



# ICT-Enabled Development of Capacity for Climate Change Adaptation

[Link to publication record in Manchester Research Explorer](#)

## Citation for published version (APA):

Heeks, R., R., U., & Pant, L. (2011). *ICT-Enabled Development of Capacity for Climate Change Adaptation*. Centre for Development Informatics, Institute for Development Policy and Management (IDPM), University of Manchester.

## Citing this paper

Please note that where the full-text provided on Manchester Research Explorer is the Author Accepted Manuscript or Proof version this may differ from the final Published version. If citing, it is advised that you check and use the publisher's definitive version.

## General rights

Copyright and moral rights for the publications made accessible in the Research Explorer are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

## Takedown policy

If you believe that this document breaches copyright please refer to the University of Manchester's Takedown Procedures [<http://man.ac.uk/04Y6Bo>] or contact [uml.scholarlycommunications@manchester.ac.uk](mailto:uml.scholarlycommunications@manchester.ac.uk) providing relevant details, so we can investigate your claim.



# ***ICT-Enabled Development of Capacity for Climate Change Adaptation***

**LAXMI PRASAD PANT & RICHARD HEEKS**  
University of Waterloo & University of Manchester

2011

***Centre for Development Informatics***  
**Institute for Development Policy and Management, SED**  
University of Manchester, Arthur Lewis Building, Manchester, M13 9PL, UK  
Tel: +44-161-275-2800/2804, Web: <http://www.manchester.ac.uk/cdi>

The research presented in this publication is the result of the "Climate Change, Innovation and ICTs" project funded by Canada's International Development Research Centre (<http://www.idrc.ca>). This publication and other project outputs can be found at: <http://www.niccd.org>

IDRC  CRDI

Canada



## Table of Contents

<b>Executive Summary</b> .....	<b>3</b>
<b>1. Introduction</b> .....	<b>4</b>
<b>2. Information, Knowledge and Climate Change Adaptation</b> .....	<b>5</b>
2.1 Climate Change Adaptation Strategies.....	6
2.2 Climate Change Adaptation Processes .....	7
<b>3. ICT-Enabled Development of Climate Change Adaptive Capacity</b> .....	<b>8</b>
3.1 ICT Infrastructures for Climate Change Adaptation.....	9
3.2 ICT-enabled Information and Knowledge Exchange .....	11
3.2.1 Local Information and Knowledge Generation.....	11
3.2.2 Access to External Information and Knowledge.....	11
3.2.3 Two-way Exchange of Information and Knowledge.....	12
3.3 Opportunities and Challenges of Using ICT for Climate Change Adaptation	13
3.3.1 ICTs and Self-organising Systems of Adaptive Capacity Development.....	15
3.3.2 Transforming Conventional Telecentres into Mobile Teleservices .....	18
<b>4. Conclusions and Recommendations</b> .....	<b>19</b>
<b>Bibliography</b> .....	<b>22</b>

## List of Illustrations

Figure 1. Typology of climate change adaptation strategies .....	6
Figure 2. Three archetypes of ICT infrastructure .....	9
Figure 3. Climate change adaptive capacity development framework .....	16
Figure 4. ICT-enabled climate change adaptive capacity development framework.	17
Table 1. Project examples of different mobile-related ICT architecture models .....	10
Table 2. Deliberate and emergent strategies for climate change adaptation .....	14

## **Executive Summary**

Climate change and related stressors are posing an increasing challenge to livelihoods in low-income communities. Those communities need to develop the capacity to adapt to climate change: coping with short-term shocks and long-term trends. ICTs will form an essential part of that development.

Mobile technologies have been the dominant force in ICTs, and we review here a number of initiatives that have successfully combined local and external information and knowledge. We find these initiatives have made a valuable contribution to deliberate, pre-planned strategies for adaptation, focusing on the informational role of ICTs and combining local and external capacities (though limited in their development of local capacity). However, we argue that climate change adaptation also demands emergent actions that cannot be foreseen in advance, and which require the development of communities more as self-organising systems. This will require ICTs to be transformational as much as informational, developing collective as much as individual capacities.

As yet, though, signs of self-organisation through mobile-based applications appear limited. While no panacea, we suggest that a reworking of telecentre models – creating new 'mobile-telecentre' architectures that support the development of local infomediaries – may be one way to help develop local capacities that are more congruous with the demands of an emergent strategy perspective on climate change adaptation. More generally, we see ICTs' contribution most likely coming not through climate-specific applications but through information systems that address the broad range of vulnerabilities in a holistic and systemic manner.

# 1. Introduction

*"Mobile phone access will soon be universal. The next task is to do the same for the internet."*<sup>1</sup>

Statements as optimistic as this about information and communication technologies (ICTs) in developing countries are widespread. Yet availability of emerging technologies to address the complex problems of the twenty-first century is relatively limited, particularly among the poor. One such complex problem is climate change<sup>2</sup>. Climate change is negatively impacting livelihoods of already vulnerable communities that survived over centuries on local knowledge and practices<sup>3</sup>. Stresses include abnormal changes in air temperature and rainfall, increases in frequency and intensity of drought, heat and cold waves, and floods and landslides. Climate change is also associated with changes in seasonality, rainfall patterns, and the emergence and re-emergence of water-borne, vector-borne and food-borne diseases<sup>4</sup>.

Recognising the urgency of addressing these problems, expert – often science-based – knowledge about climate change has been well established, but knowledge about existing and potential adaptation strategies and their positive and negative development impacts on livelihoods is still emerging. Thus more work is needed to understand how to build capacity to adapt to climate change and to reduce ecological, economic and human vulnerability at the community level. It is already realised that climate change is one among several causes of vulnerability, and thus there is a need to adopt holistic, systems approaches to develop adaptive capacity to multiple stresses. Partly in recognition of this need, the emerging theory and practice of climate change adaptation is converging with the field of development studies<sup>5</sup>, and beginning a scholarship of new ways to develop climate change adaptive capacity<sup>6</sup>.

Creation, storage, exchange, regulation and application of information and knowledge are a key part of developing climate change adaptive capacity.<sup>7</sup> Particularly when knowledge is held by a myriad of public and private stakeholders, an integration of local adaptation practices and expert recommendations is difficult to achieve. There are technological as well as social, economic, political and cultural barriers to this component of adaptation, often complicated by physical isolation of rural and remote communities. In the face of increasing frequency and intensity of climate change, this paper argues that ICTs can facilitate the processes of knowledge integration and learning that form part of capacity for adaptation<sup>8</sup>.

---

<sup>1</sup>The Economist, 2009: 13.

<sup>2</sup>The use of the term 'climate change' in this paper includes climate variability, extreme weather events and related stresses, and 'climate change adaptation' refers to "[a]djustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." (IPCC, 2007: 869).

<sup>3</sup>UNFCCC, 2007.

<sup>4</sup>Morens et al., 2004; Smit & Wandel, 2006; Hardoy & Pandiella, 2009.

<sup>5</sup>Pant & Hambly Odame, 2009.

<sup>6</sup>Adger, 2006; Gallopin, 2006; McLaughlin & Dietz, 2008.

<sup>7</sup>Data is a set of discrete, objective facts, which becomes information when a pattern is imposed through processes such as contextualisation, categorisation, calculation, and condensation. Knowledge is a fluid mix of meaningful experience, values, contextual information, and expert insights that provides a framework for evaluating and incorporating new experiences and information (Röling, 1990; Davenport & Prusak, 1998).

<sup>8</sup>Kelly & Adolph, 2008; Chiabai, 2009.

In spite of the potential of ICTs to facilitate climate change adaptation – particularly through increasing access to, and control over real-time data, information and knowledge – this remains one of the least explored areas in research<sup>9</sup>. In practice, too, ICTs' potential has been limited by the divide in the coverage, uptake and use of digital technologies among vulnerable communities<sup>10</sup>. Telecentres and cyber cafes have been established to bridge this digital divide, but these models of facilitating public access to ICTs have limitations<sup>11</sup>. Particularly in rural and remote areas, the ability of telecentres to contribute to adaptive capacity-building has been limited by their uncertain economic viability, technical problems, skill shortcomings including digital illiteracy, and social, economic, cultural, political and psychological barriers to accessing and using ICTs in such centres<sup>12</sup>. In parallel with the travails of the telecentre model, there has been an explosive increase in the availability and use of mobile phones in poor communities, and these must therefore be central to any consideration of ICTs' role vis-à-vis climate change adaptive capacity. We are also seeing emergence of more sophisticated mobile devices such as smart phones and Personal Digital Assistants (PDAs)<sup>13</sup>. This paper therefore sets out to investigate the use of ICTs – particularly mobile devices but also their relationship to more traditional telecentre models - in the development of climate change adaptive capacity.

