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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

ICT and adaptation of agriculture to the effects of climate change

Recommendation ITU-T L.1504

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ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Recommendation ITU-T L.1504

ICT and adaptation of agriculture to the effects of climate change

Summary

Recommendation ITU-T L.1504 provides a description of how the use of information and communication technology (ICT) can help sustain the agricultural sector in the event of poor yields or disasters triggered by climate change. The possible impacts of climate change on agriculture and farming communities are described. This is followed by an outline of what measures are needed to adapt the sector and how ICT can play a role in this. The Appendices share some examples of best practices in different countries with details of specific ICT implementations.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Keywords

Agriculture, adaptation, climate change, information and communication technologies (ICTs), food security, smart agriculture.

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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Introduction

It is likely that the biggest impacts of climate change will be on the agricultural sector and food security over the next few decades [b-Brown and Funk]. Indeed, climate change is leading to more extreme weather events being experienced globally. These pose an especially great danger to the livelihoods of farming communities and can lead to starvation and migration of populations.

The purpose of this Recommendation is to:

– Offer useful information to decision makers concerning areas of possible adaptive action using information and communication technologies (ICTs) in both developing and developed countries. This Recommendation also aims to explore the role of ICT in the overall food security chain encompassing: monitoring, research, planning, production, storage, transportation and distribution.
– Describe state-of-the-art ICT applications and systems, in addition to hybrid systems where traditional means of dealing with climate change adaptation effects are used hand-in-hand with new technologies in order to reach large and small-scale farmers and others speedily and with minimum cost.
– Provide examples of success stories of ICT usage in agricultural sector adaptation to the effects of climate change with the intention of making others aware and encourage their possible adoption.
– Facilitate understanding of the role of ICT in the agricultural sector for adaptation to climate change, paving the way for the adoption of ICTs to climate-smart agriculture in particular achieving increased productivity and enhanced resilience of small-scale farmers to the effects of climate change.

Recommendation ITU-T L.1504

ICT and adaptation of agriculture to the effects of climate change

1 Scope

This Recommendation includes a review of the effects of climate change on agriculture and agricultural communities. It recognizes the need for adaptation and the use and dissemination of relevant innovative techniques. It explores adaptation plans and the potential of ICT in supporting the adaptation of the agricultural sector to cope with the effects of climate change with reference to [ITU-T L.1500]: *Framework for information and communication technologies and adaptation to the effects of climate change*, and [ITU-T L.1501]: *Best practices on how countries can utilize ICTs to adapt to the effects of climate change*. Examples are given from different countries of best practices on the use of ICT systems and tools to adapt the agricultural sector.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T L.1400] Recommendation ITU-T L.1400 (2011), *Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies.*

[ITU-T L.1410] Recommendation ITU-T L.1410 (2014), *Methodology for environmental life cycle assessments of information and communication technology goods, networks and services.*

[ITU-T L.1500] Recommendation ITU-T L.1500 (2014), *Framework for information and communication technologies and adaptation to the effects of climate change.*

[ITU-T L.1501] Recommendation ITU-T L.1501 (2014), *Best practices on how countries can utilize ICTs to adapt to the effects of climate change.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 climate change [ITU-T L.1500]: Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. The Intergovernmental Panel on Climate Change (IPCC) uses a relatively broad definition, referring to a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

The IPCC makes a distinction between climate change that is directly attributable to human activities, and climate variability that is attributable to natural causes. For the purposes of this report, either definition may be suitable depending on the context of analysis.

3.1.2 climate change adaptation [ITU-T L.1500]: Adaptation to climate change can be defined as the adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects. It refers to changes in processes, practices and structures to moderate potential harm or benefit from opportunities associated with climate change.

3.1.3 food security [b-WFS]: Food security exists when all people, at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

3.1.4 agricultural sector [b-ILO, 1999]: The science, art, and business of cultivating soil, producing crops, and raising livestock also referred to as farming.

3.1.5 climate-smart agriculture (CSA) [b-FAO, 2014]: CSA is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change.

3.1.6 small-scale farmers [b-FAO, 2012]: Pastoralists, forest keepers and fishermen who manage areas varying from less than one hectare to 10 hectares. Smallholders are characterized by family-focused motives such as favouring the stability of the farm household system, using mainly family labour for production and using part of the produce for family consumption.

3.1.7 vulnerability to climate change [b-IPCC]: The degree of susceptibility to harm, damage or loss as a result of climate change impacts or events.

3.1.8 climate change resilience [b-ECA, 2009]: Having the ability to plan for, survive, recover from and even thrive in changing climatic conditions.

3.1.9 climate variability [b-WMO]: Climate variability, is defined by the world meteorological organization as "variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events". In simpler terms, variability is the range of climate compared to its average. The fluctuations comprising climate variability can influence patterns of rainfall, temperature and other variables on timescales anywhere from a few weeks to a few decades.

3.1.10 climate change mitigation [b-UNEP]: Climate change mitigation refers to efforts to reduce or prevent emission of greenhouse gases. Mitigation can mean using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behaviour.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AAS	Agromet Advisory Services
AGRISNET	Agriculture Information System Network
AICRPAM	All India Coordinated Research Project on Agrometeorology
A-MMP	A Mission Mode Project
APY	Acreage, Productivity and Yield
ATMA	Agriculture Technology Management Agency
AWS	Automatic Weather Station
CAP	Central Agricultural Portal

CERES	Crop Estimation through Resource and Environment Synthesis
CLAES	Central Laboratory for Agricultural Expert Systems
CRIDA	Central Research Institute for Dry land Agriculture
CSA	Climate-smart Agriculture
DAC	Department of Agriculture and Cooperation
DSSAT	Decision Support System for Agrotechnology Transfer
e-SAP	Electronic Solutions Against Agricultural Pests
FIF	Field Information Facilitators
FAO	Food and Agriculture Organization of the United Nations
FCMS	Farm Crop Management System
FCO	Fertilizer Control Order
GDD	Growing Degree Days
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information Systems
IARI	Indian Agriculture Research Institute
ICAR	Indian Council of Agriculture Research
ICT	Information and Communication Technology
IDRC	Canadian International Development Research Centre
IFAD	International Fund for Agricultural Development
IIHR	Indian Institute of Horticulture Research
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
ITK	Indigenous Traditional Knowledge
IVRS	Interactive Voice Response System
KCC	Kisan (Farmer) Call Centre
KKMS	Kisan Knowledge Management System
KVK	Krishi Vigyan Kendra (farm science centres)
LAI	Leaf Area Index
MAI	Moisture Adequacy Index
MALR	Ministry of Agriculture and Land Reclamation
MCIT	Ministry of Communications and Information Technology
NARS	National Agricultural Research System
NeGP-A	National e-Governance Plan in Agriculture
NADAMS	National Agricultural Drought Assessment and Monitoring System
NFSM	National Food Security Mission

NHM	National Horticulture Mission
NIC	National Informatics Centre
NICRA	National Initiative on Climate Resilient Agriculture
NRSC	National Remote Service Centre
RKMP	Rice Knowledge Management Portal
RKVY	Rashtriya Krishi Vikas Yojana (national agriculture development scheme)
RML	Reuter Market Light
RS	Remote Sensing
RSS	Rich Site Summary
SCM	Supply Chain Management
SMS	Short Message Service
UAS	University of Agriculture Sciences
UECS	Ubiquitous Environment Control System
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
USD-ARS	U.S. Department of Agriculture Research
WHO	World Health Organization
WLAN	Wireless Local Area Network
WMO	World Meteorological Organization
WMS	Web Map Service

5 Conventions

None.

6 Motivation and impacts of climate change on the agriculture sector

6.1 Motivation for climate change adaptation

Climate change is one of the most complex challenges that humankind has to face in the current and future decades. The changes and the severity of the changes we are facing are expected to increase. As the change process seems to be almost irreversible, it has become 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 changes will be on the agricultural sector and food security over the next few decades [b-Brown and Funk]. Indeed, extreme weather changes in climate, currently being experienced globally pose especially great danger to the livelihoods of farming communities and to a number of countries whose economic backbone is agriculture. The climate change phenomenon is being expressed in unpredictable and erratic rainfall, long droughts and increased temperatures even at high elevation areas. Increasingly unpredictable weather has led to poor yields, a reduction in crop varieties, land related conflicts, food insecurity and reduced incomes leading to poverty. In addition, changes in land use have significantly impacted on the carbon-cycle, contributing to changing climatic conditions. A key component of climate adaptation involves building resilient systems that can withstand shocks and rebuild themselves when necessary.

Agriculture contributes about 45% of the gross domestic product (GDP) of developing countries, with more than 75% of their populations relying on agriculture for employment. Yet, sadly, the sector has been in decline over the past 40 years and poor farmers have largely remained poor [b-Jimenez, 2013]. This failure is due to many factors. Agricultural productivity is faced with climate change challenges including negative effects on natural resources such as declines in soil fertility and arable land as well as unreliable rainfall, drought, etc. Agriculture is the source of livelihood, so starvation can occur in dependent communities as a result of climate change. This can lead to mass migrations and population displacement if the adaptation process fails.

Information and communication technology (ICT) can play a vital role in sustaining agriculture, where ICT can provide the farmer with the information needed (for example, market prices, sources of seeds, new planting methods, etc.) to be able to increase agricultural productivity. Knowledge and information play a key role in overcoming constraints and are essential for building and strengthening the capacity of the multiple stakeholders involved in adaptation strategies at micro and macro levels. ICTs, Internet based applications, mobile phones, tele-centres, community radio, etc. provide the opportunity to improve the creation, management, exchange and application of relevant climate change information and knowledge.

Enhancing food security while contributing to a mitigation of climate change and preserving the natural resource base and vital ecosystem services, requires the transition to agricultural production systems that are more productive, use inputs more efficiently, have less variability and greater stability in their outputs and are more resilient to risks, shocks and long-term climate variability. More productive and more resilient agriculture requires a major shift in the way land, water, soil nutrients and genetic resources are managed to ensure that these resources are used more efficiently. The World Bank [b-World Bank] and the Food and Agriculture Organization of the United Nations (FAO) [b-FAO, 2014] stress the so called 'climate-smart agriculture (CSA)' approach, to manage climate issues. This CSA approach aims to achieve the following outcomes:

– Increased productivity: produce more food to improve food and nutrition security and boost the incomes of farming communities, many of whom rely on agriculture for their livelihoods.
– Enhanced resilience: reduce vulnerability to drought, pests, disease and other shocks; and improve capacity to adapt and grow in the face of longer-term stresses like shortened seasons and erratic weather patterns.
– Reduced emissions: Pursue lower emissions for each calorie or kilo of food produced, avoid deforestation from agriculture and identify ways to suck carbon out of the atmosphere.

New approaches are needed to meet sustainable development challenges. According to the FAO Director General "A broad portfolio of tools and approaches should be explored to eradicate hunger, fight every form of malnutrition and achieve sustainable agriculture. The international community needs to find new and innovative ways of working together if it is to meet the goals laid out in the UN's new sustainable development agenda."

Creative approaches to tackling today's development challenges, embodied by the 17 sustainable development goals (SDGs) are a necessity. "The SDGs are interlinked and call for new combinations in the way policies, programmes, partnerships and investments should pull together to achieve common goals and produce the most needed public goods".

