Communication for Sustainable Development Initiative

Technical Paper

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The Role of Information and Communication Technologies for Community-Based Adaptation to Climate Change

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The Role of Information and Communication Technologies for Community-Based Adaptation to Climate Change

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List of Acronyms

AIACC	Assessments of Impacts and Adaptations to Climate Change
APF	Adaptation Policy Framework
APSIM	Agricultural Production Systems Simulator
COSMIC	Country Specific Model for Intertemporal Climate
DSSAT	Decision Support System for Agrotechnology Transfer
DSS	Decision Support Systems
ETNO	European Telecommunications Network Operators' Association
FAO	Food and Agriculture Organization of United Nations
GIEWS	Global Information and Early Warning System for food security
GIS	Geographic Information Systems
GPS	Global Positioning System
GCM	General Circulation Model
ICASA	International Consortium for Agricultural Systems Applications
ICT	Information and Communication Technology
ICT4CCA	ICT for Climate Change Adaptation
IDRC	International Development Research Centre
IDS	Institute of Development Studies
IFAD	International Fund for Agricultural Development
IIED	International Institute for Environment and Development
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
ITU	International Telecommunication Union
MAACV	Model of Agricultural Adaptation to Climatic Variation
NAPA	National Adaptation Programmes of Action
NICCD	Network on ICTs, Climate Change and Development
NGO	Non-Government Organization
NREL	Natural Resource Ecology Laboratory of Colorado University
NTIWG	National Technical Implementation Working Group
OECD	Organisation for Economic Co-operation and Development
PRECIS	Providing Regional Climates for Impacts Studies
RKB	Rice Knowledge Bank
RKC	Rural Knowledge Centre
SAAO	Sub-Assistant Agricultural Officer
SEI	Stockholm Environment Institute

SRDI	Soil Resources Development Institute
SDSM	Statistical Downscaling Model
UDMC	Union Disaster Management Committee
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention for Climate Change
UTIWG	Upazila Technical Implementation Working Group
WMO	World Meteorological Organization
WWF	World Wildlife Fund

Introduction

Climate change is one of the most complex challenges that humankind has to face in the next decades. As the change process seems to be irreversible, it became urgent to develop sound adaptation processes to the current and future shifts in the climate system. In particular, it is likely that the biggest impacts of change will be on agricultural and food systems over the next few decades (M. E. Brown, C. C. Funk, 2008). Some scientists (Lobell et al., 2008), due to the application of crop modeling tools, have pointed out that climate change is likely to reduce food availability due to a reduction in agricultural production.

The Intergovernmental Panel for Climate Change (IPCC), a committee of the United Nations that collects and reviews the most important scientific contributions to this issue every five years, provided evidence that higher frequency and diffusion of climate fluctuations is likely to produce more severe and frequent droughts and floods, which are the main causes of short-term fluctuations in food production in semiarid and sub-humid areas. Sub-Saharan Africa and South Asia occupy the majority of these lands, meaning that the poorest regions of the world are going to face the highest degree of instability in food production (J. Bruinsma, 2003). J. Schmidhuber and F. N. Tubiello (2007) contributed investments in communications as an effective mean to address future climate change.

Within this framework, it is crucial to identify information and communication systems that the farmers need in order to cope with the new conditions. This is particularly true for poor smallholder farmers, as in Africa the majority of African farmers do not have access to the scientific and technological advances that support agricultural decision-making because of the lack of reliable communication networks (M. Boulahya et al, 2005). With regard to agronomic research, one of the major challenges will be studying the needs of policy makers and how to report and communicate research results in an effective way for supporting the adaptation of food systems to climate change (J.S.I. Ingram et al, 2008). To the same aim, in 2001 the IPCC underlined the local conditions that could determine if a community is likely able to adapt to changes and, among others, have the ability as decision-makers to manage information, which was particularly stressed (IPCC, 2001).

I – ICT and Climate Change

Information and Communication Technology (ICT) is a wide term that refers to all computer-based advanced technologies for managing and communicating information. It is broader than *Information Technology* (IT) which is defined as "the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware" (Information Technology Association of America, 2008).

Within the ICT domain, what is typically stressed by the users' communities is the great potential of ICT tools regardless of their ultimate goals. Usually, ICT is employed for three major actions: (1) to record data and information, (2) to transform the data and information into knowledge which can be shared and, eventually (3), communicate the data, information and knowledge.

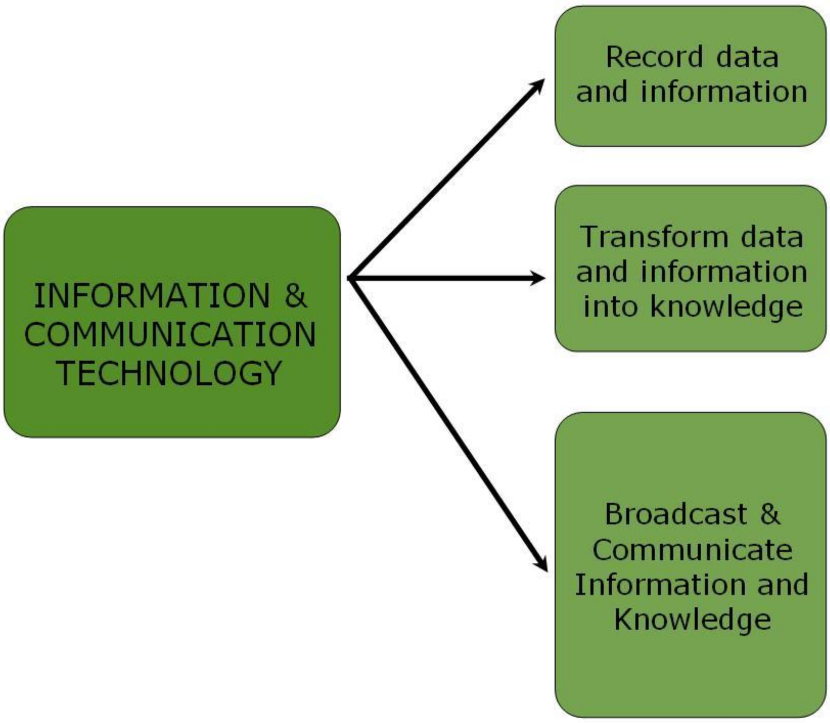

Figure 1. The main functions of ICTs

Many scientists think that applying technologies to solve complex problems such as climate change (or at least to limit its effects) is not a sufficient operation. Such a positivist approach is even more inadequate when applied to the field of Development or to environmental problems, as in the case of climate change, because of the extreme complexity of the systems involved.

This specification does not want to debate the role of technologies, which will play a primary part in the reduction of greenhouse gases' emissions, as in the control of future vulnerabilities and in the adaptation to the new climatic conditions. However, it is fundamental to underline that technologies will have to be framed in the wide context of activities finalized to coping with climate change: technologies will be a fundamental resource if their application is recognized, avoiding self-referentiality and partition among the various actors of the system.

Therefore, there is the necessity to conduct on a case by case basis an appraisal of the opportunity to introduce a particular technology within the peculiarities of the target system: every process of adaptation or mitigation should be examined and the best technology between the different families of technologies could then be chosen.

At the current state, ICTs did not play a fully significant role in the climate change sector: ICT has been applied in the study of this issue, but the application of ICTs in the mitigation and adaptation domain is still missing to a large extent. As many international analysts noticed, ICT is greatly absent in this field, especially if we separate the systems based on information management (such as Information Systems) from the technologies that are more oriented to communication services. In any case, the application of Information and Communication Technologies in the field of climate change is unanimously invoked by experts and institutions, who recognize the technologies as an effective mean to fight climate change. Moreover, ICTs still offer unexpressed potentialities in the study and in the search of solutions, due to their limited employment in this field of climate change. This aspect makes it even more urgent to study and apply these technologies.