The following section reviews strategies and processes in the development of climate change adaptive capacity, particularly seeking to understand the role of information and knowledge. Section 3 begins with an overview of the ICT architecture models which may underpin capacity-building. Identifying mobile technologies as most-widespread, it reviews some empirical examples of their application, seeking to understand how they relate to climate change and capacity to adapt. Through a deeper conceptualisation of the role of ICTs in adaptation, Section 3 then argues that there are adaptive capacity shortcomings in some of the existing initiatives which a combination of telecentres and mobiles may at least partly address. Finally, conclusions are drawn, and a set of recommendations provided for using ICTs to facilitate the National Adaptation Programmes of Action (NAPA) that are being implemented across developing countries.

## **2. Information, Knowledge and Climate Change Adaptation**

This section reviews climate change adaptation strategies and processes, identifying a key necessary component to be the integration of external, expert knowledge and local adaptation practices. This sets the scene for understanding the role of ICTs.

---

<sup>9</sup>Ospina and Heeks, 2010a; 2010b.

<sup>10</sup>Fuchs & Horak, 2008; Heeks, 2009.

<sup>11</sup>From now on telecentres refer to all kinds of public Internet access facilities in low-income countries.

<sup>12</sup>Ariyabandu, 2009; Pant, 2009; Brown, 2010.

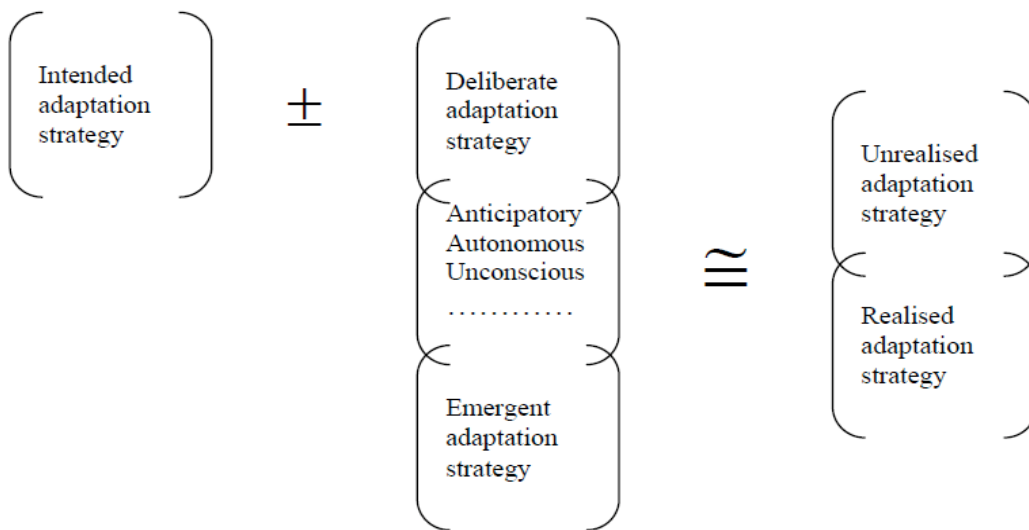
<sup>13</sup>Personal Digital Assistants (PDAs) are low-cost, simple-to-use and energy-efficient handheld computers, and Smart Phones use 3G mobile technology with data connection capability.

## 2.1 Climate Change Adaptation Strategies

Climate change adaptation requires creativity and innovation. Human creativity is the key source of adaptation to local and global changes. While creativity represents new ways of thinking<sup>14</sup>, innovation is the process by which that novel thinking is transformed into new products, new processes, new structures and new institutions in response to climate change (and other stressors such as natural resource degradation, civil unrest, and financial and economic downturns)<sup>15</sup>.

Creative thinking and innovative action can be applied strategically to climate change in two main ways: deliberate and emergent (see Figure 1)<sup>16</sup>. Deliberate planning and implementation will be part of the response to climate change, but development contexts and communities are so multi-dimensional that they must be understood as complex adaptive systems<sup>17</sup>. As such adaptation strategies will also be emergent from these systems, and thus there is a need to understand creativity and innovation from a systems perspective. A relevant systems perspective could be that drawn from the work on innovation systems, defined as the network of public and private organisations, enterprises, and individuals which is focused on bringing new products, new processes, and new forms of organisational structure into economic, environmental and social use together with the institutions and policies that affect the way these different agents interact, share, access, regulate, exchange and use existing and new data, information and knowledge<sup>18</sup>.

**Figure 1. Typology of Climate Change Adaptation Strategies**



Source: Author Pant with reference to Mintzberg and Waters (1985) and Mintzberg (2007)

Innovation systems literature focuses on multiple sources of innovation beyond just 'top-down' scientific research, and emphasises the importance of drawing on

<sup>14</sup>Amabile, 1996.

<sup>15</sup>Bacon, 1901; Ruttan, 1971; Shapiro, 2002.

<sup>16</sup>The father of business strategy Henry Mintzberg and his colleagues (Mintzberg et al., 1976; Mintzberg and Waters, 1985; Mintzberg, 2007) argue that deliberate and emergent strategies are the two ends of a continuum along which real-world strategies to address complex problems such as climate change can be formulated.

<sup>17</sup>Hall & Clark, 2010.

<sup>18</sup>Lundvall, 1992; World Bank, 2006.

information and knowledge from 'bottom-up' practice<sup>19</sup>. In this context, individual as well as collective capacity to put existing and new knowledge into practice is crucial as capacity includes "abilities, skills, understandings, attitudes, values, relationships, behaviours, motivations, resources and conditions that enable individuals, organisations, networks/sectors and broader social systems to carry out functions and achieve their development objectives over time."<sup>20</sup> Thus capacity is an emergent property of a system that comes through the interrelationships and interactions among various elements of the system, including biophysical, technological, social, political and cultural components<sup>21</sup>. Adaptive capacity can therefore be understood as innovation capacity, which entails agile systems of collective context-specific skills, practices, routines, institutions and policies to put existing and new information and knowledge from research as well as practice into productive use in response to technological, economic, social, climatic and environmental challenges and opportunities<sup>22</sup>. Specifically in the field of climate change, adaptive capacity refers to "[t]he ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."<sup>23</sup>

We can then draw four conclusions in our recognition of the relevance of innovation to this systems-based understanding of adaptive capacity development. First that data, information and knowledge will be key resources within adaptation to climate change. Second that adaptive capacity will involve the capacity to access, assimilate, create and utilise data, information and knowledge. Third that, for a community, this will specifically require some means to integrate the local and the external. Fourth (and a point returned to later) that we need to recognise capacity as both individual and collective.

## 2.2 Climate Change Adaptation Processes

As presented in the previous section, putting local and external information from research and practice into collective learning, innovation and action is central to the development of climate change adaptive capacity. An entry point to facilitate the adaptation processes will therefore be to recognise that there are multiple stakeholders with multiple knowledge traditions that shape their handling of data and information. Building on this and the work of Brown<sup>24</sup>, we can suggest a three-step process of developing adaptive capacity as follows.

Firstly, identify the range of stakeholders and worldviews that relate to the core problem. For example, what do climate change and climate change adaptation mean to stakeholders such as scientific communities, and local communities, and public and private sector actors? Specifically in the context of climate change, scientific data and information are available on the greenhouse gases and other causes of climate change, but there are (and will be) different views and different understandings regarding actual and potential impacts of climate change vis-à-vis agriculture, food security, natural resource management, and patterns of infectious

---

<sup>19</sup>Biggs, 1990; DFID, 2005; Lenné, 2008.

<sup>20</sup>CIDA, 2000: 2.

<sup>21</sup>Morgan, 2005.

<sup>22</sup>Hall, 2005.

<sup>23</sup>IPCC, 2007: 869.

<sup>24</sup>Brown, 2010.



disease. In particular, local communities may well have quite different worldviews on these issues to those espoused by the scientific community.

Secondly, identify the multiple knowledge traditions – multiple ways of data collection, of transforming the data into useful information and knowledge, and of storage, exchange, regulation and application of information – that these different stakeholders adhere to. For example, how do the data, information and knowledge systems of local communities in relation to climate change and adaptation compare to those of external stakeholders?

Thirdly, consider how these differing information and knowledge resources can be integrated as part of building capacity for climate change adaptation. It is clearly important to bridge the divide between local and external/expert systems, but the presence of the different worldviews and different information and knowledge systems presents a challenge to this activity.

