ICT4Adaptation: ICT for Climate Change Adaptation

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Virtual Adaptation Project

This report describes the outcomes of a short project to explore the potential roles of information and communication technologies (ICT) in climate change adaptation, funded by the Cabot Institute's Open Call for 2012/2013 (Cabot Institute, 2012). The initial goals of the project were to:

- Gain a high-level overview of the landscape of climate change adaptation, including the range of challenges that climate change presents
- Identify potential roles of ICT in climate change adaptation, with a tentative initial (orientating) focus at the community level and the applications of mobile device applications

The project involved a review of relevant literatures and current practices, as well as informal interviews and conversations, and has led to the development of a prototype framework for the characterisation of ICT projects (ICT4Adaptation) and the proactive generation of ideas for potential ICT4Adapation initiatives. This report provides an introduction to the potential roles of ICT in climate change adaptation, and outlines the current and evolving practice in ICT for adaptation. It goes on to describe the prototype framework and its systemic and generative nature.

ICT4Adaptation Background

Climate Change Adaptation

The direct predicted manifestations of climate change are diverse: increases in extreme weather events such as extreme rainfall or heat waves, extended periods of drought, changes in seasonality, glacial melting, chronic sea level rise, ocean acidification, coral bleaching, temperature changes in water-bodies, changes in geographical ranges of species, etc. (Smit & Pilifosova, 2001 and Akoh et al., 2011).

The impacts of these manifestations on humans and natural ecosystems are diverse and are highly contextual. For example, increases in the incidence and intensity of extreme weather events such as intense rainfall can lead to a wide range of acute impacts, such as localised and regional flooding, coastal inundation, and structural infrastructure damage. These in turn may lead to immediate consequences such as loss of life, injury, interruption of food and energy supplies, and communication disruption which require disaster recovery actions and remediation. In addition, they may have medium- to long-term impacts such as heightened requirements for expensive flood defences, the degradation of ecosystems or farmland, the displacement of peoples; changes in business model viability and insurability, etc.

The capacity of individuals, households, communities, and whole societies to adapt in order to cope with increased risks of acute shocks and to adapt to the longer term impacts of climate change can be thought of in terms of a related set of concepts:

- *Resilience* (Ability to resist, absorb, accommodate and recover from a shock)
- *Vulnerability* (Propensity to suffer harm from exposure to external shocks and stresses)
- *Adaptive capacity* (Preconditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements--see for example, Ospina and Heeks (2010a), Nelson et al (2007), Smit and Wandel (2006), Smit and Pilifosova (2001)

Climate change adaptation can be defined in a wide range of ways. A typical definition is given by (Smit & Pilifosova, 2001): *"Adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change."*

In sustainable development terms, climate change presents specific challenges, such as the need for efficient and effective disaster recovery, and demands proactive adaptation measures to mitigate risks and if possible benefit from climate change-induced long-term trends and associated acute shocks. However, climate change also both multiplies and amplifies existing development challenges and associated vulnerabilities (Kalas & Finlay, 2009). The vulnerability and adaptive capacity of a community to cope with climate change impacts is in large part dictated by the community's broader development context; positive development status is broadly reflected in higher adaptive capacity, if not adaptive practice (Ospina & Heeks, 2010b). In this context, climate change adaptation sits within the larger sustainable development context.

It is useful to highlight that the term *development* is used differently in different contexts in the literatures scanned for this project. For example, in the context of ICT4D (ICT for Development – see 'ICT & Climate Change Adaptation' below), development generally refers to developing countries and communities, and in particular 'poor and marginalized' peoples in such contexts (Unwin, 2009 p1). Whereas what we call ICT4Adaptation (ICT for Climate Change Adaptation) applies to *sustainable development* in the contexts of both developing and developed countries and communities. That said, ICT4D is closely analogous to what we call ICT4Adaptation and there are many lessons to be learnt from ICT4D.

There are a myriad of forms of climate change adaptation that are highly contextual. The extent of this range is illustrated by Smit & Pilifosova (2001) in Table 1. For example, possible responses to Climate Change impacts (function/effects in Table 1) include *retreating* from an impact, *accommodating* changes, *protecting* against change or efforts at *preventing* changes, etc. Responses may be more or less *spontaneous or purposeful*, *proactive or reactive*, *localized or widespread*, etc. Any particular actual response can be thought of as being made up of a set of states shown in the table.

Table 1- Bases for characterizing and differentiating adaptation to climate change (Smit & Pilifosova, 2001)

General Differentiating Concept or Attribute	Examples of Terms Used
Purposefulness	Autonomous ↔ Planned Spontaneous ↔ Purposeful Automatic ↔ Intentional Natural ↔ Policy Passive ↔ Active Strategic
Timing	Anticipatory ↔ Responsive Proactive ↔ Reactive Ex ante ↔ Ex post
Temporal Scope	Short term ↔ Long term Tactical ↔ Strategic Instantaneous ↔ Cumulative Contingency Routine
Spatial Scope	Localized ↔ Widespread
Function/Effects	Retreat - Accommodate - Protect Prevent - Tolerate - Spread - Change – Restore
Form	Structural - Legal - Institutional - Regulatory - Financial – Technological
Performance	Cost - Effectiveness - Efficiency - Implementability – Equity

ICT & Climate Change Adaptation

ICTs increasingly play ubiquitous, pervasive and critical roles at virtually all levels of human life. They provide the infrastructures, tools, and contexts ranging from highly personal and intimate communications between individuals and their social circles all the way through to those on which global trade, knowledge exchange, and diplomacy rely. As such, ICT is a fundamental factor in virtually any sustainable development context; indeed, it may provide the data and analytical tools needed to identify the existence of a development issue. For example, satellites, sensor networks, and climate modelling systems helped identify climate change as a phenomenon itself. ICT may 'simply' enable infrastructures and systems on which development initiatives rely such as mobile communications, or may be a key component of a project itself.

