles Cliche and Miguel Saravia emphasise a point that is implicit to all of the texts gathered here: that the global poor and marginalised will be most severely affected by climate change. However, the purpose of their emphasis is to serve as a spur to the inaction perceived in global efforts to address climate change. Cliche and Saravia draw attention to the fact that there are not only practical challenges in meeting the adaptation needs for water security, but that governments, civil society, businesses – us – have a moral responsibility to *actively* address these challenges. This is particularly so given that the impact of climate change on water security for the poor can already be broadly predicted, and that the growing interest in the issue can be set in the context of addressing other development imperatives.

Taking this as a cross-cutting consideration in their analysis, the authors offer an overview of climate change and its challenges in the LAC region, drawing attention to several key issues. For instance, while the region is effectively a "superpower" when it comes to renewable water resources – accounting for more than 30% of the world's renewable water resources – this does not accurately convey the dramatically unequal distribution of those resources across the continent. This they call a "spatial variability" that is largely due to the concentration of the freshwater around the Amazon, Parana-Plata and Orinoco rivers. As the authors explain:

> [I]n Peru, two thirds of the population lives in the dry part of the Andes and coastal zone where less than 2% of the country's water flows. In Mexico, less than 10% of the land receives half of the annual rainwater [and] the Atacama Desert extending from northern Chile to southern Peru along the Pacific coast of South America is the driest region of the world (Cliche and Saravia, 2012, p. 35).

This extreme spatial variability has the potential to worsen already existing disparities in socioeconomic development in the region, and is likely to place pressure on regional negotiations on water distribution.

All of the regional reports point out that the impact of climate change on water security is only one of several multiplier effects impacting on water security generally. Here Cliche and Saravia show that water resources are already under strain due to the impact of "agriculture and mining, aquifer depletion, deforestation and deterioration of watersheds and replenishment areas" (ibid., p. 34). Related to these practical issues are inadequate country and regional development plans, where, as the authors put it, "a dominant economic development model is one that favours products, firms and regions with a comparative advantage, and social programmes and safety nets for the rest" (ibid.). Similarly, close to 90% of the agricultural output in the region is rain-fed, while irrigated crops are mostly set for the export market, which means that this production, as the authors point out, "is important in the national economies, but less so for local staple food supply" (ibid., p. 37). This status quo is held in place by a policy approach where it has generally been the norm to "view climate change as an environmental problem" and there are "significant weaknesses regarding the inclusion of adaptation strategies in sustainable development plans" (ibid.,

p. 34). Therefore the economic policy imperatives driving a region that already accounts for 12% of the world's greenhouse gas emissions lay fertile ground for the potential impacts of climate change to be felt severely.

In line with the e-resilience framework for the application of ICTs in contexts of climate change developed by Ospina and Heeks (2010), the authors categorise the use of ICTs for water security according to five key resilience variables: robustness, scale, redundancy, rapidity, flexibility, self-organisation and learning. The authors produce four categories: climate modelling (which they relate to robustness and scale), early warning systems (rapidity, redundancy and self-organisation), decision-support systems (robustness and self-organisation), and knowledge management (learning and sharing).

Of particular interest, they argue that there is a significant information and knowledge gap at the grassroots level. For instance, when it comes to climate modelling, they argue that a tension exists between localisation of climate data and reliability:

> There is a huge challenge particularly for mountain and hillside rain-fed agriculture in Central America and the Andes, where local climates are very complex, and where reliable historical and current meteorological and hydrological data series are rarely available (Cliche and Saravia, 2012, p. 41).

Similarly, when considering early warning systems, key challenges remain at the local level, in particular when it comes to last-mile technology. Decision-support systems also need to combine traditional knowledge with modern scientific practice "in the context of intra-annual climate variability, for which weather forecasting is of limited use, and local knowledge is losing its traditional references" (ibid., p. 44). For the authors, e-access "does not seem to be a major impediment for [ICT] deployment in climate change or other applications" (ibid., p. 39). Mobile phones are the most widely used technology, with most of the countries enjoying a ratio of about 50 phones per 100 people. Yet while "[t]he LAC region has seen an explosion of internet-based platforms and networks for information exchange and knowledge sharing" the authors also find that, in practice, "few local actors engage in formal learning processes, which involve basic documentation and analysis of local practice and sharing it with others who are not their day-to-day partners and co-workers" (ibid., p 46).