New modes of governance are also needed; "Along the way, it is fundamental for countries to embrace modes of governance that look beyond sector-specific government ministries, such as agriculture, health and education, to find innovative solutions for complex development problems. We must count on a broad portfolio of tools and approaches to eradicate hunger, fight every form of malnutrition and achieve sustainable agriculture." These tools, which include both agro-ecology and biotechnology, ought to serve the needs of family farmers, whose empowerment should be a central part of sustainable development interventions.

The FAO DG further stated "Today, nearly 80 percent of the extreme poor and undernourished people live in rural areas, most of them are family farmers who grow food, but not enough to avoid hunger or escape extreme poverty". He noted that, at the same time, these same family farmers produce the largest proportion of the food consumed worldwide and underlined their role as "key actors in achieving food security for all".

Small scale farmers are especially vulnerable to climate change [b-Lasco et al., 2011]. Although reducing emissions is an important element for sustainable agriculture and food supply, it is not a major focus of this Recommendation. Instead, Recommendations in the ITU-T L.1400 series address methodologies to assess the impact of ICT solutions on greenhouse gas (GHG) emissions. ICT can aid small-scale farmers in taking advantage of opportunities and can mitigate some of the risks. One example of risk reduction is supply chain management software (SCM). Even small-scale farmers can profit from supply chain management, for example by choosing the best time to harvest.

With a focus on both nutrition and the impact of climate change, the FAO Director General also stressed the need to strengthen food value chains to ensure a nutrition-sensitive approach to food production and diets, from the farm to consumers' tables. This includes empowering consumers to make better dietary choices, for example through improved labelling, by ensuring accurate advertising and undertaking effective nutritional education campaigns. The wide-reaching effects of climate change are another key factor in requiring responses from across government ministries and economic sectors in order to address the full range of impacts on people's lives and livelihoods.

"Poor family farmers are driven off their land by prolonged drought, coastal fishing communities are losing their homes because of rising sea levels, and pastoralists are forced to migrate in search of land on which their cattle can graze," Graziano da Silva (FAO Director General) said speaking about the realities of farmers' lives. "The rural poor are the most exposed to these threats, and they are the least equipped to deal with them." Reminding the audience that FAO's mandate is directly linked to at least 14 of the 17 SDGs, he stressed the FAO's commitment to helping governments implement new governance mechanisms and data tools to achieve their SDGs, closing with the plea that "No one must be left behind."

6.2 Impacts of climate change on the agriculture sector

The impact of climate change on the agriculture sector, which is often characterized by poverty, remoteness and marginalization, makes it particularly vulnerable especially if the ecosystem is fragile, infrastructure is weak and transportation is difficult. The agro-community should therefore be included in the decision-making process.

Climate change has already significantly impacted the agricultural sector in the form of reduced yields and more frequent extreme weather events and is expected to further impact both directly and indirectly on food production, changes in mean temperature, changes in rain patterns, changes in water availability, the frequency and intensity of extreme weather events, salinization and loss of biodiversity. All of these factors will have profound impacts on agriculture. The extent of these impacts will depend on the intensity and timing (periodicity) of the changes and also on their combinations, which are more uncertain. [b-FAO, 2014], [b-World Bank]. For example, researchers at the international rice research institute (IRRI) headquarters near Manila in the Philippines have found that for each 1°C rise in average temperature, rice yield drops by about 10%. The IRRI research shows that rice pollination is especially sensitive to temperature and that warmer conditions lead to increasing sterility. It is predicted that rice production in central, western and south-western Japan will come under increasing pressure, while global warming may be advantageous for farmers in northern Japan, including Hokkaido [b-British Embassy Tokyo], [b-MAFF, 2013]. Farmers in the Philippines have already reported a number of climate change-related abnormalities in terms of resurgence of pests and diseases in rice, corn and fruit trees. For instance, farmers have reported that a very destructive rice disease called 'tungro' has reappeared. Also they report that damage to corn plants by the corn stem borer has been reduced and was even reported to have disappeared in some places. Fruit trees are severely affected by surges in temperature and sporadic rainfall, which cause massive flower abortion, failed fruit development and massive scale attacks of insects such as aphids [b-Lasco et al., 2011]. This can lead to reductions in production and lower incomes in vulnerable areas. These changes can also affect global food prices [b-FAO, 2014].

Climate change may have beneficial as well as detrimental consequences for agriculture. The vulnerability of the agriculture sector due to climate change may vary in different regions and climate change may have different impacts on different crops. Warming climate and decreasing soil moisture can also result in an increasing need for irrigation. There is a need to optimally utilize water resources for more resiliency. Benefits to agriculture might be offset by an increased likelihood of heat waves, drought, severe thunderstorms and tornadoes.

With the virtually certain likelihood of warmer and more frequent hot days and nights, there are projected to be increased insect outbreaks impacting agriculture, forestry and ecosystems. Agricultural bio-diversity may also be threatened due to these changes. Pests, weeds and disease may have more survivability, while transmission may have higher adverse impact as hosts may be more susceptible. Crops may be vulnerable due to changes in ambient factors and interplay of these factors may impact different phases of growth of the crop and may adversely affect the yield and quality of the crop.

The agriculture sector also becomes vulnerable due to changes in pests and, because of climatic change, there may be higher survival rates of pests and which may have more damaging effects. Climate change may affect boundary areas which are suitable for growing a particular crop. Climate change may also affect the cost of running greenhouses as increased cooling may be required.

7 Climate change adaptation measures for the agriculture sector

7.1 Need for adaptive crop treatment

7.1.1 Development of climate ready crops

Development of new crop varieties with higher yield potential and resistance to multiple stresses (drought, flood, salinity, etc.) will be key to maintaining yield stability. Wider tolerances may be needed in multiple dimensions. For example, heat-stress may require the launch of research efforts and of specialized breeding programmes to increase heat tolerance. Quantification of crop requirements will improve their ability to survive. Improvements in water-use, nitrogen-use efficiency, etc. may be helpful for assessing the appropriateness and the rating, wherever possible, of newly developed climate-ready crops. The risks of climatic change could be reduced and the adaptation process could be strengthened by the availability of new varieties with increased tolerance.

7.1.2 Crop diversification

Diversification of crop seed varieties, including replacement of plant types, cultivars and hybrids with new varieties developed for increased growth or heat tolerance, is being advocated as having the potential to increase productivity in the face of temperature and moisture stresses. Diversification of crops as opposed to specialization may increase resilience. However there is need to quantify the impact of crop diversification on resilience and better natural resource management. Diversification of crops may require learning or training related to new types of crops in more areas than may be required in the case of one specialized crop. Land usage and management activities may be different and the market for the farm products may also vary. Farmers and associated workers will need frequent knowledge updates in a wider number of areas. Information, including market information, may be required on all aspects of new crops and this information needs to be updated on regular basis.

7.1.3 Relocation of crops in alternate areas

Climate change may affect the productivity of crops and the impact may be different in different regions and for different types of crops. There is need to identify the crops that are more sensitive to climate variability and relocate them to more suitable areas or regions through improved research and educational networks.

7.1.4 Adjusting the cropping season

Adjusting planting dates could minimize the effect of higher temperatures inducing sterility. The cropping calendar may be adjusted to take advantage of more favourable weather during the growing season. This may require changes in the cropping system including finding suitable crops or cultivars, changing the crop intensities and planting different types of crops. It will also require collaboration with the country's meteorological services so as to forecast rains and seasons. Farmers may have to adapt to changing hydrological regimes by changing crops. Changing the cropping season activity will require agricultural planners to first understand and then disseminate the information to farmers. It can be very difficult to follow so many changes, especially in the case of farmers who may be familiar with local practices which have evolved over many generations. ICT tools including calendars or reminders may help to a great extent in following the planned activity and in obtaining the desired results.

7.2 Need for management of resources

7.2.1 Efficient use of natural resources

Changes are needed in farm management practices including land management, soil management, and water usage and conservation. The efficiency of resources (e.g., soil, water, etc.) and inputs may be improved with resource-conserving technologies or techniques such as zero-tillage. This may provide immediate, identifiable and demonstrable economic benefits such as reduction in costs or increased yields. Cost reductions can come from savings in water usage, fuel usage and labour as well as through the timely establishment of crops. This may require awareness among farmers of the various kinds of savings which can be achieved by adopting resource conserving technologies. Farmers should also be able to make comparisons among multiple options in a user-friendly manner.

7.2.2 Land use management

Changing land-use practices such as changes in the location of crops and in livestock production, rotating or shifting production between crops and livestock, shifting production away from marginal areas, altering the intensity of fertilizer and pesticide application as well as capital and labour inputs can help reduce risks from climate change in farm production. This may require adjustment in the crop sequences, timing of the field or farm activities that are to be carried out and changes in input types/quantities/timings of fertilizers, etc. These changes in farming practices may require development of capabilities for concerned farmers so that they can readily accept these changes and successfully manage them.

7.2.3 Harnessing indigenous technical knowledge

There is a wealth of knowledge on a range of measures that can help in developing technologies to overcome climate vulnerabilities. There is a need to harness knowledge, social learning, and community based approaches and fine-tune them to suit the modern needs. Traditional ecological knowledge of working practices which have stood the test of time could provide insights and viable options for adaptive measures. Indigenous practices of conservation, management, weather forecasting, risk adjustments acquired through experience, experimentation and accumulated knowledge need to be consolidated and presented in more structured manner that could be potentially useful for others, or as feedback to developers of tools and techniques to enhance capacity to adapt to the impacts of future climate change.

7.3 Need for risk protection / mitigation mechanisms

7.3.1 Improvements in pest management

Climate change affects the incidence of pests and the virulence diseases of major crops. This is because climate change will potentially affect pest/weed populations, host populations and pest/weed/host interactions. Some potential adaption strategies may involve developing pest/disease resistant crop varieties, adoption of integrated pest management through consideration of crop variety, crop rotation, etc. Pest management may also include preferences or emphasis on natural or biological control. Pest forecasting using simulation modelling tools may help in taking proactive measures. There may be other alternatives like location change and alternative production techniques for crops.

7.3.2 Weather forecasting and weather based crop insurance schemes

Weather forecasting and early warning systems can be very helpful in minimizing risks of adverse climate events. ICT could greatly help researchers and administrators in developing contingency plans by enhancing collaboration between meteorological bodies and telecom agencies. Effective crop insurance schemes should be designed to help the farmers reduce the risk of crop failure due to these events. Both formal and informal, as well as private and public, insurance programmes need to be put in place to help reduce income losses as a result of climate-related impacts. However, information is needed to frame policies that encourage effective insurance opportunities.

8 The ecosystem of the agriculture sector to be involved in adaptation

The ecosystem of the agricultural sector has many stakeholders e.g., farmers, farming communities, scientists, policy makers, private sectors, non-profit organizations, agricultural laboratories, field workers, markets, research institutes, management professionals, input suppliers, technical experts, self-help groups, government agencies, knowledge intermediaries, etc.

Knowledge intermediaries may be agriculture extension officers i.e. trained professionals drawn from local residents to complement and contribute in the 'last-mile' with insider knowledge of the local context. These experts play a pivotal role in the effective delivery and local appropriation of the messages related to climate change awareness, mitigation, adaptation and monitoring. The agriculture sector has many processes for information and knowledge exchange: e.g., face-to-face meetings, field visits, training of local stakeholders, personalized identification of sources of credit/funding and the delivery of knowledge via the agricultural supply chain.

Constraints in information and knowledge transfer may include content appropriateness, literacy, digital literacy, skill set, digital scepticism, age-related, etc. Content appropriateness may also depend upon whether information is for the wider area or for the local level as well as the format in which it is delivered, taking account of livelihood priorities. This may be requirement for forecasting, modelling, and making projections. Adaptation and mitigation strategies may also require information about agricultural practices, resources such as machinery, seeds and fertilizers and processes such as planting, weeding and harvesting as well as output processes such as post-harvesting procedures and access to markets.

