
Improving Climate Risk Management at Local Level – Techniques, Case Studies, Good Practices and Guidelines for World Meteorological Organization Members

R. Martínez, D. Hemming, L. Malone, N. Bermudez,
G. Cockfield, A. Diongue, J. Hansen, A. Hildebrand, K. Ingram,
G. Jakeman, M. Kadi, G. R. McGregor, S. Mushtaq, P. Rao, R. Pulwarty,
O. Ndiaye, G. Srinivasan, Eh. Seck, N. White and R. Zougmore

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/51554>

1. Introduction

Climate can be viewed in a number of ways. As a constraint or setting, climate provides the broad boundary conditions within which a range of ecosystems services function. Climate may be considered a determinant in that it may be part of a causal chain of direct or indirect events leading to a particular impact or outcome. Climate can also be viewed as a resource; this notion implies that climate has a value, could be managed and manipulated and by extension could be allocated. More often than not, climate is viewed as a hazard. Whichever of these views of climate is adopted, it is clear that climate has a close relationship with nature and society and therefore climate variability and change may pose a range of risks for environments, societies and economies.

As our understanding of the climate system and our ability to predict it into the future have improved, and as society has become more aware of the possible costs and benefits of managing (including adapting to) climate risks (see Box 1. 'Climate risk definition'), individuals, communities and organisations are seeking suitable information, tools and techniques to enable appropriate management decisions to be made. These need to be accessible, dependable, usable, credible, authoritative, responsive, flexible and sustainable.

The generic process of applying such information to climate risk decision making, including identification, assessment and prioritization of the risks followed by a

coordinated and sustainable application of resources to reduce, monitor and control the probability and or impact of detrimental effects, is known broadly as Climate Risk Management (CRM).

Box 1. Climate risk definition

There are many definitions of ‘risk’ depending on the application and context. Based on the Intergovernmental Panel on Climate Change definition of disaster risk (IPCC, 2012), climate risk can be defined qualitatively as the likelihood of unfavourable impacts occurring as a result of severe climate events interacting with vulnerable environmental, social, economic, political or cultural conditions.

It can also be defined more quantitatively, as the product of the probability of a given climate event occurring and the adverse consequences of this. As such, climate risk originates from a dynamic combination of climate hazards (e.g. extent and duration of extreme temperatures or rainfall) and the vulnerabilities (propensity or predisposition to be adversely affected) of exposed elements (e.g. communities, economic or societal sectors or ecosystems).

There are a number of challenges for CRM. Climate risks pose what has been termed a wicked problem¹. Wicked problems do not have set solutions; instead, greater understanding of the wicked problem and partial solutions to the problem evolve iteratively within the social contexts of the scientists/analysts, intermediary agents, and end users. As well, there is no commonly accepted methodology for assessing and prioritising climate risks, identifying key thresholds in these risks, or for considering what are important criteria for managing these risks.

Current challenges for climate risk decision makers include identification of and assessing timely, reliable and appropriate climate risk information and then using that information to make well informed decisions. These are not simple processes given the complexity of the social and institutional mechanisms, the multiple potential sources of climate information (not all of which is consistent or authoritative or easy to understand), and the multi-faceted nature of information, that are often involved in such decisions. Appropriate approaches and principles should be adopted to foster collaborations among climate risk information users and providers, and enable the implementation of effective management actions.

The World Meteorological Organization (WMO) and partnering agencies have recognized the needs of users of all kinds for relevant, actionable climate information for CRM and are taking steps to address those needs. Thousands of scientists and decision makers from climate and other disciplines met at World Climate Conference-3 (WCC-3, 31 August to 4

September, 2009, Geneva, Switzerland) to discuss the issues, and concluded that a Global Framework for Climate Services (GFCS) was needed to organize and provide users with the climate information, products and services appropriate to their requirements. Following WCC-3, a major report (WMO-No 1065) on the GFCS outlined, *inter alia*, current capabilities around the world, the needs and opportunities for climate services and recommendations. The GFCS is designed to mainstream climate science into decision making at all levels and help ensure that every country and every climate-sensitive sector of society is well equipped to access and apply relevant climate information, enabling an adjustment of planning and decisions to optimize the given situation. The application of climate services must therefore involve close interaction between all stakeholders including the providers and the users, and requires concerted multi-disciplinary efforts². The ultimate goal of GFCS is to: “Enable better management of the risks of climate variability and change at all levels, through development and incorporation of science-based climate information and prediction into planning, policy and practice.”

In 2011, the WMO agreed to implement the GFCS, and is working with partnering agencies to develop or strengthen the many contributions to the GFCS, in terms of observations, monitoring, research, services and capacity development, all with a user focus and engagement. As part of this effort, experts from around the world are collaborating to scope requirements for CRM, develop methods for interacting effectively with user communities, and improve applications of climate information for user benefit.

Motivated by the need to ensure the effectiveness of the GFCS, and the associated requirement to improve the practical application of CRM at local levels, in order to reduce climate impacts, build resilience to climate variability and change and contribute to poverty reduction and development, the WMO Task Team on Climate Risk Management (TT-CRM) organized a CRM Symposium in Guayaquil, Ecuador in October 2011. Experts in a wide range of climate and risk disciplines from all the continents and key agencies working with WMO on the GFCS implementation attended. The overarching aim of the Symposium was to help both providers and users of climate information in the development and application of information on climate variability and change, in an operational ‘no regrets’ sense, for minimizing climate-related risks and maximizing any opportunities that may. As a result of this international meeting, innovative approaches for CRM were discussed, practical examples of best practice were highlighted, and guidance for appropriate processes, tools and techniques to adopt were proposed.

In this chapter, key points and outcomes from the WMO Symposium on CRM are highlighted, including proposing a definition of CRM (see Box 2. ‘Climate Risk Management (CRM)’), and recommendations on CRM for WMO Members. The aim is to provide a useful document to all who are interested in establishing or improving CRM processes and systems at the local level (particularly village to country scales). Throughout the chapter, conceptual discussions are complemented with real-life case studies and lessons learnt and shared by experts who are involved in CRM across different sectors and in academia.

Box 2. Climate Risk Management (CRM)

The World Meteorological Organization Task Team on Climate Risk Management (TT-CRM), based on the expert guidance from the Symposium on CRM, proposes a definition of CRM as a **systematic and coordinated process in which climate information is used to reduce the risks associated with climate variability and change, and to take advantage of opportunities, in order to improve the resilience of social, economic and environmental systems.**

2. The process of CRM

Many CRM frameworks, that include different key steps and elements (actors, tools, techniques etc.), have been developed to provide guidance and a degree of consistency for applying risk management to a range of climate-related issues^{3,4,5,6}. These frameworks tend to be conceptual and general so that they can be easily applied to a wide range of concerns by both technical and non-technical users, and may vary in their foci and level of detail ranging from international to local, or general to sector specific.

Despite the variety of frameworks and tools for assessing and managing climate risks, utilisation of the output to enable decision making is advancing rather slowly⁷. Continued guidance by risk management experts to begin the CRM process with user and provider engagement and collaboration has often not been considered, and assessments are still typically conducted by scientists and then the information is handed to users in a one-way exchange - the so called top-down approach - that often does not promote effective decision making. It is important to continue to promote collaboration between assessors and stakeholders (providers and users of climate information) at all stages of the CRM process, to enable all parties to understand the steps involved in the knowledge to action pathway, and therefore to facilitate effective and sustainable CRM responses.

The WMO Symposium on CRM discussed various CRM frameworks and steps, which has enabled the TT-CRM to identify the following key steps that are considered essential to consider in a CRM process. These should not be regarded in a linear manner, but rather combined in an iterative or cyclical order:

- User and provider engagement and collaboration
- Climate risk assessment
- Communication and dissemination of climate risk knowledge, information and tools
- Adaptation and capacity development
- Monitoring, evaluation and improvement

Some of the key points for each of these steps are highlighted below, and practical examples, to demonstrate good practice on how they have been applied to real-life CRM projects, are provided.