The potential of ICTs to play a role in climate change adaptation has thus far received little consideration (though see Akoh, 2011; Finlay, 2011; Ospina & Heeks, 2010b). The nearest analogous domains are ICT for Development (ICT4D—see e.g., Global Pulse, 2013; Heeks, 2010; Unwin, 2009) and ICT for climate change mitigation (e.g., The Climate Group, 2008), about which much more has been written.

Box 1 briefly describes an illustrative example of a widely cited ICT4D project, DrumNet, which was based in Kenya (PRIDE AFRICA, 2013 and IDRC Communications, 2013). The DrumNet project was designed to bring together key actors along a supply chain (buyers, banks, and farm retailers) and to link them to smallholder farmers through a dedicated ICT-based transaction platform. It utilises mobile phone based information and financial services to farmers and shows examples of various characteristic facets or roles that ICT is seen to offer in ICT4D and ICT for Adaptation activities and the potential benefits they could bring. (Campaigne & Rausch, 2010) state that as of 2010, "DrumNet has piloted its approach in Kenya's horticultural and oilseed sectors, serving more than 3,000 farmers across five provinces."

However, published reviews of DrumNet also highlight that as with any significant development or ICT4D project the long-term implementation is likely to have problematic issues (Ashraf, Giné, & Karlan, 2008 and Campaigne & Rausch, 2010). For example (Ashraf et al., 2008) describe how lack of international food safety standards certification by small farmers in one region led to refusal of exporters to buy crops and the collapse of the system in that region. See also the 'Identified Gaps and Areas of Further Exploration' section below.

Box 1: Example of mobile technology enabled ICT4D Project: DrumNet

The DrumNet project was designed in the early to mid 2000s to help small-scale, and generally poor, farming families in Kenya gain both better prices for their produce and increased access to credit. Such farmers generally have very limited access to non-local markets, and what access they have is typically via intermediaries who can take advantage of the farmers' limited market information. The farmers therefore get significantly lower-than-market value for their produce. In addition, such farmers have very limited access to credit or banking services which means they cannot invest or save effectively to help step out of the cycles of poverty, (PRIDE AFRICA 2013 and IDRC Communications 2013).

The ICT-based elements of DrumNet provide farmers (in local groups) with market information, financial services (including micro credit), and the ability to make transactions via their mobile phones. These abilities disintermediate traditional agricultural resale networks, in principle, enabling the farmers to gain direct access to markets, banking and credit services to enable the savings and investment required to improve income levels, wellbeing, and resilience of families and communities.

While it was not possible in the timescales of this project to fully review the literature on the implementation and longer term impacts of DrumNet, as with any larger scale ICT4D project there appear to have been significant longer term implementation issues, see main text.

DrumNet enabled the targeted provision of information to key stakeholders, the delivery of services otherwise challenging or impossible to provide, and brought about important changes in power and market relations (e.g. via disintermediation of brokers), see 'Project Outcomes' section below for further examples.

Of course the design, manufacture and use of ICT is itself a source of greenhouse gases (GHG), a cost that must be included in any meaningful assessment of its potential benefits in other ways. In addition, the very ubiquity of ICT itself brings with it significant potential for fragility in the face of acute climate change impacts, e.g. failures in ICT infrastructure could themselves lead to amplification of climate change impacts, such as disruption of food supplies and other logistically vital services (see for example (Tomlinson et al., 2012). Tomlinson et al. also argue that ICT can and should have a pre-emptive role in helping prepare to cope with potential wide-scale societal collapse that may be caused by climate change or indeed any other cause.

In recent years a number of frameworks have been developed that aim to help frame and systematise the assessment and conceptualisation of ICT4Adaptation activities including Ospina and Heeks (2010b), Souter et al (2010), Karanasios, et al (2011). For example, Ospina and Heeks' e-Resilience framework (Ospina & Heeks, 2010b) builds on the concept of livelihood systems to emphasize ICTs' potential for reducing climate change vulnerability through building resilience. In addition there have been a number of reports and researchers actively drawing together concepts, knowledge and early case-studies, such as Kalas and Finlay (2009) and Ospina (2012) as well as broader reviews of the more transformational use of ICTs in developing world contexts (eTransform AFRICA, 2012).

Project Outcomes

This project entailed a brief review of literatures relevant to ICT4Adaptation (see reference list). This provided an overview of the background context to ICT4Adaptation outlined in the sections above.

It also initially identified a diverse range of current and potential roles for ICTs in the contexts of adaptation. Some of these are directly related to meeting challenges associated with climate change, such as:

- *provision of early warning systems for extreme weather*
- *sharing knowledge of adapted farming practices*
- *awareness raising of climate-related risks*
- *co-ordinating disaster recovery information*
- *supporting consultation and participation in developing adaptation policies*
- *provide training in flood management*
- *sensor networks providing data to aid adaptation decision making*
- *gathering and analysing information for vulnerability assessments*

The majority relate to broader development goals, through improving resilience, reducing vulnerability and improving adaptive capacity. These include, *improving access to market information, enabling more effective political advocacy, sharing of farming practices and empowering local communities and individuals though disintermediation and improving institutional transparency*.

