ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

CLIMATE CHANGE, AGRICULTURE AND ICT: AN EXPLORATORY ANALYSIS

R.K.P. Singh and K.M. Singh

Climate change is a long term change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions or the distributions of events around that averages (i.e. more and fewer extreme weather events. It may be limited to a specific region or may occur across the whole world. Climate change reflects a change in the energy balance of the climate system i.e. changes the relative balance between incoming solar radiation and outgoing infrared radiation from Earth.

In the context of climate variation, anthropogenic factors are human activities which affect climate. The scientific consensus on climate change is that climate is changing and these changes are in large part caused by human activities and it is largely irreversible (Susan Soloman *et.al*, 2009). Consequently, the debate is shifting to reduce further human impact and to find ways to adapt to change that has already occurred and is anticipated to occur in the future. Of most concern in these anthropogenic factors is increase in CO_2 levels due to emissions from fossil fuel combustion, followed by aerosols and cement manufacture. Other factors including land use, animal, agriculture and de-forestation are also of concern in the roles they play-both separately and in conjunction with other factors in affecting climate, micro-climate, and measures of climate variables.

The unimpeded growth of greenhouse gas emissions is raising the earth's temperature. The consequences include melting glaciers, more precipitation, erratic weather events, and shifting seasons. The accelerating pace of climate change, combined with global population and income growth, threatens food security everywhere. Agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields crops of desirable while encouraging weeds and pest proliferation. Changes in precipitation patterns increase the likelihood of short run crop failures and long run production declines. Although there will be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative, threatening global food security.

Population in the developing world, which are already vulnerable and food insecure, are likely to be the most seriously affected. About half of the economically active population in developing countries relied on agriculture for its livelihood and three-fourths of world's poor live in rural areas. Agriculture and human well-being will be negatively affected by climate change.

- In developing countries, climate change will cause yield declines for the most important crops. South Asia will be particularly hard hit.
- Climate change will have varying effects on irrigated yields across regions, but irrigated yields for all crops in South Asia will experience large declines.

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

- Climate change will result in additional price increases for most important agricultural crops-rice, wheat, maize and soyabean. Higher feed prices will result in higher meat and milk prices. As a result, climate change will reduce the growth in meat and milk consumption slightly and cause a more substantial fall in cereal consumption.
- Calorie availability in 2050 will not only be lower in the no-climate change scenario, it will actually decline relative to 2000 levels throughout the developing world.
- By 2050, the decline in calorie availability will increase child malnutrition by 20 percent relative to a world with no climate change.

The complexity of processes is exacerbated within contexts characterized by increasing climatic uncertainty, more frequent and intense seasonality, limited access to information, poverty and resource constrains. And it is within these contexts that Developing country farmers are facing tough decisions that can either hinder or strengthen their ability to cope and adapt to the challenges posed by the changing climate.

Experiences from the field suggest that "*environment related information ranks high in the needs of rural populations in developing countries* and that the increasing diffusion of technologies such as mobile phones provides a potentially powerful platform for the dissemination of relevant information. The T.V. and Mobile emerged as important source of climatic information in rural area in Bihar, India (Singh and Aggarwal, 2011).

But the availability of information is not enough to foster processes of adaptation and change. The following areas of ICT potential in decision-making can be identified:

● **ICTs helping Farmers Transition from Short-term to Long-term Planning:** By facilitating the production and access to climate models and projections, ICTs can contribute to the identification of future and emerging risks and opportunities associated with climate change. Local decision-making can be informed by alternative scenarios, and the diversification of livelihoods, farming practices, or skill sets required to deal with change can be considered as part of long-term planning.

● **ICTs helping to Bridge the Gap between Researchers, Advisers and Farmers:**

By making climate change-related information more accessible and relevant to the local actors (e.g. through Web-based materials designed in the local language and addressing local priorities, or through text messages with simple, strategic content delivered to farmers' cell phones) ICTs can contribute to improve the information and knowledge sharing between key stakeholders.