2.1. User and provider engagement & collaboration

Breuer and colleagues⁸ compared the traditional research model, in which researchers develop new technologies or tools that extension agents (professionals trained in skills such as communication and group facilitation, and usually also in technical areas of the sector they serve) deliver to end users, to a pipeline that delivers water. They proposed an alternate loop model, in which the loop encircles end-users, extension agents, and researchers with diverse opportunities for interactions among this co-learning community. The symposium supported this approach, and further recommended that science-based learning communities or communities of practice use as many methods as possible for engagement and collaboration.

In this section the engagement of agricultural stakeholders, particularly through experiences with the Southeast Climate Consortium of the United States of America (USA) (SECC), is emphasized. However, the same principles could be applied successfully for CRM decision makers in other sectors, for example water resource managers, coastal community planners, or wildlife managers.

The work of extension agents has been particularly successfully applied in the agricultural sector. Opportunities to engage end-users, e.g. farmers, in the process of developing a decision support system have included surveys, interviews, sondeos, workshops, focus groups, working groups, presentations and displays at association meetings, and on-line feedback^{8,9,10}. An example of good practice in this sector has been the SECC, who developed AgroClimate (see <http://agroclimate.org/>), an on-line decision support system for extension agents and end users, using all of the engagement opportunities described above^{8,11,12}.

Box 3. Steps for engaging farmers and outreach workers

1. Ask what they want.
2. Listen.
3. Give them what you think they asked for.
4. Ask them whether you've given them what they need.
5. Listen.
6. Observe whether they use the information or tools that you have given them.
7. Modify what you have provided.
8. Go back to step 4.

The most important points for engaging farmers and outreach workers as research collaborators identified through the experiences of SECC are straightforward: 1) knowing which questions to ask; and 2) listening to the answers. The various methods that were used for engagement with end users follow the basic iterative steps outlined in Box 3. 'Steps for engaging farmers and outreach workers', but each is unique in terms of the depth and breadth of information that they can evoke.

By providing a range of engagement methods, individuals can self select how they will engage in the community, depending on their level of interest, availability of time, and willingness to commit to an activity. This ability of community members to select the engagement activities in which they will participate applies to nearly all members of the community, including end-users, extension agents, and researchers. The exception to the self selection clause is a core team of three or more individuals who are fully committed to the community. The SECC strives to have a team that includes at least one social scientist (anthropologist or rural sociologist), climate scientist, and agricultural scientist. The ability of this committed team to work together will be the most critical factor in the success of the engagement.

Two of the engagement methods noted above – sondeos and working groups (both powerful and less commonly used in other reported participatory research approaches) – are further described:

2.1.1.1. *Sondeos*

A sondeo (Spanish for sounding) is a semi-structured discussion in which a two- to three-person multi-disciplinary team engages one or two people from the target audience in conversation⁸. Most of the sondeos conducted for the SECC have been part of a graduate course in field research methods. The students and their instructors meet to discuss the problem of interest and to agree on a general set of questions to ask. These questions are a guide to conversation, rather than a formal questionnaire. The course members divide into small multi-disciplinary teams to conduct their conversations, typically at the residence or place of work for the people of target audience. For the agricultural community, extension agents have been vital in helping identify people from diverse target audiences, where the targets have included small and large farms, vegetable growers at farmers markets, farmers with and without irrigation, and others.

An important benefit to a conversational approach is that it often elicits key issues that the researcher could not have anticipated, issues that would likely have been missed with an interview or survey that has a list of pre-established questions. In keeping with its conversational nature, the researchers do not take notes during the conversation. Rather, when the conversation is completed, each researcher writes their own synthesis of the discussion. In one day, a single team can usually complete three or four discussions, which typically last about one hour, followed by note writing.

At the end of each day, all teams assemble to discuss their findings and to identify new questions that will guide conversations on the following day. Some questions may be retained throughout the sondeo in order to provide continuity, but the discussions evolve day-by-day as teams engage in conversations, learn, share their learning, and modify their conversation guide questions. After one week of field work, the course identifies a leader to write the sondeo report. Examples of SECC sondeo reports can be downloaded from <http://SEClimate.org/pubs.php>.

2.1.2. Climate working groups

A working group includes members from science and the broader community who meet regularly, typically 3 or 4 times per year, to engage in dialogue on the new findings from science, information and technology needs of the broader community⁹. The steps for building and nurturing a climate working group are outlined in Table 1. The SECC has successfully established working groups for agricultural and water supply utility communities. Both have about 25 to 30 members and both are highly productive, yet each has distinct features that reflect the differences among the communities.

A key element to the success of a climate working group is commitment, both on the part of the individual members of the groups and the institutions that they represent, if any. For example, most members of the water supply utility climate working group represent a particular water provider, city, or agency. If a member of any particular institution is not able to attend a meeting, the participating institutions identify an alternate who can attend. This policy provides both continuity and assures that the institutions have also committed to the working group.

Phase 1: Exploratory	<ul style="list-style-type: none"> • Identify key stakeholder groups and individuals • Assess climate-related concerns and priorities • Map network of stakeholder groups • Discuss interest in development of a climate working group • Identify potential participants and assess their interest in working together
Phase 2: Group building and goal setting	<ul style="list-style-type: none"> • Identify convener and facilitator for an exploratory meeting • Convene stakeholders to exchange information and explore scope for a climate working group • Discuss expectations and establish short- and long-term goals • Define group norms and roles
Phase 3: Implementation	<ul style="list-style-type: none"> • Develop a work plan and timeline • Identify gaps in expertise and experience • Develop sub-groups as needed to address specific topics
Phase 4: Monitoring and feedback	<ul style="list-style-type: none"> • Define outcome and process criteria to track progress • Include time for reflection and feedback for iterative group adaptation

Table 1. Phases and activities for the building and nurturing a climate working group. Source: Bartels et al. (2011)⁹.

By far, these climate working groups demand the greatest level of commitment from the learning community for any of the engagement methods that have been tested, but it is precisely this commitment that helps them advance science. The climate working groups help researchers build collaborative relationships with different stakeholder groups for on-going learning, both by the scientists and the stakeholders. They link research with real-world decision needs to help improve resource management strategies of stakeholders as

well as improving the research and education programs of the science community. Most importantly, climate working groups engage members from diverse stakeholder groups that might not otherwise interact and promote the legitimacy of the science community as a source of information and technology that is relevant to solving the wicked climate problems that society faces.

2.2. Climate risk assessment

As with the definition of climate risk, or CRM, there are many definitions of risk assessment. A common theme across most is the requirement for a process and/or technique that provides information with which to assess the key risk or risks. For example, the Society for Risk Analysis proposes that: “Risk assessment is the process of establishing information regarding acceptable levels of a risk and/or levels of risk for an individual, group, society, or the environment” (see: http://www.sra.org/resources_glossary_p-r.php).

Risk assessments involve analysis techniques, methodologies and tools that have the key quality of assessing uncertainty (a common quality of risk), either quantitatively or qualitatively, and representing this as some measure of likelihood and/or probability. Climate risk assessment is used to help decision makers optimize resources for responding to climate-related disasters and reducing risks and impacts associated with current and future-projected climate variability and change. It is one of the first stages of CRM, and involves identification and synthesis of hazard and vulnerability information/data that is relevant to the specific climate-related risks identified through the ‘User and provider engagement and collaboration’ step. One very important consideration in all climate risk assessments is the balance between the quantification of climate hazards (intensity, frequency and/or duration) and the approach to estimate the main elements of vulnerability on the ground i.e. level of exposure, poverty, exclusion, education, organizational capacity, infrastructure among others. Both hazard and vulnerability estimations may be validated using historical information of climate events and changes in socio-economic vulnerabilities and associated impacts. However, such assessment may encounter problems, for example, in some cases quality of data may be poor, data may not be available, skill of forecasts at different scales can be low. As well, even if the climate information is complete and correct, the user may not access it, or may not understand or know how to apply it.