Figure 1 - Example of Flood Warning web-service provided by the Environment Agency in England and Wales

Box 2 gives an illustrative example of existing flood alerting services from the UK Environment Agency, which uses a range of ICT-based channels to provide warnings of flood risks to communities, business and individuals. The UK Environment Agency is responsible for delivering sustainable flood and coastal erosion risk management solutions across England and Wales and for overseeing the delivery of solutions by Local Authorities and Internal Drainage Boards. In this role they provide a range of flood warning information services to householders and business using a variety of ICT channels. Figure 1 shows an example of one of their flood warning web services that enable 3rd party web sites, such as those run by local authorities and community groups, to include up-to-date flood warning information. Such services enable users to prepare for acute flood risks proactively. These ICT-based services complement other alerting systems, e.g. mobile loud hailers.

Understanding how effective such measures are and how best to provide such alerts is a complex issue – see for example Twigger-Ross, Fernández-Bilbao, Tapsell, Walker, & Watson, 2009. Many issues arise in relation to the ICT solutions, e.g. ensuring that those without direct access to the ICTs are alerted (see ' Identified Gaps and Areas of Further Exploration' section below).

> **Box 2: Examples of UK Environment Agency Flood Alert Services**
>
> - Web pages providing risk identification service and guidance and advice on flood risk and how to prepare for potential flooding (http://www.environment-agency.gov.uk/homeandleisure/floods/)
> - Floodline Warnings Direct service that residents and businesses at risk of flooding can sign up to in order to get alerts by land-line telephone, mobile phone and e-mail (https://fwd.environment-agency.gov.uk/app/olr/home).
> - Alert web-widgets (http://www.environment-agency.gov.uk/homeandleisure/floods/137543.aspx) that enable 3rd parties such as local government and news agencies provide up-to-date warning information on their own websites.
> - Live data on river levels from monitoring stations (http://www.environment-agency.gov.uk/homeandleisure/floods/riverlevels/default.aspx)

Underpinning many of these applications and potentials were a range of what might be thought of as requirements or sometimes pre-requisites for a potential application of a specific ICT; for example, necessary and robust infrastructure, access to appropriate ICTs, appropriate and enforced regulation, bodies of reliable knowledge, long term commitments to maintain and develop systems, and existence of trusted brokers.

These pre-requisites highlight the issue that ICT-based applications must function within a diversity of contexts within which Climate Change Adaptation must take place, from highly economically developed nations and communities through to those struggling under multiple acute and chronic development pressures in poorer nations. Different ICTs have different characteristics, such as technical, economic, political and social pre-requisites, and specific features or affordances that mean they are suited to particular roles in particular contexts, e.g. basic mobile phones have characteristics that make them more viable for providing an effective means of communication in many poorer developing world contexts than smart-phones or desktop computers.

This mapping of the relationships between ICT characteristics/affordances and adaptation context seemed critical in understanding the many roles that ICT may play in adaptation in any practical situation. Given that one of the core goals of this project is to identify potential applications of ICT for climate change adaptation, we focused on developing a means of identifying or at least understanding the mappings between ICTs and concrete adaptation contexts.

Our analysis and reflection led us to find a range of inter-related perspectives on that mapping, that together appear to offer the potential for creating a *generative framework*, i.e. a means of generating ideas for potential ICT/adaptation-context mappings. These perspectives are outlined below.

Causal Chains of Climate Change

The first and highest level perspective is illustrated in Figure 2. The impacts of climate change can be thought of as a set of interlocking causal chains. Starting with a primary impact (e.g. changes to weather patterns), leading to physical consequences, generally on a fairly large scale, which in turn lead to human and ecosystem level impacts and on to consequences for individuals and communities.

Figure 2 illustrates a specific example of such a causal chain. Driven by the primary impact of ‘changes in weather patterns’ that may eventually lead (in this example) to loss of income and food sources at the community level, which may have acute consequences (e.g. requiring emergency response) and/or chronic consequences, requiring longer term adaptation.