Based on this assessment, they identify four critical research areas in support of the application of ICTs in the field of climate change and water sustainability: ICTs in vulnerability mapping, ICTs in integrated water management research, ICTs in the "last mile" challenge of early warning systems, and ICTs in social learning and knowledge sharing. They argue that researchers "seldom integrate social considerations that play a key role in the capacity of communities to prepare, cope and adapt" (ibid., p. 47) and call for the inclusion of both socioeconomic and biophysical data in vulnerability assessments. At the same time, weak policy considerations means that "[e]xcept in some extreme cases, the planning and management of water resources do not take account of climate information" (ibid., p. 48). A further challenge is posed by the privatisation of water data, which cannot easily be accessed for public planning. These mean that the integrated management of water is reactive rather than proactive, inhibits innovation and is unable to cope with the increasing demands of urbanisation and the poor. This, the authors argue, necessitates a policy review to unlock the potential for ICTs to be used at the local level to address inequalities in access to water.

In their report on the African region, Washington Ochola and Samuel Ogada-Ochola emphasise that any impact of climate change will be compounded by basic developmental inequalities, such as illiteracy, poor governance, weak institutions and infrastructure, limited access to health facilities, armed conflicts, and limited access to technology. They support Cliche and Saravia's contention that the strategic use of ICTs should have a pro-poor bias, especially in a region where, similar to LAC, water resources are unevenly distributed: "more than 40% of Africans live in arid, semi-arid and dry subhumid areas and about 60% live in rural areas and depend on farming for their livelihoods" (Ochola and Ogada-Ochola, 2012, p. 58).

The authors highlight the impact of water scarcity on agriculture and domestic water security, pointing out that the water available per capita for domestic use is below the global average and that most countries in Africa have fallen behind in meeting their water and sanitation targets. In the agricultural sector, risk factors include crop damage and disease, and variability in rainfall, both in intensity and duration, which makes it difficult to predict how agricultural systems will perform over the long term. Their summation for a continent

considered the most vulnerable for climate change is bleak:

> The hydrological effects of climate change as well as constraints on public water supply in especially the arid and semi-arid regions of Africa urgently require priority attention to forestall the already occurring inter-sectoral, inter-institutional and transboundary conflicts. Many river basins, lake basins and watersheds in Africa are stressed by population increase, intensive agriculture and changing hydrological regimes. Because of this, they are highly vulnerable to climate change. Appropriate institutional and technological solutions must continue to be designed (ibid., p. 60).

While e-readiness is improving in many countries in Africa, and there are indications that the take-up of water-management technology is also increasing (including tools for "water prospecting, gauging and water withdrawal control, water source mapping, water service provision [and] water pollution tracking and control" (ibid., p. 61), critical challenges to upscaling the use of ICTs include limited awareness of technological choices, limited access to funds, a lack of clarity on appropriate technologies at the local level, risks facing the commercial viability of large investments, limited infrastructure, and a weak policy environment.

Presenting several examples of the application of ICTs in water management on the continent, the authors contend that both mobile technology (used at the local level), and the roll-out of broadband infrastructure in the region hold strong potential for water management – the first already applied in a number of grassroots projects (e.g. for data gathering and reporting, as well as for water vending). Yet significant work still needs to be done in unlocking innovation at the local level to improve the potential of communities to adapt in the context of water stress.

The authors argue that there are overarching themes that should determine the research agenda of ICTs in the context of water management and security. These include: an emphasis on devices and technologies for water systems management (considering issues such as platforms, sensor networks, security, efficiency, speed, survivability and reliability of such applications and systems); a focus on wireless networks; and the use of data for decision making. Within these considerations, specific research focus areas could include: the use of open source technology; online monitoring; topic-specific evaluations of enabling infrastructure; research into water resource governance systems; research into the application of traditional knowledge for water security; and using technologies for fairer water distribution in communities and between countries.

Despite the progress in human development in the Asia and Pacific region, Rajib Shaw reminds us in his report that the region is still home to two thirds of the world's poor, with strong gender inequalities and country-specific development divides. At the same time, there is a strong dependency on water resources for socioeconomic and cultural security among the region's poor, who are in effect frequently left excluded from the rapid development felt around them:

> While urban and industrial growth power the region's rapidly growing commercial economy, the rural poor remain dependent on the benefits provided by ecosystems. Land and water resources are the foundation for the agricultural production, fisheries and aquaculture that provide nutrition and income (Shaw, 2012, p. 74).