Indicators of climate-related risks (impacts, hazards and vulnerabilities) are often used to focus a risk assessment on the specific areas of interest for the decision maker. Indicators are values that can be monitored (and/or modelled) to assess changes in the state of a system, and are important tools for simplifying complex processes, with potentially multiple drivers and feedbacks, into useful and accessible information. Defining which indicators are appropriate for decision makers, as well as climate monitoring or projection purposes can be a complex process, and many different approaches have been adopted^{13,14,15,16}. One of the more common approaches used for indicator-based studies uses the driving force-pressure-state-impact-response (DPSIR), pressure-state-response (PSR) or driving force-state-response (DSR) which organize indicators in the context of a causal chain^{17,18,19}.

Climate risk assessments typically include statistical analyses of historical climate indicator records and assessment of information on climate-sensitive impacts, together with understanding of the climate mechanisms and the cascade of processes leading to these impacts. Geographical information and mapping may also be used to assess the zones where impacts are recurrent and are associated with human losses and/or infrastructure damages. Temporal changes of impacts and their related climate hazard characteristics are also often a key part of climate risk assessment, and may be directly linked with social, economical or environmental variables which may change exposure and resilience. In an ideal world, there would be millions of meteorological stations contributing to development of an accurate idea of the historical evolution of climate variables. The reality is, however, that there are not enough meteorological stations, the available stations are not evenly distributed in time and space, available data are not always digitized or shared, and there can be problems in some cases in the quality, completeness or homogeneity of the available data. Notwithstanding such issues, individual climate records measured at specific places integrate the history of the complex interactions between land, air, sea, ecosystems, and community in those locales. The final result is expressed in those climate records and consequently the history of this whole interaction process is reflected in time series of the measured values, or of their departures from a chosen reference period.

Analysis derived from climate indices/indexes, such as that provided by the CCI/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI) (see <http://www.clivar.org/organization/etccdi/etccdi.php>) is a powerful tool that can be applied at local level. In places where high quality climate records (preferably long period, minimal gaps, and homogeneous) are available, the information that can be delivered through such climate analysis is absolutely useful, in conjunction with social and economic and other information for that locale, in DRR, adaptation and CRM processes. Such information is more accurate and in most cases more appropriate than that generated by downscaled models, but in zones where there are no available stations, information generated by downscaling is the next best alternative.

Climate risk assessment may also include a future element, utilising climate change projections and/or 'what-if' scenarios to explore the potential impacts of future scenarios of change. Practical obstacles to using information about future conditions are diverse, ranging from limitations in modeling climate system complexities (e.g. projections having coarse spatial and temporal resolution, limited predictability of some relevant variables, at scales that matter for decision making and forecast skill characterization), to procedural, institutional, and cognitive barriers in receiving or understanding climatic information, and the capacity and willingness of decision-makers to modify actions^{20,21}. In addition, functional, structural, and social factors inhibit joint problem identification and collaborative knowledge production between providers and users. These include divergent objectives, needs, scope, and priorities; different institutional settings and standards, as well as differing cultural values, understanding, and mistrust^{22,23}.

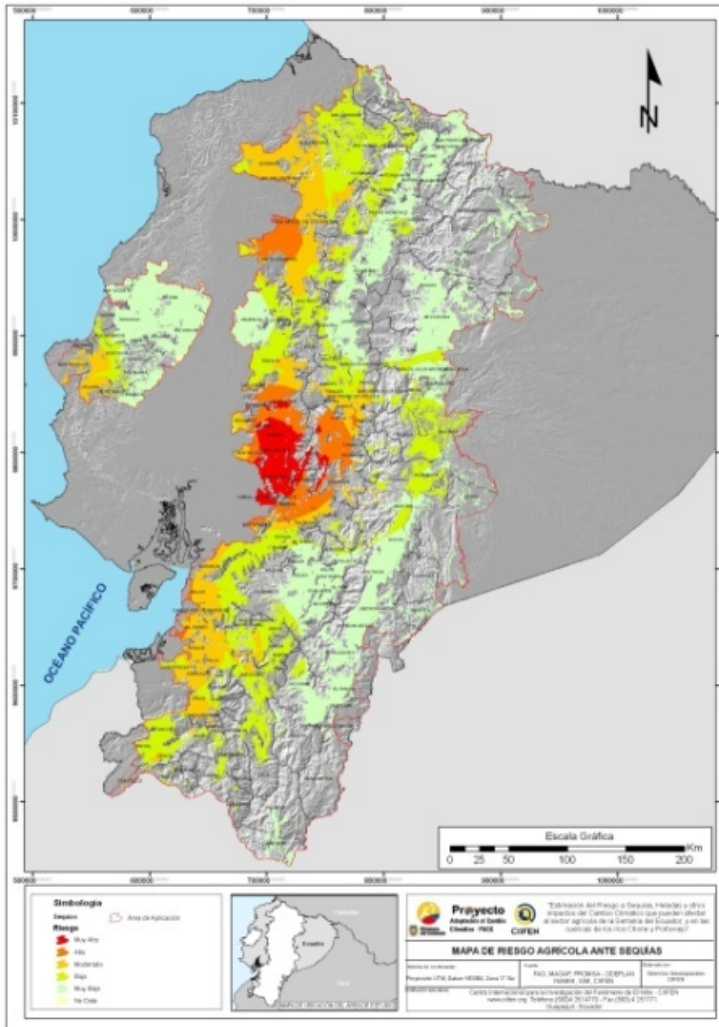


Figure 1. Climate-related risk map for agriculture in the highlands of Ecuador. Color scale: Red: high risk; Light green: low risk; Grey: no data. Source: MAE (2012) www.ambiente.gob.ec

A fundamental part of risk assessment is related to vulnerability. However, it is very difficult to provide a unique formulation or set of indicators for vulnerability, as these will vary across sectors, geographically and in response to socio-economic conditions. A typical view of vulnerability considers the combination of several elements: the level of exposure (of an element which must be specified, e.g population, livelihood, infrastructure, etc.), the level of susceptibility which is a degree of how much the natural hazard can affect it, less or divided by the coping capacity of the exposed element which includes all the factors of resilience in the community, livelihood, infrastructure, etc.). While increases in the level of

exposure and susceptibility both increase vulnerability, increases in coping capacity reduce it. This approach mixes physical exposure (i.e. the presence (location) of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by physical events and which, thereby, are subject to potential future harm, loss, or damage) with the social determinants of vulnerability. According to the most recent IPCC-SREX Report (2012)²², the IPCC describes vulnerability as the propensity or predisposition to be adversely affected. Every location on the planet has its own vulnerability profile and a specific evolution pattern. Historically this vulnerability pattern can be approximated with some social or economical indicators, statistics of disaster or land use multi-temporal comparison. The central focus of climate risk assessment is to understand the relevant climate hazards and their evolution over time, together with the vulnerabilities and how these have evolved, and a likely to change in the future, in a particular area. It is not possible to implement CRM or adaptation actions only with climate scenarios. This information must be complemented with the estimation of current vulnerability and potential future evolution.

No single, consistent approach for conducting risk assessments has emerged, instead a range of different techniques have been used²⁴. The choice of a particular technique is influenced by several factors, including: the goal of the assessment, the exposure units to be studied (an exposure unit is defined as the sector, location or activity being assessed), availability of data, choice of models suitable for the projection of future outcomes, and the time frame involved. A major challenge for future climate change assessments is the uncertainty associated with future projections and the propagation of this uncertainty throughout an impact assessment³. One approach has been to give a range of uncertainty bounded by low and high scenarios of climate change. However the outcomes of such analyses may be too broad for planning effective adaptation.

An example of a successful climate risk assessment for the agricultural areas in the highlands region of Ecuador was developed in 2011 by the International Research Center on El Niño (CIIFEN), Ecuador. This was requested by the Ministry of Environment as part of the National Plan for Adaptation. For the assessment, agricultural areas were identified based on up-to-date satellite information, and specific field verification. Information and indicators for agriculture aptitude, erosion, hydrological deficit, level of access to water for irrigation, type of soil, were considered, and social and economical indicators were selected. All information was analyzed spatially at parish level and combined to produce a vulnerability map covering the Ecuadorian highland region. This was further combined with historical climate hazard maps of “dry consecutive days” and “high temperature indexes”, as reported in the Second National Communication of Ecuador to the UNFCCC, 2009²⁵. The resultant map of the climate risks for the agricultural sector in the highlands of Ecuador (Fig. 1) is currently used by national and local authorities to assign priorities, allocate resources and address the key elements involved in the vulnerability of the agriculture sector to cope with the potential climate hazards based in the historical trends.