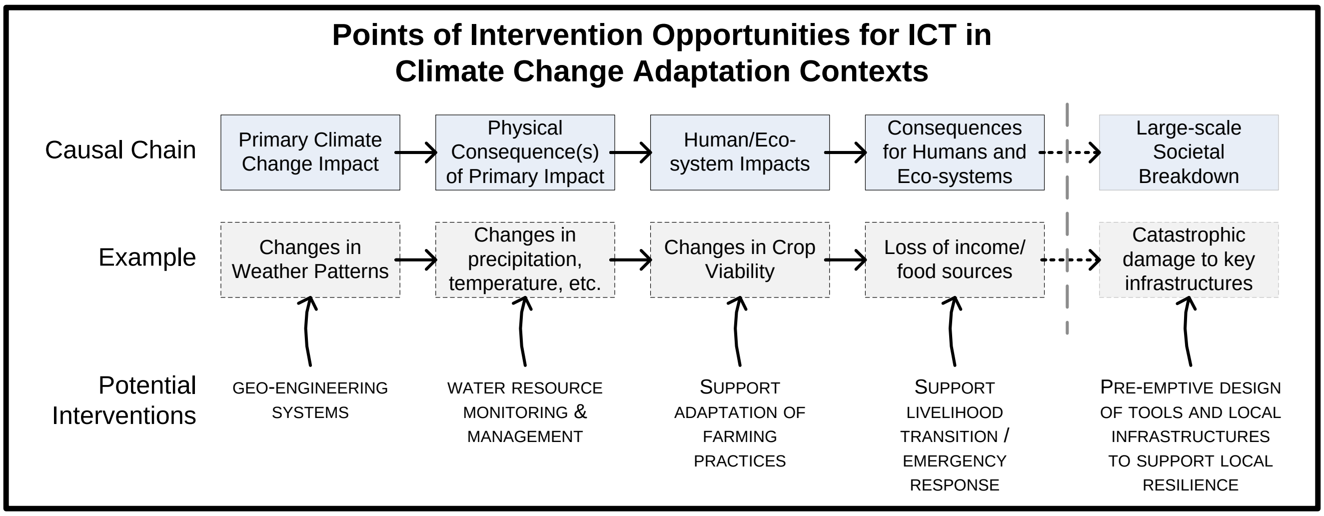

Figure 2

This perspective shows that there are opportunities for adaptation interventions (of any kind) at different stages in that causal chain. The most pre-emptive is at the level of reducing or mitigating the primary cause or impact, all the way through to the most reactive response where an acute emergency must be responded to.

At the extreme end of this set of causal chains is the latent potential for very large-scale disruption, due, for example, to cumulative localised impacts on food supply or combinations of climate change and wider environmental and societal factors such as financial or potential energy crises. Tomlinson et al. (2012) argue that ICT also has a role to play in preparing for the possibilities of such large-scale societal collapse.

ICTs can have potential roles to play at all points in the chains shown in Figure 2. The potential interventions on the bottom row are examples taken from our literature scan of potential roles that ICT can play. For example, the use of automated sensor networks in water resource management underlie the flood alert services (illustrated in Box 2) and the use of social networking services in helping disseminate information about and support the use of new farming practices (see for example Ospina, 2012), etc.

ICT ECOSYSTEMS

A second perspective relates to ICTs themselves. Figure 3 illustrates the very large scope of ‘ICT’ and the components of what can be thought of as an ICT ecosystem. Initially we attempted to create some form of taxonomy of ICTs that would enable us to develop a mapping between the features/affordances of classes of ICTs and adaptation contexts. However it quickly became clear that a particular ICT used in practice, at least in adaptation contexts, is always both a collection of other ICTs and part of a larger system of ICTs.

For example, a mobile phone is composed of processor chips, screen, keyboard, aerial, microphones, etc. It requires an operating system and application software to manage the hardware and interactions with the user. It is also dependant for its function on the existence of mobile telecommunications infrastructures and other ICTs that can receive and do something useful with the data received from the original mobile phone, be that another mobile phone of a business colleague or an SMS (Short Message Service) based information service.

The ecology perspective applies at all scales of what might be thought of as ICTs. For example the concept of so-called *smart cities* (The Climate Group, Arup, Accenture, & University of Nottingham, 2011), which, broadly speaking, embodies a vision of ICTs providing highly detailed, rich and integrated information infrastructures for cities that enable more efficient and effective use of resources, thereby contributing to climate change mitigation and meeting adaption needs. A 'smart city' would be a very large-scale integrated ecosystem of many of the ICTs outlined in Figure 3.