Within agricultural contexts, often characterized by poverty, remoteness and marginalization, ICT can enable new responses to the challenges posed by more frequent and intense climate events. ICT can become a strategic enabler of action to create awareness about, mitigate, monitor and adapt to climate change within agriculture. ICT can help in adoption of innovative strategies based on emerging and traditional knowledge and information tools.

9 Trends in ICT which are relevant to the agriculture sector

Recent increases in ICT affordability, accessibility and adaptability have resulted in their use even within rural homesteads relying on agriculture. New innovations have proliferated including small devices such as mobile or smart phones, infrastructure such as cloud computing facilities and especially online applications (for example, applications that transfer money or track an item moving through a global supply chain). Many of the information needs that could improve smallholder livelihoods can be fulfilled with the effective and easy use of ICT.

The following trends have been the key drivers in the use of ICT in the agriculture sector, particularly for farmers or producers [b-source book]:

– Low-cost and pervasive ICT connectivity,

– Adaptable and more affordable tools,

– Innovative business models and partnerships, and

– The democratization of information, including the open access movement and social media.

10 ICT components which are relevant to the agriculture sector

The following are frequently used ICT components in the agricultural sector:

– ICT systems: data storage, computational resources;

– ICT network: communication network, fixed line, mobile network, satellite network, for data acquisition and knowledge dissemination;

– ICT media types: audio, video, text, image;

– ICT applications: data analytic models, expert systems, forecasting models, early warning systems;

– ICT tools: blogs, discussion forums, RSS feed, social networking, spatial geo-tagging tools, online trainings, crowd sourcing, mobile apps;

– ICT end-user devices/access points: mobile feature phones, mobile smart phones, PCs, community internet access points e.g., touch kiosks;

– Internet of things (IoT) devices: wireless sensor networks; and

– ICT device features: personal information management tools e.g., calendar, reminder.

11 How ICT can help sustain the agricultural sector

11.1 ICT to monitor site conditions including land use planning

Among the various ICT possibilities, geographic information systems (GIS) and remote sensing (RS) technologies represent two key tools for land planning and management.

GIS offers the opportunity to gather multiple layers of information, drawn from different sources, into one spatial representation. This can be particularly useful in reaching consensus over land planning when users have different values and preferences linked to a given territory.

Similarly, RS technologies are a valuable tool for monitoring land resources (e.g., vegetation, water bodies, etc.), especially when a single institution is in charge of monitoring a wide area. Retrieving data directly from the field is expensive and time consuming.

Nonetheless, GIS and RS cannot completely substitute for local, on the ground observations. Finding the appropriate balance between remote and in-situ monitoring is often a delicate issue. To overcome some of these challenges, it is essential to inform GIS and RS frameworks through participatory processes in order to identify appropriate and transparent methods and systems. The process behind the deployment of GIS and RS should be open and explicit so communities do not perceive the technologies as tools for hidden agendas [b-FAO, 2012].

Examples of how remote sensing and GIS can help in adaptation of the agricultural sector are given in Appendix I and Appendix II.

11.2 ICT to promote knowledge sharing and improve management

Studies based on practical field experience show that farmers experiencing difficulties often do not use the proper dosage or chemical type, or fail to manage a water resource efficiently, or experience difficulties when changing cultivation patterns or crops, mainly due to a lack of appropriate information. This in turn leads to increased production costs as well as being potentially harmful to human health and the environment.

ICT can support the management of agriculture's impact on the environment. For example, integrating ICT into irrigation management is a high priority need in this area because climate change has impacted on access to water resources [b-FAO, 2012].

Examples of how knowledge sharing can help to improve the management of the agricultural sector are given in Appendix III and Appendix IV.

11.3 ICT use in agricultural expert systems

An agricultural expert system is used to provide agricultural specialist assistance for farmers in decision making such as in the case of unprecedented changes in the climate, soil or other factors. An agricultural expert system simulates human reasoning about a problem domain, rather than simulating the domain itself. It also performs reasoning over representations of human knowledge and solves problems by heuristic or approximate methods.

An example of how expert systems can help in adaptation of the agricultural sector to the effects of climate change is given in Appendix V.

11.4 ICT to distribute climate-smart agricultural information to/from farmers

There is great potential for mobile information services to push information on climate-smart agriculture to farmers and other actors in the agricultural value chain. The ability to collect large amounts of sensor data (e.g., remote soil sensors, etc.) with mobile technology has the potential to provide information that may lead to new climate-smart solutions. Mobile technology creates the opportunity for farmers to become data collectors at a local level. This makes it possible to obtain real-time feedback and spot trends such as the movement of pests, which could in turn be used to alert other farmers [b-FAO, 2012].

An example of how mobile information services can help in the adaptation of the agricultural sector to the effects of climate change is given in Appendix VI.

11.5 Computer modelling and agricultural forecasting

Modelling the weather for agricultural forecasting involves monitoring daily solar radiation, maximum and minimum air temperatures, precipitation, etc. Soil inputs include drainage and runoff coefficients, first-stage evaporation and water-holding characteristics for each individual soil layer. The model also requires saturated soil water content and initial soil water content for the first day of simulation.

The modelling approach allows forecasting of, for example, the time for early planting in order to get the maximum economic yield at harvest. Early prediction of diseases and insect pests is also important to help the farmers avoid unnecessary heavy spraying of pesticides and to take the necessary actions to avoid dangerous diseases.

Proper management nowadays depends on accurate irrigation scheduling that reduces the cost of irrigation and minimizes problems related to the misuse of water. Computer modelling is also used to calculate water and fertilizer requirements, disease and insect predictions and planting dates.

An example of how computer modelling can help in the adaptation of the agricultural sector to the effects of climate change is given in Appendix VII.

11.6 ICT for risk management

Providing early warning systems to mitigate risks (such as variable weather, pests and diseases, price volatility, etc.) for smallholder farmers in a highly fragmented environment remains a challenge. Weather and pest information are often the focus of risk-mitigating information systems. Satellite imagery has been evolving to allow for more micro-level analysis for insurance purposes, but these products are still largely unattractive for small individual farmers.

Field sensors have great potential here. However, more work is needed to calibrate these to in-situ monitoring and expertise in data interpretation is required. Overall, serious challenges remain in packing a set of information that brings full value to the farmer as an information user, including the need for the various information providers and holders to collaborate [b-FAO, 2012].

An example of how risk management can help in the adaptation of the agricultural sector to the effects of climate change is given in Appendix VIII.

11.7 ICT for automatic control of greenhouses

A combination of sensing networks and information processing systems enables automatic control to maintain the best environmental conditions in greenhouses and protect against changing climatic conditions. Optimization of environmental conditions is not a simple function, for example opening ventilation windows when in-house temperature increases could affect humidity and concentration of CO_2 in the greenhouse. The system should judge from multiple sensor information sources and such systems need to be inexpensive to be accepted by small-scale farmers.

An example of how ICT can be used for automatic control of greenhouses is given in Appendix IX.

Appendix I

Remote sensing application applied to agriculture in Africa

(This appendix does not form an integral part of this Recommendation.)

Remote sensing refers to the activities of recording, observing, perceiving (sensing) objects or events at far away (remote) places. Remote sensing techniques are widely used in agriculture and agronomy. In fact, a remote sensing image can provide spatial coverage of a field and can be used as a proxy to measure crop and soil attributes.

In many developing countries like Ghana, agricultural statistics are utilized in different incompatible formats (such as tabular forms and graphs) that lack geo-referencing of administrative areas. However, in geographical terms, administrative areas are arbitrary, varying in size, shape and time and this poses serious problems for mapping or for interpreting spatial patterns in statistical data and integrating this data with other data sets.

Remote sensing plays an important role as an auxiliary variable in the production of agricultural statistics, where area frame or multiple frames sample designs are used. Remote sensing can also be used at the design level as well as at the estimator level. At the design level, the most typical use of remote sensing data is in the area frame construction and stratification. Remote sensing data can also be used to optimize the sample design where a previous ground survey was not performed; in fact, spatial characteristics (e.g., correlograms) of variables of interest can be estimated on the basis of photo interpretation of remote sensing images.

The agricultural area in Egypt is composed of the Nile delta and the Nile valley and is the main contributor of food production, trading activities and national economy. It is also the most densely populated area in Egypt. Over the last four decades, vast areas on the desert fringes of the Nile valley and Nile delta were reclaimed using mostly Nile water in order to increase economic assets and relocate a significant portion of the population. The changes in land use in the Eastern Nile Delta of Egypt were summarized as follows:

– the urban settlements increased considerably with a high rate of annual increase

– there was a slight increase in the total cultivated area while the annual rate of agricultural reclamation decreased significantly in the last few years

– the rate of change for desert areas remains stable. There is an urgent need to activate the agricultural reclamation effort to run in parallel with the urbanization processes in this area.

The agricultural land area is determined by climate and water availability.

The Nile is the main source for irrigation, Egypt's total water budget is estimated at about 58 billion m^3, 95 per cent of which is drawn from the Nile (55.5 billion m^3), the remaining five per cent is resourced from groundwater and rainfall. Inflowing Nile water is stored in Lake Nasser and shared between Egypt and Sudan. Rain falls mostly in winter and on the Mediterranean coast and does not exceed 130-170 mm.. The per capita water share is 815 m^3 per year. Agriculture uses 80 percent of Egypt's water resources [b-Abou-Hadid, 2015].

Agricultural surveys, based on GIS schemes, using satellite images and topographic maps and field surveys were carried out during the 2008/2009 winter and 2009 summer seasons to determine the total land cover of the Nile delta and valley. This was done using recent (2006) digital shape file data from the central laboratory for agricultural climate (CLAC) for different geographic layers (roads, railways, irrigation channels, water bodies and cultivated areas) and SPOT 5 satellite images (2007). The data shows that in 2008 the cultivated area of wheat was about 2.9 million feddans (1 feddan = 0.42 hectares) according to the Egyptian ministry of agriculture and land reclamation

(MALR) statistics, while according to the GIS and field survey the cultivated area of wheat in the same year was about 2.5 million feddans.

There was about 13% difference between the two concerned methods (GIS plus field survey) and MALR's conventional statistical method. However, the cultivated barley area in 2008 winter season was 148 thousand feddans according to GIS plus field survey data, whilst the conventional statistical data was 181 thousand feddans. The GIS plus field survey data showed that the area of cotton had decreased sharply in the season of 2009 to 250 thousand feddans compared to 284 thousand feddans with the MALR's conventional statistical method.

The water budget during the winter survey for the whole crop pattern had increased from 11 billion cubic meters in 1980 to 24 billion cubic meters in 2013, while the water budget during the summer survey had increased from 20 billion cubic meters in 1980 to 25 billion cubic meters in 2012. The average water budget for the whole crop pattern in Nile delta and Nile valley was 49 billion cubic meters during 2012/2013.

Appendix II

NeGP-A initiatives for geo-spatial visualisation, analysis and decision making services in India

(This appendix does not form an integral part of this Recommendation.)

The Indian Department of agriculture and cooperation (DAC) of the ministry of agriculture and farmer welfare is implementing the national e-governance plan in agriculture (NeGP-A) as a mission mode project (A-MMP), covering the agriculture, livestock and fisheries sectors. The project aims to address the needs of the farming community and other related stakeholders, through provision of relevant information and services through the various delivery channels available locally to assist them in making rational decisions for raising farm productivity and farm income.

