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Venkataraman Balaji
Peter Q Craufurd

Working Paper No. 78

CGIAR Research Program on Climate Change,
Agriculture and Food Security (CCAFS)



RESEARCH PROGRAM ON
**Climate Change,
Agriculture and
Food Security**



Working Paper

Using information and communication technologies to disseminate and exchange agriculture-related climate information in the Indo-Gangetic Plains

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Abstract

This report documents and analyses emerging trends in the delivery and exchange of climate information in institutionalized agricultural extension systems, as well as through information and communication technologies for development (ICT4D) efforts that have a rural–agricultural focus. Such an analysis aims to give a clearer indication of how to best direct potential future investments in sharing climate change information with non-institutional stakeholders.

The analysis covers four countries across the Indo-Gangetic Plains (IGP): Bangladesh, India (Punjab, Haryana, Uttarakhand, Uttar Pradesh, Bihar and West Bengal States), Nepal (Terai Region), and Pakistan (Punjab Province). The critical potential impacts of climate change across the IGP include drought, flooding, glacial lake outburst floods, and variability of river runoff and coastal salinity.

Keywords

Climate information; agricultural extension; information and communication technologies for development; Indo-Gangetic Plains

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Acronyms

IGP Indo-Gangetic Plains

ICT4D Information and communication technologies for development

Introduction

This report documents and analyses emerging trends in the delivery and exchange of climate information in institutionalized agricultural extension systems, as well as through information and communication technologies for development (ICT4D) efforts that have a rural–agricultural focus. Such an analysis aims to give a clearer indication of how to best direct potential future investments in sharing climate change information with non-institutional stakeholders.

The analysis covers four countries across the Indo-Gangetic Plains (IGP): Bangladesh, India (Punjab, Haryana, Uttarakhand, Uttar Pradesh, Bihar and West Bengal States), Nepal (Terai Region), and Pakistan (Punjab Province). The critical potential impacts of climate change across the IGP include drought, flooding, glacial lake outburst floods, and variability of river runoff and coastal salinity.

Agricultural extension in the countries of the Indo-Gangetic Plains

Agricultural extension systems across these countries and regions are, in general, public in character. They are mostly organized as departments or directorates under federal or state governments, with agricultural universities playing a minor role in management. Such public extension systems have a mandate to disseminate agricultural information to farmers in Bangladesh, Nepal and Pakistan.

In Bangladesh, the key national agricultural research and extension institutions sit under the Ministry of Agriculture, and in Nepal they reside under the Ministry of Agriculture and Cooperatives. This structure, with a single umbrella ministry that covers both agricultural research and extension, allows for better coordination between research and extension. Each district of Pakistan has its own agency to manage agricultural extension services, along with sister organizations responsible for such issues as water management, fisheries, livestock, soil conservation, and forestry. Besides the district extension services, other long- and short-term, area-based and countrywide programs also provide advisory services to farmers, including extension departments in agricultural universities. The organizational structure of agricultural research and development in Pakistan is somewhat complex. Public agricultural research is conducted by federal and provincial government agencies and by various higher education agencies. Research conducted at the provincial level is mostly adaptive, which is closely linked to extension.

India follows the U.S. model of the land-grant system of organization with a number of state and regional agricultural universities responsible for agricultural education, extension and research in their regions. This system is more effective than that of Pakistan at fostering linkages across the education, extension, and research communities.

The extent of nongovernmental organization (NGO), private sector, and input-delivery service involvement in agricultural extension varies across Bangladesh, Nepal and Pakistan. In Nepal, public institutions are dominant, with limited NGO and private sector involvement. In Bangladesh, NGOs disseminate much more information than the private sector does. In Pakistan, all these mechanisms operate in parallel, although the role of private sector and fertilizer and pesticide suppliers is much larger than that of NGOs.

In India, agriculture is largely a matter of state legislation although the federal government legislates on food production and storage and regulation of international commodity trading. Although agricultural research receives direct federal support and has a department that presides over the Indian Council of Agricultural Research (ICAR), extension is almost entirely a state matter, with federal agencies involved only in advanced training.