1.1 Information technologies and climate change: the adaptation and mitigation dimensions

In order to tackle climate change, three main strategies are available: mitigation, adaptation or both. The application of information technologies in this sector follows the approach of applying it to mitigate climate changes as well as to adapt to changes (or both, in some cases). For this reason it is important to understand the differences between adaptation and mitigation in the technological context, before analyzing how technologies can contribute to both strategies.

Adaptation is older than Mitigation. Strategies of adaptation to climate change have been employed by man throughout all of history, while mitigation initiatives have been designed only when the scientific community determined a possible interaction between human actions and climate. Therefore, adaptation processes can also begin from the application of techniques already used and handled in various ways from all human communities.

Interaction with different sectors. Mitigation is connected mainly to the energetic sector, while adaptation actions are necessary for all the associate-economic fields (health, agriculture, water management, etc.). These fields have their own specific actors and their own series of institutional, economic and normative barriers. This means that the technologies applied should have high levels of variety and granularity.

Availability of technologies in Developing Countries. Many positive examples of application of technologies for adaptation in developing countries already exist. The nature of technologies varies in response to the different local requirements, determined by the specific environmental systems and socio-economic situations, going from coastal protections to new techniques of farming. It must also be noted that technologies that may be considered obsolete in some countries could be functional to solve adaptation problems in other areas of the World and this can stimulate the opening of communication channels between different communities on climate change related issues.

Cost of technologies. The main part of activities in the field of mitigation need big investments and this happens for some adaptation processes which deal with geo-engineering too (as coastal protection, for example). However, the main part of adaptation activities can be realized at a small scale, without the need for investments of big capitals.

Technological transfer issues. In the adaptation processes the technological transfers are more complex than in mitigation ones. This is due to the fact that the impacts of adaptation tend to be site-specific and this means that the know-how is less easily transferable. It is indispensable to identify effective methodologies to diffuse experiences and techniques to the communities that must face the challenge of adaptation to new environmental and climatic conditions: in this field ICTs can play a primary role and offer a fundamental contribution.

1.2 ICT for mitigation

Technology, particularly ICTs, are important carriers to reduce greenhouse gas emissions. Several associations demonstrated that it is possible to reduce the emissions of CO_2 in a substantial way through ICTs, replacing transfers with data transmissions and making our economic system more sustainable. In this sense WWF and ETNO defined a road map for the reduction of fifty million tons of CO_2 emissions within 2010.

This kind of approach can be seen as appropriate to Developed Countries and useless in Underdeveloped Nations, but this is not true. The employment of ICT is also fundamental for the progress of developing countries, in which the lack of infrastructure can be an incentive to invest in digital services and there is a need to face phenomena with access to the energetic sources and be aware of the accelerated urbanization (in fifteen years half of the global population will live in cities). Moreover, institutions like FAO could capitalise their know-how at local level and their experience in the application of ICTs in rural areas to foster the development of digital services and, more generally, information infrastructures. This could have several benefits within the environmental to the economical areas.

1.3 Technologies for adaptation

Technologies are commonly considered one of the key elements to develop, plan, implement and manage adaptation strategies to climate change. It is useful to highlight the main categories of advanced technologies because they will probably be involved in the adaptation processes; information systems, communication technologies and other advanced technologies. In this paper the advanced technologies will not be described, but it is important to remember that biotechnologies, nanotechnologies and (geo-) engineering, among the others, are likely to play a big role in the next future.

Regarding information and communication systems and technologies, it must be noted that the possible solutions developed within the field of ICT for Climate Change Adaptation (ICT4CCA) vary significantly, depending on the nature of the local context, due to the wide range of impacts that climate change can have on different sectors at different levels. A real ICT4CCA sector does not even exist yet, as to date the contributions of ICTs in the climate adaptation arena have come from different branches of its domain. For example, remote sensing techniques have been employed for environmental monitoring purposes and decision support tools have been designed to guide users in the planning and implementing adaptation processes.

Information-based technologies

In this field, there are multiple systems and tools through which it is possible to constantly monitor the land climate, estimate its variability on different temporal scales and develope climate change scenarios. These systems are the main instrument to study causes and effects of climate change: in particular through them it is possible to make forecasts of global and local climate change and variability, building the base adaptation as well as mitigation initiatives can be planned.

It is important to distinguish two main fields of application: long term climate change and short-term climate variability, upon which most of the adaptation strategies have been currently put into operation. The study of climate change can be recognized starting from the analysis of its current variability and building scenarios on it. Many systems and technologies manage the information produced through the study of climate variability, adapting them to their specific purposes. For example, in FAO’s Global Information and Early Warning System for food security (GIEWS), climate variability is monitored to achieve food security, generating early warning messages when it is necessary.

An up-to-date matrix which summarizes the features of the systems and tools applied in the field of climate change adaptation is available in Annex 1.

Communication-based technologies

The application of communication-based technologies in the climate change field is specific to information and knowledge transfer, as well as to raising awareness. The outbreak of the World Wide Web and the birth of the so-called Information Society gave pervasive and capillary tools for networking to the communities, to which it is now possible to link villages once isolated. For these remote communities it has become finally possible, at least in theory, to access technical progresses, which improves their living conditions. Through Communication systems, which should complementarily be employed with traditional media, it is possible to create groups of various persons interested to specific topics, offering them tools of memorization and management of data. The activities in this field will be further facilitated from the spreading of Web 2.0 tools, to which there will be the opportunity to build systems of massively distributed collaboration at an advanced level.

1.4 Information systems for climate change adaptation: an overview of main applications at a regional to local level

Based on the analysis of the UNFCCC and IPCC[1], at the present time it is possible to recognize three major categories of information systems developed to study the issue at local to regional level. The three main categories of information systems, which encompass both computer-based tools and theoretical methodologies, are the following:

- comprehensive systems and methodologies for institutions
- downscaling tools for working at national and sub-national level systems
- tools for specific sectors (e.g. agriculture, forestry, etc.) and/or specific purposes (e.g. adaptation management)

The first category comprises essentially theoretical methodologies based on different assumptions and approaches, developed to identify and quantify climate change

[1] See both the “Compendium on methods and tools to evaluate impacts of, vulnerability and adaptation to climate change” from UNFCC and the Third Assessment Report (TAR) and the Fourth Assessment Report (AR4) from IPCC.

impacts (e.g. IPCC Guidelines, UNEP handbook), assess vulnerability to climate change (e.g. UNEP Adaptation Policy Framework, APF) or do both kind of analysis (e.g. Assessments of Impacts and Adaptations to Climate Change, AIACC; UNFCCC Guidelines for National Adaptation Programmes of Action, NAPA) at an institutional level with a systemic approach.

The second category includes all the tools needed to produce climatic data at an appropriate scale for impact modelling and scenario development at local to regional levels (e.g. the 'Statistical Downscaling Model', SDSM; the 'Country Specific Model for Intertemporal Climate', COSMIC; the 'Providing Regional Climates for Impacts Studies' tool, PRECIS). Downscaling tools are applied in order to develop climate information at high resolution through the processing of global climate models built with General Circulation Models (GCM): these global models cover areas of 150-300 kilometres, so they cannot be used to study climate impacts at local levels. Two different downscaling techniques do actually exist: the dynamic technique and the statistical technique (Patz et al, 2005). The former is the most complex and expensive method and it's the result of the application of high-resolution and regional climate models: it's particularly useful in data-poor regions, but it requires high computing power and expertise. Statistical downscaling (often used jointly with atmospheric/weather generators) is a two-step process, which starts from the definition of statistical relationships between GCM-scale variables (assumed constants) and observed small-scale variables; the second step is the application of this relationship to the results of GCM experiments. Compared to the former technique this method is cheaper and simpler to use, but it needs a large quantity of data and therefore it can be applied in data-rich areas only.