The NeGP-A project for geo-spatial visualisation, analysis and decision making services involves a framework for initiatives in NeGP-A being developed and may include baseline information and related planning of services (see Figure II.1). Baseline information includes information and maps up to sub-district level, irrigation infrastructure information from the national remote service centre (NRSC) using a web map service known as 'Bhuvan' and information on irrigated areas (from the NRSC-water resource information system) and land holdings. Related planning services include:

– Rainfall maps (district, sub-district level)
– Moisture adequacy index (MAI)
– National agricultural drought assessment and monitoring system (NADAMS)
– Field condition photographs
– Agro-advisories
– Drought management
– Contingency plans and implementation
– Fisheries
– Marketing
– Animal husbandry (AH)

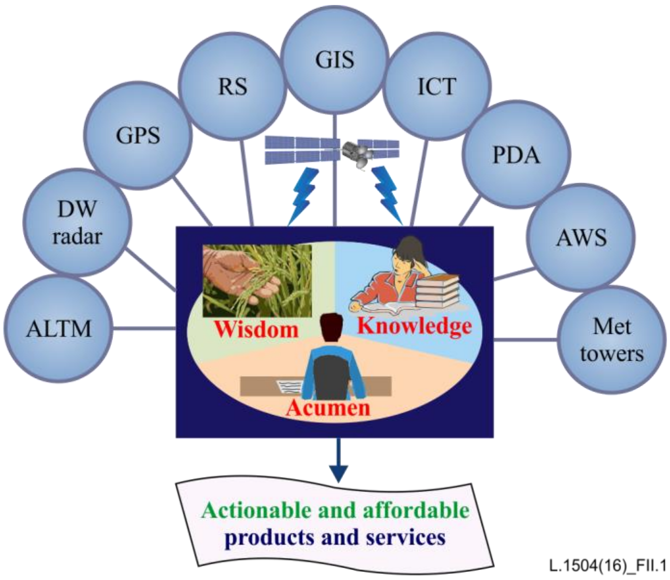

Figure II.1 – Convergence of geospatial technologies: inclusive, participatory and coordinated local area development

2D Bhuvan, a web map service (WMS) application developed using open source GIS tools, provides a mapping interface with detailed imagery and embedded map data to offer powerful, user-friendly mapping technology to organize satellite and map data. Bhuvan has tools such as administration layers, navigational map, my drawing, add point, add line, add polygon, area measurement, distance measurement, pan, etc. Bhuvan also has services such as land, weather, ocean and disaster services. Bhuvan 3D directly takes users from a 2D page to an exact latitude, longitude and altitude on the 3D Globe display page. Some of the pilot Bhuvan services include field data collection/ soil mapping for agriculture and rapid fire risk assessment for countryside and forests. Figure II.2 shows how field data is collected using geo-ICT.

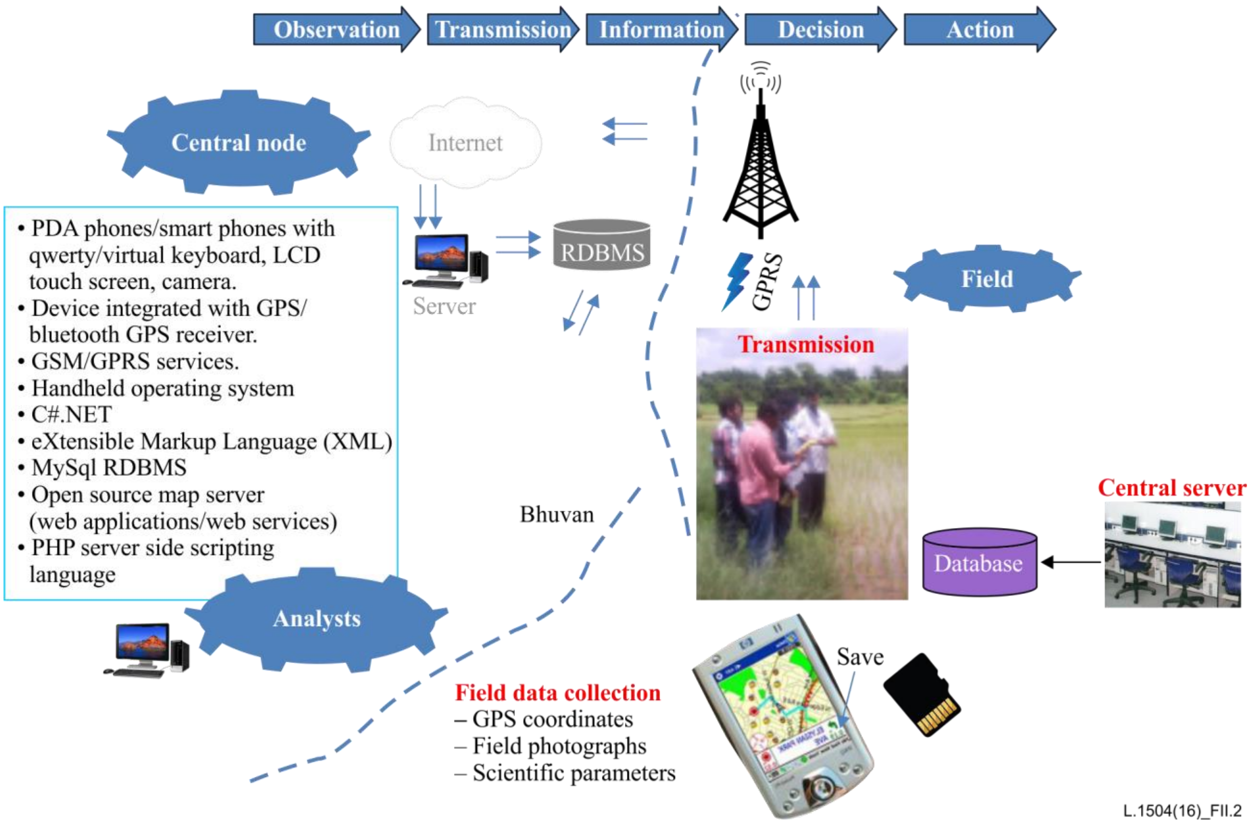

Figure II.2 – Field data collection using geo-ICT

Appendix III

ICT in agriculture sector adaptation to climate change – India

(This appendix does not form an integral part of this Recommendation.)

III.1 Introduction

India is a large country with diverse climate zones. Two thirds of the area is rain dependent, there is a high dependency on the monsoon. There is a high degree of diversity in seasons, crops and farming systems. The climate and the availability of water resources are closely linked. The Indian agricultural sector is characterised by small holdings, poor coping mechanisms and low penetration of risk management products.

Agriculture represents a core part of the Indian economy and provides food and livelihood activities to much of the Indian population. While the magnitude of climate change impact varies greatly from region to region, climate change is expected to impact agricultural productivity and shifting crop patterns. The policy implications are wide reaching as changes in agriculture would affect food security, trade policy, livelihood activities and water conservation issues, impacting a large proportion of the population.

Climate change risks having a direct effect on productivity and quality of produce, while indirect effects include soil fertility, livestock and fishery stocks, soil and water resources and crop health. Contributory factors in this are a prevalence of submerged rice cultivation, unscientific use of fertilizers, gas emission from livestock, low concentrations of organic matter in soil, etc.

The Indian Department of agriculture in cooperation with the ministry of agriculture and farmers welfare have undertaken various measures to promote climate resilient initiatives and the use of ICT in agriculture sector. To mitigate the climate change challenge by adopting better agricultural management practices, the recommended practices include:

– Efficient use of water / water harvesting
– Climate resilient crop varieties
– Crop diversification and crop alignment
– Organic farming
– Soil health card based integrated nutrient management
– Feed management of livestock
– Agro-forestry

Government schemes and policy initiatives in this regard include:

– Soil health card scheme
– Pradhan Mantri Krishi Sichai Yojana – national mission to improve farm productivity and ensure better utilization of the resources
– Paramparagat Krishi Vikas Yojana – initiative to promote organic farming
– National Agro-forestry and bamboo mission
– Mission for integrated development of horticulture
– National mission on agriculture extension and technologies
– National initiative on climate resilient agriculture
– National mission on sustainable agriculture
– National agro-forestry policy
– National policy for management of crop residues

– Ration balancing program

III.2 NICRA

In view of the impact of climate change, the Indian council of agricultural research (ICAR), with funding from the Indian ministry of agriculture, launched the 'national initiative on climate resilient agriculture' (NICRA) with the three main objectives of undertaking strategic research on climate change adaptation and mitigation, technology demonstrations in farmers' fields to cope with the current climate variability and capacity building of different stakeholders on climate change awareness. The scheme was launched in February 2011.

The key infrastructure facilities being set-up include high throughput phenotyping platforms at the Indian agriculture research institute (IARI), the central research institute for dry land agriculture (CRIDA) and the Indian institute of horticulture research (IIHR), open air temperature and carbon dioxide elevation systems, animal calorie meters with waste disposal systems, climate control walk-in plant-growth chambers and a fully equipped research vessel for studying marine fisheries.

Under strategic research, a large number of germ plasms of major food crops are being phenotyped for multiple abiotic stresses such as drought, heat and low temperatures. Experiments on carbon sequestration and conservation agriculture have been initiated at several locations as a mitigation strategy. Real-time pest and disease surveillance studies were initiated at several locations in relation to weather factors.

Likewise, studies on the impact of climatic factors on both freshwater and marine fisheries were started both under controlled and field conditions. The complete life cycle analysis and carbon and energy foot-prints of coastal aquaculture are being studied. Demonstrations of the available technologies in farmers' fields with a participatory approach in climatically vulnerable districts of the country to cope with climate variability are being conducted.

This programme involves local stakeholders at village, block and district levels. Simple interventions such as supplemental irrigation using harvested rain water, planting of drought tolerant and short growth duration varieties have made a significant difference to the production and income of the farmers in the villages exposed to drought and delays in the monsoon.

Automatic weather stations are being established in the Krishi Vigyan Kendra (KVK) i.e., farm science centre premises to enable subject-matter specialists in the KVKs to generate agro-advisories on a real-time basis. Block-level advisories are being pilot tested in a few districts.

Under the sponsored and competitive grants component, projects are covering key areas such as the impact of climate change on pollinators, germplasm collection from climate hot-spots, hail-storm management, estuarine fisheries and the socio-economic impacts of climate change.

In evolving strategic research on climate change, the foremost task would be identification of climatic risk prone areas. This in turn has to be followed by a determination of location specific climatic risks and then strategies to overcome them. Also, the utility of Agromet advisories to minimize the losses due to aberrant weather over the short-term and climate change over a long-term basis has to be assessed. In this backdrop, the all India coordinated research project on agro-meteorology (AICRPAM)-NICRA project has been initiated with the following objectives:

– To create a weather and crop information acquisition and monitoring system through automatic weather stations (AWS) and field information facilitators' (FIF) networks
– Delineate hotspots for weather anomalies at a micro-level through benchmark surveys and climatic analysis at selected districts/villages/sites for the principal cropping/farming systems
– Quantification of crop responses to weather and its extremes by integrating statistical and dynamic modelling techniques

– Customizing micro-level Agromet advisories and their efficient dissemination through ICTs

– Development of strategies to combat weather extremes through field research

– Conduct awareness/training programmes on climate change and workshops for capacity building on agro-meteorology advisories.