Linking agricultural extension to ICT4D and agrometeorological information

Agrometeorology (“agromet”) concerns interactions between meteorological and hydrological factors on the one hand, and agriculture – including horticulture, animal husbandry and forestry – on the other. In addition to the climate and its local variations, agrometeorology is also concerned with artificial modifications to the environment, such as windbreaks, irrigation, glasshouses, various forms of land use, and the effects of climate change. An agricultural meteorologist can help farmers use their land more effectively.

Agromet advisories and tailored weather forecasts allow farmers to optimize the timing of sowing, planting, fertilizer application, irrigation, harvesting, and spraying of pesticides and herbicides, and improve cropping pattern selection. Ultimately, such improvements will help increase production, reduce losses, and lower production costs.

Impact studies suggest that farmers can increase production by 10% if they have access to good agromet advisories. Despite this, there has been a general failure to link agricultural extension with national initiatives in e-governance (use of ICT by the public sector to improve

information and service delivery, encourage citizen participation in decision-making, and make government more accountable, transparent and effective) or other multi-stakeholder ICT4D efforts. For example, although India is host to nearly half of the developing world's ICT4D projects, fewer than 5% of Indian projects are directly or indirectly linked to agricultural extension. Contemporary digital means of information dissemination, especially publicly accessible Internet, are almost non-existent in Nepal and are extremely limited in Bangladesh, though Pakistan has made some progress in this area. In general, public extension priorities do not focus on disseminating ICT-enabled climate information or weather forecasts.

Meteorological data collection and dissemination is essentially controlled by the public domain in all four countries. In India, this occurs through the India Meteorological Department under the Ministry of Earth Sciences; in Nepal through the Department of Hydrology and Meteorology (DHM) under the Ministry of Environment; in Bangladesh through the Bangladesh Meteorology Department (BMD) under the Ministry of Defence; and in Pakistan through the Pakistan Meteorology Department (PMD), also under the Ministry of Defence. These various departments also contribute to the global exchange of meteorological data.

In India, a wide variety of channels and modes are used to disseminate climate information to farmers, with conventional mass media continuing to play the primary role. The India Meteorological Department has a dedicated Agro-Meteorology Division that has a long history of operating agro-advisory services, and the Indian Council of Agricultural Research (ICAR) runs the All-India Coordinated Project on Agro-Meteorology. Although agromet advisories are also made available via the Internet, there is no effort by the promoters of Indian ICT4D initiatives to link the various sources of data and information to create new services for the farmers. Similarly, despite some collaboration between agricultural and meteorological institutions in Bangladesh, Nepal and Pakistan, none of the IGP countries appear to possess any well-organized, institutionalized agromet systems or ICT-mediated agricultural development efforts to manage agromet data and deliver location-specific weather and seasonal climate forecasts, products and advisory services to farmers.

Bangladesh, Nepal and Pakistan, like India, have initiated ICT4D pilot projects that have had some success in harnessing ICT for development. Some pilots have demonstrated how ICT can be used to strengthen market linkages and commodity value-chain linkages, as well as research-extension-farmer linkages. However, these pilots have largely remained isolated and have not been fully integrated into the agricultural research and extension systems. Although mobile telephone use continues to grow rapidly in all the IGP countries, Internet use remains

limited. Looking at the overall state of the Internet and ICT access and use in agricultural research and development, Pakistan can be considered as fairly advanced, while Bangladesh and Nepal are developing rapidly.

At the regional and international levels, some initiatives exist on the use of ICT in the agricultural and environmental sectors. These relate to early warning systems, disaster reduction, adaptation to climate change, bringing weather services to rural areas, and ICT in the economics of climate change. Results from these initiatives are not yet available. The United Nations Framework Convention on Climate Change (UNFCCC) National Adaptation Programme of Action to Climate Change (NAPA) has several projects in Bangladesh and Nepal that are related to food, agriculture and environment, but none of these focuses on ICT or ICT-mediated information dissemination.