According to Shaw, the negative impacts of climate change in the region are likely to be felt in hydropower outputs and surface water availability: "In North China, irrigation from surface and groundwater sources will meet only 70% of the water requirement for agricultural production, due to the effects of climate change and increasing demand" (ibid., p. 75). Key challenges include rising seawater levels, the increased salinity of water, the frequency and intensity of droughts and floods, and pressure placed on sanitation and urban water management: "Developed environments like cities generate higher surface runoff in excess of local drainage capacity, causing local floods. Many urban drainage facilities are in bad shape due to lack of cleaning and maintenance" (ibid., p. 76). Water-related threats include epidemics from vector-borne diseases, while "malaria, dysentery and diarrheal diseases have a significant statistical correlation with changes in climate parameters" (ibid., p. 77).

The sweeping take-up of mobile technology in the region – even while country differences exist – suggests that, as in other regions surveyed here, it will play a critical part in climate change adaptation strategies. Shaw also specifically points to the potential of mobile broadband internet access, which is arguably less likely to play a key role in the immediate future in poverty-wracked regions on continents like Africa, where there often is no access or access is expensive. However, the author tempers his assessment of the potential for tech-

nology generally to play a key role given that "the rural-urban digital divide in some developing countries and disparities between sub-regions remain a major development challenge in Asia and the Pacific" (ibid., p. 78). This, he argues, means that policy bottlenecks that inhibit the widespread take-up of ICTs should be addressed.

While Shaw also draws attention to the potential application of traditional ICTs for the purposes of adaptation, such as television and radio, he finds that digital gaps, even at this level, pose serious challenges for public service messaging in the event of emergency or local-level learning:

> Television is also the most powerful means for mobilising social resources to support disaster response and rehabilitation efforts. Although most of the population centres in the region are covered by television and radio through cable and satellite transmission systems and local broadcasting networks, many least-developed and low-population areas still remain out of reach of such services (ibid.).

The author highlights a number of examples of the application of ICTs in the water sector, including projects promoting livelihoods adaptation; sensor networks used to assist farmers in improved water management; using GIS tools for micro-level drought preparedness; using ICTs for regional flood information systems and glacial monitoring and for groundwater management at the local level; and using mobile technology in early warning systems, e.g. for extreme weather events and floods.

He identifies five areas that should assist any emerging research strategy in the field. First, he highlights the potential of the Climate and Disaster Resilience Index (CDRI) – which has five dimensions, physical, natural, institutional, social and economic – in shaping a research agenda. In line with Cliche and Saravia who argue for socioeconomic and biogeographic information to inform policy, Shaw argues that:

The [CDRI] helps to find out the strength and weakness of different socioeconomic, institutional and physical dimensions for drought resilience. Because of this government and different organisations can prioritise the sector for policy considerations, provide inputs for policy formulation and help to minimise the drought risk (ibid., p. 86).

Shaw also suggests that multi-stakeholder cooperation is critical in setting the research agenda: "Often governments, NGOs and businesses accentuate what divides them rather than recognise their shared values. At the same time, research conducted in universities and other isolated forums often does not reach the intended beneficiaries" (ibid.). Third, the author points to the need for interconnectivity in order to address the digital divide in adaptation strategies. Regional cooperation, he says, should focus on developing appropriate solutions that address digital differences: "Any future research agenda needs to articulate the technological differences between countries, so that the capacity-building and technological limitations and possibilities can be properly understood" (ibid.). Similar to the other authors gathered here, Shaw points to the need to link modern and traditional approaches, and the need for ICTs to "consider the interface between traditional skills and knowledge" (ibid.). Finally, he argues for the importance of drawing on already established networks when formatting a research agenda in order to strengthen its impact.

In the final chapter to this book, Tina James outlines emerging research questions in the field of ICTs, climate change and water. As the author notes, these are drawn directly from the workshop help in Johannesburg in July 2011. They should therefore be considered preliminary considerations in the field that could inform future agendas – agendas which are in turn dependent on the theoretical approach of researchers, donors or research institutions (one approach being suggested by the framework in Chapter 2, developed by Ospina, Heeks and Adera).