Some of the recent activities of NICRA include:

– Development of map products comprising weekly, monthly and seasonal rainfall maps, heat and cold wave maps using the real-time AWS weather data and using spatial interpolation techniques.

– Outreach activities such as micro-level agro-meteorology advisories, economic impact of agro-meteorology advisory services (AAS), farmers' awareness programmes, farmers' feedback on AAS, micro-level agro-climate analysis, indigenous traditional knowledge (ITK) related to agriculture meteorology documentation, interventions in NICRA villages. Agro-meteorology advisory services are shown in Figure III.1.

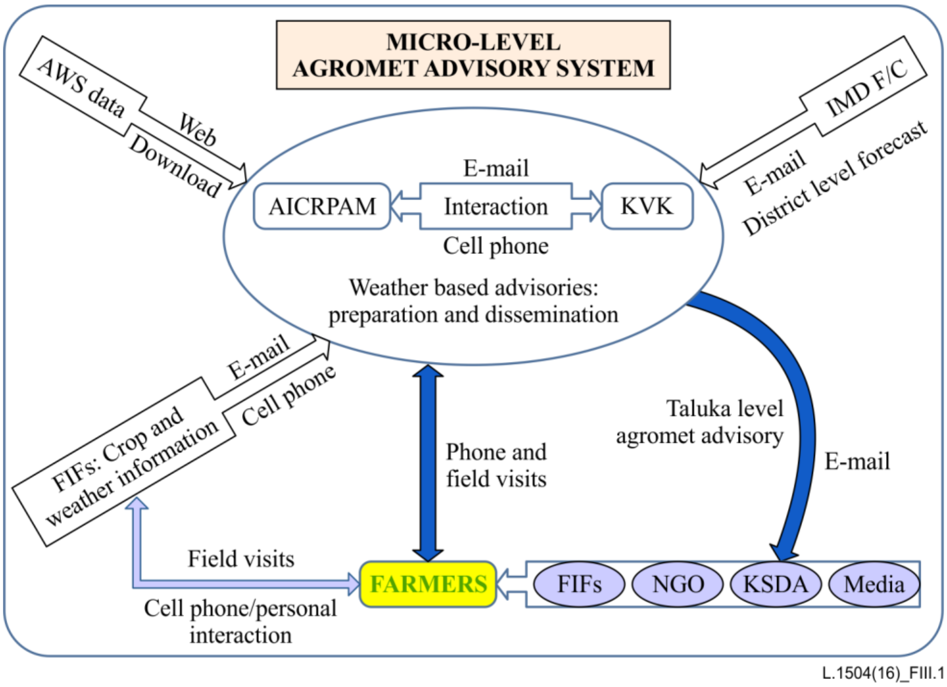

Figure III.1 – Flowchart of agro-meteorology advisory services adopted in one Indian state

III.3 Best practice in R&D and use of big data; strengthening of statistical computing for the national agricultural research system in India

The national agricultural research system (NARS) has been carrying out comprehensive research and technology demonstration activities on coping with climate change under the flagship programme of ICAR on the national initiative on climate resilient agriculture (NICRA).

Statistical computing support is useful for improving the quality of agricultural research and makes it globally competitive and acceptable by way of publications in international journals. The NARS project provides technical support on the statistical analysis of data, keeping in mind the accuracy and precision of analysis. It is expected to create a healthy statistical computing environment for the benefit of the scientists in NARS by way of providing advanced, versatile, innovative and state-of the art high-end statistical packages and enable them to draw meaningful and valid inferences from their research.

Appendix IV

Adapting cultivation methods to changing climate conditions in Japan

(This appendix does not form an integral part of this Recommendation.)

IV.1 Tea use case

In the case of tea cultivation in Japan, frost in spring damages new tea leaves and reduces both the yield and the quality. Tea farmers traditionally avoid such frost by using fans or by sprinkling water on leaves. Sprinkling water is also effective for insect pest control and reduces the use of pesticides.

Farmers traditionally depend on experience and investigations in the field (e.g., checking the moisture content of soil by hand, studying the balance of water and air in the soil) to schedule such operations. By utilising ICT, farmers can receive automatic alerts (e.g., e-mail) to determine the best timing for insect pest control and when tea plants gain freeze resistance (some plants gain freeze resistance after exposure to low temperature for certain period of time). This increased efficiency has the additional benefit of reducing use of water and electricity.

IV.2 Viticulture use case

In Koshu, grape flowers bloom in June and grapes become ready for harvesting in September. In viticulture, one of the factors used for prevention of diseases and judgment of harvest timing is the change in atmospheric temperature. The optimal harvesting time of wine grapes can be judged by the cumulative temperature difference between the maximum temperature and minimum temperature after flowering. The cooling extent, on the other hand, can be judged by the cumulative hours where the atmospheric temperature goes below 22°C after the summer heat peak. However, it is not an easy task to accurately track the temperature, because it changes every minute and farmers generally judged the timing of their farm work and harvesting from past experiences and gut feeling.

Harvest time requires temperature information, while cooling extent requires time information when the temperature is below 22°C. For both of these, cumulative values are needed, where monitoring of the vines 24 hours a day becomes the key. It also requires prompt collection and analysis of measurements.

To achieve all of these requirements, farmers decided to install sensors in the vineyards and measure the atmospheric temperature 24 hours a day at 10-minute intervals through a multi-sensing network. The measured data are automatically sent to a PC at the management office of the vineyard, which enables reviewing of the exact vineyard temperature information for any given day and time of the year.

This sensing project brought various benefits to the winemaking work, including a drastic reduction in man-hours required for measurement, effective disease prevention and pest control based on precise temperature data, growing of good quality grapes and improved quality of the resultant wine. It also reduced the amount and frequency of pesticides used, minimizing the exposure of workers to pesticides. Later, rain gauges and hygrometers were added to the system, extending the types of information available. In the following year, the system was linked to the agricultural computing cloud 'Akisai', which enables real-time monitoring, anywhere anytime, of the vineyard not only through the PC at the winery management office but also through portable terminals. Figure IV.1 shows an overview of the vineyard system.

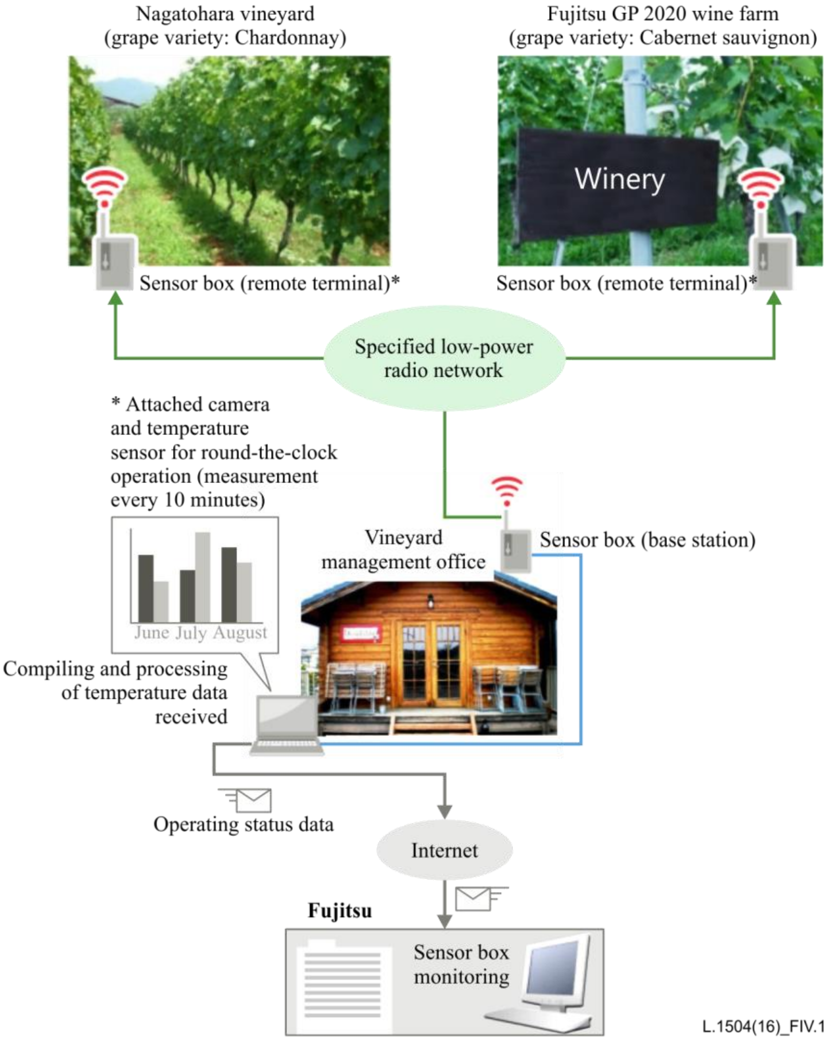

Figure IV.1 – Overview of vineyard system

Appendix V

Agricultural expert system in Egypt

(This appendix does not form an integral part of this Recommendation.)

V.1 Agriculture expert system – Best practices, Egypt

In order to remain competitive, the modern farmer often relies on agricultural specialists and advisors to provide information for decision making. Unfortunately, agricultural specialist assistance is not always available when the farmer needs it, especially in the case of unprecedented changes in the climate, soil, water resources, etc. In order to alleviate this problem, expert systems were identified as a powerful ICT tool with extensive potential in agriculture. The characteristics of the agricultural expert system include simulating human reasoning about a problem domain, rather than simulating the domain itself, performing reasoning over representations of human knowledge and solving problems by heuristic or approximate methods.

In 1987 an expert system technology was identified as an appropriate technology to speed up agricultural desert development in Egypt. The central laboratory for agricultural expert systems (CLAES) was established for agriculture management. It is domain independent and can be used with any commodity. CALES consists of three separate modules: an executive, a scheduler and an expert system shell [b-G.N.R. Prasad, 2006].

In 1991, serious efforts began in Egypt to develop crop management expert systems for different crops. A prototype for an expert system for cucumber seedlings production was developed. This prototype has six functions: seeds cultivation, media preparation, control environmental growth factors, diagnosis, treatment, and protection. Figure V.1 shows the CLAES application.