One method of addressing divergent worldviews and systems practices is the use of intermediaries. Intermediaries play important roles in bringing heterogeneous actors together, particularly the public and private, formal and informal, external and local, and rural and urban actors engaged in knowledge production, storage, exchange, regulation and application<sup>25</sup>. Individual and/or organisational intermediaries can play diverse brokering roles depending on a particular context: boundary spanning, social and environmental activism and innovation, and generating positive social and environmental changes. Our particular interest here, though, is their role as 'infomediaries' in information and knowledge brokering: bringing together information and knowledge from multiple and differing sources, and blending it in order to provide this important foundation for climate change adaptation.

In doing this, however, intermediaries face many barriers. They are constrained by the structural and institutional frameworks within which they operate. They are challenged by the capacity and resources limitations such frameworks often impose. They face the more technical challenges of accessing data and synthesising data formats drawn from different knowledge traditions. Given the recent diffusion of digital technologies in developing countries, the question then arises of whether ICTs can help address some of these barriers to formation of the informational basis for climate change adaptive capacity; either in an informational sense or in a more structural and transformative sense.

### **3. ICT-Enabled Development of Climate Change Adaptive Capacity**

To address the issue of how ICTs can help develop climate change adaptive capacity, this section first introduces the archetypes of ICT infrastructure. It then reviews some field experiences of using the dominant technology type – mobile – to address climate-relevant development challenges. But a deeper understanding of ICTs' role in climate change adaptation suggests there are limitations to current models which a rehabilitation of the telecentre model might partly address.

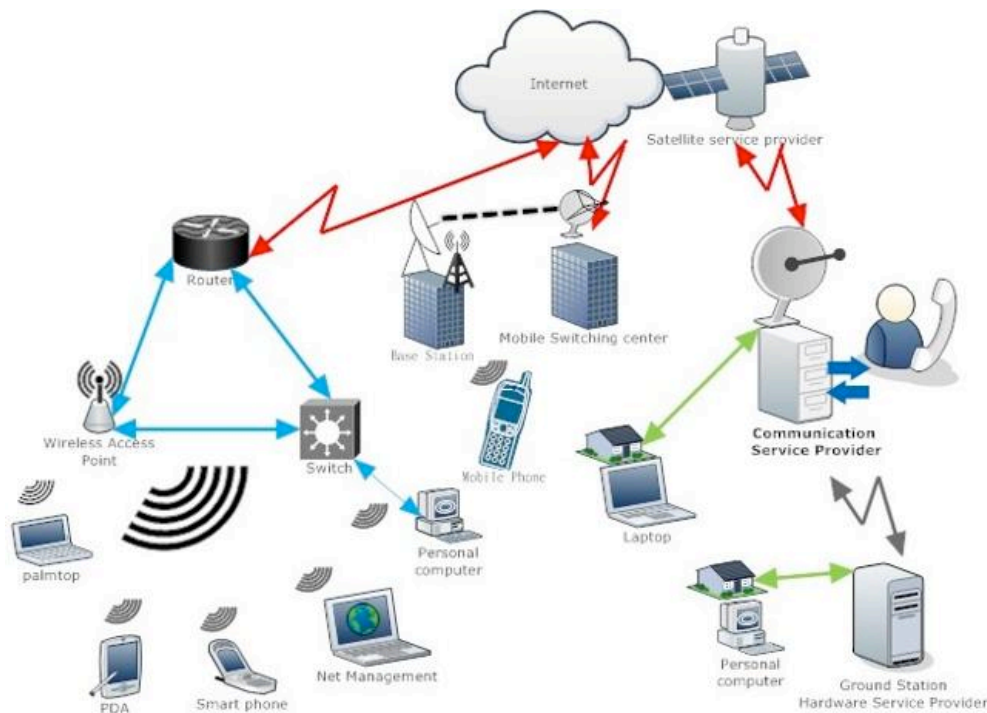
---

<sup>25</sup>Klerkx & Leeuwis, 2008; Klerkx et al., 2010.

### 3.1 ICT Infrastructures for Climate Change Adaptation

We can identify six main categories of ICT architecture of relevance to climate change adaptive capacity-building in developing countries: advanced Internet network-based, ordinary mobile phone-based, telecentre-based, a combination of ordinary mobile phone and telecentre, a combination of ordinary mobile phone with central Internet-linked server, and a combination of emerging ICTs with conventional media, such as radio and television. The first three of these are illustrated in Figure 2. The advanced Internet network – incorporating the type of wireless devices only just emerging in low-income countries – is shown at the left side of the diagram. Ordinary mobile phone-based access to cellular networks is depicted in the middle. As the quote at the very start of the paper indicated, this is becoming universally accessible but with a limited data transfer functionality given the relatively slow roll-out of 3G mobile telephony<sup>26</sup>.

**Figure 2. Three Archetypes of ICT Infrastructure**



Source: Author Pant with reference to personal communication with B.M. Bhattarai (2010)

The third category is the telecentre-based Internet access architecture illustrated on the right side of Figure 2. The telecentre model of public ICT services was initially conceptualised as a way to provide telephone services when wired telephones were still rare and before mobile phones were really available. With emergence of the Internet in the 1990s and, in developing countries, early 2000s, telecentres gradually transformed into public Internet access points. Now, with increasing access to Internet through mobile devices, telecentres may need to transform further.

<sup>26</sup> Compared to 2G mobile services that are virtually isolated from the Web, 3G mobile services provide options for Internet access through cellular networks, including multimedia messaging services (MMS).

Such transformation is seeing appearance of the fourth ICT architecture: the combination of ordinary mobile phones and telecentres. As discussed further below, this can open new possibilities for real-time and emergency communication, and facilitate integration of local and external information and knowledge by combining the power of Internet access with the relative ubiquity of the mobile phone. That power is also harnessed in the fifth model, which uses mobile phone calls (including interactive voice response systems (IVR)) or texting to connect to a central server, or to an operator using that central server. Finally, an alternative converged infrastructure involves use of basic mobile telephony for data transfer – via voice or short messaging service (SMS) – together with community radio, television, community billboards, conventional print or a combination of these.

Given the pervasive availability of mobile devices – particularly standard phones – it is this technology that we will initially focus upon. A few examples of the mobile-related ICT architectures are shown in Table 1, with applications of relevance to climate change effects including those on agriculture and health<sup>27</sup>.

**Table 1. Project Examples of Different Mobile-related ICT Architecture Models**

<b>Project</b>	<b>Description</b>	<b>Country</b>
<b>Food security monitoring<sup>28</sup>.</b>	Use of PDAs to collect data regarding changes in food security situations [Model 1]	Nepal
<b>NetMark malaria-control project<sup>29</sup>.</b>	Use of PDAs to conduct household surveys about insecticide-treated bednets [Model 1]	Uganda
<b>Health Information Network<sup>30</sup>.</b>	Electronic data upload and download using PDAs and mobile phones to facilitate decision making among health workers located in remote health centres [Model 1/5]	Uganda, Mozambique
<b>DatAgro<sup>31</sup></b>	SMS to farmers using low-cost mobiles regarding information on weather forecasts, market prices and cultivation practices [Model 2]	Chile
<b>Fisher Friend Programme<sup>32</sup>.</b>	Weather forecasts, optimal fishing zones, market prices and related messages to fishers using mobile phones [Model 2]	India
<b>Farmers' Text Centre<sup>33</sup>.</b>	Farmers send text messages to Farmers' Text Centre where the information is processed and responses are sent back via SMS [Model 5]	The Philippines
<b>The Farmer's Friend service<sup>34</sup>.</b>	Farmers send text to a central Internet-connected server where information is processed and responses are sent back [Model 5]	Uganda
<b>Flood Warning Systems<sup>35</sup>.</b>	Use of mobile phones to collect data for flood forecasting and forward to central early warning system, which are then disseminated via traditional media [Model 5/6]	Cambodia Laos, Vietnam

Source: Author Pant compilation

<sup>27</sup>The paucity, as yet, of ICT applications directly relating to climate change and climate change adaptation mean that we have to utilise somewhat broader applications as our examples.

<sup>28</sup>NeKSAP, 2009.

<sup>29</sup>AED, 2008.

<sup>30</sup>AED, 2008; MoH, 2010.

<sup>31</sup>Cagley, 2010.

<sup>32</sup>MSSRF, 2010.

<sup>33</sup>Pascua et al., 2010.

<sup>34</sup>The Economist, 2009.