Country Profiles

Pakistan

Meteorological systems and dissemination of agromet information

Pakistan Meteorological Department

The Pakistan Meteorological Department (PMD) is both a scientific and a service department under the Ministry of Defense. PMD conducts weather and climate research and provides meteorological services throughout Pakistan, including monitoring and advanced warning of extreme weather events such as floods, heavy rain spells and cyclones. It is also models snowmelt runoff and investigates land-use change in the context of climate change. PMD has five regional centers (Karachi, Lahore, Multan, Peshawar and Quetta) and more than 70 meteorological data-collection stations across the country, extending from several thousand feet above the ground level close to glaciers down to considerable distances off-shore. A member of the World Meteorological Organization (WMO), PMD recently upgraded to a fast grid computing environment, which allows it to deal with voluminous and multidimensional datasets of fine resolution, including those covering climate change. The Department's work includes an agromet focus and the agency collaborates closely with the Islamabad-based Global Change Impact Studies Centre (GMISC; see below).

The objectives and responsibilities of PMD include:

- ensuring timely issue of different types of weather/flood forecasts, warnings and advisories to the national news media and concerned functionaries;
- early warning of disasters due to meteorological, hydrological and geophysical phenomena such as tropical cyclones, heavy rains, floods and earthquakes;
- socioeconomic development of the country based on the climatic and agro-climatic potential of different areas;
- boosting national agricultural productivity by providing agromet services to the farming community;
- investigating the behavior of the atmosphere and exploiting this knowledge for short and long-term weather predictions

To achieve its objectives the department has established:

- a network of observation stations to generate meteorological, geophysical and phenological data;

- a telecommunication system for speedy dissemination of data;
- meteorological offices to analyze data for issuing forecasts and warnings for aviation, agriculture, shipping, sports, irrigation etc.;
- climatological and data-processing units for scrutinizing, comparing and publishing data for appraisal of long-term weather trends and earthquakes

With respect to agromet services, PMD provides information on meteorological and geophysical matters with the objective of mitigating disasters caused by weather and geophysical phenomena, aiding agricultural development based on the climatic potential of the country, and predicting and modifying weather forecasts. Specific agromet services include rain predictions, frost predictions, provision of soil moisture information, advice on time of crop sowing/harvesting and pesticide applications; information on crop water requirements, heat and cold-wave forecasts, and special weather advisories for farmers. PMD also publishes a monthly national agromet bulletin and performs research in collaboration with regional agricultural research institutions.

The major achievements of PMD include introduction of modern flood forecasting and earthquake detection, seismic design of dams and other infrastructure development, and disaster relief schemes. Some of the major research themes include artificial rain production, groundwater detection, arid zone research, ozone measurements, solar energy and wind power.

National Agromet Centre

The National Agromet Centre (NAMC), in Islamabad (along with four Regional Agromet Centres at Quetta, Tandojam, Faisalabad and Rawalpindi; see below) was set up as part of a WMO/United Nations Development Programme-sponsored project on meteorological factors affecting crop production. The project aims to maximize production and minimize crop damage associated with meteorological phenomena. NAMC issues forecasts for the benefit of farmers and other people and organizations working in agriculture. The Centre's main objectives include:

- issuing agromet advisories;
- coordinating and liaising with national agriculture and water authorities;
- researching the relationship between crops and weather;
- establishing an agromet database for the different agroclimatic zones of Pakistan;
- sharing information on NAMC research;
- managing data processing and publication;

- issuing weather-based crop yield and production estimates for central planning and food production strategies.