● **ICTs helping to strengthen the Links between Scientific and Traditional**

Knowledge: By providing a platform to document and share both scientific and traditional knowledge through blogs, audio-files or community videos, among others, ICTs can help to strengthen adaptive practices, learning and social identity.

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

● **ICTs helping to Foster Inclusion and Connectedness:** By enhancing participation, monitoring and exchange between community members and broader networks, the use of ICTs can help to 'give a voice' to groups and individuals that could be, otherwise, excluded. The use of tools such as mobile phones and the Internet can contribute to community-based environmental monitoring, while ICT-capacity building can strengthen local-empowerment and the ability to self-organize in response to external climatic disturbances.

In sum, providing relevant information for long-term planning, building on multi-level and multi-synergies, linking both new and traditional knowledge, and facilitating more inclusive processes, are some of the areas in which ICT tools can contribute to local decision-making, helping vulnerable groups -such as farmers- to adapt more effectively to the impacts of climate change.

Amidst the magnitude and uncertainty that characterizes the climate change field, trust is a topic that is often overlooked, despite being one of the cornerstones of resilience building and adaptive capacity.

Trust is an essential element of effective communication, networking and self organization, and thus is indispensable in efforts to withstand and recover from the effects of climate change-related manifestations, being acute shocks or slow-changing trends. It's an equally important basis for vulnerable communities to be able to adapt, and potentially change, in face of the -largely unknown- impact of climatic occurrences. Associated with the belief, reliability, expectations and perceptions between people and the institutions within which they operate or interact, trust often acts as an underlying cause of action or inaction, constituting an important factor in decision-making processes.

Adaptation experiences suggest that vulnerable communities are more prone to act upon information that they can 'trust', a complex concept that could be linked to factors such as the source of the information and the local perception of it, the language used to convey the message, the role and credibility of 'intermediaries' or local facilitators that help disseminate the information, the use of local appropriation mechanisms and community involvement, among others.

Climate change Adaptation Strategies and National Programmes of Action are increasingly called to foster trust-building processes by engaging local actors and gaining a better understanding of local needs and priorities. Thus, trust building in the climate change field involves finding new collaborative spaces where the interests of all stakeholders can be heard, and both scientific and traditional knowledge can be shared and built upon towards more effective adaptive practices, and potentially, transformation.

The widespread diffusion of ICTs -such as mobile phones, Internet access and even community radios could be opening up new opportunities to use these tools in support of trust-building processes, a necessary step towards change and transformation. Research at the intersection of ICTs, climate change and development suggests the following aspects in regards to the supportive role of ICT tools towards trust:

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

● **Multi-level Communication:** ICTs can facilitate communication and trust-building between and across actors at the micro (e.g. community members), meso (e.g. NGOs) and macro levels (e.g. policy makers), fostering participation in the design of adaptation -and mitigation- strategies, as well as accountability and monitoring during their implementation.

● **Network Strengthening:** The role of social networks is key within processes of adaptation to climate change and resilience building. Trust is at the core of networks functioning. The use of ICTs such as mobile phones can help to enhance communication and the bonds of trust within and among networks, which can in turn contribute to the effectiveness of community networks' support and the access to resources.

● **Self-organisation:** The ability to self-organize is a key attribute of resilient systems, and involves processes of collaboration that require *trust* among stakeholders and institutions. By facilitating access to information and resources through both point-to multipoint and point-to-point exchange, ICTs can be important contributors to self organization and to the coordination of both preventive and reactive joint efforts in face of climatic events. They can help climate change actors to verify or double-check facts if the information source is not entirely trusted, diversifying their potential responses to the occurrence of climatic events. Additionally, ICTs can play a role towards trust by enabling the assessment of options and trade-offs involved in decision-making.