<sup>35</sup>MRC, 2009a, 2009b.

## **3.2 ICT-enabled Information and Knowledge Exchange**

We can now look at these examples of climate change-related uses of ICTs, to analyse how they are supporting the information and knowledge exchange that was seen above to be an important component of adaptive capacity.

### **3.2.1 Local Information and Knowledge Generation**

Empirical evidence is emerging on the use of PDAs and mobile phones to generate local information to enhance anticipatory adaptation. In the floodplains of the Mekong River Basin in Cambodia, Laos and Vietnam, villagers have been provided with mobile phones and flood markers, and trained to record water levels in remote areas and to report the figures to weather agencies through text messages<sup>36</sup>. Flood management experts analyse the data and convert them into flood forecast figures which are sent back to the community. The villagers then publicise the figures on local billboards established at strategic locations along the flood plain and also announce through loudspeakers.

Application of handheld digital mobile devices has also emerged in data collection, analysis and providing information for problem-solving and decision-making that can potentially enhance autonomous climate change adaptive capacity of vulnerable communities. Examples include a PDA-based food security monitoring system of Nepal<sup>37</sup>, and surveys of malaria-control project households in Uganda. It is believed that climate variability and change, and extreme weather events, such as droughts and floods have negatively impacted both food security, and vector-borne disease outbreaks, such as dengue fever in Nepal and malaria among vulnerable communities in Uganda. Handheld mobile digital devices are useful for continuous monitoring and reporting of food security such as cropping and stock details, and of relevant diseases<sup>38</sup>.

These applications therefore show particularly how a 'voice' component of adaptive capacity can be strengthened, enabling data from vulnerable communities to be attended to by external institutions, and aggregated and processed in a way that then helps protect those communities, and offers them adaptive guidance. There is, as yet, less sense within these applications that local knowledge is being much utilised or generated.

### **3.2.2 Access to External Information and Knowledge**

As with the data upload utility of handheld mobile digital devices, empirical evidence is also emerging on the use of PDAs and mobile phones to access external information from the Web. In Chile the DatAgro project transfers searchable content from the Internet into news feeds (RSS) and then the content is passed on to farmers via SMS<sup>39</sup>. Specifically-written software allows such searching to be undertaken via simple, low-cost mobile phones and slow networks with sporadic connectivity, a typical situation of prepaid mobile users in low-income countries. In the face of climate change, farmers benefit from improved access to weather forecasts and information on new and emerging production and post-harvest

---

<sup>36</sup>MRC, 2009a, 2009b.

<sup>37</sup>NeKSAP, 2009.

<sup>38</sup>Morens et al., 2004.

<sup>39</sup>Cagley, 2010.

technologies. This can help improve short-term climate-related decision-making (e.g. in relation to heat waves, rainfall patterns or potential flooding) and long-term climate-related decisions around changes to cropping choices and mixes. Recognising the need to integrate the local and the external, the project allows farmers to customise the information feeds they receive, and also provides a basis for follow-up interaction from the central project team if the content of SMS messages has not been well understood.

The Fisher Friend Programme of the MS Swaminathan Research Foundation (MSSRF) processes satellite information in order to provide weather forecast and fishing zone information in local languages via mobile phone<sup>40</sup>. Alongside the financial gains of improved fish stock location, this system can also have climate-related benefits: it has successfully forecast storms and other extreme weather events that have led fishermen to avoid particular areas or simply not put to sea. In addition, with climate change associated with changes in sea currents, the fish shoal availability information is seen as an integral part of building longer-term adaptive capacity<sup>41</sup>. Future plans include making the information available via IVR to enable hands-free and low-literacy user access, and adding global positioning system capability into the phones, to enable tracking in the event of a local weather-related disaster.

If the first set of examples represented bringing the local to the external, the examples in this section represent the reverse. They show how external information and knowledge can be brought down into local communities, and integrated into local practices that increase the capacity of those communities to adapt to various aspects of climate-related change.

### **3.2.3 Two-way Exchange of Information and Knowledge**

Although various initiatives prioritise either download or upload of data to and from the Web, there are also initiatives that focus on two-way information exchange (albeit recognising that in all the previous examples, there is always some form of interaction). The Health Information Network projects of Uganda and Mozambique have utilised existing mobile telephone networks and PDAs for this purpose<sup>42</sup>. In Uganda, this project was conceived to provide two-way communication connecting the local (rural and remote health workers) and the external (district and national health system managers). Through this project, the district/national level obtains information on, for example, emerging and re-emerging patterns of disease, and the amount of drugs and other services needed at the local level. The PDAs come with a digital 'Mobile Medical Library', including a range of reference materials that health workers consult for treatment of patients. The network also supports health information exchange via data collection and text and voice messages, so that local-level questions about treatment for particular patients can readily be answered. Via upflow, downflow and interchange of both data and information, the key stakeholders can have greater capacity to adapt to various aspects of climate change including understanding climate-related changes in disease patterns, planning for the implications of such changes, and also handling the health impacts of short-term climate-induced emergencies such as heatwaves or floods.

---

<sup>40</sup>Nanda & Arunachalam, 2009; MSSRF, 2010.

<sup>41</sup>Mittal et al., 2010.

<sup>42</sup>Jaramogi, 2010; MoH, 2010; Nakkazi, 2010; UHIN, 2010.

In the Philippines, an SMS-based system of two-way data exchange has been implemented using basic mobile phones<sup>43</sup>. Information seekers – e.g. a farmer, extension worker, agribusiness owner, or others – can send a text message to the Philippine Rice Research Institute's Farmers' Text Centre to get free guidance on rice growing. This system can provide timely information useful to minimise impacts of climate change on rice farming ranging from short-term advice on planting and harvesting in relation to extreme weather events, to medium-term guidance on planting techniques to reduce methane production or to cope with fluctuations in seasonality, to information on coping with longer-term changes to pest and crop suitability. A similar initiative in Uganda, called The Farmer's Friend service, responds to text message queries on everything from weather forecasts to pests to planting techniques<sup>44</sup>. Relatively complicated texts are relayed to human experts, who either call back within 15 minutes or promise to provide an answer within four days based on their own knowledge and/or searches via the Internet or within a locally-constructed database.

These systems are allowing a relatively-rich interchange between the local and the external. In general, the emphasis is still on local data but external knowledge. Nonetheless, these applications are forcing the two knowledge traditions to overlap, and pushing the external knowledge systems and stakeholders to at least take account of local worldviews. By thus combining the local and the external, they are creating a broader foundation for adaptive capacity and one that is thus not merely larger but also potentially more resilient.

### **3.3 Opportunities and Challenges of Using ICT for Climate Change Adaptation**

The above presentations of project examples, although brief, are symptomatic of the current picture of ICT use vis-à-vis climate change adaptive capacity; and not just because they place mobile technologies at their core. They demonstrate the way in which capacity can be built by integrating local and external data and, to some extent, knowledge. They are not climate change-specific, but they show how generic ICT-for-development initiatives can readily address climate change issues and so enhance climate change adaptive capacity. They also fit with the more general conclusion that approaches to using ICTs for climate change adaptation should be more holistic than reductionist, and should recognise the way in which climate change's main effect is the exacerbation of existing vulnerabilities. Put another way, we regard the lack of climate change-specificity in ICT initiatives as "a feature not a bug": a design approach that is to be recommended.

To investigate this further, we can turn back to the model of strategies presented in Section 2.1. We noted the distinction between deliberate, pre-planned strategies, and emergent strategies for climate change adaptation. We noted further that – given climate change is a complex problem characterised by multiple stresses and non-linear interactions – deliberate planning and implementation of adaptation interventions will not be enough. With vulnerable communities in developing countries understood as complex adaptive systems, then there must also be capacity within those systems for strategies to emerge autonomously, for example

---

<sup>43</sup>Pascua et al., 2010; The Philippine Star, 2010.

<sup>44</sup>The Economist, 2009.

in response to unexpected events. As summarised in Table 2, while deliberate strategy may work best for simple and known problems, emergent strategy would be effective in solving complex problems<sup>45</sup>. Our earlier examples show ICTs can help with both.