The third category is composed by all the information tools through which it's possible to investigate climate change issues within specific sectors: economy, human health, coastal protection, agriculture, water management, forestry and so on. The range of systems and tools belonging to this category is extremely wide, covering (or at least trying to cover) all the information-based issues of such a cross-cutting phenomenon. Finally, a few interesting tools have been developed to support local institutions in the development and management of an adaptation strategy to climate change.

A comprehensive summary of the main information systems active in these three fields is available in Annex 1. The next paragraph briefly describes the role of ICT for adaptation to climate change within the agricultural sector.

1.5 A focus on ICT for climate change within the agricultural sector

In the intersection between climate change and agriculture there are several tools available because of the high number of crops and the complexity of replicating the same conditions across different regions. Every tool allows one to analyze different processes of the agricultural sector, from local crop modelling under climate change conditions to the management of economic impacts of climate change on agriculture (variations in land value, production demand and supply, etc.), just to name a few examples. As many tools exist, it's interesting to focus on their common aspects rather than their specific peculiarities.

Some of the tools allow simulating the growth of specific crops, verifying their variations under different climate change scenarios. Usually these tools are site-specific, but they can be applied at a national and/or regional level through a link to an appropriate Geographic Information System (GIS).

The first step of the application process happens with the definition of boundary conditions (which include data on crop calendar, soil status, etc.) and input climate parameters and data (such as: temperature, precipitations, wind speed, global radiation, soil moisture, air humidity, water flows...). Some of the tools include data related to crop management conditions. The second step is the development of the growth simulation in a specific state of potential crop production (e.g. with a certain fixed amount of water resources and nitrogen production) for different management options and for a chosen climate change scenario, through the link to an appropriate GCM or an ad-hoc expert system.

The general output of this kind of software is the assessment of crop production under given scenarios, facilitating decision making at a farm level up to a whole crop system. Examples of these tools are:

WOFOST, developed by the Centre for World Food Studies, CFWS, in cooperation with the Dutch University of Wageningen: it can be applied on several different crops, such as barley, field bean, maize, potato, rice, soybean, sunflower, wheat, etc.

GOSSYM/COMAX, developed by the Universities of Clemson and Mississipi and the Agriculture Department of United States: it is the merge of the GOSSYM model, used to simulate cotton growth, with COMAX (CrOp Management eXpert, an expert system), GCMs and weather generators to study the effects of climate change on cotton production.

APSIM (Agricultural Production Systems SIMulator), developed by a consortium of universities and departments of the Australian state of Queensland named Agricultural Production Systems Research Unit (APSRU): it can be applied on more than twenty crops and plants, such as alfalfa, barley, chickpea, cotton, eucalyptus, lupine, maize, peanuts, sugarcane, sunflower, tomato, wheat, etc.

Another class of information tools is applied at a higher scale, up to the regional level, with the aim of supporting decision-making in the agricultural sector from a broader perspective. These systems can focus on a variety of factors that can influence climate change and related responses, which can either be exogenous (e.g. government policies, economy, etc.) or endogenous (e.g. location, scale, etc.) in relation to a specific farming system. As a result, these systems facilitate the planning of adaptation responses into a set of actions at a farm and regional level, starting from a comprehensive assessment of the impacts of climate change and different farming techniques on crop productivity and agro-ecological systems sustainability, up to support the adoption of appropriate agronomy techniques or setting up an agro-technology transfer system. Among these systems, some examples are:

- DSSAT (Decision Support System for Agrotechnology Transfer), developed by the International Consortium for Agricultural Systems Applications (ICASA)

- CENTURY, developed by the Natural Resource Ecology Laboratory of Colorado University (NREL)

- MAACV (Model of Agricultural Adaptation to Climatic Variation), developed by the two Canadian Universities of Guelph and Carleton.

II – ICT for Community-Based Adaptation to Climate Change

2.1 The application steps of ICT for climate change adaptation

Looking at the climate change adaptation sector, it is possible to apply the three main functions of ICTs to the development of an adaptation strategy in a specific community. First, data collection is important to constantly monitor the status of the Earth climate system. Second, it is essential to have tools for processing data and information that can guide the stakeholders in the analysis, planning and implementation of possible adaptation strategies. Finally, communication tools are needed to manage the adaptation process and build on the knowledge which is generated in order to strengthen capacities and relationships among the stakeholders within and outside the given system. Figure 2 provides a visual representation of the application domain of ICT within the climate change adaptation sphere.

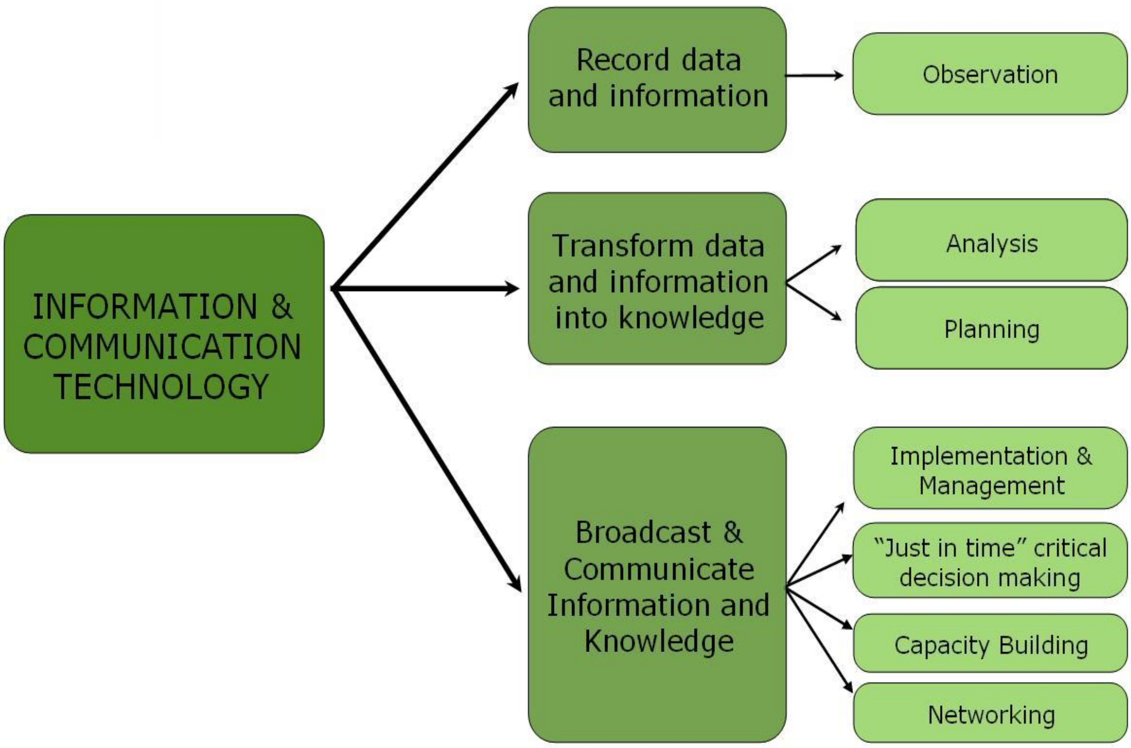

Figure 2. The role of ICT within the climate change adaptation domain

In the main steps of every adaptation process a range of ICT tools can be employed according to the specific local conditions. Particularly, the ICTs can contribute in the following seven actions:

1. Observation. This phase is crucial to understand how climate variations are occurring in a specific (regional/national/local) area. Observations can be carried out through data collection tools, such as remote sensing techniques and sensor-based networks. Data can then be stored in digital repositories and shared among the institutions committed to develop an appropriate adaptation strategy.