● **Appropriation and Infomediaries:** The role of actors that 'translate' or 'mediate' the technical and scientific information to suit the needs of the local context, is vital for the appropriation of information. Tools such as the Internet, GIS or mobile phones can support and strengthen the role of agricultural extension workers, deepening the relationships of trust that they have established with local producers affected by climate change manifestations by offering them a broader set of options and information, for example, on crop diversification or plague management, including more immediate response to their queries.

● **Transparency and Fluency:** Online platforms that provide new channels for citizens to voice their views and concerns, and that allow an interaction with decision makers, are an example of ICTs potential towards transparency and information fluency, which is an important factor in the local perception, expectations and 'trust' on local, regional and national institutions.

While at the onset of extreme events we are quick to recognize the importance of communication, we often fail to acknowledge the pivotal role of trust towards adaptation and resilience, as well as the potential of innovative tools such as ICTs to help fostering trust, strengthening networks and collaboration. But as important as discussing the potential of ICTs towards trust building in adaptive processes, is discussing the risks associated with their use. Ensuring the quality, accuracy and relevance of the information is key to avoid maladaptive practices and poor decision-making, which could potentially lead to deepen existent vulnerabilities and inequalities. Issues of power and differential access to information also need to be addressed when considering the potential of these

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

tools towards trust building, network strengthening and participatory processes – including those related to climate change.

Ultimately, ICTs could play an important supportive role helping to build and strengthen trust within vulnerable communities affected by climate change impacts, as well as in

National Adaptation Plans and Programmes of Action seeking to build long-term climate change resilience with a multi-stakeholder, participatory base.

e-RESILIENCE AND e-ADAPTATION

Vulnerability, adaptive capacity and resilience are concepts that have been broadly discussed and analyzed in the climate change adaptation literature for many years. They constitute closely linked, albeit complex areas of analysis that are key to understand the effects of climate related hazards and shifting trends in developing contexts. At the same time, within those contexts, ICTs – particularly mobile phones – have been diffusing rapidly (Heeks, 2010). This diffusion has been accompanied by an increasing body of literature on the potential and challenges of digital technologies. Part of that potential is the ability to address climate change. Yet a review of the literature on ICTs and climate change shows not only is the literature overall fairly limited to date, but there are particular deficiencies in discussion of developing country priorities and climate change adaptation (Ospina and Heeks, 2010).Review of the existing literature on ICTs, climate change and development indicates that the potential of digital technology has not yet been integrated into a systematic understanding of adaptation and resilience, let alone from the perspective of a conceptual framework.

One way to understand the potential contribution of ICTs to climate change adaptation – and based on the model of livelihood systems which includes component of livelihood systems vis- à-vis other system components: supporting human capital, supporting financial capital, etc: supporting formal institutions, supporting informal institutions; and so on. What has been missing in all cases – those dealing with climate change or with other development issues – is an understanding of the foundational issue – resilience – and the way in which ICTs can support the development of resilience.

ICTs can help strengthen the physical preparedness of livelihood systems for climate change related events through applications such as geographic information systems (GIS), and positioning and modeling applications. These can contribute to design of defenses and determination of their optimal location~ both making the livelihood system more robust.

ICTs can also strengthen institutions and organisations needed for the system to withstand the occurrence of climatic events, including the support of social networks and the facilitation of coordinated action (Duncombe, 2006). For example, ICTs can strengthen social networks through enhanced communication within those networks; communication that increases the network bonds by building trust and a sharing of norms and values.

ICTs can help increase the breadth and depth of assets to which households, communities, etc have access. ICT can facilitate access to a broader set of capital assets,

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

fostering the ability of livelihood systems to recover from climate related events. Illustrating this potential, ICTs available in Village Resource Centres in rural India have enabled end users to interact with scientists, doctors, professors and government officials located in urban locations (Nanda and Arunachalam, 2009). This has increased the information assets available (e.g. oceanic weather forecasts), and human capital (e.g. via tele-health and e-learning), all of which help when climate related events occur.