**Table 2. Deliberate and Emergent Strategies for Climate Change Adaptation**

	<b>Intended strategy</b>	<b>Unintended strategy</b>
<b>Anticipatory</b>	Deliberate strategy, e.g., early warning systems. Effective in simple and known systems	
<b>Autonomous</b>		Emergent strategy, e.g., agriculture and health information systems. Effective in complex adaptive systems

Source: Author Pant

Deliberate strategies can be anticipatory as well as intended. Anticipatory adaptation strategy involves proactive use of ICTs in planned adaptation to climate change and related stresses before actual impacts are known but when the general nature of those impacts is known, such as mobile phone use in flood warning systems in the Mekong River Basin<sup>46</sup>. In this case multi-purpose information networks potentially useful at the time of extreme events, but not necessarily dedicated to climate change alone, would be effective in creating a nimble information and knowledge infrastructure for overall capacity development of relevant stakeholders. Examples of intended use of ICTs in response to known climate change stresses include the use of PDAs and mobile phones to identify optimal fishing zones in response to decreasing and/or changing fish stocks in the Indian Ocean<sup>47</sup>. These intended uses of ICTs can specifically facilitate planned climate change adaptation, such as sustainable harvesting of natural resources from ecosystems that are already vulnerable.

Emergent strategies are not planned in advance and can be autonomous as well as allowing for unintended impacts; they therefore emerge when a need arises. Autonomous, emergent adaptation strategy can make use of ICT initiatives set up without actually knowing and/or specifically targeting climate change impacts. Examples include the use of PDAs and mobile phones in food, agriculture and health information systems in Nepal, Chile, Uganda and Mozambique<sup>48</sup>. At the time of additional stresses caused by climate change and extreme events these networks provide the capacity for real-time exchange of information and knowledge for agile problem-solving and decision-making. Similarly, ICT-enabled exchange networks that are established for economic and social development interventions can have emergent use during the time of extreme events albeit such uses may initially be unintended. For example, the two-way information exchange systems cited above that are operational in food, agriculture and health also help develop adaptive capacity to handle additional stresses in the face of climate change. However, this – by-and-large – represents potential applications for these ICT initiatives rather than use for which we have actual evidence at present.

<sup>45</sup> Snowden & Bonne, 2007.

<sup>46</sup>MRC, 2009a.

<sup>47</sup>AED, 2008; MSSRF, 2010.

<sup>48</sup>NeKSAP, 2009; Cagley, 2010; UHIN, 2010.

Further, we must recognise a key difference between the two strategies and the demands they place on ICT-enabled systems and capacities. Deliberate, planned strategies can rely significantly and principally on capacities external to the local community. Hence, in the pre-planned uses of ICT systems noted above, the local is often the 'junior partner' to the external. Most of the systems involve connections and they are additive of capacities at local and national level. But it is the community – in the main – that taps into capacities of the wider world much more than vice versa. Yet emergent responses to climate change rely far more on local capacities: conceptually that is inherent to the notion that these are autonomous more than anticipatory; and practically that may be the case at least with extreme climate-related events when it may be more difficult to draw on external capacities for assistance.

We therefore turn to ask what kinds of capacities these ICT systems are building. That requires us to understand more about the emergent capacities of self-organising systems in relation to climate change.

### **3.3.1 ICTs and Self-organising Systems of Adaptive Capacity Development**

To build a model of ICT-related climate change adaptive capacity, we start by recognising that the risks of climate change derive from Crichton's "risk triangle"<sup>49</sup>. This asserts that risk arises from a combination of the intensity and frequency of particular climate change-related *hazards*, such as floods or droughts, the degree of *exposure* to those hazards (for example exacerbated by absences of drainage or irrigation systems), and the inherent *vulnerability* of the particular population; that vulnerability being greater for those who are poor, elderly, chronically-ill, etc<sup>50</sup>. Given that hazard is largely outside the sphere of human control (if we set aside the issue of climate change mitigation actions), then climate change adaptation becomes the process of seeking to reduce exposure and vulnerability. This is done (see Figure 3) by making improvements in assets (natural, physical, financial, human, social, cultural and political capital), social structures (at various levels), and institutional processes (both formal such as policy and law, and informal such as custom and culture)<sup>51</sup>. If successful, this reduces the triangular 'area' of risk and uncertainty.

---

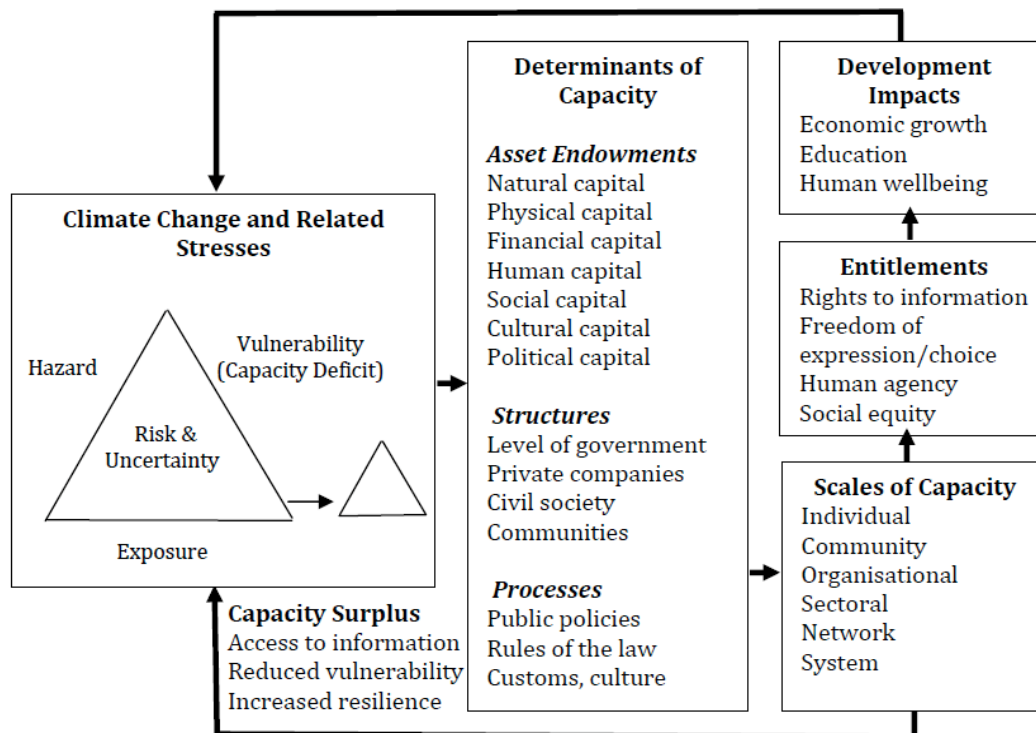
<sup>49</sup>Crichton, 1999.

<sup>50</sup>Hardoy & Pandiella, 2009.

<sup>51</sup>Crichton, 1999.



**Figure 3. Climate Change Adaptive Capacity Development Framework**



Source: Author Pant with reference to Crichton (1999), Chambers & Conway (1992), Scoones (1998), CIDA (2000), and Sen (1999)

Using Figure 3's foundation, we can then modify this framework in order to take a greater focus on the role of ICTs (see Figure 4). From this we recognise that the main determinants of ICT-enabled development of climate change adaptive capacity will be asset endowments (both technical and human), organisational structures of relevance to ICT, and the institutional environment including ICT policies and the ICT-related habits and practices of multiple stakeholders.

There are two structural features of this ICT-related capacity development. First, that it is multi-level: capacity development for climate change adaptation demands action to develop individual, organisational, network and system level capacity to bring positive economic, environmental and social change<sup>52</sup>. When interrogating ICT initiatives, we must therefore ask at what level capacity is being developed. Second, Clarke & Oswald<sup>53</sup> caution that the conventional approaches to development of climate change adaptive capacity view skills and knowledge as things to be transferred to fill a deficit, in specific individuals, organisations, networks and systems without due considerations of collective capacity development for emancipatory change; unleashing the potential of vulnerable communities, economies and ecosystems to self-organise. As argued earlier, the latter is particularly important if emergent strategy on climate change is to be enabled.