2. Analysis and planning. Data is analyzed by scientists and policy makers in a cooperative environment in order to plan and design sound adaptation strategies. ICT supports the analysis of climate change scenarios through software-based modelling systems, like the ones described in the above paragraph: these tools (e.g. software-based models, Decision Support Systems –DSS- and GIS) facilitate the development of adaptation plans capable to carry out a what-if analysis for different sectors on a multi-stakeholder basis.

3. Implementation and management. The nature of adaptation interventions varies depending on a wide range of elements, such as the set of stakeholders, the sector and the scale of application. As a result, ICT supports the implementation and management of adaptation strategies with a wide variety of tools: among them being, forecasting tools, early warning system and resource management systems play a prominent role in this phase.

4. "Just in Time" Critical Decision-Making. ICTs can help to get the right information to the right people at the right time to enable them to respond properly to risks. This step is particularly important in those initiatives targeting the existing climate vulnerabilities, whether they are related to climate-related disasters or affect people's livelihoods.

5. Capacity building. In this phase ICT can be employed for raising awareness and advocacy (particularly through the use of the Internet), as well as for providing *ad hoc* on and off-line training for facing climate change challenges.

6. Networking. ICTs play a key role in producing, storing, retrieving and comparing information related to climate change issues. This allows both North-South and South-

South knowledge sharing and the development of partnerships aimed at facing climate change challenges in different areas of the world.

7. Monitoring and evaluation. The final stage of any adaptation process embeds monitoring and evaluation activities. Rather than being the last activity in chronological terms, it must be highlighted that the performance of any initiative must be constantly verified in order to reach the goal previously defined in the planning step. ICT tools provide an effective way to analyse, store and communicate the impact of an adaptation strategy. GIS are likely to be at the forefront of supporting monitoring and evaluation of adaptation strategies, due to their layer-based nature which includes large geo-referenced information and the related information.

The ICTs, as defined in the first chapter, can hence support all the application steps of an adaptation strategy. Nevertheless, an *ad-hoc* process it is needed when dealing with a community-based initiative because of both the small scale of every community-based intervention and the necessity to plan any adaptation process according to the specific social, economic and cultural system of the community. The next paragraphs will provide a framework to the application of ICTs for community-based adaptation to climate change initiatives.

2.2 The need for a tailored approach in community-based initiatives: the role of Information and Communication for Development

For a successful employment of ICT at the community-level it is fundamental to frame it within Communication for Development, meant to be as the systematic application of processes, strategies and principles of Communication aimed at bringing positive social change (Quebral, 1973).

Information and Communication are both key sides of every technological system and no development can happen without the design of an appropriate Information and Communication strategy. In this section both facets of Information and Communication are examined in order to propose an integrated approach in the next chapter.

Information

To implement an adaptation strategy for a given system (whether it is ecological, social, economic, etc.) in response to climate inputs is not an easy task for those countries that have limited economic resources and low levels of technological knowledge. For this reason, to set up knowledge dissemination initiatives and sharing mechanisms through appropriate information and communication methods and tools is strictly required to implement sound climate change adaptation processes.

Indeed, knowledge sharing and technological transfer is essential to improve the management of the natural resource base, whether this can be affected by climate-related events or not. For example, if the latest findings on agricultural input management would be equally shared across information-rich and information-poor countries many of the mistakes from soil mismanagement could be easily avoided.

As stated by Tompkins and Adger (2004), strengthening communities' capacity to adapt and be resilient in the way they manage natural resources is a critical entry point for climate change related adaptation. As a result, even providing rural communities with appropriate information tools on natural resources management *per se* would allow a greater positive gain in terms of communities' ultimate capacity to face climate-related shocks and variations.

Information tools also play an important role in the domain of "early warning" applications. Rural producers need to be aware of the latest threats that can affect their activity and, in turn, their food security (and their communities'). For example, some recent crisis caused by locust invasions in Sahel could have been avoided with a faster dissemination of information in rural areas. The same happens with natural disasters, whose frequency and intensity is likely to be increased by climate change. Information tools become even more important, as natural disasters can directly affect human societies. Information can help in saving lives, preventing collateral damages and replicating sound environmental protection practises. In this sense civil protection plans, which are the first step to manage natural disasters, can be prepared through a data and information collection related to the specific environmental and territorial history of an area and the possible consequences of natural disasters. Data is then examined in order to design evacuation and monitoring plans and finally *ad hoc* early warning systems are developed to prepare communities on what to do when natural calamities do occur. For example, the hurricanes that hit the Caribbean Countries in 2004 caused remarkable physical and economic damages, but the number of deaths was highly lower than in the past, thanks to the use of appropriate information tools.

Another positive result of information management in this field is the increased capacity of sharing data and knowledge between different communities. This activity allows the fast dissemination of best practises as well as an increased efficiency in the implementation of similar environmental programs (avoiding the waste of both economic and temporal resources). A positive example is offered by the recent earthquake in Haiti, where, thanks to the coordination of some NGOs[2], the aid agencies had the chance to plan their rescue and recovery plans minimizing time loss and multiplication of efforts.

Communication for Development

Communication for Development (ComDev), as stated by Nora C. Quebral[3], is "the art and science of human communication linked to a society's planned transformation from a state of poverty to one of dynamic socio-economic growth that makes for greater equity and the larger unfolding of individual potential". Broadly speaking, ComDev is a participatory approach aimed at supporting knowledge and information sharing among people and institutions by integrating the use of various communication strategies, media and processes. Specifically, ComDev strategies seek to respond to knowledge and information needs of rural knowledge institutions and vulnerable groups with the ultimate goal of targeting developmental goals. To do so, it is required to do a full-fledge participatory communication planning process, which is generally structured on six different phases[4]:

1. *Preliminary situation assessment*, which often makes use of the Participatory Rural Communication Appraisal methods. This step helps in the following actions: (a) identification and segmentation of the potential stakeholders of the system to-be-implemented and their information needs (audience analysis); (b) study of the issues to be addressed by the communication initiative and the factors that characterize the local environment, including the possible communication resources already available

[2] Among the others, *Inveneo* (http://www.inveneo.org/) set up a telecommunication infrastructure immediately after the disaster and *ITHACA* (http://www.ithaca.polito.it/) provided a GIS to guide the rescue&recovery operations

[3] Quebral, Nora (23 November 2001). "Development Communication in a Borderless World".

[4] (Johns Hopkins School of Public Health, Center for Communication Programs, 1997; and SADC Centre of Communication for Development, 2001)

(situation analysis); and (c) analysis of the program to be planned as well as the institutional framework through which the intervention will be implemented.

2. *Communication strategy design*, through which an appropriate strategy for the Communication Action Plan is developed to serve the expected outcomes of the initiative: program goals and objectives are defined, the data collected in the previous step are interpreted to identify the best methods, messages and approaches to be utilized for the implementation of the intervention.

3. *Participatory design of messages and discussion themes* is the phase that requires the highest rate of creativity among project stakeholders. This step, which needs to be participatory to reach developmental goals, includes the definition of messages and the identification of appropriate media and communication channels.

4. *Communication methods and materials development* involves the “physical” preparation of the selected communication methods and materials, which are usually pre-tested in this phase to make them adhere to the original idea of the initiative.