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Figure V.1 – CLAES

V.2 Expert systems implemented at CLAES

The central laboratory for agricultural expert systems (CLAES) helps farmers throughout Egypt to optimize the use of resources and maximize food production. Figure V.1 shows a screenshot of the CLAES site. According to [b-CLAES] the expert systems developed at CLAES include:

a) The crop expert system

System name (see [b-CLEAS])	Availability (see [b-CLEAS])	Sub-system (see [b-CLEAS])
Cucumber	Desktop	Variety selection, Plant care, Diagnose, Treatment, Irrigation, Fertilization
	Online	Irrigation, Fertilization
Orange	Desktop	Assessment, Plant care, Diagnose, Treatment, Irrigation, Fertilization
Lemon	Desktop	Assessment, Plant care, Diagnose, Treatment, Irrigation, Fertilization, Multimedia
Citrus	Desktop	Assessment, Plant care, Diagnose, Treatment, Irrigation, Fertilization, Multimedia
Rice	Desktop	Variety selection, Land Preparation, Diagnose, Treatment, Irrigation, Fertilization
	Online	Variety selection, Land Preparation, Diagnose, Treatment, Irrigation, Fertilization
Wheat	Desktop	Variety selection, Land Preparation, Diagnose, Treatment, Irrigation, Fertilization, Harvest
	Online	Variety selection, Land Preparation, Diagnose, Treatment, Irrigation, Fertilization, Harvest
	Regional	Variety selection, Land Preparation, Diagnose, Treatment, Irrigation, Fertilization, Harvest
Beans	Desktop	Plant care, Diagnose, Treatment, Irrigation, Fertilization
	Online	Treatment
Grape	Desktop	Plant care, Diagnose, Treatment, Irrigation, Fertilization, Multimedia
	Online	Diagnose, Treatment
Tomatoes	Desktop	Diagnose, Treatment, Irrigation, Fertilization, Database
	Online	Diagnose
Melon	Desktop	Plant care, Diagnose, Treatment
Faba bean	Desktop	Variety selection, Land Preparation, Diagnose, Treatment, Irrigation, Fertilization
	Regional	Variety selection, Land Preparation, Planting, Diagnose, Treatment, Irrigation, Fertilization

System name (see [b-CLEAS])	Availability (see [b-CLEAS])	Sub-system (see [b-CLEAS])
Strawberry	Desktop	Plant care, Diagnose, Treatment, Irrigation, Fertilization
Mango	Desktop	Plant care, Diagnose, Treatment, Irrigation, Fertilization, Multimedia
Barley	Online	Plant care, Diagnose, Treatment, Agricultural Operations

b) Animal expert system

System name (see [b-CLEAS])	Availability (see [b-CLEAS])	Sub-system (see [b-CLEAS])
Cattle and buffalo	Desktop	Desktop
Sheep and goats	Desktop	Desktop
	Online	Online
Poultry	Online	Online

c) Systems being developed

- Cotton: variety selection, land preparation, diagnosis, treatment
- Potato: diagnosis, treatment
- Wild animals

d) CALES sub-system services

- The irrigation subsystem: The main goal of this subsystem is to produce a schedule for irrigation of a particular farm. An irrigation schedule should demonstrate the water quantity related to each time instance. The calculated water quantity should also be adapted according to some farm characteristics such as intensity of plants, efficiency of drainage system, etc.
- The fertilization subsystem: The main goal of the fertilization subsystem is to determine the fertilization requirements for the citrus crop. Fertilization requirements include several aspects such as the fertilizer's type, quantity, the fertilizer's application method, and the intervals between applications.
- Plant care subsystem: The main goal of the plant care subsystem is to predict from the last crop and plastic tunnel characteristics, the possibility of having a pest problem. Based on this information it produces a schedule of operations to be done to protect the plant from any expected disorder.
- The diagnosis subsystem: This subsystem performs two primary functions. First, it concludes the causes of user complaint. Alternatively, it can verify/reject a user assumption if the user suspects a given disorder(s) and wants to obtain a treatment. This subsystem takes into account the possibility of a plant being infested with more than one disorder at a time, and so the user can select more than one value for an attribute of an observation. The system can conclude the causes of all user complaints in one session.
- Disorder treatment subsystem: The purpose of this subsystem is to advice the user about the treatment operation of the infected plant. The output of this subsystem is the

treatment schedule. The output includes a complete specification about the treatment operation: disorder name, material name, material quantity, mode of entry, method of application, the tool used in the treatment operation, application time, and advice. The treatment subsystem takes into account the seriousness of the disorders, and so it orders the treatment operations according to their seriousness. Figure V.2 shows the disorder treatment subsystem.

- The assessment subsystem: This subsystem has two functions. The first one is evaluate a new farm in a given location for determining the possibility of cultivating specific crops. The second function is to evaluate a given farm that is already productive and to give recommendations concerning how to improve its conditions to get greater yields.

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Figure V.2 – Disorder treatment subsystem

e) Collaborating institutions

- The electronic research institute, ministry of scientific research, Egypt
- Field crops institute, agricultural research centre, Egypt
- Information systems centre, faculty of engineering – Ain Shams University, Egypt
- University of Florida, United States
- Pennsylvania State University, United States
- Michigan State University, United States
- George Mason University, United States
- Swedish Institute for Computer Science

f) Khobara expert systems

Khobara is an agriculture knowledge management expert system that developed through localized community. The system was launched in 2013. The systems aims to investigate the most efficient agriculture knowledge management and utilize solutions that can empower farmers with expertise and knowledge in an easily optimized manner to improve their agricultural productivity, thereby sharing in overcoming the problem of agriculture and food security in Egypt. The system developers were keen to build a sustainable, valid, efficient, and easy to use system using the following:

- 6 capacity building and validation workshops

- 4 focus group meetings with knowledge experts
- 1 focus group meeting with CLAES
- Tool questionnaire
- Training questionnaire
- Peer review questionnaire
- Expert system rating scale
- Ongoing evaluation (face book groups, messaging, individual contacts).

g) Khobara crops expert systems

Khobara avails of 37 crops expert systems and sub-systems available free on the Internet and easily browsed on mobile phones [b-Khobara]. These systems cover the following crops: apricot, onions, watermelon, pomegranate, barley, corn, cucumber, tomato, grapes and dates.

h) Collaborating partners

- Egypt's ICT trust fund, affiliated to the ministry of communications and information technology (MCIT), Egypt
- The central laboratory for agricultural expert system (CLAES)
- The horticulture value chains (Salasel)
- The United Nations development program (UNDP)
- The Canadian international development research centre (IDRC)
- The international fund for agricultural development (IFAD)

i) Characteristics of Khobara system

- Free service, provided by agriculture experts'
- Promote experiences in profitable ways by using ICT tools (mobile and Internet)
- Accumulate renewed experiences which facilitates communication between experts and beneficiaries
- Develop a quick communication tool that serves beneficiaries' needs immediately
- A technical service that is used by experts to upload his/her scientific, career and social biography
- An access to a distinguished community that has the best Arab expertise in different fields
- Utilise the services of Egypt ICT trust fund that support experts' capabilities in producing and disseminating of knowledge
- Support the Egyptian national agriculture economy through the reduction of agriculture production costs. This is done through proper diagnosis of waste margins that result from agriculture operations
- Generate profits to institutions through their provision of their specialized consultancy services to companies and farms inside and outside Egypt, which contributes to their sustainability
- An easily browsed service that could be used through the Internet or on a mobile device by farmers or experts. It also enables the developed expert system tool to instantly support their recipients
- Provide a diagnostic tool that is easily accessed by agricultural extension workers in farming communities

- An educational, informative and professional tool for graduates and researchers in the agriculture field
- Contribute to enriching experts' knowledge and experiences through partnership and networking, in addition to community evaluation features
- Enable a quick decision-making tool that treats plants; especially through using the "plants photo examination service" which provides prompt solutions for urgent agriculture problems.

V.3 Early warning system for epidemic crop diseases

First weather stations are set up in specified locations. As weather data is received it is used in two different ways. Data is collected in order to create a weather data base. Weather data is also entered into forecasting software to analyze the data and decide whether or not to spray. Depending on the message from the central expert epidemic warning application, instructions are transmitted about the treatments and procedures needed in each particular case. Wireless sensor networks used in forecasting systems can improve the efficiency of all the agricultural applications. For example, fighting plant disease epidemiology can be improved by the remote collection of environmental parameters affecting the disease development. Such collected data is wirelessly communicated to a central expert system to take instantaneous decisions and initiate early warnings. Hence, farmers can instantaneously react to any alerts.

Appendix VI

Computer modelling of weather data and agricultural forecasting

(This appendix does not form an integral part of this Recommendation.)

VI.1 Computer modelling

Computer modelling is used to calculate water and fertilizer requirements, disease and insect predictions and planting dates.

Disease and insect predictions are determined according to the agro-climatological data especially air temperature and soil moisture. Proper disease prediction is conducted by built-in software utilizing agro-climatic data for each region in Egypt. Growing degree days (GDD) are used for the prediction of diseases and insects.

Planting dates for different vegetable crops are also determined according to the agro-meteorological data, especially soil temperature at different depths. Research is being conducted to find the precise soil temperature required for each cultivar of different vegetable species. This is important for selecting the proper cultivation time and area, in the case of newly reclaimed lands or in order to achieve the best germination and avoid major diseases and/or pests [b-Abou-Hadid].

Uniform distribution of irrigation water and fertilizers, pests and diseases prediction, and planting dates are major problems in different climatic regions in Egypt. The old land is characterized by uneven field surfaces, short furrows and small basins, deep percolation, water and fertilizer losses, soil profile heterogeneity and other soil characteristics that all affect water and fertilizer distribution. Early planting is one of the options for summer cultivated crops in order to get the maximum economic yield at harvest time. Early prediction of diseases and insects is important to help the farmers avoid heavy sprays of pesticides and for taking the necessary actions to avoid dangerous diseases.

Proper management nowadays depends on accurate irrigation scheduling that reduces the cost of irrigation and minimizes problems related to the misuse of water. Early pest and disease forecasts and warnings allow suitable time for taking the necessary actions to avoid chemical sprays. Proper calculation of sowing dates ensures uniform plantation and reduces the cost of sowing seeds in several crops. These agro-management practices require real time weather data covering the country. The central laboratory for agricultural climate (CLAC) has established a system that covers more than 30 agro-meteorological stations. Dissemination of information is one of the CLAC activities through various mass media facilities.

VI.2 Crop modelling

Crop modelling programmes are currently needed to study the impact of climate change on agricultural production. This could help decision makers to implement future agricultural strategies together with different scenarios related to agricultural practices. One of these programmes is decision support system for agro-technology transfer (DSSAT), which is used to evaluate and predict wheat yield under all environmental conditions such as soil, weather, irrigation and fertilizers and simulate the yield of different wheat cultivars to select the cultivar(s) for different environments. Data taken from a field experiment carried out at Maryout (northwest coast of Egypt) during 1991-92, 1992-93 and 1993-94 growing seasons was measured to evaluate the productivity of some bread wheat varieties under rain-fed and supplementary irrigation conditions at different growth stages. The experiment included twenty-four treatments, which were the combination of four supplementary irrigation schedules: (i) only rain-fed 170 mm of rainfall; (ii) one irrigation at heading stage 480 m^3/ha; (iii) one irrigation at milk ripe stage 480 m^3/ha; and (iv) two irrigations at the above stages (960 m^3/ha) and six wheat varieties (i.e., Sakha 8, Sakha 69, Giza 155, Cham 4, Cham 6 and Gomam).

Predicted and measured grain were compared and the results indicated that there were significant and favourable differences between the six wheat cultivars where Cham 4 and Giza 155 cultivars had the higher grain yield under rain-fed treatment. Whereas, under one supplementary irrigation treatment Sakha 69 cultivar recorded a higher grain yield followed by the Cham 6 cultivar. Moreover, Cham 6 and Sakha 69 cultivars produced a higher grain yield under the two supplementary irrigation treatments. On the other hand, there was a significant increase in the grain yield with increasing supplementary irrigation times. The potential impact of climatic change on wheat production was evaluated by simulation of wheat production under climatic change conditions by the year 2040 compared to the predicted production under current conditions. In this respect results indicated that the grain yield increased differently according to the wheat cultivar. This may be due to the positive effect of duplication in CO2 on wheat as C3 plants.

Wheat is considered to be one of the main crops both in Egypt and worldwide. Enormous efforts were carried out to reduce the vast gap between production and consumption of wheat. A level of self-sufficiency will not be achieved unless researchers manage to make better use of resources and new technology transfer. Researchers can change wheat cultivars, fertilizer levels, irrigation regime and agricultural practices to maximize wheat crop yield under the current conditions. The breeder usually records data and makes his selection on the basis of a large number of agronomic characters among which significant positive and negative correlations may exist.