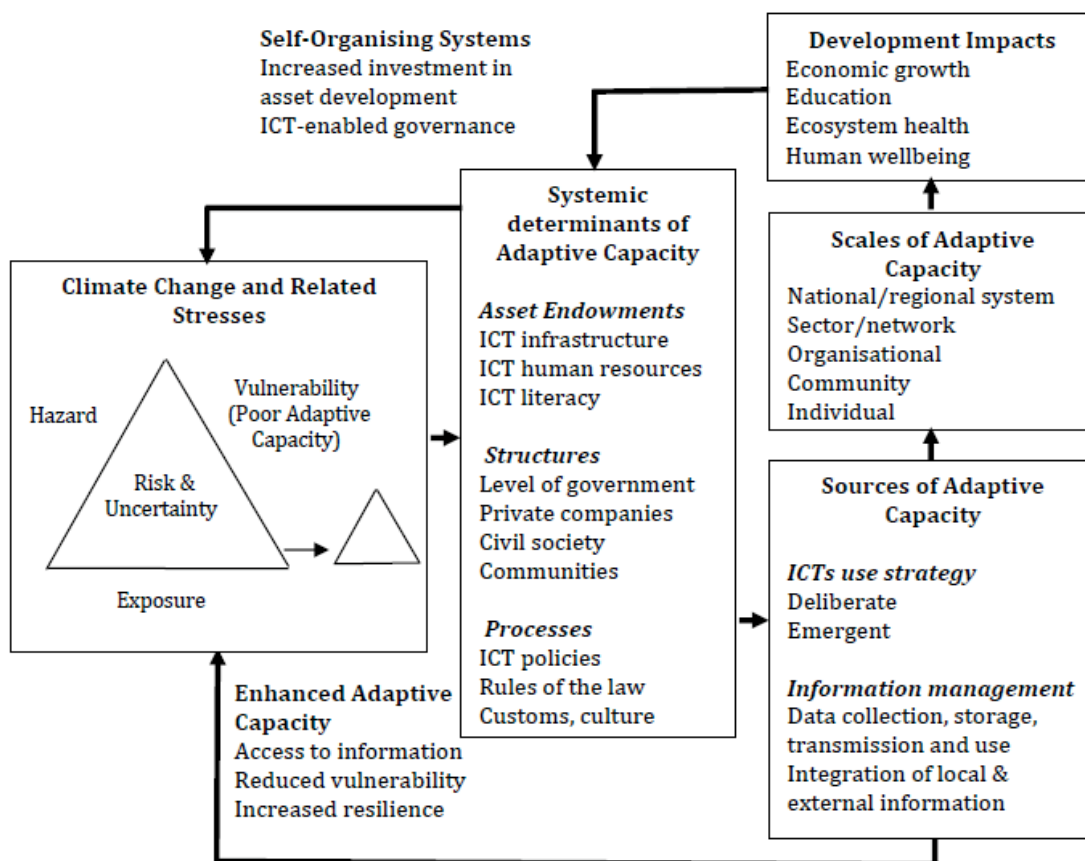
<sup>52</sup>CIDA, 2000.

<sup>53</sup>Clarke & Oswald, 2010.

Building these ideas into our framework as shown in Figure 4, we can note two main ICT-relevant feedback loops that we require to operate if communities are to build climate change adaptation capacity. The first is an *informational loop*. Very much along the lines already discussed and illustrated in the examples, this involves the development of ICT-related asset endowments which then draw together data and knowledge from various levels and sources, and generate improved access to information. This improves local knowledge, decision-making and problem-solving action (see examples above) and so reduces vulnerability and increases resilience.

The second is a *transformational loop*. This moves beyond a simple information management perspective, to a deeper structural view, recognising that ICTs may be utilised to alter the structural location of capacity; in particular transforming community systems to enable them to become more self-organising and, hence, facilitating the type of autonomous, emergent strategy-making that we have argued will be one key part of the response to climate change.

**Figure 4. ICT-enabled Climate Change Adaptive Capacity Development Framework**



Source: Author Pant with reference to Figure 3.

Armed with this deeper perspective on ICTs and climate change adaptation, we can now re-view the ICT experiences to date that were outlined above. From this, we see that – while there was potential for ICT-for-development projects to support both deliberate and planned strategies – in practice, our evidence to date is that

they have been working far more in the top-down, pre-planned, anticipatory mode than in the autonomous and emergent mode. Phrased in Figure 4 terms, the informational loop is certainly working but has largely been about the insertion of external data and knowledge into local communities, potentially increasing dependency rather than autonomy and self-reliance. The transformational loop has largely not been seen to work so far – communities have not particularly become more self-organising, they have not particularly developed local informational capacities – or, at least, not to the extent necessary given the demands being placed on them by the increasing intensity and frequency of climate change and related stressors. And, given the growing model of individuals using mobile phones or PDAs to connect to distant server systems, any capacity-development has tended to be atomised with no role for a community-based infomediary. Far from creating the collective capacity identified above as crucial, the type of ICT initiatives that are currently in vogue might even, then, be dispersing that capacity.

### **3.3.2 Transforming Conventional Telecentres into Mobile Teleservices**

What, then, can be done to help develop the climate change adaptive capacity that is local and self-organised, and which can support emergent strategies? We must be clear that there are no panaceas. However, it may be time to look again at the local telecentre. As noted above, telecentres have had a relatively bad press in recent years, fuelled by failed projects and recognition of the many challenges and barriers they face.

One reaction to this has been functional, particularly the development of telecentre multi-functionality. In service breadth terms, this has meant telecentres providing as broad a range of ICT-related services as possible, moving well beyond the traditional confines of e-government, e-agriculture, e-health, etc. In service depth terms, this has meant telecentres moving beyond digital data flow to provide the "information chain" support necessary to turn that digital data into developmental impact: digital literacy training; assistance with online searching about jobs, weather, pest risks, etc; support for finding sources of capital, goods, etc<sup>54</sup>. In locational terms, this has meant incorporating telecentres in multi-use locations such as meeting places, libraries, markets, etc<sup>55</sup>.

We noted above that "adaptive capacity will involve the capacity to access, assimilate, create and utilise data, information and knowledge". The mobile- and PDA-based models described earlier develop individual capacity within communities to access and, sometimes, create data. By contrast, it can be seen that telecentres develop both individual and collective capacities across the whole range of information and knowledge activities. One key asset of telecentres is the telecentre operator, who – as an infomediary – becomes an important part of community capacity; for example in performing the role identified earlier of mediating between local and external sources of data and knowledge. They have thus frequently been shown to assist in: identifying external data sources for local users, explaining external knowledge frames, and in translating local 'knowledge traditions' for external users<sup>56</sup>.

---

<sup>54</sup> Heeks & Kanashiro, 2009.

<sup>55</sup>E.g. initiatives in Cape Town, South Africa (Chigona & Licker, 2008) and in Chile (Kleine, 2010) that incorporate telecentres within public libraries.

<sup>56</sup>GIS, 2010.

Yet the reach of telecentres still remains limited. Mobility is the answer. One approach has been to physically bring the telecentre to the users. In North India, telecentre operators have brought *tele-thela* – carts equipped with ICTs – into peri-urban and rural settlements providing a range of services to the communities, such as telephone calls, email, Internet browsing and digital literacy classes<sup>57</sup>. Similarly, the well-known "telephone ladies" in Bangladesh are increasingly moving on from circulating around their village with mobile phones to providing mobile Internet services using netbooks and laptops<sup>58</sup>. The operators then represent "mobile intermediaries" who not only bring both technology and adaptive capacity to individuals, but also represent a collective source of capacity that is steadily being built within the community<sup>59</sup>.

An alternative approach to telecentre mobility is to bring the telecentre virtually to the users by adopting 'Model 4' of the ICT architectures discussed above: the combination of telecentre and mobile phone. There are already a number of projects using this model, which have demonstrated their value. For example, the "Warana Unwired" project in Western India enabled farmers – whether at home or in the field – to access telecentre services via SMS-based mobile phone<sup>60</sup>. While at one level similar to the initiatives that connect users in poor communities to server-based services in the national capital (as per 'Model 5' above), there is a crucial difference here that the connection is via the local telecentre operator. Not only are they able to 'infomediate' both ways better than a distant contact, bridging the gap between local and external information and knowledge, for example by explaining guidance to the farmers. But in doing so and in learning, they are building capacity that is captured within the local community. This therefore supports the type of capacity necessary for a more self-organised and emergent approach to climate change adaptation.

## 4. Conclusions and Recommendations

ICTs will play a crucial part in the development of climate change adaptive capacity in developing countries. They will do this in four ways: i) by combining existing data in new ways; ii) by enabling access to new data, information and knowledge; iii) by reducing costs of access to transactions and services; and iv) by their productive role in ICT-based enterprise. Our focus here has been largely on the first two applications, with the more transactional and productive roles that ICTs can play set aside due to lack of evidence, at least in relation to climate change adaptation.

The dominant pattern of thinking on climate change adaptation has been top-down, deliberate, planned. This is a vital part of capacity building, but it is only a part. There needs to be equal recognition that many climate change adaptive actions will be emergent – unplanned and arising from within individual communities and regions that should be understood as complex adaptive systems. The application of ICTs to climate change adaptation must also be shaped by this equality of recognition.