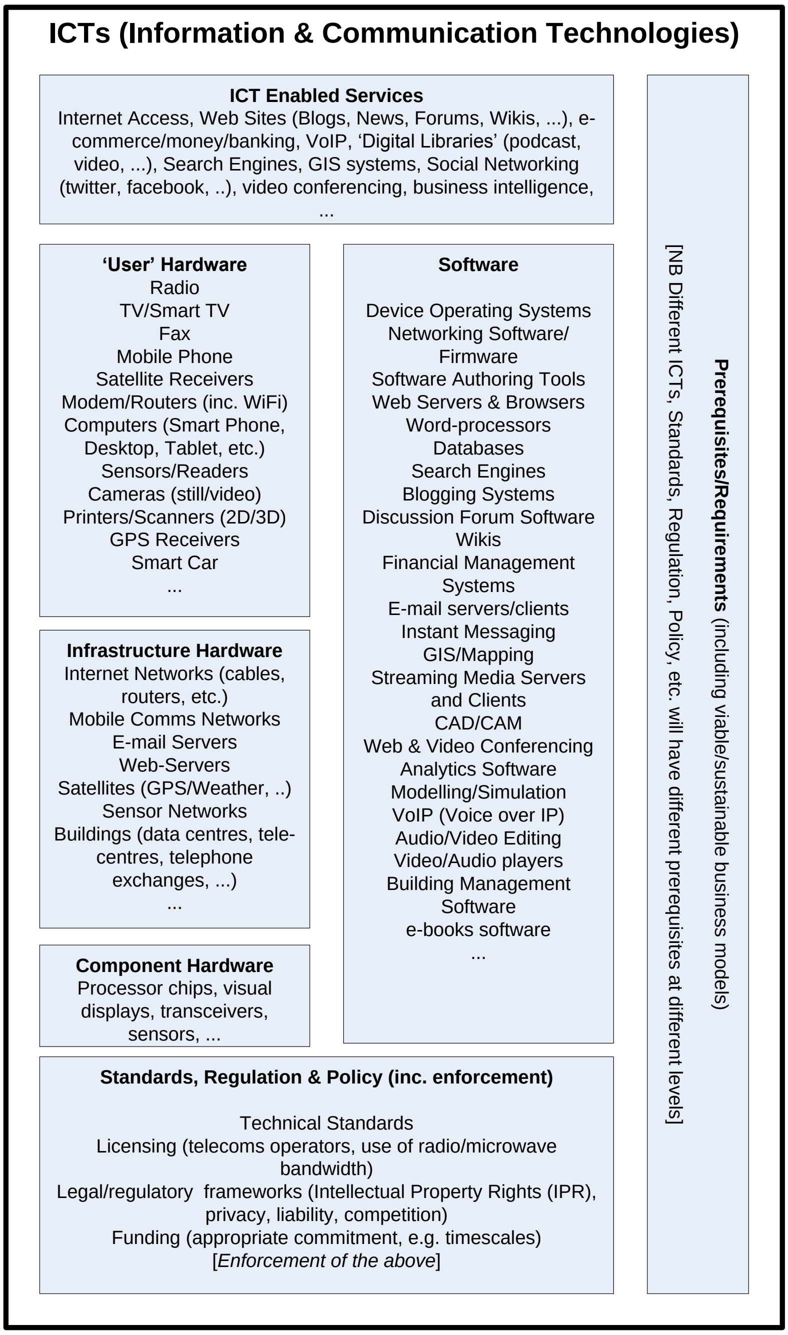

Figure 3 - Illustration of a conceptual framework of the components of an ICT ecosystem

Figure 3 includes technical standards, regulation, and policy. It may be debatable whether these are ICTs or even technologies themselves, however their roles as components in the ICT ecosystem are critical.

There are many other ways of categorising ICTs. For example, Unwin (2009 p80) notes the importance of conceptualizing ICT in an ICT4D context and makes a distinction between ICTs for 'information capture', 'information storage' and 'information sharing/communication' including both hardware and software in each category. He also notes other frameworks, including that of Hamelink (Unwin, 2009 p77) who also distinguishes 'processing technologies' and 'display technologies'. Once again these categories are not taxonomies of ICTs but components of composite ICTs that manifest as particular devices, software or solutions generally within a larger set of ICT enabled systems.

An important aspect of the ecosystem metaphor is that it highlights change and evolution as well as inter-dependency. As technologies and their wider context changes (social, economic, environmental, etc.) the impacts of those changes propagate through the ecosystem. New ICTs co-evolve with other factors, and can be thought of as competing for niches (application domains, market share, etc.) within that larger eco-system.

However the metaphor breaks down quickly if pushed too far. For example, while the Internet or World Wide Web can be thought of as technologies in such an ecosystem, they are also global scale technological platforms on which other technologies exist and are developed – it may not be helpful to think of many aspects of these or other ICTs using an ecological metaphor. In addition the nature, mechanisms, and rate of change are significantly different to that of natural ecosystems.

Identifying ICT Enabled Adaptation Opportunities

Finally, we produced a tentative model of the factors that together appeared to help identify potential roles of particular ICTs in particular adaptation contexts. This model is built on the previous two perspectives and ideas from other conceptual frameworks identified in the literature scan, for example from Ospina and Heeks (2010b), Souter et al (2010) and Karanasios, et al (2011).

The model provides a perspective on the relationships between key factors in any climate change adaptation context, combined with characteristics of ICTs and their potential roles to help identify potential ICT for Adaptation opportunities.

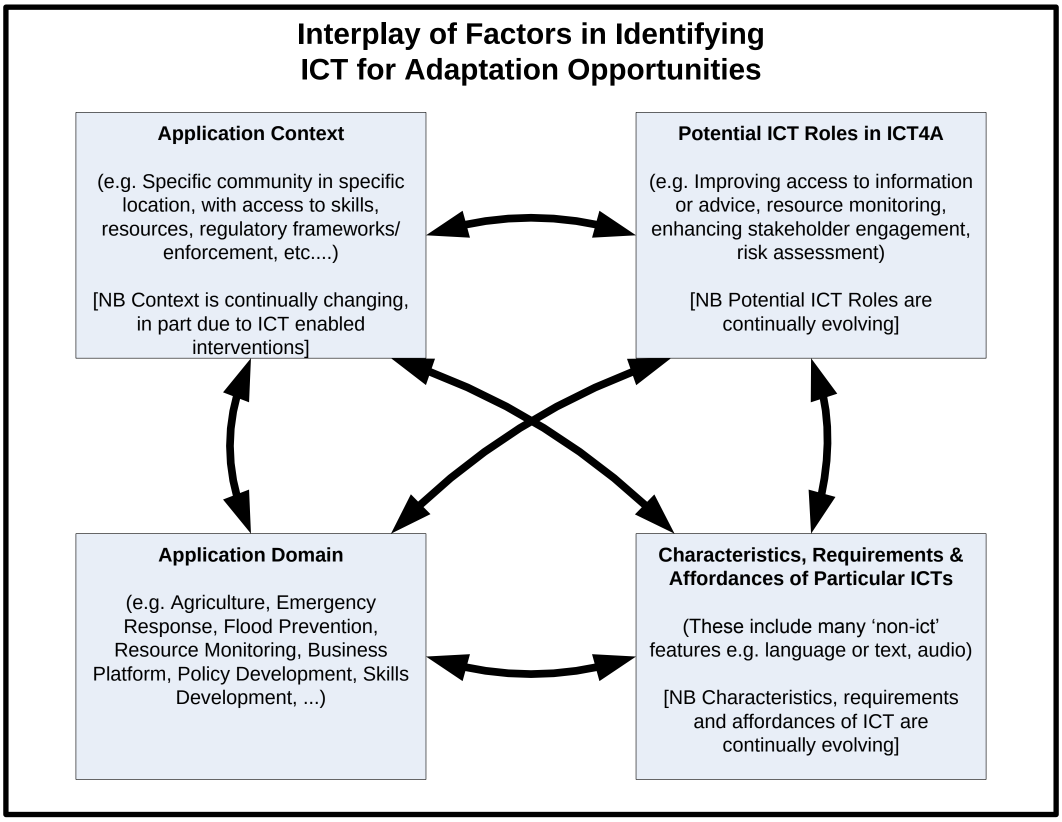

Figure 4 - Model of interplay of factors in identifying adaptation opportunities for ICTs