Regional Agromet Centres (Rawalpindi, Faisalabad, Quetta and Tandojam)

The objectives/functions of the Regional Agromet Centres include:

- preparing annual regional crop–weather reports and using these for agromet crop modeling for major crops of different regions;
- collaborating with regional agricultural scientists, actively participating in field research, and providing processed data as and when required;
- transmitting regional information on crops and animals to NAMC;
- preparing and disseminating agromet advisories for farmers in consultation with local agricultural authorities;
- providing technical assistance in establishing new agromet observation stations;
- performing calibration of and maintaining agromet instruments;
- training local technical agricultural and agromet personnel

Dissemination of agromet data to farmers through media

Farmer bulletins are provided to all regional radio and television stations and newspapers. PMD provides information on the rainfall and dry spells, predicts the amount of rainfall likely to occur in Pakistan during the winter period (December to February), and advises where supplementary irrigation might be beneficial.

Climate change and disaster management

Climate change and its potential impacts threaten the security of Pakistan’s water, food, and energy. The most important potential climate change threats to Pakistan are identified as:

- increased monsoon variability;
- rapid recession of Hindu Kush–Karakoram–Himalayan glaciers, leading to increased water inflow to the Indus River System, and reduced capacity of natural reservoirs due to glacier melt and rise in snowline;
- increased risks of floods and droughts;
- increased siltation of major dams resulting in greater loss of reservoir capacity;
- severe water-stress and heat-stress in arid and semi-arid regions, leading to lower agricultural productivity and reduced power generation;

- increased upstream intrusion of saline water into the Indus delta, adversely affecting coastal agriculture, mangroves, and breeding grounds of fish;
- threatened coastal areas (including the city of Karachi) as a result of sea-level rise and increased cyclonic activity due to higher sea surface temperatures

The Global Change Impact Studies Centre

The GCISC helps national planners and decision makers develop policy in light of the changing global environment, in areas such as climate, water, energy, food, agriculture, health, ecology and new technologies. The main objectives of GCISC include:

- keeping track of the current and likely future trends of climate change, globally and within Pakistan;
- analyzing and evaluating the likely impacts of climate change on key socioeconomic sectors in Pakistan;
- identifying how science and technology may be called upon to cope with adverse impacts, and to advise national planners on the appropriate approaches;
- enhancing national capacity for climate change research;
- raising public awareness of climate change-related issues

GCISC's research activities are grouped under four sections: Agriculture, Climatology, Water Resources, and Environment and Trans-boundary Pollution. Agriculture and Water Resources in particular have major agromet implications:

Agriculture: This section studies the likely impacts of climate and technological change, both positive and negative, on agricultural production, and identifies appropriate measures for coping with negative impacts. This research helps national planners develop mitigation strategies and incorporate them into national development plans.

Water Resources: The objectives of this section include assessment of likely climate change impacts on Pakistan's freshwater resources, identification of appropriate coping mechanisms for adverse impacts by computer modeling to simulate various hydrological processes in the Indus River Basin, and using validated models to quantify changes in river inflows as a result of projected climatic changes in the region.

ICTs for technology transfer and linkages

In July 2006, an Expert consultation on agricultural extension, research–extension–farmer interface and technology transfer took place in Bangkok, Thailand. All four IGP countries were represented at the event, which identified the need for the agricultural sector to explore

and tap the potential of ICTs for agricultural extension. The role of ICTs was split into two elements – information access and networking – that are critical in the research–extension–farmer–market interface and technology transfer process. Put simply, the storage and retrieval of research results facilitates information access while telecommunications facilitates networking.

Nepal

Meteorological systems and dissemination of agromet information

Department of Hydrology and Meteorology, Ministry of Environment

The Government of Nepal began hydrological and meteorological activities in an organized way in 1962. The Department of Hydrology and Meteorology (DHM) has headquarters in Kathmandu and three basin offices: Karnali Basin Office in Surkhet, Narayani Basin Office in Pokhara and Kosi Basin Office in Dharan. DHM monitors all Nepal's hydrological and meteorological activities. The scope of work includes the monitoring of river hydrology, climate, agrometeorology, sediment, air quality, water quality, limnology, snow hydrology, glaciology, and wind and solar energy. As a member of the WMO, DHM contributes to the global exchange of meteorological data.