---

<sup>57</sup>Singh. 2007.

<sup>58</sup>The Economist, 2009.

<sup>59</sup>Kiran et al., 2009

<sup>60</sup>Veeraraghavan et al., 2009.

To date, ICT applications – which are dominated by mobile technology-centred models – have also been dominated by the 'planned strategy' worldview. They have been quite good in an informational role that links the local and the external: sometimes concentrating on upload from local to external, sometimes on the reverse download, sometimes on exchange between the two. These applications have been quite poor at delivering a transformational role that truly builds local adaptive capacity. Even where they link local and external, this has not been a meeting of equals: communities bring their data, external experts deliver their information, their knowledge and their worldviews. The different knowledge traditions of these two groups mean this exchange is not always as effective as it might be.

The telecentre model with its local infomediary has the potential to partly challenge this current status quo, but has itself been challenged from all sides: the technical, the socio-political and the financial. One way forward may be the integration of mobile devices with local telecentres, but this model has been rather rare compared to the mobile-devices-with-national-servers architecture.

While implementing their National Adaptation Programmes of Action, developing countries are invited to bear in mind the following recommendations:

1. Climate change cannot readily be separated out as an issue for local communities: it exacerbates and is exacerbated by other vulnerabilities. There has been concern at the lack of climate change adaptation-specific ICT applications. Given, the indivisibility of climate change from other development issues, this may be no bad thing. It may make more sense to understand the climate change-related uses of existing ICT projects and systems, rather than seeking to develop new applications that are climate-specific.
2. In the balance between the local and the external in current ICT applications, the emphasis has been too little on the former, too much on the latter; even running the risk of reducing local capacities and increasing dependency on those from outside. Emergent actions demand the greater development of local capacities e.g. those within individual communities. An acid test, then, for ICT projects will be the extent to which they truly develop those capacities with a true appreciation of diverse knowledge traditions. Where local users are, for example, providing climate impact-related data, can they be made more than just dumb data sources? Can their knowledge and practices be incorporated into the information system?
3. The same issue applies for that part of adaptation-relevant systems which offers external information, often wrapped within an external knowledge framework. Such information will almost always require 'translation' if it is to be relevant to local knowledge traditions and local practices. How will that local translation capacity be fostered and engineered into the system? Expanding this point more generally, effective use of data requires an 'information chain' of resources that enable the data to be accessed, assessed, assimilated, applied and actioned. Adaptation project design must ensure that the resources necessary to complete that entire chain – from data through information and decisions to actions – are either available or can be created.
4. Mobile phones are an incredible technology and their significant perceived value within poor communities is reflected in their very rapid diffusion rates. As a result, climate change-related projects are likely to be mobile-dominated for many years.

But mobiles can atomise capacities, can deliver only the first part of the information chain. Adaptation project design needs to incorporate some means for collective capacity development. That may often be through infomediary development. While not the only model, the telecentre operator is one possible hub for this, with new telecentre architectures based around smart mobile 'info-carts' or around mobile-plus-fixed-telecentre presenting possible ways forward. The technology question is thus not 'mobile phone or telecentre?' but how to implement 'mobile-telecentre'.

Finally, further research on the use of ICTs for developing climate change adaptive capacity needs to look at how nation states have proposed to use a range of ICTs in their National Adaptation Programme of Action. Specific research questions can relate to whether and how existing ICT architectures are being utilised to enhance national, regional and local adaptive capacity, and what are the strategic priorities to develop and/or expand ICT infrastructure over time and space. We also need to understand how ICTs can be used in ways that move beyond their basic 'data flow' role: with ICTs now able to handle digital transactions, and able to form the basis for new ICT-based enterprises, how can these newer roles contribute to capacity building?

We have recommended the value of avoiding climate change adaptation-specific ICT applications, but how does this materialise in practice. Are there such specific applications emerging in field projects and, if so, what lessons can we learn? The same questions also apply to the 'mobile-telecentre' models advocated above: these are as yet quite rare, and we need to better understand their good and bad practices and, more importantly, impact on local capacity formation.

Finally, we need research to empirically test the conceptual framework developed in this paper and to understand more about two issues put forward. What role will local infomediaries play in climate change adaptation? Is the telecentre operator the only model here or will there be others, perhaps more emergent from within communities? And what of emergent actions on climate change adaptation: what are these, and how can we better understand the role of ICTs in supporting them?

## Bibliography

- Adger, W. (2006) 'Vulnerability', *Global Environmental Change*, vol. 16, no. 3, pp. 268-281.
- AED. (2008) *PDA's and Beyond: Innovative Technologies and Applications Accelerate Development*. Washington D. C.: Academy for Educational Development (AED).
- Amabile, T. M. (1996) *Creativity in Context: Update to the Social Psychology of Creativity*. Colorado, USA: Westview Press.
- Ariyabandu, R. (2009). *Role of Telecentres as Knowledge Networks: Successes and Challenges*. Bangkok: Information and Communication Technology and Disaster Risk Reduction Division, United Nations Economic and Social Commission for the Asia and Pacific (UN-ESCAP).
- Bacon, F. (1901) *The New Atlantis (Written in 1626)*. New York: P. F. Collier & Son.
- Biggs, S. D. (1990) 'A Multiple Source of Innovation Model of Agricultural Research and Technology Promotion.' *World Development*, vol. 18, no. 11, pp. 1481-1499.
- Brown, V. A. (2010) Collective Inquiry and Its Wicked Problems. In V. A. Brown & J. A. Harris & J. Y. Russell (Eds.), *Tackling Wicked Problems: Through the Transdisciplinary Imagination*, pp. 61-81. London, UK: Earthscan.
- Cagley, M. (2010) 'From the Web to the Phone: Information System Sends RSS Feeds to Chilean Farmers via SMS', *ICT Update*, vol. 53, no. 10, pp. 1-5.
- Chambers, R. & Conway, G. (1992) 'Sustainable Rural Livelihoods: Practical Concepts for the 21st Century.' *IDS Discussion Paper 296*. Brighton, UK: Institute for Development Studies.
- Chiabai, A. (2009). *Analysis and Use of Information and Communication Tools in the Economics of Climate Change*. Bilbao, Spain: Basque Centre for Climate Change (BC3).
- Chigona, W. & Licker, P. (2008) 'Using Diffusion of Innovations Framework to Explain Communal Computing Facilities Adoption Among the Urban Poor', *Information Technologies and International Development*, vol. 4, no. 2, pp. 57-73.
- CIDA. (2000). *Capacity Development: Why, What and How*. Ottawa: Canadian International Department Agency.
- Clarke, P. & Oswald, K. (2010) 'Introduction: Why Reflect Collectively on Capacities for Change?' *IDS Bulletin*, vol. 41, no. 3, pp. 1-12.
- Crichton, D. (1999) The Risk Triangle, pp. 102-103. In J. Ingleton (Ed.), *Natural Disaster Management*, pp. London: Tudor Rose.
- Davenport, T. H. & Prusak, L. (1998) *Working Knowledge*. Boston, Massachusetts: Harvard Business School Press.

DFID. (2005) Evaluation of DFID Renewable Natural Resources Research Strategy 1995-2005. London, UK: Department for International Development's Central Research Department and Evaluation Department.

Fuchs, C. & Horak, E. (2008) 'Africa and the Digital Divide', *Telematics and Informatics*, vol. 25, pp. 99-116.

Gallopín, G. C. (2006) 'Linkages Between Vulnerability, Resilience and Adaptive Capacity', *Global Environmental Change*, vol. 16, no. 3, pp. 293-303.

GIS. (2010) *Infomediaries: Brokers of Public Access*. Seattle, WA: Global Impact Study, University of Washington.

Hall, A. (2005) 'Capacity Development for Agricultural Biotechnology in Developing Countries: An Innovation Systems View of What it is and How to Develop it', *International Journal of Development*, vol. 17, pp. 611-630.

Hall, A. & Clark, N. (2010) 'What do Complex Adaptive Systems Look Like and What are the Implications for Innovation Policy?', *Journal of International Development*, vol. 22, no. 3, pp. 308-324.

Hardoy, J. & Pandiella, G. (2009) 'Urban Poverty and Vulnerability to Climate Change in Latin America', *Environment & Urbanization*, vol. 21, no. 1, pp. 203-224.