The model is illustrated in Figure 4. The four factors are:

- Application context, e.g. characteristics of a specific community, infrastructure available, economic, and political context, etc.
- Application domain, e.g. agriculture, water resource management, emergency response, etc.;
- Potential role(s) of ICT4Adaptation, e.g. improving access to information, resource monitoring, enabling community engagement, etc.
- Characteristics, requirements, and affordances of particular ICTs characterised in Figure 3, e.g. cost, necessary infrastructures and user skills, maintainability, portability, etc.

The factors are shown inter-linked by arrows. The arrows illustrate that the factors are inter-dependant; a change in one may drive change in the others.

For example, a change in *application context*, such as a change in access to skills within a community, may well add *new potential roles for ICTs* that were previously unavailable. It may mean that previously irrelevant *characteristics of ICTs* become relevant and may change the detailed nature of targeted *application domain* or possibly change prioritisation of which domain(s) are targeted.

The model is both systemic and generative. Systemic in that any single change in any factor may have knock on impacts on other factors – as described above – which may in turn themselves have knock on impacts, quite possibly feeding back to the original factor. It is generative, of potential opportunities for ICT4Adaptation, in that by specifying a set of options or contexts for a given factor or factors, e.g. specifying an application context and application domain will constrain the range of choices for potential ICT roles and the ICTs (because of their characteristics, requirements and affordances), leading to and hopefully stimulating the identification of potential opportunities in that constrained context.

Illustrative Use of the Model

Table 2 (below) gives some illustrative examples of possible values, dimensions or spectra for each of the various factors. In practice it is likely that the starting points or constraining factors would be the application context and application domain. Here we illustrate the generative nature of the model by starting with a range of application contexts and domains.

One common differentiating factor in the *application context* is 'developed'/'developing' nation context. This distinction is potentially problematic for a number of reasons, but it is generally used as a proxy for a more specific set of contexts, e.g. availability of infrastructures, levels of poverty, health indicators, access to education, scale and types of businesses, scales of social welfare systems, etc. Another key differentiating contextual dimension is urban/rural. Here we use variations of these two application context factors, with a primary focus on the 'developed'/'developing' distinction, to illustrate how the model can help identify potential roles for ICT in Adaptation.

Application Context	Potential Roles of ICT
• 'Developed'/Developing Country • Rural/Urban • ICT Infrastructure Available • Levels ICT 'Literacy' • Levels of literacy/numeracy • Homogeneous/Heterogeneous community • Sub-community (e.g. farmers)/'public community' • Political and regulatory environments	• Information/Advice/Sharing • Resource/Situation Monitoring • Enhanced Stakeholder Engagement • Risk Assessment • Enabling Accountability & Transparency • Community Empowerment – open engagement, crowd-sourcing, etc. • Supporting Distributed Communities • Simulation of future scenarios
Application Domain	**Characteristics, Requirements & Affordances of Particular ICTs**
• Farming/Agriculture • Water Resource Management • Business/Livelihood • Education & Training • Health • Settlement/Displacement • Disaster Preparedness, Response, Management and Recovery • Empowerment of communities and social change	• Enable/support 1:1; 1:Many; Many:1; Many:Many communication • Presentation of information Video/Audio/Text/Visualisation • Persistent/Transitory • Sensor/Activator • Individual 'push'/ Collective • 'Push'/'Pull' of information • Interaction modalities (keyboards, voice, etc.) • Quality of interaction/communication possible • 'Smart'/'Dumb' (e.g. degree of processing, analysis, etc.) • Contextual Awareness (e.g. location)

Table 2 - Examples of 'states' of the high level factors in Figure 4

In order to illustrate the use of the model, we focus on two (arbitrary) *application domains*, i) reducing health risks from changes induced by climate change, and ii) planning for mitigation of increased occurrence of acute impacts of climate change (such as extreme weather). Finally we chose two categories of potential role for ICT, i) monitoring for policy development and ii) support of people affected by acute impacts.

This set of 2 (application contexts) x 2 (application domains) x 2 (potential ICT roles) gives us a set of 8 possible combinations. Table 3 shows an example of potential ICT4Adaptation applications.

The examples in Table 3 illustrate the generative nature of the framework, showing both the diversity of potential applications and also how common components, such as mobile device based alerting systems, can have multiple roles. There are existing incidences of some of these examples in place or under development; however, the point here is to show how the matrix provides a framework to identify potential ICT for Adaptation applications.