5. *Implementation* is the translation of the design phase into the realm of practice. To this aim, the organization in charge for the implementation of the communication initiative has to manage the initiative through its own staff (which may require *ad hoc* training) and partners that can be gathered by networking. After the definition of human and/or institutional resources, in charge for the initiative, the communication program is launched and carried out. At the same time activities are monitored to verify that the communication is successful.

6. *Evaluation* is the last step of Participatory communication planning and it is usually associated with the monitoring of activities from the previous step. Both the planners and the managers of the communication-based initiative can achieve a better understanding of the on-going work and its eventual impacts, adjusting decisions according to the partial results as well as planning for program sustainability. The impact analysis can be carried out in different stages of the communication-based initiative and it is usually based on baseline data collected in the Preliminary situation assessment.

This process is particularly helpful within the context of community-based adaptation to climate change, where social learning as well as multidisciplinary and multi-stakeholder action are essential to address climate-related vulnerabilities. Given the high degree of uncertainty and the low understanding associated to climate change, Communication plays a fundamental role in making the stakeholders of a rural system aware of vulnerabilities but capable of considering the possible strategies needed to strengthen their resilience to climate shocks and change.

2.3 A step-by-step approach for ICT applications in CBA initiatives

Communication for Development can effectively support the development of an ICT-powered adaptation strategy and its implementation in every step, from data collection to monitoring and evaluation phase.

Both Communication and Information are essential when promoting community-based adaptation, which mainly targets small communities in the developing world that are vulnerable to climate change due to their dependence on natural resources and/or their location in areas prone to climate-related shocks (Huq and Reid, 2007). Adaptation initiatives at the community-level can build on existing natural resources management or disaster risk management practises, but there is often a need to broaden the set of stakeholders involved in the development and implementation of an appropriate strategy in order to deal with climate change issues. This is due to the complexity of the phenomenon, which requires different forms of expertise and capacities to be involved for developing a sound adaptation process.

Fostering resilience at the community level on natural resources management is definitely a win-win strategy, but trying to directly target climate change implies the participation of various professionals from different sectors and institutions. Information technologies and ComDev can make a difference by linking the different capacities and ensuring that communities are at the centre of an adaptation effort.

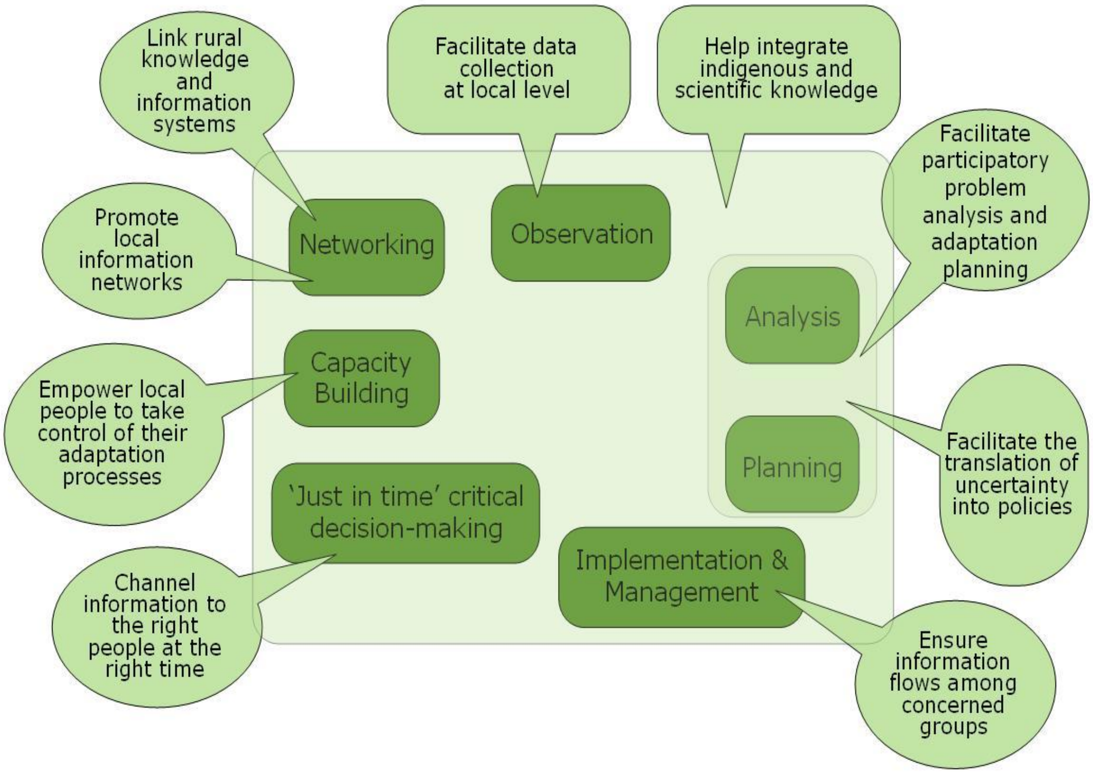

Figure 3. A ComDev approach for ICT applications in CBA

As shown in figure 3, every step of a community-based adaptation initiative can benefit from ComDev methods and tools to reach its specific goals. To empower a local community making it responsible of its own adaptation is essential and to have ComDev catalyze an open participation in every stage of the initiative, even in those activities that are usually the domain of scientists and researchers. Indeed, to make people aware of climate change risks and capable of understanding its complex facets is essential, as well as to partner with the community representatives in the different steps of an adaptation initiative. As climate change impacts are highly site-specific, communities are the first resource to face this issue given their knowledge of the local social, cultural and agro-ecological system. ComDev can promote their participation in the study of possible impacts, identifying risks, threats, vulnerabilities and opportunities for collaborative change.

Specifically, ComDev has a great potential in supporting multi-stakeholder action through the application of ICTs in several ways, such as:

- Facilitate data collection at local level with tracking tools, handheld devices, etc.

- Integrate indigenous and scientific knowledge through knowledge bases, databases, Geographic Information Systems, etc.

- Facilitate of participatory problem analysis and adaptation planning through the participatory) application of downscaling tools, modelling software and decision support systems, among others.

- Facilitate the translation of uncertainty into practical policies through support systems, collaborative project management tools, monitoring systems, etc.

- Ensure information flows among concerned groups through information systems and networking tools.

- Channel information at the right people at the right time through appropriate media through community-based early warning systems, mobile phones, radios, etc.

- Empower local people to manage their adaptation efforts, providing them with guidelines, media, e-learning modules, etc.

- Promote local information networks through web portals, virtual consultations and other traditional and Web 2.0 tools that are useful to discuss and define agendas for adaptation, disseminate best practises, monitor initiatives and so on.

- Link rural knowledge and information systems through intermediate agents and adequate information management tools, that can promote data integration across different domains (i.e. GIS for spatial integration, etc.).

In the next figure (Figure 4), proposed is a possible scheme for the design and implementation of a community-based adaptation putting in evidence of information flow and highlighting the functions of ComDev. The first step includes the collection of climate and sector data (specific to the scope and scale of the intervention), which are blended with information and data coming from external (often web) resources. Afterwards the implementing agency acts as a focal point for integration, analysis and interpretation of data in order to map vulnerabilities and plan an appropriate adaptation strategy in cooperation with the partner community. At this point communication material is prepared to reach the local stakeholders through the available channels. Depending on the scale and the temporal dimension of the intervention (critical decision-making versus longer-term planning) the right channels are selected to disseminate information and knowledge. It is important to emphasize the role of the community, that on one hand receives information and on the other can both provide feedback and participate in the development and implementation of the initiative from the very beginning.