Heeks, R. (2009) *The ICT4D 2.0 Manifesto: Where Next for ICTs and International Development?*, Development Informatics Working Paper no.42. Manchester, UK: Institute for Development Policy and Management, University of Manchester. Available: <http://www.sed.manchester.ac.uk/idpm/research/publications/wp/di/>

Heeks, R. & Kanashiro, L. L. (2009) *Remoteness, Exclusion and Telecentres in Mountain Regions: Analysing ICT-Based "Information Chains" in Pazos, Peru*, Development Informatics Working Paper no.38. Manchester, UK: Institute for Development Policy and Management, University of Manchester. Available: <http://www.sed.manchester.ac.uk/idpm/research/publications/wp/di/>

IPCC. (2007). *Climate Change 2007: Appendix I: Glossary*. Cambridge: Cambridge University Press.

Jaramogi, P. (2010) *Ministry of Health to Link with Remote Health Units* [Online], Available: <http://www.newvision.co.ug/D/8/13/721329>.

Kelly, T. & Adolph, M. (2008). ITU-T Initiatives on Climate Change. *IEEE Communications Magazine*, October 2008, pp. 108-114.

Kiran, M. S., Watkins, J. & Tacchi, J. (2009) 'The Role of Mobile Infomediaries: a BOP approach', paper presented at *eIndia International Conference*, Hyderabad, 25-27 August

Kleine, D. (2010) 'ICT4What? - Using the Choice Framework to Operationalise the Capability Approach to Development', *Journal of International Development*, vol. 22, pp. 674--692.



Klerkx, L., Aarts, N., & Leeuwis, C. (2010) 'Adaptive Management in Agricultural Innovation Systems: The interactions Between Innovation Networks and their Environment', *Agricultural Systems*, vol. 103, no. 6, pp. 390-400.

Klerkx, L. & Leeuwis, C. (2008) 'Delegation of Authority in Research Funding Networks: Experiences with a Multiple Goal Boundary Organization', *Science and Public Policy*, vol. 35, no. 3, pp. 183-196.

Lenné, J. M. (2008) 'Research into Use: Managing Achievements for impact', *Outlook on Agriculture*. vol. 37, no. 1, pp. 23-30.

Lundvall, B.-Å. (1992) *National systems of innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

McLaughlin, P. & Dietz, T. (2008) 'Structure, Agency and Environment: Toward an Integrated Perspective on Vulnerability', *Global Environmental Change*, vol. 18, pp. 99-111.

Mintzberg, H. (2007) *Tracking Strategies*. New York: Oxford University Press.

Mintzberg, H., Raisinghani, D., & Theoret, A. (1976) 'The Structure of "Unstructured" Decision Process', *Administrative Science Quarterly*, vol. 21, no. 2, pp. 246-275.

Mintzberg, H. & Waters, J. A. (1985) 'Of Strategies, Deliberate and Emergent', *Strategic Management Journal*, vol. 6, pp. 257-272.

Mittal, S., Gandhi, S., & Tripathi, G. (2010) *Socio-Economic Impact of Mobile Phones on Indian Agriculture. Working Paper No. 246*. New Delhi, India: Indian Council for Research on International Economic Relations.

MoH. (2010). *Press Release: UHIN Strengthens Health Systems and Improves Quality of Healthcare*. Kampala, Uganda: Ministry of Health.

Morens, D. M., Folkers, G. K., & Fauci, A. S. (2004) 'The Challenge of Emerging and Re-emerging Infectious Diseases', *Nature*, vol. 430, pp. 242-249.

Morgan, P. (2005) *The Idea and Practice of Systems Thinking and Their Relevance for Capacity Development*. Maastricht: European Centre for Development Policy Management.

MRC (2009a) *Villagers Provided with Cell Phones to Help Improve Accuracy of Flood Warnings* [Online], Available: [http://www.mrcmekong.org/MRC\\_news/press09/Laos-Villagers-provided-with-cell-phones21-9-09.htm](http://www.mrcmekong.org/MRC_news/press09/Laos-Villagers-provided-with-cell-phones21-9-09.htm).

MRC. (2009b) 'At Risk Villagers Trained to Help Report Floods', *Mekong News* vol. 2009/2, July-December 2009.

MSSRF. (2010). *Twentieth Annual Report 2009-2010*. Chennai, India: M. S. Swaminathan Research Foundation (MSSRF).

Nakkazi, E. (2010). *Uganda to Adopt Electronic Health Records System* [Online], Available:

[http://www.newsciencejournalism.net/index.php?/news\\_articles/print/uganda\\_to\\_adapt\\_electronic\\_health\\_records\\_system/](http://www.newsciencejournalism.net/index.php?/news_articles/print/uganda_to_adapt_electronic_health_records_system/).

Nanda, S. & Arunachalam, S. (2009) *Reaching the Unreached*. Chennai: Jamsetji Tata National Virtual Academy (NVA) and M S Swaminathan Research Foundation (MSSRF).

NeKSAP. (2009). *Nepal Food Security Monitoring System*. Paper presented at the Global Learning Forum 2009, 15-18 June 2009, Cairo, Egypt.

Ospina, A. V. & Heeks, R. (2010a) *Unveiling the Links between ICTs & Climate Change in Developing Countries: A Scoping Study*. Manchester: Centre for Development Informatics, Institute for Development Policy and Management, SED University of Manchester.

Ospina, A. V. & Heeks, R. (2010b) *Linking ICTs and Climate Change Adaptation: A Conceptual Framework for e-Resilience and e-Adaptation*. Manchester, UK: Centre for Development Informatics Institute for Development Policy and Management, University of Manchester.

Pant, L. P. (2009). *Learning Networks for Bridging Knowledge Divides in International Development: Approaches and Initiatives*. Bonn, Germany: European Association of Development Research and Training Institutes (EADI).

Pant, L. P. & Hambly Odame, H. (2009) 'Innovation Systems in Renewable Natural Resource Management and Sustainable Agriculture', *African Journal of Science, Technology, Innovation and Development*, vol. 1, no. 1, pp. 103-135.

Pascua, S. N., Zagrado, R., Asis, O. R. M., Domingo, O., & Maloles, J. (2010). *Enhancing Knowledge Networking Through Short Messaging Service: The Farmers' Text Center Experience*. Paper presented at the 23rd National Rice Research and Development and 40th Crop Science Society of the Philippines (CSSP) Scientific Conference and Anniversary.

Röling, N. G. (1990) The Agricultural Research-Technology Transfer Interface: A Knowledge Systems Perspective. In D. Kaimowitz (Ed.), *Making the Link: Agricultural Research and Technology Transfer in Developing Countries*, pp. 1- 42. London: Westview Press.

Ruttan, V. W. (1971) Usher and Schumpeter on Invention, Innovation and Technological Change. In N. Rosenberg (Ed.), *The Economics of Technological Change*. Middlesex: Penguin Books.

Scoones, I. (1998) 'Sustainable Rural Livelihoods: a Framework for Analysis', *IDS working paper 72*. Brighton, UK: Institute for Development Studies.

Sen, A. (1999) *Development as Freedom*. Oxford: Oxford University Press.

Shapiro, S. M. (2002) *24/7 Innovation. A Blueprint for Surviving and Thriving in an Age of Change*. New York: MacGraw-Hill.

Singh, R. J. (2007) 'For Want of Connectivity Push, IIT's infothela project struck', *Indian Express*, September 25, 2007, pp.

Smit, B. & Wandel, J. (2006) 'Adaptation, Adaptive Capacity and Vulnerability', *Global Environmental Change*, vol. 16, no. 3, pp. 282-292.

Snowden, D. J. & Bonne, M. E. (2007) 'A Leader's Framework for Decision Making.' *Harvard Business Review*, November 2007, pp. 69-76.

The Economist. (2009) 'Mobile Marvels: a Special Report on Telecoms in Emerging Markets', *The Economist*, vol. September 2009, pp. 1-14.

The Philippine Star. (2010). *Cell Phones Tapped for Rice Industry Development*. Nueva Ecija, Philippines. August 08, 2010.

UHIN. (2010). *Uganda Health Information Network, Phase-IV October 2007 – April 2010: Summary Report For UHIN Final Stakeholders Meeting*, May 29, 2010.

UNFCCC. (2007). *Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries*. Bonn, Germany: United Nations Framework Convention on Climate Change (UNFCCC), Climate Change Secretariat.

Veeraragavhan, R., Yasodhar, N. & Toyama, K. (2009) 'Warana Unwired: Replacing PCs with Mobile Phones in a Rural Sugarcane Cooperative', *Information Technologies and International Development*, vol. 5, no. 1, pp. 81-95.

World Bank. (2006) *Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems*. Washington, D. C.: The World Bank.