Table 3 – Illustrative Examples of Potential ICT4Adaptation applications:
i.e. ideas stimulated by the use of the model outlined in Figure 4

	Application Context	**Application Domain**	**Example ICT Role**	**Example of Potential ICTs, Outline of Intervention Idea**
1	Industrialised nation (UK). Rural & Urban. Medium term adaptation to change in climate leading to increased ranges of animal species	Health - risks of increase in number of mosquito borne diseases	Monitoring of occurrence and range of mosquitoes	ICT-based system for integration of data and statistics from range of distributed sources, at different scales. For example health authorities, central and local governments, community/crowd-sourced (automatically e.g. via Twitter and systematically via explicit recruitment). Example technologies, Web 2.0/Linked Data
2	Industrialised nation. Rural. Medium term adaptation to increased risks of disruption due to natural disasters, e.g. flooding, forest fires, landslides. In rural contexts	Planning for mitigation of acute impacts. Support of displaced peoples in period (possibly extended) after an acute impact	Short and medium term accommodation and integration of displaced people into nearby communities	Suite of services that support emergency service workers in placing displaced people within nearby communities, e.g. register of displaced peoples and 'match making' with volunteers who offer support, e.g. temporary accommodation (within the community), physical and support resources.
3	Industrialised nation. Urban. Short to long term adaptation to increased risks of extreme temperature variations.	Health – reducing risks to people who are vulnerable to extremes of temperature	Identification and support of vulnerable people	System to support local community workers/leaders to identify people e.g. elderly, those who live alone, etc. who are vulnerable to acute impacts of climate change, e.g. extremes of temperature. Including system to identify and co-ordinate support needed at time of impact.
4	Non-industrialised nation. Rural. Medium term adaptation to increased risk of flooding	Planning for mitigation of acute impacts. Identification of flood risk areas.	Modelling and monitoring flood risk for policy development	Use of crowd sourced data from mobile phones (volunteers or paid people from communities) to monitor water levels at specific times. Requests for measurements to be made sent out as alerts. Enabling systematic collection of data at experimentally and analytically useful times.
5	Non-industrialised nation. Urban. Medium term adaptation to increased risk of flooding	Planning for mitigation of acute impacts. Identification of flood risk areas.	Modelling and monitoring flood risk for policy development	Same as 4. With possible additions of specific focus on drainage blockages and localised flows as well as water levels.
6	Non-industrialised nation. Urban	Health – increased risk of severe respiratory illnesses (acute asthma/severity of chronic lung disease) due to increased incidence of poor air quality	Provision of information alerts	Provision of alerts to vulnerable people and relevant authorities using various ICTs e.g. mobile phones, e-mail, etc. of times and degree of risks of poor air quality. Could also crowd source instances of acute impact on individuals to help increase effectiveness of response.
7	Non-industrialised nation.	Health – risks associated with occurrence of unfamiliar illnesses due to changes induced by climate change	Provision of health advice e.g. unfamiliar illnesses due to climate change impacts	Dissemination of guidance via community radio, community video, community news services (e.g. web/text based). Provision of alerts via same and text messages at times of acute occurrence or risk.
8	Industrialised nation.	Planning for mitigation of acute impacts on logistics (e.g. food deliveries) due to extreme weather events	Modelling and monitoring of logistics systems, identification of vulnerabilities	Modelling (e.g. agent based, event based modelling), of logistic systems under range of scenarios to identify risks and help design resilient systems and/or contingency measures, e.g. local food stores, etc.

Multi-disciplinary

One important aspect of ICT 4 Adaptation not yet included in the model above is that of the very highly inter/multi-disciplinary nature of ICT 4 Adaptation. Heeks argues that a deep understanding of ICT4D requires a inter/multi-disciplinary perspective (Heeks, 2007). Broadly speaking, the necessity and value in such inter-disciplinary collaboration can take two forms.

The first, which is mentioned most commonly in the literature scanned for this study, is the necessary contribution of disciplines to a domain for the development of practical solutions, e.g. the development of early warning systems for acute impacts may involve necessary knowledge, skills, techniques, etc. from disciplines such as climate science, civil engineering, sociology, behavioural psychology, law and social policy, medicine and community medicine, politics, critical systems design, various aspects of ICT such as hardware design, software, and human computer interaction design, etc. Such inter/multi-disciplinary collaboration is critical and the lack of such collaboration is perhaps a key cause in cases where projects are unsuccessful.

The second is the more serendipitous application of insight, techniques, understanding from one domain to another. For example an issue was raised during an informal conversation in this project about funding for sustainable development projects. The issue being that funders tended to require firm goals for a project and highly detailed project plans prior to a project being funded. This can be highly problematic in many development contexts as it is not, and cannot be, certain what the key issues are before engagement with a community, which is an initial part of a project. A computer scientist participating in the conversation noted that that kind of situation was very much the motivation behind a methodology in software development called *agile software development*. The methodology was discussed, seen as potentially valuable, and those involved in development research projects planned to investigate further. This kind of conceptual cross-fertilisation of ideas and practices was not seen in our literature scan but seems potentially highly valuable in helping improve practices across disciplines and within development and climate change related projects.

While we have not had the time in this project to include these aspects in our model we feel that it is important to do so; see next section.

Identified Gaps and Areas of Further Exploration

In this very short project many aspects of ICT4Adaption were identified that could not yet be investigated:

- This project was primarily focused on the understanding and identification of positive roles that ICT can play in climate change adaption. There are many ways in which ICTs may have direct or unintended negative impacts. Many of these were identified during this project and some are very significant (e.g. as noted briefly above, the very ubiquity of ICTs in the provision of critical services risks making such systems fragile and thus vulnerable to damage to ICT infrastructures). Any comprehensive assessment of ICT4Adaptation should include these kinds of issues.
- The focus of this project was on communities. As illustrated in Figure 2 there are many possible points of intervention at different levels. This applies not only at the levels of impacts but also society, ranging from global to personal.
- While the systemic nature of the various factors that affect an ICT4 Adaptation intervention was identified and highlighted in the framework, it has not been investigated. We argue that studying such systemic inter-relationships is vital for a meaningful understanding of ICT4Adaption activities.