ICTs can increase the scale of available assets by combining the distant and the proximate. In relation to information assets, for example, in remote areas of the Philippines, participatory 3-dimensional modeling – a community based tool which merges GIS generated data and local peoples' knowledge to produce relief models – is being used to establish visual relations between resources, tenure, their use and jurisdiction, thus contributing to the ability of the community to deal with climate change hazards and trends (IAPAD, 2010). Mobile applications have improved the breadth of structural access by enabling integration of local producers – small entrepreneurs and farmers – into regional and global supply chains, which also broadens the scale of asset availability, typically in terms of financial and physical capital. In India, the Foundation of Occupational Development promoted the use of cell phones enabling women entrepreneurs from poor communities to exchange goods, place and receive orders, and develop new markets for their products.

Such applications can also increase the scale of institutional forces. For example, - microfinance services extend the reach of microfinance organizations (Garcia Alba et al.,2007). Not only does this increase the scale of financial assets and organizational structures; it also scales the penetration of the institutional norms and values associated with microfinance organizations. Finally, access to extended social networks through ICTs can also help asset, institutional and structural scale by improving the links between local systems and the meso/macro level organizations that play a key role in the provision of enabling environments for adaptation.

ICTs AND ADAPTIVE ACTIONS

The systemic perspective reflected in this analysis suggests that ICTs can be conceived as contributing to adaptive processes not only through their influence on resilience sub - properties, but also through their dynamic linkages with other system components, namely assets, institutions, structures and capabilities, ultimately contributing towards adaptive functioning (unless not converted into functioning due to constraints).

In the previous sections, the focus was on ICTs and resilience (albeit incorporating discussion of technology's role vis-a-vis system components). However, whether discussing system properties or components, these are essentially precursors. What practitioners, at least, are more interested in is the downstream impact of ICTs on adaptation processes.

We can assess this by considering the potential impact of ICTs in two different ways: first, with respect to livelihood systems at the macro/national level (which is key to adaptive actions); and second, their impact on the vulnerabilities identified at the

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

beginning of this study (i.e. livelihoods and finance, socio-political conditions, health, habitat and migrations, food security and water supply), which constitute areas in which the likely impact of climate change is considered to be highest, and which play a critical role in the capacity of the system to achieve development outcomes.

ICTs' potential contribution to climate change adaptation either in these ways or if thought of in terms of e-resilience cannot, however, be taken for granted. The analysis will therefore conclude by discussing some of the challenges associated with the use of ICTs in adaptation processes in practice.

ICT INFRASTRUCTURE AND CLIMATE CHANGE

The telecommunications sector can play a key role in climate change adaptation through the provision of technical and financial support, as well as the establishment of multi-sectoral alliances to implement ICT related solutions in the field (Labelle et al., 2008). At the policy level, developing country institutions can support the provision of broader access and connectivity in rural areas, particularly in marginalized regions affected by climate change related hazards or trends. Multi-sector alliances providing adequate infrastructure can be pivotal in the implementation of effective early warning systems , as well as for the provision of incentives for ICT entrepreneurs to play an active role in the diversification of local livelihoods, thus reducing dependence on natural resources and vulnerability to the impact of climatic events. Faced by the daunting risks posed by climate change to agriculture and food security, developing country structures and institutions could play an important role through the provision of national ICT based programmes that target small farmers and producers, aimed at strengthening local knowledge on crop diversification and production under variable conditions (e.g. agricultural models and techniques to reduce climate risks, on farm product management and seed management). ICTs can also strengthen the internal capacity of nationwide organizations to serve as effective facilitators of local adaptive actions.

IMPACT OF ICT ON CLIMATE CHANGE VULNERABILITY

ICTs can help build more resilient livelihoods: for instance, providing more accurate price and demand information that enables sales with higher profits or to a wider range of markets (Jensen, 2007); or by creating ICT based micro-enterprises that may provide additional and/or more robust income streams (Heeks and Arun, 2010). Again, though, there is little evidence yet viewing this from a climate change specific perspective.