Under climatic change conditions researchers need to use a crop model to predict wheat production. DSSAT is a crop model that has the ability to take the source of variability into account. Cultivars are characterized by a specific set of genetic coefficients that express the genetic potential of each genotype independently of all environmental constraints such as soil, weather, fertilizer, etc. The best available genotypes can be explored by simulating the yield of different wheat cultivars. The crop estimation through resource and environment synthesis (CERES) model was CERES-Wheat, a yield simulation model that was originally developed under the auspices of the USDA-ARS Wheat Yield. The model is also one of the main models that have been incorporated in DSSAT. The CERES-Wheat model simulates the impacts of the main environmental factors, such as weather, soil type, and major soil characteristics and crop management on wheat growth, development and yield. Input requirements for CERES-Wheat include weather and soil conditions, plant characteristics and crop management. The minimum weather input requirements of the model are daily solar radiation, maximum and minimum air temperature, and precipitation. Soil inputs include drainage and runoff coefficients, first-stage evaporation and soil albedo, and water-holding characteristics for each individual soil layer. The model also requires saturated soil water content and initial soil water content for the first day of simulation. Required crop genetic inputs are coefficients related to photoperiod sensitivity, duration of grain filling, conversion of mass to grain number, grain-filling rates, vernalization requirements, stem size and cold hardiness. If the crop is irrigated, the date of application and amount of irrigation is required. Latitude is required for calculating day length. The model can use different weather, soils, genetic and management information within a growing season or for different seasons in a single model execution. The model simulates: (i) phenological development; (ii) biomass accumulation and partitioning; (iii) leaf area index (LAI); (iv) grain growth; and (v) the soil and plant water and N balance from planting until harvest maturity based on daily time steps. When using a crop model for any application, one first has to estimate the cultivar characteristics if they have not been previously determined. Weather data, soil analysis, genetic coefficients and crop data are sufficient for a crop modelling study [b-Abou-Hadid].

Appendix VII

The central agricultural portal, information services and networks in India

(This appendix does not form an integral part of this Recommendation.)

VII.1 NeGP-AMMP

The department of agriculture and cooperation (DAC) of the Indian ministry of agriculture and farmer welfare is implementing a national e-governance plan in the agriculture sector (NeGP-A) as a mission mode project (A-MMP), covering the agriculture sector, livestock sector and fisheries sector. The NeGP-AMMP aims to address the needs of the farming community and its other related stakeholders, through provision of relevant information and services through the various delivery channels available locally to assist them in making rational decisions for raising farm productivity and farm income.

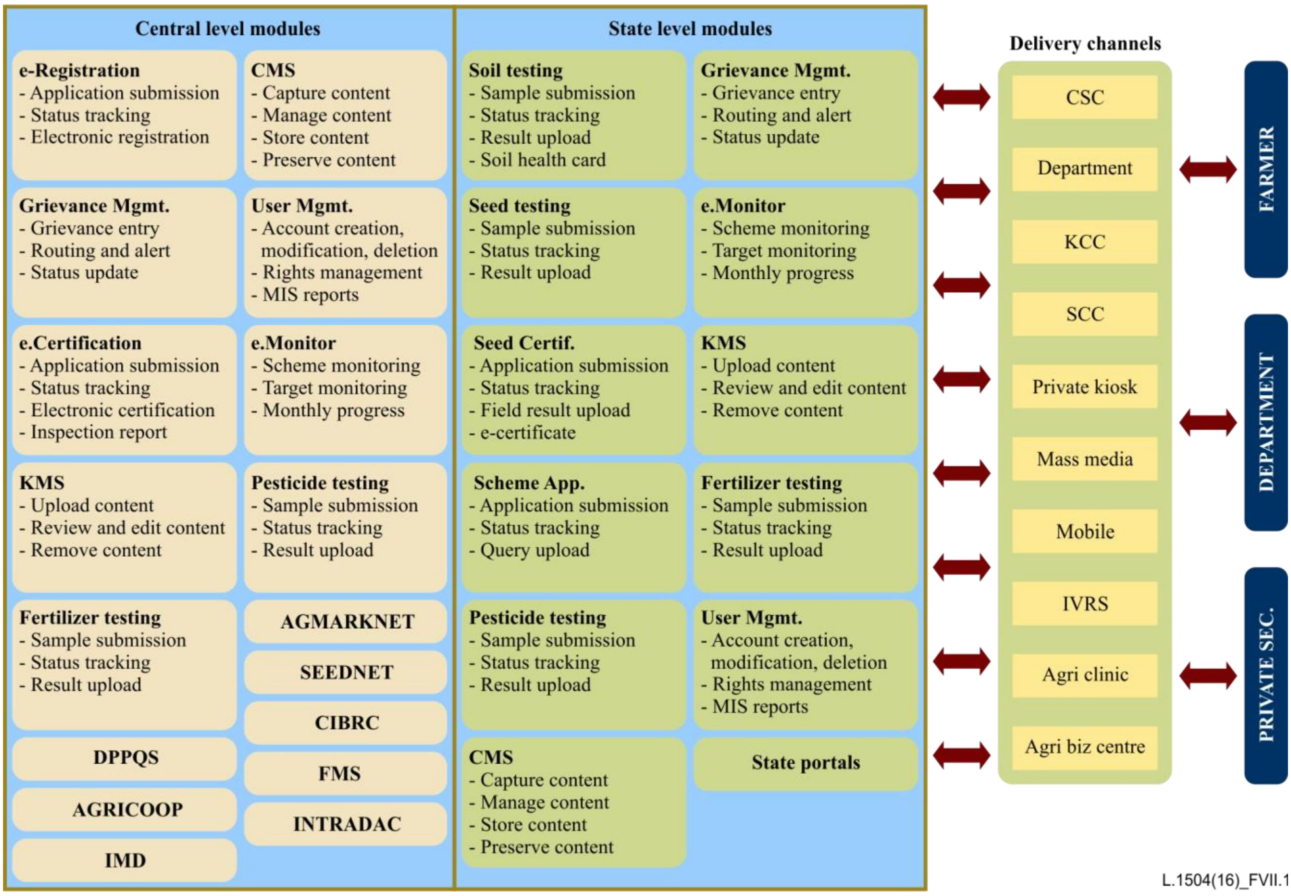

Figure VII.1 – National e-governance programme (NeGP-A) in the agriculture sector as a mission mode project

As shown in Figure VII.1, clusters of services identified under this project, will cover information on pesticides, fertilizers and seeds, soil health, crops, farm machinery, training and good agricultural practices (GAPs), forecasted weather and agro-meteorology advisory, prices, arrivals, procurement points and provision of interaction platforms, electronic certification for exports and imports, marketing infrastructure, monitoring implementation / evaluation of schemes and programs, fisheries, irrigation infrastructure, drought relief and management and livestock management.

VII.2 The central agricultural portal (CAP) – Enhancing collaborative efforts using ICT and multimedia

CAP is at the centre of the project as it provides a platform for all stakeholders (farmers, private sector and the government, research scholars) to access information, avail of services, collaborate and share knowledge. It plays a critical role in providing a single access point to government information and services related to the agriculture sector, eliminating the need to navigate multiple web sites and applications. The CAP allows to presentation of information, applications and services in a single consolidated browser view. It provides a secure and individualized view of multiple online resources and interactive services. In this sense, the CAP has become an interface between the government and other stakeholders.

Functional components of the central agricultural portal are user management, content management, the expert advisory system, the grievances redressal and management system, the national farmers' database, etc. Figure VII.2 shows the national farmers database.

Figure VII.2 – National farmers database

In addition Department and State specific e-governance initiatives in agriculture and allied sectors in conjunction with NeGP-A include:

– Strengthening of IT apparatus in the department of agriculture and cooperation (DAC) headquarters, field offices and directorates of DAC;

– Strengthening of IT apparatus in agriculture and cooperation in the states and union territories (AGRISNET);

– Development of agricultural informatics and communication (AgRIS);

– Kisan call centre.

All the IT initiatives of DAC will be integrated to enable farmers in making proper and timely use of the information available through multiple ICT channels including web portals (central/state agricultural portals), common service centres (CSCs), Internet access points, touch screen kiosks, Krishi Vigyan Kendras (KVKs) which are farm science centres, mobile phones (broadcast, IVRS, voice-recognition and interactive messaging, using unstructured supplementary service data (USSD) and Kisan (Farmer) call centres, agri-clinics through State wide area networks and State data centres and the availability of government to citizen (G2C) services. It will not only standardize and facilitate data flow within and outside the State, but will also capture the best features of various applications already implemented in different parts of the country.

VII.3 Farmers' portal

In the farmers' portal [b-G1] a farmer will be able to get all relevant information on specific subjects around his village/block /district or state. This information will be delivered in the form of texts, SMS, email and audio/video in the language he or she understands. These communication levels can be easily reached through the map of India placed on the home page. Farmers will also be able to ask specific queries as well as give valuable feedback through the feedback module specially developed for the purpose. A screenshot of the farmers' portal is shown in in Figure VII.3.

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Figure VII.3 – Farmers' portal

Other portals related to agriculture are:

– Agropedia, AgriTech, KISSAN Kerala, iKisan ,aAQUA, TNAU AGRITECH portal, ASHA, India development gateway (InDG) portal, rice knowledge management portal (RKMP).

– Some examples of ICT and intermediator knowledge workers include: e-Sagu, e-Arik, e-Choupal, Tata Kisam Sansar, Digital Green, MSSRFVKC, etc.

– Kisan knowledge management system (KKMS): KKMS is a web based portal to maintain the database of the state wide Agricultural Package of Practices distinct from the record of the farmers calling KCC. The KKMS also has links to various schemes of the DAC, the Ministry of agriculture as well as weather related databases. The FTAs access KKMS over the Internet, to obtain instant answers to queries from farmers. Every call is entered with the personal details of the calling farmer, the query of the farmer and answer provided to him.

VII.4 Development of ICT based networks/ infrastructure for agriculture sector

The Department of agriculture and cooperation **(**DAC) in collaboration with the national informatics centre (NIC) has developed a number of portals, applications and websites covering both the headquarters and its field offices/directorates. The main portals include SEEDNET, DACNET, AGMARKNET (prices and arrivals in Mandis), the national agriculture development scheme known as Rashtriya Krishi Vikas Yojana (RKVY), the agriculture technology management agency (ATMA), the national horticulture mission (NHM), INTRADAC, the national food security mission (NFSM) and acreage, productivity and yield (APY).

VII.5 Mobile phone text and voice based services

The mKisan SMS portal was created for farmers. Administration officers, scientists and experts may use this portal for disseminating information on various agricultural activities, giving topical and seasonal advisories and providing services through SMSs to farmers in their local languages. SMSs that are sent to the farmers can be broadly classified into the three categories of information, services and advisories. The content may include information about the schemes, advisories from experts, market prices, weather reports, soil test reports, etc. The farmers registered for receiving SMS messages are grouped according to the state, district, block and the crops/activities selected by respective farmers. Grouping of farmers based on their location and their preferred crop/activity helps in sending relevant messages to the farmers. The mKisan SMS portal provides a platform for the integration of service delivery under the different sectors of agriculture, horticulture, animal husbandry and fisheries. The mKisan SMS portal for farmers enables all central and state government organizations in agriculture and allied sectors to give information/services/advisories to farmers by SMS in their language preference according to agricultural practices and location.