The principal activities of DHM include:

- collecting and disseminating hydrological and meteorological information for water resources, agriculture, energy and other development activities;
- issuing hydrological and meteorological forecasts for (including for the mitigation of natural disasters);
- conducting research for policy makers and for the development of hydrological and meteorological sciences in the region;
- promoting relationships with national and international organizations in the field of hydrology and meteorology.

DHM consists of four divisions: Hydrology, Climatology, Meteorological Forecasting and Coordination. The Climatology Division includes four sections: Climatology, Agrometeorology, Wind and Solar Energy, and Data. Research on climate change is the responsibility of the Climatology Section, while the Agrometeorology Sections role includes preparation of a weather-related crop calendar.

ICTs for technology transfer and linkages

National Adaptation Programme of Action to Climate Change

NAPA (www.napanepal.gov.np) aims to help developing countries prioritize urgent and immediate climate change adaptation actions. NAPA has three major components: preparation and dissemination of NAPA documents; development and maintenance of a platform for climate change knowledge management and learning in Nepal; and development of a multi-stakeholder framework of action on climate change in Nepal. NAPA's Climate Change and Development Portal is a gateway to climate change knowledge, opportunities, people, organizations and networks. It is a starting point for conducting research on climate change topics, networking, and coordination with individuals and institutions doing work on climate change.

Bangladesh

Meteorological systems and dissemination of agromet information

Bangladesh Meteorological Department

The Bangladesh Meteorological Department (BMD) oversees all public meteorological activities in the country. It maintains a network of surface and upper air observatories, radar and satellite stations, agromet observatories, geomagnetic and seismological observatories, and a meteorological telecommunication system. BMD's headquarters and Storm Warning Centre are in Dhaka and it has a Meteorological and Geophysical Centre in Chittagong. BMD recently established 12 agromet data-collection stations across the country. The Department performs three types of weather forecasts for agriculture: short-range (up to 48 hours); medium-range (up to 10 days); and long-range (more than 10 days). Each has a role to play in farm operations and planning agricultural activities. BMD also informs farmers about the actions they should take in the event of unusual weather patterns, helping to minimize crop and income losses.

At present BMD's Agromet Division collects a range of climatic and agromet data with which it prepares advisories and bulletins for both farmers and policy makers. The Division also supports the National Early Warning and Food Information System and Department of Agricultural Extension, thereby improving the supply of timely and reliable information on the national food supply situation.

The Agromet Division plans to install satellite remote sensing and Geographic Information Systems (GIS) research facilities to improve the quality of agromet bulletins and advisory services for sustainable agriculture in Bangladesh. These new facilities will combine new research tools, including satellite remote sensing, with GIS and conventional technologies to help Bangladeshi agriculture avoid the worst effects of climate change. BMD also intends to form district-level agromet advisory committees that will tailor BMD advisories for local farming communities according to local agricultural practices. The Agromet Division of BMD can also play a key role in developing a weather index-based crop insurance scheme.

Climate change and disaster management in Bangladesh

Variations in the monsoon patterns between the Himalayan range and the southern region, along with variability from El Niño and La Niña, cause fluctuations between drought and flooding in Bangladesh. About 80% of the land in Bangladesh is flood prone with at least 20% of the area normally inundated with rainwater. During excessive flooding in the monsoon season, about 70% of the area is affected, causing particular damage to the agricultural lands.

The existing meteorological, hydrological and agromet services in Bangladesh do not have the capability to provide seasonal climate forecasts. WMO has developed recommendations to improve the country's agromet station network to ensure the timely delivery of agromet information and products. Accordingly, BMD will upgrade and strengthen its network of agromet observatories.

Use of ICTs and ICT4D projects

In Bangladesh, private sector operators are the main providers of ICTs (mobile phones, computers and internet, television channels, radio, and some fixed-line telephony). The state controls fixed-line telephony, two national TV channels and 10 radio centers and also formulates and implements ICT policy. The majority of national and international NGOs working with ICTs are developing community information centers to transmit information to rural people.