SOCIO-POLITICAL CONDITIONS

ICTs can help enable new structures within the socio-political environment which may foster inclusiveness and participation in the design and implementation of adaptation processes, thus reducing the potential for the emergence of social tensions or instability.

In the Caribbean, a study of women organic farmers found these tools strengthened networking, cooperation and advocacy among the farmers, improving their resilience in the face of climate change related changes (Tandon, 2009).

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

Health: ICTs can help monitor alterations in patterns of disease that are predicted to arise as a result of climate change. ICTs can also drive new health information back into communities, using technologies that are accessible in the field (e.g. mobile phones, community radio) to provide climate literacy on key health topics, to improve the local response to shifts in vector borne (e.g. malaria and dengue) and waterborne diseases, heat, declining food security and decreased availability of potable water ~as well as to internalize other health related adjustments that may become necessary within local communities (Kalas and Finlay, 2009).

Habitat and Migration: ICT applications can help alleviate the pressures posed by migration and redistributions of people triggered by drought, desertification or extensive flooding, among other potential impacts of climate change. Remote sensing and GIS can facilitate urban planning, thus improving the habitat conditions of displaced populations that are forced to settle in deprived and/or over populated areas. At the same time, ICTs can enable communication between family members separated or disrupted due to climate events, thus ameliorating the psychological stress these types of migrations can cause among vulnerable populations (Dempsey, 2010).

Food Security: Crop yields affected by drought or flooding, or by an overall decrease in agricultural productivity due to climate variability can create food shortages, triggering malnutrition and related problems within vulnerable populations. Within such contexts, ICTs can play an important role in support of agricultural extension services, broadening the reach of such programmes particularly in rural, marginalised area of developing regions. In many ways, this overlaps with the agricultural livelihoods role described earlier.

For tribal farmers of North-East India, for instance, where inadequate dissemination of farm information and technologies have led to low productivity and food insecurity, ICTs (including radio and television) are being used to disseminate information on pest and disease management information, among others . However, ICTs will have a food security role beyond just production~ providing information for the planning and operation of food storage, distribution, and consumption.

Water Supply: ICTs can help improve water resource management techniques, monitoring of water resources and awareness raising at the community level. With the support of ICTs, an agrarian information system can be put in place that includes software to improve the distribution of water. As with other vulnerabilities, though, most cases relate to the vulnerability generally rather than identifying ICTs' role in specifically assisting water supply management issues that are arising as a result of climate change. A single rural information system, for example, might well cover livelihoods, food security, health and water. On the one hand, this reinforces the need for a rapid expansion of climate change specific analysis of ICT projects. On the other, it indicates the value of taking a holistic perspective towards ICTs and climate change adaptation. ICTs could also contribute towards the implementation of more inclusive, participatory processes that reflect the needs and power relations that exist within local contexts. Solutions that are disconnected from the priorities and characteristics of the local not have the long

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

lasting effects that are necessary for future adaptation and the achievement of development outcomes. ICTs alone do not represent the solution to climate change adaptation; they must be an integrated part of a holistic approach.

CHALLENGES OF USING ICTs

The analysis conducted thus far indicates the existence of positive, valuable linkages between ICTs and the resilience of systems vulnerable to climate change. However, developing countries are characterised by the interplay of a complex set of stressors and inequalities including socio-political contexts where power relations and potential divisions are based on factors such as gender and ethnicity, and where the implementation of innovative ICT approaches must be assessed carefully (Duncombe, 2006). Thus, analysis of ICTs' role must also acknowledge their potential to impact negatively on livelihood systems, possibly reducing their resilience and adaptive capacity to climate related hazards, trends and variability. For example, ICTs may provide unreliable information or information that does not correspond to the local realities or that is made available in a language that is inaccessible for the local actors. This can not only undermine the potential of these tools within adaptive processes, but also contribute more generally to an increase in uncertainty or even encourage mistaken and maladaptive actions. Adaptation as a response to a particular climate related disturbance can undermine systemic resilience by making the community more vulnerable to other shocks, or by constraining generic sub-properties such as flexibility (Nelson et al., 2007). If used within adaptive actions that do not integrate or acknowledge these factors, ICTs could contribute to overall mal-adaptation for example, by focusing attention and resources on one initiative – say a disaster early warning information system – and thus drawing those assets away from application to other initiatives.