2.3. Communication and dissemination of climate risk knowledge, information and tools

The term ‘risk communication’ as used here, refers to intentional efforts on the part of one or more sources (e.g. international agencies, local government, communities) to provide information about hazards and hazard adjustments through a variety of channels among themselves or to different audiences (e.g. the general public, specific at-risk communities), for the purpose of influencing the recipients to apply the information and take appropriate action. It also includes efforts of local communities to characterize and communicate their risk-based experiences. Lindell and Perry (2004)²⁶ summarized the available research as indicating message effects include pre-decisional processes (reception, attention, and comprehension). Several studies have identified the characteristics of pre-decisional practices that lead to effective communication over the long-term^{27,28,29}.

Communicating and disseminating risk information can be very challenging. One of the first steps for effective communication is to ensure two-way communication channels, where information providers and users can interact equally and explain misunderstandings. Before starting a CRM process, it is paramount to build and apply “climate information chains”³⁰, as discussed above. This involves a complex network of institutions involved in the end-to-end process of CRM, i.e. National Meteorological and Hydrological Services (NMHSs), disaster management agencies, national and local authorities, the media, private sector, community representatives, and public and private agencies of strategic sectors such as agriculture, health, water resources. Such a complex network requires diverse means of communication, which has included web-based GIS tools with, *inter alia*, real time information updates, e-mail distribution lists, text alerts and high-frequency radio transmission which is useful for remote locations. A climate information chain should have legitimacy, credibility and be interactive. It is a kind of “living mechanism” that must be kept operational. To get people and institutions engaged in this chain, dialogues, meetings and agreements are also necessary. One example of an operational mechanism for communicating and disseminating risk information would be regional or national climate outlook forums (RCOFs and NCOFs). In these forums, climate information providers and users meet (either face-to-face or virtually), usually on the release of a seasonal climate forecast. The opportunity to share information, discuss issues and build knowledge has proven invaluable in many parts of the world (for further information and references, see http://www.wmo.int/pages/prog/wcp/wcasp/wcasp_home_en.html).

Once climate information chains are set up, the information to be disseminated should consider that climate knowledge should optimally combine scientific knowledge and indigenous knowledge. Both are necessary to ensure the effectiveness of their application. Science is not enough to contribute practical and effective solutions for CRM, but when it is linked with the local culture and experience of the communities, fantastic responses can be obtained. This is exemplified by a young member of a remote community in Ecuador drawing a risk map for his location based on all the experiences, impacts and weaknesses their community has evidenced, but with a better understanding of how the vulnerability

was built and the main climate hazards that threaten this community³¹. There is indeed considerable evidence to show that if communities at risk are actively involved in information collection and analyses then they are far more likely to rely on that information than if it is just provided to them from ‘outside’³⁰. Information is also regarded as credible to local actors if it is collected and reported by individuals recognized by the central bureaucracy and locals as responsible observers with minimal political motive, such as teachers or extension workers³². One effective way to consolidate climate information chains is through their usefulness. If such information chains become operational and communities respond effectively during planning, early preparedness and response, users become engaged and empowered by the system because they feel they are part of it.

Examples of risk information generation and diffusion efforts within disaster research and response communities include interpersonal contact with particular researchers, planning and conceptual foresight (as in Red Cross/Red Crescent brochures), outside consultation on the planning process (as per the Federal Emergency Management Agency of the USA (FEMA)), and user-oriented transformation of information and individual and organizational leadership. The characteristics of risk communication messages involve information quality (specificity, consistency, and source certainty) and information reinforcement (number of warnings) that have significant impacts on adoption of adjustments^{33,34}. Messaging should also aim to foster ‘no-regrets’ actions, in which the recipient of the information takes climate-related decisions or action to maximize positive and minimize negative outcomes of climate variability and change.

2.4. Adaptation and capacity development

The IPCC definition of adaptation to climate change is the “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”³⁵. From a conceptual point of view adaptation and capacity development are part of the overall CRM approach. In practical implementations of adaptation projects these two compartments often become indistinguishable, for example, Monsoon Forum meetings, which focus on preparedness planning for monsoon season climate variability across Asia (see <http://www.rimes.int/societal/monsoon-forum>), often also involve training sessions to build capacity across the community. However, there is a strong tendency to try to separate and manage adaptation and capacity development independently of each other, as well as from the other steps involved in CRM. This can cause a negative effect on implementation and makes the institutional information framework which is necessary to get effective responses in human systems more complex.

In accordance with the Global Adaptation Partnership (www.climateadaptation.cc), compelling climate change evidence has prompted the development and implementation of national adaptation plans around the globe, and these have generated specific within-country actions related with vulnerability and risk assessments including long-term climate observations or projections. In some places, these actions overlap with CRM (as well as

other risk management) plans of national disaster management or other government agencies. For example, the UK government Department for Environment, Food and Rural Affairs' (DEFRA) Climate Change Risk Assessment was one of the requirements from the UK government's Climate Change Act (for further details see <http://www.defra.gov.uk/environment/climate/government/risk-assessment/>).

One of the key issues for adaptation is its local nature. CRM or adaptation processes require ownership by communities, not only their authorities, for successful implementation. Such ownership is strongly connected with the perception that individuals have about the risks, the current impacts over them and how they are able to affect their integrity and progress. To encourage this perception, climate risks must be clearly identified and presented to communities, and this information must be validated with local data, information and local community feedback with experiences of how the population has coped with recent climate impacts. Setting up practices and mechanisms for coping with climate variability in the here-and-now is an important step in preparedness for future climate changes. NMHSs are important partners for providing such local climate and meteorological information to inform adaptation. Given a local perception of climate risk, it is easier to generate adaptation strategies and solutions with the community and negotiated with the authorities, and implement action plans designed by the community. Particularities in local plans are key points from the cultural and social point of view. By adopting a local focus to CRM, adaptation is necessarily a bottom up social construction implemented by local communities.

Past experience in capacity development for CRM suggests that providing a single recipe to conduct capacity development efforts has limitations. Some principles for a more comprehensive and effective approach, based on good practice, are therefore proposed as guidance:

- Consider sustainability of capacity development through continual rotation of technical staff in national and local agencies;
- Design training strategies under a “train the trainers approach”;
- Prepare educational material combining scientific and indigenous knowledge;
- Ensure a robust institutional and stakeholders network to support the capacity development process (with multi-level stakeholder coordination and communication);
- Consider blended training courses, with both face to face activities supported by e-learning systems;
- Implement accountability mechanisms for both capacity development implementers and beneficiaries;
- Ensure an effective and long-term monitoring and evaluation mechanism involving national and local institutions;
- Keep accessible databases of people trained and the impact of the capacity development in their current activities;
- Develop a long-term strategy for education (alongside shorter courses), such as the 5-year Climate Change Adaptation Degree and Master of Science (integrated) programme including agriculture, animal sciences, fisheries, forestry, biodiversity, water resources, health which has been launched by Kerala Agricultural University, India;

- Co-share capacity development efforts with beneficiaries;
- Encourage allocation of financial support from national, local or private stakeholders to support CRM capacity development;
- Develop the capacity of information providers to deliver improved information, services and products, through, for example, improving the observing networks and climate risk modeling capability.

2.5. Monitoring, evaluation and improvement

Monitoring, evaluation and improvement are important elements in CRM. Monitoring could cover organizational, financial, operational, political, regulatory and other issues. It is required to collect relevant information and data to help quantify the risks, and to assess the success (or not) of adaptation or other interventions. Evaluation is the means by which the accomplishments are compared with the expected goals and what improvements are required to complete the iterative cycle proposed for CRM, within which there is an implicit assumption that progress should be continually sought.