India

Meteorological systems and dissemination of agromet information

To optimize the use of natural resources for increasing crop production, the Indian government has started an agricultural forecasting system known as the Agrometeorological Advisory Service (AAS). The service is rendered by the India Meteorological Advisory Service through IMD. Given the high degree of weather variability, farmers benefit from climate information with seasonal forecasts before the start of the cropping season. Short and medium-range weather forecasts based on agromet advisories help farmers stabilize yields through appropriate management of agro-climatic resources and other agricultural inputs such as irrigation, fertilizers and pesticides. The agromet service contributes to crop and livestock management strategies and to operations dedicated to enhancing crop production and food security. The emphasis of the AAS system is to collect and organize information on soil and crops and amalgamate them with weather forecasts. In India, the agromet advisories are given to farmers at the scale of agro-climatic zones (of which there are 127 in India) on the basis of quantitative medium-range weather forecasts. The economic value of the agromet information, which is in the form of advisories, can be evaluated in terms of its impact on saving farm inputs, increasing crop yield and bringing economic benefits to the farming community.

IMD, in collaboration with organizations such as ICAR, Federal and State Ministries of Agriculture, and state agricultural universities, issues AAS bulletins twice a week. It also promotes cooperation between national agrometeorological institutions and those involved in the transfer of agromet information and advisories. Besides setting up an agromet observation network, IMD has developed numerical weather prediction methods to prepare district-specific five-day weather forecasts. It has also set up a network of 130 agrometeorological field units, which translate weather forecasts into district-specific agro-advisories.

These units are based at Indian institutes of technology, state agricultural universities, ICAR institutes and other organizations working in agricultural science. Advisories are disseminated using a multimedia approach involving conventional modes of communication as well as emerging technologies such as mobile phones and the Internet. Messages are also sent by SMS (Short Messaging Service) as well as voice mode to farmers who subscribe to services offered by private companies.

Dissemination of agromet advisory services through mobile phone

Crop- and location-specific agromet advisories issued through the Integrated Agromet Advisory Service (IAAS) project are being disseminated to the farming community in India

through SMS and Interactive Voice Response technology (IVR). Under the IVR system, the information from Agromet Field Units for each state are collected and stored, then converted into voice form. Farmers can call to receive information.

A number of private firms are also disseminating IAAS-generated agromet advisories through SMS and IVR. At present 16 states – Delhi, Uttar Pradesh, Punjab, Haryana, Rajasthan, Madhya Pradesh, Orissa, West Bengal, Gujarat, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Bihar, Maharashtra and Himachal Pradesh – are covered under this service. The ultimate aim is to disseminate advisories to the farmers in real-time to help them save farm inputs, increase crop yield and ultimately increase economic benefits to the farming community.

In June 2008, IMD started issuing quantitative district-level forecasts five days ahead of a weather event. The parameters include rainfall, temperature, wind speed and direction, relative humidity, and cloudiness. A weekly cumulative rainfall forecast is also provided. Farmers use the advisories for sowing and transplantation of crops, fertilizer application, predictions regarding pests and diseases and measures to control them, weeding/thinning, irrigation (quantities and timing), and harvest of crops. Farmers who use the agromet information make a net gain of around 10%.

Economic impact assessment of weather-based farm advisory services

Farmers receiving AAS reduced the cost of cultivation by 2–5% (except in the case of fruits, for which the cost of cultivation has increased by 5–10%), as a result of better fertilizer and seed selection and appropriate spraying of pesticides. For most crops, yields increased by 10–25%, with increases in fruit crops at the upper end of this range. Undertaking timely field operations through adoption of twice-weekly agro-advisories also helped improve yields. Besides the economic gains achieved through various strategies to mitigate weather induced losses, the AAS project has also helped to create a comprehensive knowledge base of various aspects on prevalent weather and climatic conditions and their implications for crop and soil management.