At the same time, it is necessary to recognize that livelihood systems in developing contexts involve complex power relations and inequities which determine access to assets and opportunities, and can turn the potential benefits of ICT interventions into situations where the power of more privileged groups is strengthened with greatest access to decision making, widening the gap with those that are most at risk. The cause of vulnerability to climate change or limited adaptive capacity is a vital component of adaptation. For example, actions that do not acknowledge the specific vulnerabilities and role of women within adaptive processes face the risk of deepening existing gaps with regard to ownership of land, rights to assets, or access to assets including financial credit. ICTs might also facilitate the adaptation of individuals, but not necessarily that of broader groups. Applications that strengthen the livelihood options of a family or group do not necessarily have the same effect at community level, in some cases deepening the gap between the 'haves' and the 'have nots' within particular communities. If ICTs are used without considering the gender and other imbalances and power relationships within a given community, the use of these tools can reinforce existing inequalities, giving voice to the interests of certain groups that may not be the most vulnerable. Therefore, ICT solutions must acknowledge the role and contribution of power and inequality to adaptation processes, targeting them if effective and inclusive adaptation is to be achieved. These examples suggest that, within contexts characterized by poverty and

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

inequality, the reduction of climate related risks is not sufficient to indicate success. The analysis of ICTs' potential requires careful consideration of the underlying factors of vulnerability within developing environments, as well as the existing institutions and structures that characterize a given livelihood system.

CONCLUSIONS

Despite the fact that much remains to be explored in terms of the role and potential of ICTs within the climate change field, the analysis conducted here sheds light on key conceptual foundations that help better understand the complex linkages that exist within vulnerable livelihood systems, and that ultimately determine the role of digital technologies in achieving development outcomes amidst an uncertain climatic future. It may be suggested that, in the event of climate change related shocks or trends within a particular context, the capacity of the system (at the household, community or national level) to respond through adaptation can be understood either as a set of components or as a set of (sub) properties, which interact to create the adaptive capacity of the system. Resilience, thus, emerges as an important property to consider in the analysis of livelihood systems that are subject to climate related changes and uncertainty; a property that interacts with assets and other components to shape the trajectory of functioning and adaptation after any acute or chronic disturbance.

The value of this approach resides in its contribution to better understand the complex set of relations between livelihood system components, properties and processes, which in turn are characterized by the presence of multiple development stressors. It can serve as a tool to explore the potential and challenges of ICTs' role within processes of adaptation, while facilitating the identification of strategies that could contribute to the enhancement of adaptive capacities, and ultimately to the achievement of development outcomes in the face of long term climatic uncertainty.

Ultimately, the challenge for developing countries resides not only in their capacity to withstand and recover from climatic events, but mostly in their capacity to adjust, change and transform amidst slow changing trends and unpredictable variability; while facing a future where the only certainty is uncertainty itself, and within which, development outcomes will be determined, to a large extent, by their ability to foster 'development epiphanies' and innovate with the support of tools such as ICTs.

REFERENCES

Dempsey, P. (2010) *How ICT is Helping in Haiti*, London: The Institution of Engineering and Technology (IET) [Online], Available: http://kn.theiet.org/news/jan10/haitiupdate.cfm .