Before implementing any monitoring, evaluation and improvements for CRM, some key indicators should be set up. It is unlikely that one single indicator can be identified to monitor all the risks (hazards and vulnerabilities) necessary to monitor the CRM process. However, to be practical, a few key indicators should be identified with the following attributes - quantitative (e.g: number of victims and cost of impacts), quality controlled based on standards (e.g: ISDR guidelines for design of EWS), and time limited.

The monitoring, evaluation and improvement step enables key oversight bodies (such as a NHMS, a regional health organization or other stakeholder) to track progress against initial conditions, and assess areas where corrective action is required. It can also be an important tool for the pursuit of resources to address gaps and deficiencies in the process, and to facilitate the dialogue between the relevant stakeholders in the risk management process at various levels, which is an essential part of a feedback loop between relevant stakeholders. Through this step the focus is kept on results – on reaching the desired goals – as well as on continual learning. It must be flexible, allowing for and even anticipating new challenges or opportunities, or new methods and understanding in the theory and application of CRM.

3. Role of early warning systems and adaptation planning within the context of disaster risk reduction and CRM

"Neither society nor the environment are static. Consequently, neither is the risk" (Alan Lavell)

It is clear that CRM may encompass a wide range of temporal and spatial scales, depending on the nature of the risks and their socio-economic context. Both climate and disaster risk are considered as some integration of hazards, vulnerabilities and exposures (see Section 1), and EWSs may be integral to the adaptation measures used to manage these risks. An important concept for Disaster Risk Reduction (DRR) taken from ISDR Glossary, 2009³⁶ concerns "the risk of disaster", which is usually expressed as 'the probability of life loss or

property destruction or damage in a given period of time'. The action of DRR usually refers to the socio-economic objective of reducing that risk. In comparison, CRM is focused more towards the longer-term application of climate information and tools in a multidisciplinary scientific context to address both the positive and negative impacts of climate variability and change on society, infrastructure and life. The concepts of DRR and CRM are therefore complementary, both including a focus on risk management, and there are mutual advantages involved in designing integrated DRR and CRM projects.

If the integration requirements of DRR and CRM are considered according to impact scales (local, regional or global), it is clear that even if some climate phenomena relate to global causes they are materialized through locally-specific contexts, causing damage or losses depending on existing capacities in those local areas. Hence, the need to focus on improving the management capabilities of both DRR and CRM is especially important at local scales. Early Warning Systems (EWS) are often central to DRR and CRM, particularly over relatively short time scales (minutes to weeks), whereas other systems and tools that focus on longer-term adaptation planning tend to be more appropriate for CRM at longer time scales (months to decades). All such measures have the common aim of reducing vulnerability, increasing resilience and improving response capacities of people, economies and ecosystems at risk.

The UN International Strategy for Disaster Reduction (UNISDR) defines early warning as "the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response". Governments often maintain EWS to warn their citizens and themselves about impending hazards, resulting for example, from health, geologic, or climate and weather-related drivers. Traditional assumptions are that effective functioning of EWS requires only prior knowledge of risks faced by communities and other users of the early warning information. Under a CRM framework EWSs are expanded to other adaptation planning measures, including technical monitoring and warning services for highlighting the risks and their potential impacts, effective strategies for dissemination of understandable warnings to those at risk, and finally, knowledge and preparedness to act³⁷. Two additional elements have been introduced, 1) awareness that risks are changing (and which new risks may arise) and, 2) the need for constructing and communicating new knowledge about future conditions that can be understood, trusted and used^{38,22}. One goal is to be prepared to use windows of opportunity for engaging and providing leadership, and for legitimizing risk management and successful communities of practice that have arisen during but also between events.

Given the links between near- and long-term climate variability and change, the early warning construct also applies to more extended timescales. For example, WMO 'Climate Watch' systems utilise near real-time and historic climate observations with proactive mechanisms for interacting between users and NMHSs to provide alerts on major climate anomalies and extremes (see http://www.wmo.int/pages/themes/climate/climate_watch.php). Improving the institutional organization of the EWS as well as the associated strategic response to crises are closely linked to developments in understanding of climate

vulnerability and governance^{39,40,22}. Countries or regions that have developed such systems may also use them to develop and inform strategic adaptation response options to climate changes, thus developing broader institutional flexibility and preparedness, and reducing societal vulnerability.

For most locations early warning is still a linear process based on a “sender-receiver” model of risk communication. In this section, the term “early warning information system” is used to describe the more integrated process of risk assessment, communication and decision support, of which an “early warning” is a central output. An early warning information system involves much more than development and dissemination of a forecast, it is the systematic collection and analysis of relevant information about and coming from areas of impending risk that: (a) Informs the development of strategic responses to anticipate crises and crisis evolution; (b) Provides capabilities for generating problem-specific risk assessments and scenarios, and (c) Effectively communicates options to critical actors for the purposes of decision-making, preparedness and mitigation. Central to the implementation of this more comprehensive vision of “early warning information systems” is a detailed examination of the root causes of the lack of early action⁴¹.

Numerous international and national EWS’ exist ^{42,43,44}. In addition, many early warnings directly and indirectly activate other warning systems in affected sectors and communities, a process that has been referred to as a cascade of early warnings⁴⁵. For the most part, EWS’ have been interpreted narrowly as technological instruments for detecting and forecasting impending hazard events and for issuing alerts. This interpretation, however, does not clarify whether information about impending events is actually communicated and used to reduce risks^{44,22,46}.

An example of good practice with an EWS is provided by the Climate Forecast Application in Bangladesh (CFAB) project. Heavy rainfall episodes in the Ganges-Bhramaputra basin (combined drainage area ~1,662,000 km²) cause human suffering almost every year. Webster & Hoyos (2004)⁴⁶ showed the possibility of using physically based statistical schemes to predict rainfall with lead times of more than 10-days in the monsoon region. Based on this and subsequent research the CFAB project, supported by Office of Foreign Disaster Assistance of the United States Agency for International Development (USAID/OFDA), was launched during the monsoon of 2003 and 2004. Long-lead forecasts for rainfall in the river basin were given using the UK-based European Centre for Medium Range Weather Forecasts (ECMWF), Tropical Rainfall Measuring Mission (TRMM) and other datasets⁴⁷. The Program was a collaboration (see Fig. 2) of the following agencies: Atmospheric and Oceanic Sciences at the University of Colorado, Boulder, Georgia Institute of Technology, ECMWF, Bangladesh Meteorological Department (BMD), Bangladesh Flood Forecast and Warning Centre (FFWC), and Asian Disaster Preparedness Center (ADPC) in Thailand. Coordinated efforts by ADPC, BMD and the Institute for Water Modeling (IWM) resulted in the development of 1-10 day discharge forecasts at major stations of two rivers (Hardinge Bridge, on the Ganges and Bahadurabad, on the Bhramaputra). The FFWC was responsible to produce local-level forecasts in other locations along these rivers. The Center for Environmental and Geographic Information Services (CEGIS)⁴⁸ disseminated flood forecasts

to communities during the monsoon season, working in close coordination with the Disaster Management Bureau (DMB) and the Department of Agricultural Extension (DAE). With the additional lead times and tailored warnings, community level flood risks were better managed. Communities were able to mobilize in advance (e.g. move livestock to higher ground, secure their fishing nets) in order to protect their livelihood assets. The project ran a second phase from 2006 to 2009 with support from USAID Bangladesh through CARE-Bangladesh. The objective was to transfer technology from the USA to Bangladesh and to build the capacity of national and local institutions for a sustainable end-to-end generation and application of flood forecast products in high-risk locations.