Observations on the delivery and exchange of climate information

The present set of reviews of the delivery and exchange of climate information in institutionalized agricultural extension systems and ICT-mediated rural agricultural development in all the four IGP countries is limited by access to information from a host of public agencies. Nevertheless, the study permitted some broad observations, which are outlined here.

Farmer as client

The farmer is increasingly recognized as a ‘client’ – i.e. a recipient of technology, knowledge and information. More importantly, the research–extension–farmer linkage recognizes the farmer’s capacity as an individual as well as a member of community-based organizations, cooperatives, farmer-interest groups and self-help groups. The farmer, as well as the extension agent, is seen as the keeper and developer of indigenous technical knowledge. Any changes in agriculture and related development activities must be farmer-centric.

The need for collaboration across disciplines

Many of the challenges for developing ICT-mediated agromet information dissemination relate to the integration of a range of functions across the research–meteorology–extension–farmer continuum. Such linkages require special expertise and multiple perspectives. Sustained interdisciplinary efforts must be made to harness a variety of scientifically well-founded policy and technological options. These options are not readily available and their development must include experts in agriculture, meteorology and ICT as well as relevant social sciences. Expertise and resources for such varied needs often tend to rest under different public departments and ministries, and the non-profit and private sectors.

The integration of agricultural research and extension is a very difficult task, and the coordination of functions and activities among agencies is an enormous challenge. There is no single, ideal model for effectively linking agricultural research and extension. The suitable mix of strategies and mechanisms depends on institutional and national policies, and the resource context of the country in question. A better approach to integration may be through multi-institutional partnerships among public and private agencies and NGOs, and alliances among these actors as well as farmers and civil society. This could be achieved through decentralization and devolution of certain research and extension functions to the private

sector.

Exploiting ICTs

ICTs are all but ubiquitous and their potential uses and impacts on the environment are many and varied. Data must be collected, analyzed, interpreted, and transformed into information that enables individuals to make smarter environmental choices. Ultimately these data must be communicated to individuals and used to inform, monitor performance, and provide feedback that motivates and rewards individuals and communities for creating sustainable livelihoods.

ICTs can provide many strategies for adapting to or mitigating the adverse impacts of climate change, as well as for the transfer and exchange of knowledge more generally. The most important roles for ICTs in climate change are likely to be in monitoring and adaptation, rather than mitigation. Examples of adaptation include preparing risk assessments, protecting ecosystems, improving agricultural methods, managing water resources, designing better buildings, constructing settlements in safe zones, developing early warning systems, improving insurance coverage, and developing social safety nets. Effective monitoring can help provide early warning of events whose frequency and severity may increase with climate change, such as storms, droughts, floods, famines and diseases. The full potential of ICTs must be harnessed if millions of farmers are to be included in research–extension–farmer linkages in a participatory sense. Without exploiting ICTs, it will be impossible to disseminate information at the required scale on, for example, changing market prices, arrivals in markets, global market scenarios and weather.

ICTs to restructure economic and social structures

Effective delivery and exchange of agromet information – and thus successful adaptation to climate change – requires that ICTs are used to systemically transform economic and social structures through networked governance. Learning how to do this is one of the major challenges facing both the ICT sector and the sustainable development community. This might begin with developing and practicing principles of networked governance that draw on the unprecedented power of ICTs to make connections and enable creativity.\

The need for interoperability

Most efforts to develop interoperable systems of e-governance have suffered from three major drawbacks: over-engineering, lack of focus on government-wide business transformation, and inadequate implementation. Interoperability – diverse systems or

organizations working together – is increasingly important to the effective use of ICTs for agricultural development.

The public sector, the private sector and NGOs all have important roles to play, with the government setting a wider regulatory and legal environment that promotes interoperability among all parties. Public research and extension systems are no longer the sole providers of agricultural services to the farming community. The private sector, farmers' organizations, cooperatives, self-help groups, para-professionals, NGOs, input suppliers and small agribusinesses are engaged in both the generation and dissemination of information, technologies and services. A key challenge is to understand how best to engineer approach sufficiently open and collaborative to ensure interoperability within the research–agromet–extension–farmer continuum, and thus allow effective agromet information dissemination and use. Councils or committees are likely to be the most appropriate bodies for strengthening linkages.