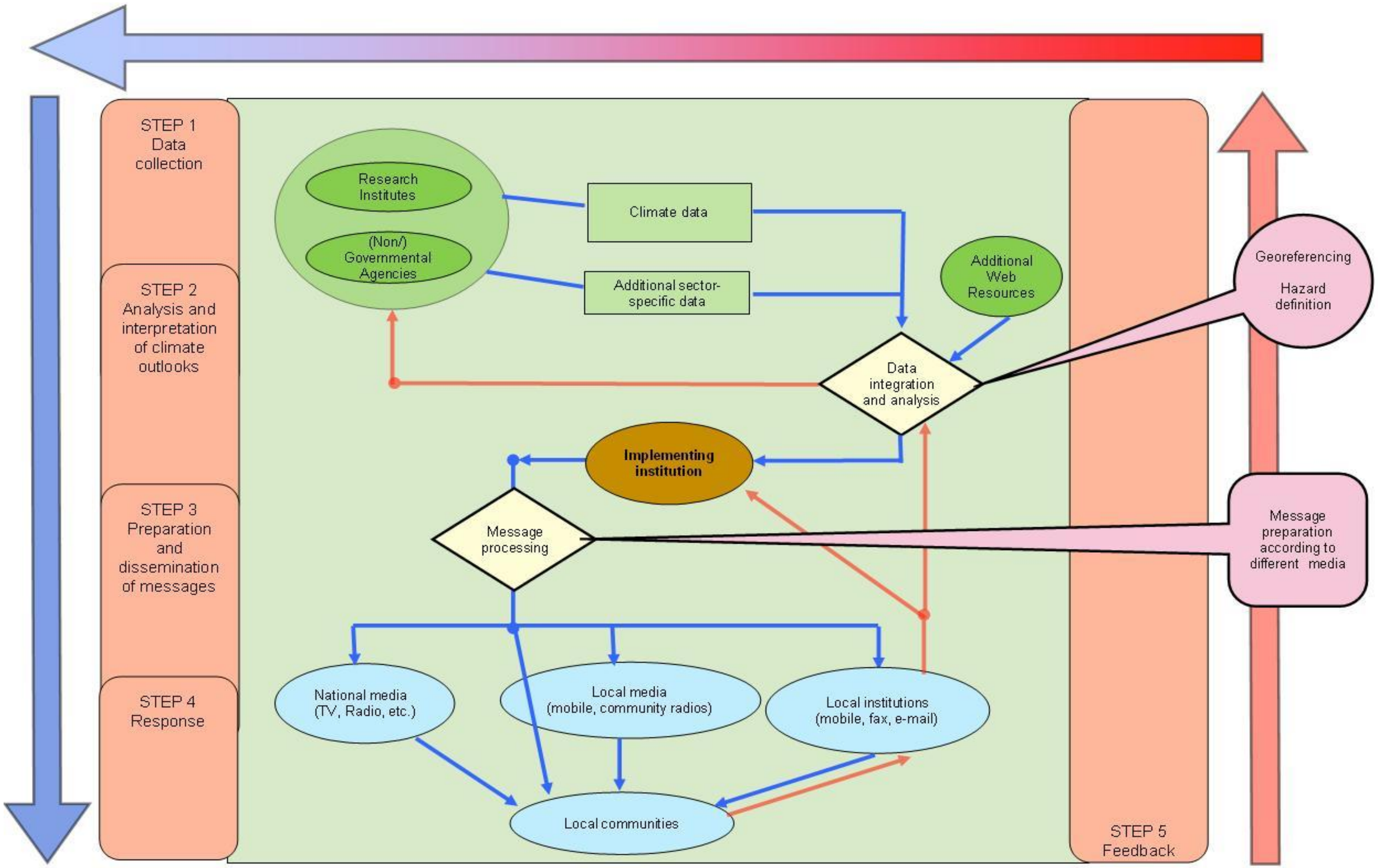

Figure 4. Information flow and Communication within the framework of CBA

III – Conclusion

Having explored the ICT4CCA sector, the resulting impression could be that this area is still the domain of pioneers, especially looking at the climate change challenge from a development perspective.

A systematic approach is still missing and most of ICT-based interventions target specific climate-related problems rather than looking at the climate change issue as a whole. Part of this is due to the high cross-sectoral nature of climate change impacts, which affect various sectors in different ways. For example, the health sector can experience challenging variation in the distribution of diseases, while changing rainfall patterns can have dramatic effects on the primary production sectors, just to name a few. A well defined ICT4CCA sector “per se” is unlikely to establish in the climate change domain, but a series of initiatives in the intersection between ICT, climate change adaptation and development are starting to create a common pattern. A community comprising research institutes, governmental and nongovernmental development organizations, public institutions and even representatives from the private sector is thus rising up, beyond their diverse core functions and missions. Even though boundaries among institutions and themes will remain, a convergence among these actors will probably lead to a new deeper analysis of the best practises already available in the application of ICT for natural resources management, with a focus on the climate-related ones and within the framework of development goals.

Some experience is already showing that this could be a rewarding pathway to face climate change, especially in those communities that strongly rely on their natural resources base. Just to name a few international players, the Network on ICTs, Climate Change and Development (NICCD) is trying to provide a framework for the sector from a broad academic perspective; development organizations and research institutes as the International Development Research Centre (IDRC), International Institute for Sustainable Development (IISD), Institute of Development Studies (IDS), International Institute for Environment and Development (IIED) and the Stockholm Environment Institute (SEI) are trying to cover the gap among the different fields with work on the ground as well as at normative level. Finally, OECD and some United Nations agencies (other than WMO, UNFCCC and IPCC) are trying to bring their perspective on these issues, such as FAO, IFAD, ITU and UNESCO. Particularly, FAO has a specific comparative advantage in the application of Communication for Development methods and tools, including traditional media as community-radio and ICTs, for rural development and natural resources management. The work carried out in the last twenty years by FAO on ComDev could represent a valuable and unique base on which to develop sound integrated strategies for climate change adaptation in the developing world.

Annex: Information systems and tools for climate change adaptation

In this annex a summary of Information systems and tools applied in the field of Climate Change Adaptation is presented. Every information system is described through its domain of application and its input/output data.

A. SUMMARY OF FRAMEWORKS AND TOOLKITS FOR INSTITUTIONS

Framework / Toolkit	Domain of application	Input / Output data	Provider	References
Adaptation Policy Framework (APF)	The APF is a complete framework for adaptation, covering the entire World at different scales (global, regional, national and sub national level) and all sectors that have to deal with climate change. Primary users are policy makers that need to focus on vulnerability assessment.	Input depends from the scope of the study and the availability of data and information related to the target area. The output is a definition of priorities for adaptation strategies and, in turn, an increased adaptive capacity.	UNDP	http://www.undp.org/climatechange/adapt/apf.html
Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors (AIACC) Toolkit	The AIACC Toolkit is a collection of best practises and tools for adaptation, covering the entire World at regional level and all sectors that have to deal with climate change. The users range from institutional stakeholders to researchers and scientists.	Input includes information related to the target area as main system driving forces and vulnerability-related information (risks, threats, exposure, etc.). The output is a set of different adaptation techniques that can be applied for reducing current and future vulnerabilities.	AIACC Project in cooperation with UNEP, WMO and IPCC.	http://www.aiaccproject.org/ http://sedac.ciesin.columbia.edu/aiacc/toolkit.html
Climate Adaptation Decision Explorer (ADx)	ADx is a software tool for screening possible adaptation options in a given context. It covers all sectors and can be applied in every region at both national and community level. Target users are analysts or engineers working with decision and policy makers.	Input data includes socio-economic factors, vulnerability to climate change and climate information (partly retrievable through SEI tools linked to ADx, as the Climate Change Explorer Tool). The output is a set of pre-screened adaptation options that can support the institution in planning an adaptation strategy.	Stockholm Environment Institute	http://www.weadapt.org/