Duncombe, R. & Boateng, R. (2009) *Mobile Phones and Financial Services in Developing Countries*. IDPM Development Informatics Working Paper Series, Paper no. 37. University of Manchester, Available: http://www.sed.manchester.ac.uk/idpm/research/publications/wp/di/documents/di_wp3

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

Duncombe, R. (2006) *Analysing ICT Applications for Poverty Reduction via MicroenterpriseUsing the Livelihoods Framework*. IDPM Development Informatics Working Paper no. 27.University of Manchester.

Garcia Alba, J., Wilke Meins, R. & Navajas, S. (2007) *M-Banking: Extending the Reach of Financial Services through Mobile Payment Systems,* Washington D.C: The Multilateral Investment Fund (MIF)/IDB, Available: http://idbdocs.iadb.org/wsdocs/getDocument.aspx?DOCNUM=1328322

Heeks, R. & Arun, S. (2010) 'Social Outsourcing as a Development Tool', *Journal of International Development*, 22(4), 441-454.

Heeks, R. (2010) 'Do Information and Communication Technologies (ICTs) Contribuite to Development', *Journal of International Development,* 22(5).
http://www.bcoalliance.org/ClimateChange

http://www.sed.manchester.ac.uk/idpm/research/publications/wp/di/documents/DIWkPpr27.pdf

IAPAD. (2010) *Participatory 3Dimensional Modelling*: Integrated Approaches to Participatory Development (IAPAD) [Online], Available: http://www.iapad.org/participatory_p3dm.htm.

Janssen, M. A. & Anderies, J. M. (2007) 'Robustness Tradeoffs in Socio-Ecological Systems',*International Journal of the Commons,* 1(1):43-65.

Kalas, P. P. & Finlay, A. (2009) *Planting the Knowledge Seed: Adapting to Climate Change using ICTs*. Building Communication Opportunities (BCO) Alliance,

Kelly, P. M. & Adger, N. W. (2000) 'Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation', *Climatic Change,* 47:325-352.

Labelle, R., Rodschat, R. & Vetter, T. (2008) *ICTs for e-Environment:Guidelines for Developing Countries with a Focus on Climate Change*. International Telecommunication Union (ITU), Geneva
http://www.itu.int/ITUD/cyb/app/docs/ituictsforeenvironme

Nanda, S. & Arunachalam, S. (2009) *Reaching the Unreached: Community based Village Knowledge Centres & Village Resource Centres,* IGNOU Jamsetji Tata National Virtual Academy (NVA), M S Swaminathan Research Foundation, Taramani, Chennai.

Nelson, D. R., Adger, N. W. & Brown, K. (2007) 'Adaptation to Environmental Change: Contributions of a Resilience Framework', *Annual Review of Environment and Resources,* 32:395-419.

Ospina, A. V. & Heeks, R. (2010) *Unveiling the Links between ICTs & Climate Change In Developing Countries: A Scoping Study*. Centre for Development Informatics, Institute for Development, Policy and Planning (IDPM), University of Manchester,
http://www.niccd.org/ScopingStudy.pdf

ICT for Agricultural Development under Changing Climate, Pages 17-28
Edited by: Krishna M. Singh and M.S. Meena
Narendra Publishing House, New Delhi
ISBN: 978-93-80428-45-1

Saravanan, R. (2008) 'Tribal Farmers Information Needs and ICT Preference Assessment, *Agricultural Extension Review,* 20(2):2729.

Singh, R K P and Aggarwal, P K (2011) Summary of Base Line Household Survey Report, Bihta Site, Bihar (India), Climate Change, Agriculture and Food Security, IWMI, New Delhi.

Soloman, S; Plattner,G K; Kuntti, R,and Frindlingstein, P(2009) *Irreversible Climate change due to Carbon dioxide Emission.* Proceedings of the National Academy of Sciences of the USA

Tandon, N. (2009) *Issues and Challenges of Climate Change for Women Farmers in theCaribbean:The potential of ICTs*. Networked Intelligence for Development (NID)/International Development Research Centre (IDRC), http://www.networkedintelligence.com/