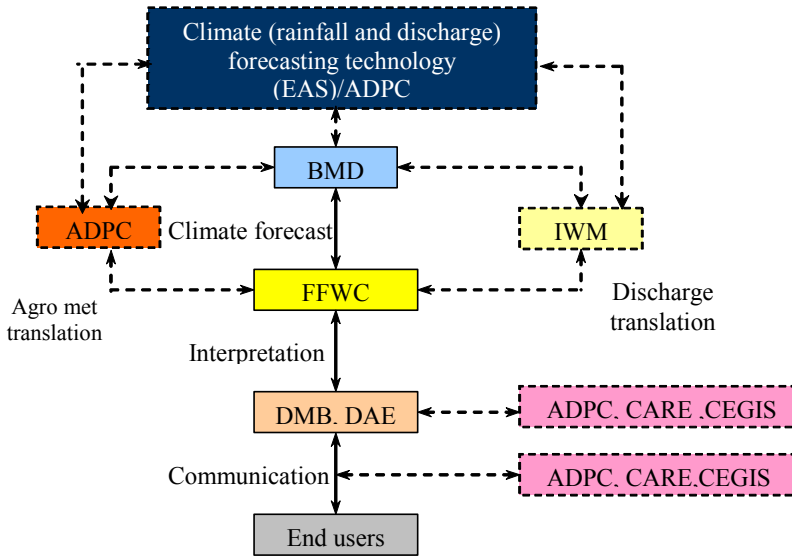


Figure 2. Institutional linkages for 1 to 10-day forecast of rainfall in Climate Forecast Application in Bangladesh (CFAB) project. Solid lines denote forecast/product flow and broken lines indicate coordination between the institutions: Asian Disaster Preparedness Centre (ADPC); University of Colorado; Georgia Tech – Earth Atmospheric Sciences (EAS); Bangladesh Meteorological Department (BMD); Flood Forecasting and Warning Centre (FFWC) of Bangladesh Water Development Board (BWDB), Disaster Management Bureau (DMB); Department of Agricultural Extension (DAE); Center for Environmental and Geographic Information Services (CEGIS); and CARE Bangladesh.

The disaster research and emergency management communities have shown that warnings of impending hazards need to be complemented by information on the risks actually posed by the hazards and likely strategies and pathways to mitigate the damage in the particular context in which they arise. Effective “early warning” thus implies information is introduced into an environment in which much about risk and vulnerability is assumed⁴⁹. Vulnerability analysis provides a contextual basis for early warning by identifying structural, water, energy, and food insecurity attributable to disruption of primary means of access including informal community safety nets⁵⁰. As is long-recognized by the disaster, food and water security communities, and more recently the climate adaptation research

communities, successful early warning information systems integrate "input" and "output" indicators. Input indicators include measures of production potential, including rainfall, soil conditions, heat and crop and livestock growth. Output indicators include nutritional indices, behavioral indicators, and signals of economic activity, that deal with the food, water and other supply situations or changes in demand that result from scarcity⁵¹. The timing and form of climatic information (including forecasts and projections), and access to trusted guidance to help interpret and implement the information and projections in decision-making processes may be more important to individual users than improved reliability and forecast skill.

Experience provided by the U.S. National Integrated Drought Information System (NIDIS) and the United States Agency for International Development (USAID) Famine Early Warning System (FEWSnet) drought early warning information systems developed in the USA has led to the following recommendations for developing EWS:

- Develop a Governance structure.
- Frame the goals and objectives of international and country and intervention strategy from a securities perspective (water, food etc), e.g FEWSnet, NIDIS.
- Strengthen the scientific and monitoring foundations to support early warning.
- Specify of reliable information provided by forecasts, especially for key climate features i.e. ENSO.
- Improve understanding of the modulation and combined impacts of interannual and decadal-scale variations on agricultural and meteorological drought duration and severity.
- Place multiple indicators within a statistically consistent triggering framework-cross-correlation among units for rapid transitions (e.g. climate and vegetation mapping) before critical thresholds are met from onset to severity.
- Develop risk and vulnerability profiles of drought-prone regions and locales including impact of climate change adaptation interventions on food and water availability, access, and use.
- Develop indicators and methodologies to assess the risk to environmental services, value and costs of environmental degradation, and impacts of water and crop subsidies.
- Inventory and map local resource capabilities (infrastructure, personnel, and government/donor/ngo-supported services) available to complement food and water program operations.
- Conduct gaming scenarios with planners and decision makers for selected past and projected events to:
 - Improve understanding on whether and how best to use probabilistic information with scenarios of potential surprise and cumulative risks at each scale.
 - Map decision-making processes and identify policies and practices that impeded or enable the flow of information among information system components.

The NIDIS and FEWSnet experience also provides a good example to demonstrate that successful drought early warning information systems have explicit foci on: (1) integrating

social vulnerability indicators with physical variables across timescales, (2) embracing risk communication as an interactive social process and, (3) supporting governance of a collaborative framework for early warning across spatial scales⁴⁶. Forecasts need not be perfect to make early warning useful. For longer-term EWS, it is also important to note that although a trend in the drought-based indicators may serve as a warning, the actual point of transition or threshold (e.g. dune mobilization) to increased severity remains difficult to predict.

Traditional warnings, with justification, remains an important source of climate information in many rural communities. At the community level, farmers in Zimbabwe and Malawi have identified local language radio programs as credible and accessible mechanisms to deliver forecasts if they occur with follow up meetings with extension agents or other intermediaries⁵². Internet based tools, such as Google maps, and graphical tools are already being used for participatory, large-scale information development. However, these tools are inherently limited in communicating the relevant local context and the consequences (positive and negative of information use). For most locations, the governance context in which EWSs are embedded is also key. The links between the community-based approach and the national and global EWSs are weak at present⁵³. Improving the complementarity and legitimacy of both approaches is a new challenge to address especially in developing the institutional foundations for global climate early warning information systems envisioned by the Global Framework on Climate Services (see section 1. Introduction).

There is a critical need to approach and support early warning through DRR and Climate Change Adaptation (CCA)^{54,22}, and the overarching processes involved in CRM. This requires a framework that uses climate change scenarios not above but within risk and vulnerability profiles, thereby capturing the nature of capabilities and decision-making networks. These form the basis for effective EWS design and implementation. The cases above, and other efforts, have demonstrated that social protection and early warning information interventions can provide DRR while helping to meet the goals of adaptation to changes in extreme events. Furthermore, sustainable development prospects are very dependent on the effectiveness of the many networks of EWS⁵⁷. In these networks, subtle rules of interaction emerge that shape the context in which resource-related decisions are taken, and the rules are negotiated and made^{55,56}.

To ensure that DRR and CRM are integrated utilising appropriate systems, information and tools, some transversal capacities need to be established between the scientific community studying and analyzing the climate information (at timescales relevant to both DRR and CRM), and the decision-makers who are required to consider the full spectrum of the impacts of climate variability and change. Decision makers across all facets of society also need to be aware of the changes, risks and impacts threatening their societies and find appropriate ways to adapt to and protect these from the most damaging changes. They should also consider climate as a resource, with beneficial aspects that can be exploited, through application of timely and appropriate climate information, tools and products.

4. Case studies demonstrating effective CRM practices

CRM is designed to be a practical process to be implemented on the ground. People, policies, environmental issues, governance, information, cultural aspects among other elements should be organised to communicate in an appropriate manner to deal with extreme weather- and climate-related risks. There is no single CRM solution for a particular situation in any part of the world. However, over time, there are increasing success stories demonstrating good practices for a wide range of CRM situations. The following case studies are examples of such good practice in CRM for different locations and development sectors.

4.1. CASE STUDY 1: Using probabilistic seasonal forecasting to improve farmers' decision in Kaffrine, Senegal (Ousmane Ndiaye, Robert Zougmore, Jim Hansen, Aida Diongue, El Hadji Seck)

Although agriculture and pastoralism occupy 80 per cent of the population in the Sahel, climate information is not yet widely integrated into farm management decision systems. However, many efforts have been made in the region to produce climate information such as the yearly climate outlook forum preceding the incoming rainy season⁵⁷. Yet, this hasn't benefitted the user community, particularly the most vulnerable to climate variability and change. This paper documents one ongoing demonstration project in Kaffrine, Senegal, within the peanut growing basin, where rural communities, policy-makers and relevant institutions are testing the use of probabilistic seasonal forecasts for managing climate risk. The process, from training the farming community to evaluating the use of the forecast information, is outlined.