CRiSTAL Community-based Risk Screening Tool – Adaptation & Livelihoods	CRiSTAL is a tool to support community-based adaptation to climate change. Target users are project planners and project managers that work at local level in rural areas.	Input data are autonomously generated through an assisted question&answer process by the user: specifically, the user defines the current climate context (e.g. climate hazards already affecting project area), the livelihood context (e.g. key resources for local livelihoods), the link between project resources and climate hazards, the changes needed to reduce vulnerabilities. Output is a better understanding of the way projects can be planned and managed to increase adaptive capacity in the target area.	International Institute for Sustainable Development (IISD), Intercooperation - Swiss Foundation for Development and International Cooperation, the International Union for Conservation of Nature (IUCN) and the Stockholm Environment Institute (SEI, US office)	http://www.cristaltool.org/
IPCC Technical Guidelines	The guidelines are a complete framework for adaptation, covering all regions and all sectors that have to deal with climate change. Users are generally researchers and scientists that need to identify and quantify the possible impacts of climate change.	Input depends from the scope of the study and outputs are appropriate strategies to reduce the impacts of climate change	IPCC UNITAR can provide training for the use of the Guidelines.	http://www.ipcc-data.org/guidelines/index.html
NAPA Guidelines	The guidelines are an analytical framework for adaptation, covering all Least Developed Countries at national level in all their sectors that have to deal with climate change. Users are institutions that need a conceptual framework for vulnerability assessment and identification of adaptation priorities.	Input includes a vulnerability assessment for the target area as well as information related to any ongoing adaptation efforts. The output study sets priorities in adaptation to climate change.	UNITAR, which provides training material through its website.	http://www.napa-pana.org/
UK Climate Impact Programme (UKCIP) Risk, Uncertainty and Decision-Making Framework	The UKCIP Framework is a complete framework covering the entire World at regional scale and all sectors that have to deal with climate change. Primary users are decision makers that need to frame climate adaptation into their institutional framework and have to deal especially with risks and uncertainty.	Input is provided by climate and non-climate scenarios related to the target area as well as by its stakeholders through a step-by-step analysis of their goals, climate risks and ongoing adaptation efforts. The output is a set of possible optimal adaptation options.	Environmental Change Institute, Oxford University	http://www.ukcip.org.uk/

UNEP Handbook	The Handbook is a first generation framework for adaptation, covering the entire World at different scales (global, regional and national level) and all sectors that have to deal with climate change. Primary users are institutions.	Input includes physic and socio-economic (qualitative and quantitative) data related to the target area. The output is a range of possible impacts of climate change as well as adaptation strategies	UNEP (which provides direct assistance to its Country Members for the application of the Handbook)	http://www.unep.org/dec/docs/UNEP_Climate_Change_Handbook.pdf
Performance Acceleration Climate Tool (PACT)	PACT is a toolkit and a conceptual framework for adaptation, targeting institutions that have to assess and improve their response capacity to climate change.	Input data are gathered through a workshop-like process, where the institution self-assesses its response capacity under the guidance of a PACT expert. The output is a range of strategies that the organization can adopt to improve its response capacity at different levels.	Hampshire County Council (HCC) and Alexander Ballard Ltd	http://www.alexanderballard.co.uk/projects.php?id=13

B. SUMMARY OF FREE DOWNSCALING TOOLS

Through the following tools it is possible to build regional to national models.

System / Tool	Domain of application	Input/Output data	Provider	References
Statistical Downscaling Model (SDSM)	SDSM can be applied to all regions and all sectors that have to face the impacts of climate change. Intended users are climatologists.	Input data includes observed daily meteorological data for the statistical calibration of the model; in addition, the tool needs data developed through Global Circulation Models to develop forecasts. The output is a set of climate scenarios for the target area with parameters like minimum and maximum temperature, precipitation, humidity.	Robert L. Wilby (King's College London), Christian W. Dawson (Loughborough University)	https://co-public.lboro.ac.uk/cocwd/SDSM/
Country Specific Model for Intertemporal Climate (COSMIC)	COSMIC can be applied at national scale for 158 Countries of the World. Users can be researchers in the area of climate impact modelling as well as policy analysts.	Input data includes a selected GCM and a selected greenhouse gases' emission scenarios, other than climate parameters for climate modelling; for the spatial reference a target country has to be selected. The output includes parameters as mean monthly temperature and precipitations, annual mean shift of temperature, sea rise level and CO_2 concentration.	University of Illinois at Urbana-Champaign	http://crga.atmos.uiuc.edu/COSMIC/index.html
Providing REgional Climates for Impacts Studies (PRECIS)	PRECIS can be applied to all regions of the world with a minimum area of 25'000 square kilometres. Intended users are climatologists.	The input consists of climate parameters and boundary data, which are needed to create lateral boundary conditions: this data can be provided for free by UK Met Office if the request comes from a developing country. The output includes climate means variables (monthly, seasonal, annual and decadal; daily and hourly means can be selected, too) with a horizontal resolution of 50 km.	Hadley Centre, United Kingdom Met Office	http://precis.metoffice.com/
Model for Assessment of Greenhouse-gas Induced Climate Change – A Regional SCENario GENerator (MAGIC/ SCENGEN)	MAGIC/SCENGEN can be applied to all regions of the world. Intended users are researchers in the field of climate system.	Input data includes information from selected greenhouse gases' emissions scenarios (SRES), gas cycle models and climate models. The output includes parameters as mean global temperature projections and sea rise level, changes and absolute values of temperature and precipitations and the likelihood of their variation.	Climate and Global Dynamics Division, National Center for Atmospheric Research	http://www.cgd.ucar.edu/cas/wigley/magic c/

C. SUMMARY OF SECTOR-SPECIFIC TOOLS

Tools to support adaptation within the agriculture sector

System / Tool	Domain of application	Input/Output data	Provider	References
Agricultural Production System sIMulator (APSIM)	APSIM is a software tool for modelling climate change impacts on crop production for different crops and forests. It can be applied to all regions of the world at regional, national and local level. Target users are agronomists.	Input data includes soil properties, climate data, cultivar peculiarities and information regarding agricultural management. The output is a set of indicators for different climate change scenarios on expected crop production and possible soil erosion.	State of Queensland; University of Queensland; Commonswealth Scientific and Industrial Research Organisation	http://www.apsim.info/Wiki/
Decision Support System for Agrotechnology Transfer (DSSAT)	DSSAT is a decision support system for assessing the possible effects on local agricultural production and its component (e.g. soil, crop phenotype, etc.) of a series of events and phenomena (management options, climate variability and change, etc.). It can be applied to all regions of the world and can be linked to a GIS. Target users are agronomists.	The data that DSSAT receives as input are local soil data, climate data and information regarding agricultural management. The output is the definition of how crop production and its components would be affected by different climate change scenarios.	International Consortium for Agricultural Systems Applications	http://www.icasa.net/dssat/
GOSSYM/ COMAX	GOSSYM/COMAX is a software tool that can be applied to model climate change impact on cotton. It can be applied to all locations all the world. Target users are researchers, cotton farmers and operators of the agricultural sector.	Input data includes parameters like soil moisture and bulk density for each soil horizon and weather data (temperature, wind speed, solar radiation and humidity). The output is an estimate of crop production and yield components under different conditions, including the effects of climate change.	USDA; Mississippi State University; Clemson University	http://ecobas.org/www-server/rem/mdb/gossym.html
Information and Decision Support Systems (IDSS)	IDSS is a decision support system developed to support climate change adaptation in the agricultural sector. It has been tested at both national and regional level in South America, but can be applied to all the regions of the world. Target users are agronomists, policy makers and farmers.	Input data includes parameters describing soil properties, climate data, information regarding land use, data related to agricultural inputs and local statistics of agricultural production. The output consists in the possible variations of crop production under different climate change scenarios, as well as a definition of associated risks.	Center for International Earth Science Information Network (CIESIN), Earth Institute, Columbia University	http://sedac.ciesin.columbia.edu/aiacc/methods.html http://portal.iri.columbia.edu/