- There are many significant problematic issues at a very practical level with the use of ICTs for adaptation, for example associated with digital exclusion p56), sustainable implementation (Ashraf et al., 2008). Including such practical issues is critically important in any ICT4Adapation project and should be included in any development of this work.

There are a wide range of potential directions of possible follow-on work that could derive from this project.

References

Akoh, B. (2011). Transformation-Ready: The Strategic Application of Information and Communication Technologies to Climate Change Adaptation in Africa (eTransform Africa). International Institute for Sustainable Development.

Akoh, B., Bizikova, L., Parry, J., Creech, H., Karami, J., & Echeverria, D. (2011). *Africa Transformation-Ready : The Strategic Application of Information and Communication Technologies to Climate Change Adaptation in Africa Final Report* (p. 149).

Ashraf, N., Giné, X., & Karlan, D. (2008). *Finding Missing Markets (and a Disturbing Epilogue): Evidence from an Export Crop Adoption and Marketing Intervention in Kenya*. doi:10.1596/1813-9450-4477

Cabot Institute. (2012). Virtual adaptation: An investigation into the potential of mobile and social media to support communities in adapting to climate change. University of Bristol. Retrieved March 1, 2013, from http://www.bristol.ac.uk/cabot/research/casestudies/2012/32.html

Campaigne, J., & Rausch, T. (2010). *Bundling Development Services with Agricultural Finance: The Experience of DrumNet* (p. 2).

eTransform AFRICA. (2012). *The Transformational Use of Information and Communication Technologies in Africa* (p. 20).

Finlay, A. (2011). *Climate Change as a Strategic Priority for ICT4D Organisations: Current Attitudes, Responses and Needs* (p. 31).

Global Pulse. (2013). Global Pulse: Harnessing innovation to protect the vulnerable. Retrieved February 13, 2012, from http://www.unglobalpulse.org/

Heeks, R. (2007). Theorizing ICT4D Research. *Information Technologies and International Development*, *3*(3), 1–4. doi:10.1162/itid.2007.3.3.1

Heeks, R. (2010). Policy Arena Do Information And Communication Technologies (ICTs) Contribute To Development? *Journal of International Development*, *22*, 625–640. doi:10.1002/jid

IDRC Communications. (2013). Cellphones are improving agriculture in Kenya. Retrieved March 1, 2013, from http://www.idrc.ca/EN/Resources/Publications/Pages/ArticleDetails.aspx?PublicationID=147

Kalas, P. P., & Finlay, A. (2009). *Planting the knowledge seed: Adapting to climate change using ICTs: Concepts, current knowledge and innovative examples* (p. 57).

Karanasios, S., Heeks, R., & Ospina, A. (2011). *New & Emergent ICTs and Climate Change in Developing Countries* (pp. 1–39).

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to Environmental Change: Contributions of a Resilience Framework. *Annual Review of Environment and Resources*, *32*(1), 395–419. doi:10.1146/annurev.energy.32.051807.090348

Ospina, A. V. (2012). Notes on ICTs, Climate Change and Development: ICTs' relation to climate change mitigation, monitoring, strategy and adaptation in developing countries. Retrieved December 5, 2012, from http://niccd.wordpress.com/author/angelicaospina/

Ospina, A. V., & Heeks, R. (2010a). *Unveiling the Links between ICTs & Climate Change in Developing Countries: A Scoping Study*.

Ospina, A. V., & Heeks, R. (2010b). *Linking ICTs and Climate Change Adaptation : e - Resilience and e - Adaptation*.

PRIDE AFRICA. (2013). Our Featured Project - DrumNet. Retrieved March 1, 2013, from http://www.prideafrica.com/ourwork.php

Smit, B., & Pilifosova, O. (2001). Chapter 18: Adaptation to Climate Change in the Context of Sustainable Development and Equity. In IPCC (Ed.), *Working Group II: Impacts, Adaptation and Vulnerability*.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, *16*(3), 282–292. doi:10.1016/j.gloenvcha.2006.03.008

Souter, D., Maclean, D., Akoh, B., & Creech, H. (2010). *ICTs, the Internet and Sustainable Development: Towards a new paradigm* (p. 40).

The Climate Group. (2008). *SMART 2020: Enabling the low carbon economy in the information age*. The Climate Group.

The Climate Group, Arup, Accenture, & University of Nottingham. (2011). *Information Marketplaces The New Economics of Cities* (p. 52).

Tomlinson, B., Silberman, M. S., Patterson, D., Pan, Y., Blevis, E., Interpretation, E., & Francisco, S. (2012). Collapse Informatics : Augmenting the Sustainability & ICT4D Discourse in HCI. In *CHI'12*. Austin, Texas, USA.

Twigger-Ross, C., Fernández-Bilbao, A., Tapsell, S., Walker, G., & Watson, N. (2009). *Improving flood warnings: Final report Improving Institutional and Social Responses to Flooding* (p. 76). Bristol: Environment Agency.

Unwin, T. (2009). *ICT4D : information and communication technology for development*. Cambridge University Press.