ICTs to tackle environmental challenges

Using the Internet and ICT tools, research communities can tackle developing-country environmental challenges in six ways:

1. environmental monitoring using data recording technologies and systems, and GIS;
2. environmental analysis using various computational and processing tools;
3. environmental planning at the international, regional and national level;
4. environmental management and protection;
5. impact and mitigating effects of ICT use;
6. environmental capacity building

Increasing the scale of ICT benefits

There have been many pilot projects that have successfully harnessed ICTs to strengthen research–extension–farmer linkages, but increasing the scale of these remains a challenge. ICTs such as the telephone (landline as well as mobile), video-conferencing, e-mail, the internet and satellite communication are being used by researchers, extension agents and, more recently, farmers, with very positive results. However, ICTs are yet to be extensively integrated into the research–extension systems in a way that makes information available to clients. Linking successful ICT pilots with farmer field schools may be one way of providing information services – including those related to climate – and building capacity on a wider scale. Such approaches enhance the understanding of farmers' needs, and thus help redress and improve the existing situations for delivering agromet services.

Achieving effective climate information exchange

A framework for climate information exchange and advisory services must blend a top-down approach with a bottom-up one. Expert advisories would flow top-down whereas empowered farmers' organizations and rural community-based organizations would support and facilitate local-level, real-time data gathering. A combination of rural ICT centres and mobile telephony-linked data-transmission systems will need to be tested on different scales. Reliable real-time information will substantially improve the quality of advisory services. Trials conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) over the last five years demonstrate that such an effort is feasible and can be sustained with very limited resources.

This review underscores the need for research in all four IGP countries to determine appropriate strategies for managing information on risk, disaster management and forecasting weather in the short term, and climate variability and its impacts on agriculture in the medium to longer terms. This requires data management for risk mitigation and aversion, especially related to weather and biological stresses such as pest infestation and disease. Data management is also required for capacity development.

Selecting best practices and sharing them widely will enhance research–extension linkages and contribute to effective delivery and exchange of agromet information. There is also a need to encourage international collaboration and support to increase the use and accessibility of ICT tools. Research networking and increased accessibility of online computing services would play a crucial role in this context.

Conclusion: CCAFS' role in delivering and exchanging climate information

There is a clear opportunity for the Consultative Group on International Agricultural Research (CGIAR) Consortium and its partners to initiate a program on the use of ICTs for delivering and exchanging climate information. The resources in Bangladesh, Nepal and Pakistan are inadequate to undertake such a program without external assistance. The CGIAR Program on Climate Change, Agriculture and Food Security (CCFAS) may wish to consider several follow-up actions:

- Invite national experts to review this report and incorporate the suggested changes, and

circulate the revised version widely in each country and with CGIAR partners associated with CCAFS.

- Organize national or regional multi-stakeholder consultations and planning meetings with invitees representing a wide range of agriculture, meteorology, ICT and GIS expertise from public, private, NGO and international agencies.
- Focus on nationally important priorities related to agromet and associated information dissemination options with emphasis on the mass media, use of mobile phones and ICT more generally. Focus also on the capacity-development needs, at various levels (including research) and in various agencies (including the CGIAR), required to build a durable architecture for ICT-mediated climate information services in support of agriculture.
- Review and identify the needs, priorities, opportunities and potential partners (and their roles and responsibilities), and agree on a time-bound framework that is anchored in best practices.
- Launch pilot projects that will clearly demonstrate how to bring together disparate strands of agricultural extension, meteorological services, agromet research, GIS, and internet-enabled mobile phones to build the capacity of national agricultural research and extension systems (NARES), as well as that of the CGIAR itself.

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