Model of Agricultural Adaptation to Climatic Variation (MAACV)	MAACV is a tool for modelling the possible adaptation processes within the agricultural sector. It can be applied in all regions of the world at both local or regional level, even if it better targets developed countries. Target users are the stakeholders of the agricultural sector, starting from farmers.	Input data consists in the definition of possible influences (of both systems and human activities) on adaptation responses. The output is a classification of a set of driving forces and possible responses that are involved in a target adaptation process.	University of Guelph, Canada	http://www.uoguelph.ca/gecg/page.cfm/home
ORYZA2000	ORYZA2000 is a software tool that can be applied to model climate change impact on rice. It can be applied to all locations of the world at both local and regional level and the software can be linked to a GIS. Primary target users are agronomists.	Input data includes parameters describing soil properties, daily climate data (such as minimum and maximum temperature, early morning vapor pressure, mean wind speed, precipitation, solar radiation) and information related to crop management. The output is an estimation of rice production and its variations under a set of climate change scenarios.	International Rice Research Institute; Wageningen University and Research Centre	http://www.knowledgebank.irri.org/oryza2000/
WOFOST	WOFOST is a software tool that can be applied to simulate the behaviour of various crops under changing climate conditions. It can be applied to all locations of the world at both local and regional level. Primary target users are agronomists.	Input data includes parameters describing soil properties, climate data (such as rainfall, temperature, wind speed, global radiation, air humidity, soil moisture content) and information related to crop management. The output is an estimation of crop production and its variations under a set of different climate change scenarios.	Wageningen University and Research Centre	http://www.kennisonline.wur.nl/KB/KB-01/006/047/ http://ecobas.org/www-server/rem/mdb/wofost.html

Tools to support adaptation within the water sector

System / Tool	Domain of application	Input/Output data	Provider	References
Agricultural Catchments Research Unit (ACRU)	ACRU is a software tool that can be applied to simulate the potential impact of climate change on catchments an crop production. It is usually applied at local level. Target users are agronomists and hydrologists.	Input includes weather data (e.g. minimum and maximum temperature, rainfall), information related to the catchment (such as location, area, altitude and configuration), parameters describing the land cover and soil properties (texture, depth). The output is an estimation of crop production and hydrological balances under different climate change scenarios.	University of Natal	http://www.ukzn.ac.za/unp/beeh/acru/
AQUACROP	AquaCrop is a software tool through which it is possible to simulate yield response to water for various crops, including yield prediction under different climate change scenarios. It can be applied to all locations of the world at farm, district and regional level. Target users are water managers, field engineers and extension agents.	Input includes climate and crop data (if field data are not available FAO CLIMWAT database is a linked database that can be used as source), as well as information describing soil properties, water supply and irrigation management. The output essentially consists in a range of possible strategies for water management under climate change conditions.	Food and Agriculture Organization of United Nations (FAO)	http://www.fao.org/nr/water/aquacrop.html
Soil and Water Assessment Tool (SWAT)	SWAT is a software tool that can be applied to the study of climate change impacts on soil/water resources of a target area at local to regional level. Target users are researchers in the field of hydrology and agriculture.	Input includes information on the configuration of the target watershed, climate data (e.g. rainfall, solar radiation, temperature, humidity, wind speed, etc.), hydrological data (e.g. surface runoff, evapotranspiration, etc.) and information related to the agricultural domain (e.g. land cover, crops, inputs, management practises, etc.). The output is a description of the effects of management and changes on the region.	United States Department of Agriculture (Agricultural Research Service)	http://swatmodel.tamu.edu/
"Water Evaluation And Planning" system (WEAP)	WEAP is a decision support system for water resource planning that can be used to understand the possible impacts of climate change to water demand and supply. It can be applied at local to regional level. Primary users are policy makers.	Depending on users' goals input can include data related to the water system and its components, information regarding current and future water supply and demand (depending on the target sector), economic data and pollution parameters. The output is a set of possible strategies to plan water management and what-if scenarios describing (among others) the impacts of climate change on water.	Stockholm Environment Institute (SEI)	http://www.weap21.org/

Platforms and databases on climate change adaptation, including CBA

System / Tool	Description	Provider	References
Adaptation Action Database - UKCIP	This database collects experiences of adaptation to climate change provided by different organizations based in UK. The search engine allows the users to search adaptation actions by region, sector or adaptation activity.	United Kingdom Climate Impact Programme (UKCIP)	http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=286
Adaptation Learning Mechanism (ALM)	ALM is a global web-based platform for knowledge sharing. The platform provides a wide range of resources (climate data, case studies, guidelines, tools) to support vulnerability assessment and adaptation to climate change in different sectors (agriculture, coastal zone management, disaster risk management, water and health).	United Nations Development Programme (UNDP)	http://www.adaptationlearning.net/
Community-Based Adaptation Exchange (CBA-X)	CBA-X is a web platform that links researchers and practitioners in the field of community-based adaptation to climate change. The web portal is a valid resource for news and events, as well as for retrieving policy resources, case studies, videos and tools in this field.	Eldis Community (from the Institute of Development Studies, Sussex)	http://community.eldis.org/cbax/
Climpag: Climate Impact on Agriculture	Climpag is a website developed by FAO acting as a focal point for climate change in the agriculture sector. Through the website it is possible to access to documentation, training material, methods and tools for impact assessment and support to adaptation.	Food and Agriculture Organization of United Nations (FAO)	http://www.fao.org/nr/climpag/
TEChnologies for Agriculture (TECA)	TECA is a web platform collecting proven technologies for smallholder farmers, aimed at promoting knowledge sharing across institutions and practitioners working in the field of Rural Development. Within the database a special section has been dedicated to technologies for disaster risk reduction and climate change adaptation.	Food and Agriculture Organization of United Nations (FAO)	http://www.fao.org/teca/
UNFCCC Database on local coping strategies	The database aims at facilitating knowledge sharing and transfer on coping strategies among different communities that have faced (and/or have to face) similar hazards or climatic conditions. A description of possible adaptation actions are suggested depending on the climate hazard and/or impact and/or coping strategy provided by the user.	United Nations Framework Convention for Climate Change (UNFCCC)	http://maindb.unfccc.int/public/adaptation/
WEADAPT Platform	WEADAPT is a web platform that links researchers and practitioners in the field of climate change adaptation. On the website a series of tools and methodologies (developed through the WEADAPT Partnership) are available to support the professionals working in this area.	Stockholm Environment Institute (SEI)	http://www.weadapt.org/

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UNFCC – "Compendium on methods and tools to evaluate impacts of, vulnerability and adaptation to climate change"

"The good news is we know what to do. The good news is, we have everything we need now to respond to the challenge of global warming. We have all the technologies we need, more are being developed and as they become available and become more affordable when produced in scale, they will make it easier to respond. But we should not wait, we cannot wait, we must not wait..."

Al Gore, speech at National Sierra Club Convention; September 9, 2005