4.1.1. Background

Rainfall in the Sahelian region of West Africa experiences strong variability over time-scales ranging from intra-seasonal (including long dry spells and false onset) to inter-annual and decadal. At the longest time scale, climate change is shifting the desert boundary and altering the landscape. This strong variability has an impact on many sectors, including health, agriculture and water management. The major impacts of climate variability in this region make CRM an imperative for the livelihoods of Sahelian communities. Each time scale of variability requires a specific climate risk plan.

As is the case in most French colonized countries in Africa, ANACIM, the national weather service of Senegal, is in charge of providing meteorological services to the country. ANACIM, in partnership with the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS), initiated a pilot project in 2011 to test the usefulness of probabilistic seasonal forecast information to peanut farmers in Kaffrine. In addition to ANACIM, the key stakeholders participating in the project include local government technical services, local farmers and NGOs. A big challenge in the training was to go through many key and important steps in achieving good CRM, including producing

skillful seasonal forecasts at district level, presentation of probabilistic seasonal forecasts using easy-to-understand terminology, training farmers with the new information for them and translate this into decisions. This study concludes with lesson learned during the initial year of the project.

4.1.2. *Building trust*

The approach used in the project was to help the various stakeholders identify strategies for successful CRM using seasonal forecasting. The project sought to build the trust of farmers, while working with all relevant local organizations. In West African's culture, trust is the most important requirement in order to be effective in a viable partnership. A common saying states, "the manner to give is better than what is given". In order to build trust with farmers and foster a sustained relationship, a workshop that included 30 farmers from 6 villages around Kaffrine was planned. Since ANACIM does not have the legal mandate to implement any agricultural strategy, partnership with the local agriculture department representative (SDDR) was ensured. The SDDR has the mandate to monitor activities related to the farming system, and also has arbitration authority in case of conflicts over issues such as farm allocation, fertilizer subsidizing, buying harvest products. SDDR was a natural contact point with farmers, since they had already developed a long time partnership and has their trust. It was very important that the project team not appear as a stranger in the system, but work through a known entity. Association was developed with other local technical services including agricultural advisers from the national agency for agricultural and rural advice (ANCAR), which has a presence nationwide at district level and a mandate to advise farmers in term of agricultural strategies. Volunteers from World Vision, a Christian charity that assists children and invests a lot in agriculture in the district of Kaffrine, also participated. Participants included individual farmers, and members of farmer organizations such as JAPPANDO. Women represented about 30 per cent of those participating.

4.1.3. *Training*

Consistent with the strong oral tradition, time was reserved during the workshop to allow farmers to interact with the experts team. On the first day of the workshop, the floor was given to farmers to describe their experiences with forecasting the weather and climate. The technical experts started with differentiating the concepts of weather (imminent) and climate (longer term), as these concepts are interchangeable in the local language.

4.1.4. *Connecting with farmers' indigenous knowledge*

A challenge for the CRM approach was to enable farmers to trust and use scientific information. There was a clear need for a common ground, where farmers would use the new scientific seasonal forecasting approach proposed to them without feeling that their indigenous approaches to seasonal forecasting were being rejected. In this culture, the scientists would lose credibility if the farmers were to think the scientists were saying that

their elders were wrong and only the scientists were right. The strategy was to listen to them and understand the aspects of their traditional knowledge that might be climate related. The farmers were welcomed as guardians of knowledge passed from generation to generation, and invited as experts to share their indigenous climate knowledge. According to their tradition, being elder means possessing wisdom. The farmers were asked to specify whether each indicator was for immediate weather, or for climate conditions for the upcoming season. Some of the indicators were clearly just coincidental events with no apparent link to the climate, but many were very much related to climate and specifically with the high humidity and high temperature associated with the monsoon system (Table 2). After carefully listening, the scientists acknowledged the farmer’s memories and explanations.

Climate variability	Indicators
Onset of the rainy season	When the wind changes direction to fetch the rainfall Apparition of stars shaped as elephant Birds crying as if it calls men to go to field and woman to stay at home Early flowering of many trees species: Néré, dimb, tamarinier, sone Butterflies and libellees are numerous Some persons feel heavy in their body Hot night time
Major rainy event	When wind is shifting direction When dark clouds become white
Good rainy season	When snakes and frogs are more numerous than usual The shooting star direction indicates which zone will receive excess rain this year Net appearance of seven stars in the sky
Good cropping season	When the rain is settled in June the 24 th and we start the millet around the 14 th of July we can expect good harvest
End of the season	When frogs start chanting When the sky is high When we observed dew in the morning

Table 2. Quotes from farmers on their perceived climate variability indicators

4.1.5. Explaining the basis of seasonal forecasting

Another challenge was how to explain to farmers, in easy-to-understand terms, how climate forecasts work. Many farmers knew about weather forecasts, communicated through the weather bulletin on national TV. But the real challenges were to convince them that the rain could be forecast one to two months ahead, and to help them to understand the probabilistic nature of forecasts at this lead-time. The basis of seasonal forecasting was explained to the farmers by calling upon their intuition. When asked, “When it is hot, why do people go to the beach?” they responded that the sea breeze brings fresher air. They were then asked,

“Then why? Isn’t it the same sun that heats both land and ocean? Why then does the ocean get cooler in summer?” It was explained that ocean has better memory of the past compared to the continent. Ocean remembers the heat of the past days and weeks. That’s why, on a very hot day people go to the beach to benefit from ocean memory of the past weeks. Similarly, when it is cold, the ocean still remembers recent warm days. The ocean’s heat memory is the basis for seasonal forecasting. As rain comes from clouds, clouds come from water vapor, and most water vapor from the ocean, they could see how ocean temperature could control rain. The farmers were also informed that satellites are used to monitor ocean temperature throughout the world, and computers quantify the likelihood of rain in Senegal. This very simplistic explanation helped them to make sense of scientific seasonal forecasts, and was sufficient to convince them to trust the forecast during this first contact.

4.1.6. *Getting past the technical language barrier*

The next challenge was to explain the probabilistic nature of the forecast, which is less intuitive than a deterministic rainfall amount. To start with, the farmers were asked to recollect from their memory the last 5 rainy seasons and rank them from the wettest to the driest. With a pluviograph (Fig. 3), it was explained how rainfall is recorded in millimeters, and what 1mm of rain means. One mm of rain was poured into the soil, then the farmers were asked to compare it with the quantity of rain that they consider sufficient to plant their crops. They indicated that they plant when the soil wetting front is greater than the span of an average man’s hand. To help them interpret what a seasonal total means, a discussion was held on how the temporal distribution of rain relates to the seasonal total. It was clear for the farmers that a seasonal forecast gives an idea of the total, but no information about its distribution in time. One farmer explained the difference between a good rainy season and a good cropping season, which was a clear indication that they understood the seasonal forecast output. The farmers were informed also what could potentially be forecast and what could not.



Figure 3. Training farmers to read a rain gauge.

4.1.7. Probability of exceedance graphs

It was decided to express the forecast as a probability of exceedance of rain instead of the probability of occurrence of the three tercile categories that meteorological services in West Africa officially issue in their seasonal forecasts. Farmers understand the notions of uncertainty and probability, but understanding and acting on formal probability formats is challenging. To help them understand the new probability of exceedance format, an exercise of classifying the last 5 years of rainfall that they recollected from memory was conducted (Fig. 4). A chart of 30 years of Kaffrine rainfall data was provided. The farmers could see that it is very likely that they would get at least as much rainfall as the driest year, and very unlikely that they would get more than the wettest year. The middle years represent “normal” conditions. How to identify the 25th, 50th and 75th percentiles of rainfall from the graph was discussed. The idea that a dry forecast would shift the distribution toward the left and wet forecast to the right was introduced. Hypothetical wet and dry forecasts were discussed until the farmers appeared to understand what they meant. As the probability of exceedance is a cornerstone of the training, the farmers were divided into four groups. Two groups were given probability of exceedance forecasts for hypothetical dry years and the other two groups were given hypothetical wet years. The farmers were asked to discuss what they would do differently if this were the actual forecast for the upcoming season. Each group reported back on their forecast and strategies. The whole group was encouraged to comment on these strategies.