A large number of web-based transactional services are also being provided to farmers in various states and also by organisations/departments of the government of India. These range from issuance of soil health cards, provision of subsidized agricultural inputs and analysis of pests/diseases, etc. Quite a few such services are in development under the national e-governance plan-agriculture or other body.

Farmers can register for this service by calling the Kisan call centre on a toll free number or through the web portal. SMS based registration is also provided. Farmers can select their preferred crops/activities. This also includes activities under animal husbandry, fisheries and dairy in addition to agriculture and horticulture. Farmers' preferences for Mandi prices are also recorded. The language preference of the farmers is also taken into account and determines the language of the SMS. This portal is being further strengthened by the introduction other options such as USSD, interactive voice response system (IVRS), voice broadcast (outbound calls) and mobile applications (resident and Internet based) for various platforms, etc.

VII.6 Kisan (Farmer) call centre (KCC)

To harness the potential of ICT in agriculture, the Ministry of agriculture took the initiative of launching the "Kisan call centres (KCCs)" scheme in 2004 aimed at answering farmers queries via a telephone call in the farmers own dialect. These KCCs located in different parts of the country cater to the farmers from different states. All KCC locations are accessible by dialling a single nation-wide toll free number through a landline and using mobile numbers of all telecom networks 7 days a week from 6.00 a.m. to 10.00 p.m. The Kisan call centre agents known as farm tele advisors (FTAs) with the prescribed minimum academic qualification in the field of agriculture and excellent communication skills in respective local languages attend these calls. The DAC intends to rapidly enhance coverage of farmers under this most important and convenient tool for agricultural extension.

Other than the Kisan call centre service, some other examples of mobile/ telephone based services are: IFFCO-IKSL (IFFCO Kisan sanchar limited), Reuter market light (RML), mKrishi, Nokia Life Tool, spoken web, fisher friend project, lifelines, etc.

Appendix VIII

ICT based risk management applications in India

(This appendix does not form an integral part of this Recommendation.)

VIII.1 Forecasting

The agricultural meteorology division (Agromet) of the Indian meteorological department provides field information such as weather forecasting and severe weather warnings, etc. Details of district wise rainfall maps, weather parameters and weekly rainfall probability are also given. Users can avail of services such as SMS advisory for states and districts, alerts/warnings for states, drought aridity anomaly reports, etc. Observations on Agro AWS data, satellite images and products are available. Training, research publications, brochures and other information about agro-meteorology are provided. Users can also locate agro-meteorology centres across the country.

VIII.2 Fertilizer quality control application

The fertilizer control order (FCO) has stipulated detailed specifications on fertilizers to be sold in the country for agricultural purposes. It also specifies detailed procedures for the sampling and analysis of each fertilizer. Laboratories take samples of imported fertilizers at the discharge port for analysis. Laboratories analyse samples taken from field (warehouses/dealers/retailers) as well as from the manufacturing plants. The fertilizer quality control application is for fertilizer quality control [b-h1] and includes mixtures of nutrients in its master list. Micronutrient fertilizers are state/ area specific. It also prepares provisional and customized lists. Inspectors are provided with the mobile numbers and digital signatures of the concerned officials that are to be included. Product details of samples collected, analysed and found to be non-standard are incorporated and details of referee samples and the courier are included.

VIII.3 Testing and tracking applications

The Indian government have also undertaken initiatives using ICT. Some of the initiatives for example include those of Gujarat state that have implemented a programme for e-tracking of farm mechanization and farm ponds. Initiatives of Odisha state include e-pest surveillance to minimize pest damage. Other initiatives include online licensing and monitoring of input sales and stock, online fund management for various schemes, extension reforms, subsidies, etc. A farm crop management system (FCMS) initiative has been undertaken by Tamil Nadu state.

VIII.4 Practices for enabling real time pest management solutions

The University of Agricultural Sciences (UAS), Raichur, India (www.uasraichur.edu.in) have developed an IT-enabled handheld device providing electronic solutions against agricultural pests (e-SAP), that provides information to farmers in real time on pest-related problems. This is a web-based application system which facilitates the flow of information from the farmer to farm scientists and back. This system operates with 2G/3G/WLAN and can also work off-line with data transfer immediately upon the availability of a telecommunication network. The system uses multiple media e.g., audio, image, etc. and also uses GIS for geo-coordinates.

The e-SAP system helps the extension workers, who are not experts, to collect specimens directly from the farmer's field and send it to the scientists and experts in real time. Field scouts involved in the e-SAP project visit farmers' crops, diagnose pest problems, estimate the extent of problems and provide a solution directly in the field. The system also generates/provides data points on crop and pest situations, images, geospatial coordinates, coloured with data, etc. The system also generates graphs enabling prudent decision-making at various levels.

Experts can also get connected and view field situations and listen to the problem before conveying their decisions. Experts can quickly handle undiagnosed field problems over their smart phones. The application not only enables capture of multiple images of the crop, but also makes it possible for the user to record his opinion as he speaks. These images and audio files along with other relevant details like geo-coordinates and crop and farmer details are transferred via the cloud in real-time. Designated experts receive an alert regarding the transmission and can access information using e-SAP's web application. The application also allows inter-expert exchange of information before posting their suggestions to the field device.

Pest identification: e-SAP helps to identify pests through high-quality images that characterize pests and their symptoms are adapted to intuitively guide users in identifying the pest. Audio assistance in the local language is provided at every step. The user merely needs to touch a relevant image at each of the steps to identify the problem-causing organism.

Pest surveillance: e-SAP also helps to determine the extent of the pest problem prevalent in each farm, intuitively built pest-specific survey forms are supported to quantify damage caused by various pests. Data are automatically analysed based on the survey and the pre-determined economic threshold values for each pest.

A schedule of recommended management strategies can be made available against each pest after determining the extent of damage. The strategy takes into account the crop, crop age and crop part affected. The user may adopt strategies depending on the automated suggestion made on the basis of the survey conducted.

Pest information: To supplement the knowledge of users, details of each pest are made available on the field device, which is available offline and updated online.

Farmer database: An important feature of e-SAP is the ability to capture farmer-specific data in the field and a build database of the activities of each farmer. All relevant details of each farmer, including images, are captured on the field device and a database is created in the cloud, which is accessed through the web application. Every farmer is identified by a unique number while a log of all his activities across time is created and made available for further use.

Data analysis and reporting: Data captured from various field devices are fed into several databases in the cloud, which are then made available for viewing over the GIS across any defined time and any chosen set of parameters. Users can access automated graphs/tables over e-SAP's web application. Points on GIS maps and continuously updated graphs/tables allow real-time monitoring of pest situations across any defined space.

Decision support system: A micro-level decision support system is provided on the field device for taking decisions on adopting pest management strategies. e-SAP also makes provision for macro-level decision support in the web application.

Feedbacks: As with respect to the adoption of technologies and assessment of technologies by field users, provision is made to capture feedbacks in the form of multimedia content such as audio and images and intuitive grading.

Content management: e-SAP allows for real-time dissemination of pest management technologies and other information to all/designated field devices. Information on new pests or new information on existing pests, new/modified pest identification routes, additional/new symptoms, new survey plans and new management strategies can be remotely updated.

Appendix IX

Automatic optimization of environmental conditions in greenhouses - Japan

(This appendix does not form an integral part of this Recommendation.)

ICT enables automatic optimization of environmental conditions in greenhouses. Examples of functions in a greenhouse controlled by ICT and related climate events are shown in Table IX.1.

Table IX.1 – Examples of functions in a greenhouse controlled by ICT and related climate events

Functions	Related climate events
Mitigation of severe increase/decrease of temperature	Sudden increase/decrease of temperature
Control temperature by outside air	High/low temperature
On/off funs	Heat
Open/close windows	High/low temperature
On/off ceiling fan	Drought
Open/close insulating curtains	High/low temperature and humidity
Avoidance of strong wind	Strong wind
Avoidance of air blowing from ceiling windows	Strong wind and high/low temperature
Avoidance of rains	Rains

For example in a town in Japan, where greenhouse-based production of tomatoes and strawberries is a thriving industry, a system was installed to improve production stability and efficiency, which is capable of finely controlling greenhouse temperatures, humidity, sunlight and other growing conditions by measuring and accumulating such data in the cloud, see Figure IX.1.

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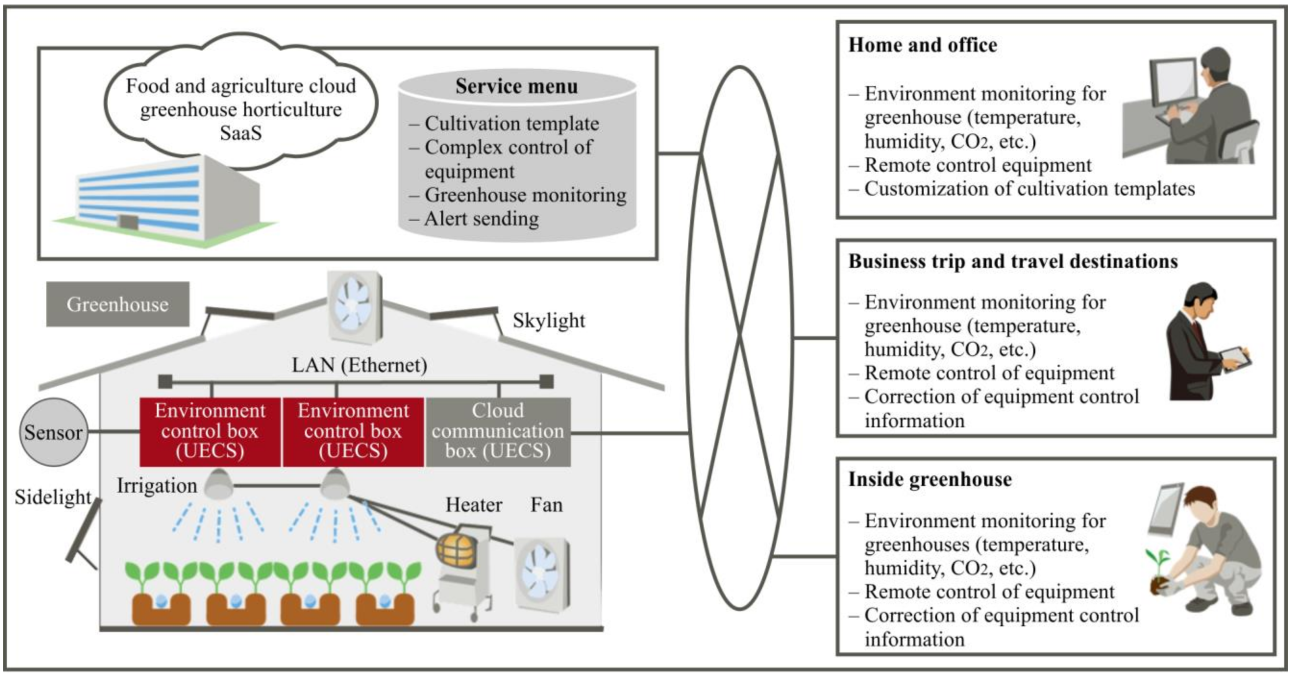
Figure IX.1 – Remote data monitoring and facility environment control

This system employs the ubiquitous environment control system (UECS) information standard for plant cultivation. UESC enables the use of a smartphone and other devices to remotely manipulate devices and equipment for controlling temperature, levels of sunlight and other environmental conditions. This system is selected for easy installation, the possibility of retro-fitting and low implementation and maintenance costs. An example of UECS is shown in Figure IX.2.



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(Source: Fujitsu)

Figure IX.2 – Greenhouse environment control using UECS

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