James notes several factors to consider when developing a research agenda. These include a move away from an ICT-centric approach in favour of a needs-based focus to water security. Clarity on what should be considered a "community" is also necessary, as is scalability, drawing on past experience, and developing a shared vocabulary (including, for example, whether a project aims to address climate change or variability). She draws attention to one of the contributions the ICT4D sector can make to the field of water security: "The use of ICTs in creating new opportunities for communications and collaboration between stakeholders is [...] recent and in this area there may be room for innovation and taking on board the lessons learned from other ICT4D applications" (James, 2012, p. 92). The importance of the practical link between knowledge and practice is also highlighted by the author, as well as attention to the dynamics or needs implicit in "community-driven" or "community-owned" initiatives.

James then identifies five key emerging research areas in the field: improving the management of water resources; strengthening the capacity of vulnerable communities to deal with climate change-induced water stress; creating more effective governance mechanisms to manage scarce water resources; building partnerships, networks and stakeholder collaboration through the use of ICTs; and supporting knowledge sharing, improved communications and dissemination for awareness raising and decision making. Usefully, specific research questions are offered for each category, such as, "What are the potential socioeconomic barriers to be addressed to implement a successful community-based monitoring system?" (ibid., p. 94) or "What targeted communications strategies are needed to improve adaptability to climate change?" (ibid., p. 95) and "How can ICTs be used to develop and support the implementation of such strategies?" (ibid.).

As suggested in this introduction, there are several overlaps between the authors' conclusions in the chapters gathered here. The authors show that using ICTs for water management is not necessarily an emerging field, but rather one that has attracted fresh currency in the context of climate change. This has implications for developing a research agenda given that there is potential to draw on the body of existing theoretical thinking and practical experiences in the field, including the experience of ICT4D practitioners in implementing grassroots ICT projects in communities.

Water security is also not just a climate change issue. As has been pointed out, climate change is likely to exacerbate development problems that already exist. Issues such as poverty divides and population growth, which in itself will increase water stress in communities, will be magnified through the lens of climate change, even while climate change is likely to introduce new challenges due to impacts on water cycles and availability.

The application of ICTs for adaptation in contexts of water stress faces a central challenge: a lack of e-readiness in many communities, despite the proliferation of mobile phones, limits the scope of local ownership and the potential of using ICTs for adaptation. This calls for the simultaneous unlocking of policy bottlenecks that might inhibit the take-up of ICTs in vulnerable communities. At the same time, while there is a desire and some potential for scalability, generalised assumptions regarding the potential of ICTs to catalyse innovative adaptation at the local level cannot apply. Innovative models are conditional on the e-readiness of any one local community. Adaptation implies localisation, in format and language, amongst them. Asia shows that even traditional ICTs – such as TV and radio – pose a challenge for local-level learning. Similarly, mobile strategies will differ, for instance, in regions like Asia and Africa, and between countries in these continents. Given this, it is unlikely that anything but rudimentary one-size-fits-all technology applications at the local level – with local ownership and usage – is likely to be feasible.

While policies need to be unlocked at the national and regional levels to unblock bottlenecks that inhibit innovation, and while regional and national ICT initiatives – for instance for data sharing and mapping – hold potential, local-level application can best be served through methodological approaches that determine the appropriateness of local innovation strategies using ICTs. These should, as the ICT4D sector well knows, incorporate local practice and knowledge for buy-in into innovation and adaptation. Given this, there is a need to pay attention to local-level variables, even while this may pose challenges for scalability.

The chapters also point to the need to link to local knowledge, resources and practice when implementing ICT strategies. While the regional studies argue for a close analysis of the implications of ICTs at the local level, also supported by the research questions emerging from the Johannesburg workshop, Ospina, Heeks and Adera offer a meta-level conceptual approach that allows for variability and consideration of local-specific dynamics. Their model draws out the specific role of ICTs, but does not necessarily promote an ICT-centric approach.

All authors writing here emphasise the need for pro-poor strategies, and for research agendas to foreground the impact of climate change on water security in vulnerable communities. Cliche and Saravia state this as a moral imperative – that there is a need to act now, and that sufficient data exists to justify that action. It is hoped that this publication does its part in challenging and unlocking some of the inhibitors to action. ■

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