Figure 4. Farmers sorting seasonal rainfall.

4.1.8. Communicating the forecast

After the training, the next step was to build a communication strategy to ensure that the information will reach the farmers effectively. A discussion of the best way to communicate the seasonal forecast revealed a number of options. Among the means identified, cell phones appeared first as a cheap technology. This option is accessible, since most of the farmers have a cellular phone, and is consistent with the traditional use of oral communication. Local radio was the other promising means of communicating forecast information. All of

the participating farmers listen to the radio, but the listening quality of the radio is very poor when they are on the farm. Some NGOs and farmers association leaders recommended e-mail as a possibility. The administrative authority who was present mentioned the government's network of heads of village. In case of an extreme event, this can be used to reach each village within an hour. The local authority showed his support and promised to help with access to this facility. To avoid conflicts between farmers' organizations, other farmers recommended sending the information through the SDDR, who knows how to contact them.

4.1.9. *From theory to practice*

A week after the training work, ANACIM sent a group of experts to call a meeting to communicate the actual July-September 2011 seasonal forecast with the farmers. Twenty-two attended. Some key points from the training were revisited: good rainy season versus good cropping season, probability of exceedence interpretation, plausible management response strategies, definition of 1mm. Rain gauges were distributed to some representatives of farmers' organizations who expressed need for this tool, and the meaning of a millimeter of rain was again demonstrated. The forecast was presented with an explanation on how to interpret it (Fig. 5). The forecast in this case was "normal to above-normal." As the year before, 2010, had been exceptionally wet – the highest on record – it was indicated that rainfall this year (2011) would probably be less than 2010. Some explanations about what the seasonal forecast did not say were also offered. Recommendations on any particular management strategies were not made, but rather it was left open to each farmer to decide. Considering that this was a first contact with them, it was preferred to build trust first before offering recommendations.



Figure 5. Training on interpreting the probability of exceedance.

4.1.10. *Keeping in touch*

Through this project, funds were available to undertake two field visits during the season, and also to call selected farmers from time to time. When the first big rainy event occurred, some farmers were asked if they planned to use the seasonal forecast, whether they spread

the word, how the rain was, etc. It was not a forecast but rather a monitoring exercise. It was good to touch base. During the first field trip in selected villages (October 12-13 2011), some farmers made major decisions, such as borrowing money from the bank to invest more in their farm, or hiring workers. Another field visit was made around the end of the cropping season (October 18-22, 2011) to conduct surveys on expected yield.

4.1.11. Evaluation of the seasonal forecast

In January, three months after the rainy season, when farmers have sold their crops and finished their farming work, an evaluation workshop was organized in Kaffrine to assess the use and usefulness of the seasonal forecast strategy. Local extension services were present, as well as farmers' organizations. Fifteen of the farmers who attended the training workshop in June were invited back, along with 13 other farmers who hadn't received information about seasonal forecasting. During the January workshop, participants assessed both 2011 seasonal rainfall and the performance of various crops grown in the district. The participants took the opportunity to discuss in three groups, and interpret the information presented. One group included 12 farmers that had received the forecast and adjusted some decisions in response to the forecast (group I). The next groups included 3 participants who did receive the forecast but didn't make any adjustment to their farming practices (group II), and the last group consisted of 13 farmers who had never received any climate forecast information (group III). They were asked to document actions taken, problems encountered, and recommendations. Group I understood from the workshop that a short cycle crop was suitable because the season was to be less than 2010, but rainfall would be enough. The main problems they listed were: the high spatial variability of the rainfall, the late occurrence of the first rainfall which made it difficult to judge when to start planting, a long dry spell, and early termination of the season. They wanted to know or get: the starting date, finer forecast information in space, a weather bulletin each two weeks, and more training to better understand the forecast. Group II did not use the seasonal forecast because they had already bought their seeds at that time which made it difficult to change any of their farming strategy. Group III, who had never received any climate information, indicated that they had thought 2011 would be like 2010. They missed the opportunity of a long season in 2010, and were prepared to catch up the next year by choosing a long cycle variety, buying fertilizers and hiring wage laborers. The group members concluded that their problem was that they didn't know anything about the course of the rainy season and needed to be part of the group that received seasonal forecast training.

4.1.12. Lesson learned and way forward

The Workshop participants were given the chance to evaluate the whole process – from farmer selection, to organization of the workshop, to training agenda – in order to identify what is needed for improvement. There is a need to improve the communicating system by using already existing channels. World Vision recommended that training more trainers

would be the best way. Overall, the farmers appreciated the experience of last year and welcomed more training.

Seasonal climate forecasts could have considerable potential to improve agricultural management and livelihoods for smallholder farmers. But constraints related to legitimacy, salience, access, understanding, capacity to respond and data scarcity have so far limited the widespread use and benefit from seasonal predictions in the Sahel region. The existing constraints reflect inadequate information services, policies or institutional processes in the region. However there is great potential to overcome these constraints. An approach is suggested that packages: i) seasonal and onset forecasts, ii) opportunity for farmers to implement strategies, and iii) insurance tools in case of extreme variable or dry years. Even when the seasonal rainfall or onset matches the forecast, poor farmers wouldn't profit if they don't have access to funds or crop varieties to implement any forecast-based strategy. And it turns out that in Kaffrine, there is often false start of the rainy season, making it imperative to provide farmers with alternatives, for example through index insurance.

As work with farmers in Kaffrine on the forecast continues, research is being conducted and a working group on improving prediction of intra-seasonal variability has been set up. Crop producers and seed bank will be invited into the process, to allow farmers to access suitable varieties for forecast-based strategies. There is some work on index insurance in the region, and it is planned to reach out to involve such groups in this effort. Through this approach it is hoped to gain success, avoid frustration and build long-term partnerships.

4.2. CASE STUDY 2: Climate risk management of plantation crops in the humid tropic region of Kerala, India (G.S.L.H.V. Prasada Rao)

The global economy has adversely been affected to a considerable extent due to weather related disasters which are not uncommon in the recent past. It is true in the case of the Indian economy too. The year 2010 was the warmest year ever recorded, followed by 2009 in India.

Climate model simulations indicate that a marked increase in rainfall and temperature over India could be seen during the current century. The maximum expected increase in rainfall is likely to be 10-30 percent over central India, with temperatures projected to increase between 2 and 3°C by the end of the 21st century.

More frequent storm surges and increased occurrence of cyclones in the post monsoon period, along with increased maximum wind speed are also expected along the coastal belt. As a result, the occurrence of floods and droughts, cold and heat waves and sea level rise may adversely affect the food security to a large extent across India, as seen in 2009, 2002 and 1987. Such impacts also influence plantation crops, which are predominantly grown in the humid tropics like Kerala, in the southwest of India (between latitudes

8°15'N and 12°50'N and longitudes 74°50'E and 77°30'E). The location map of Kerala is given in Fig. 6.



Figure 6. Location map of Kerala. Source: www.mapsofindia.com

4.2.1. Rainfall and thermal regimes of Kerala

The annual rainfall across Kerala is highly variable, averaging about 3000mm, but varying between less than 1000mm to greater than 5500mm.

Seasonally, rainfall is bimodal, due to the influence of both the summer and winter monsoons, with maximum monthly rainfall (>600mm) during the summer monsoon in June and July, and winter monsoon rainfall (200-300 mm) during October. Heavy rainfall during the summer monsoon, followed by a prolonged dry spell is a characteristic feature of the humid tropics, which is particularly prominent in the case of the northern districts, including Kasaragod, where the influence of winter monsoon is negligible (Fig. 7).

Annual average surface air temperature varies between 25 and 30°C, with a seasonal range between around 18°C in winter and 35°C in winter. The altitude across Kerala varies from

below mean sea level to above 1500m, and temperature varies significantly with altitude. Accordingly, a sequence of crops is grown across the altitudinal range (see Table 3).

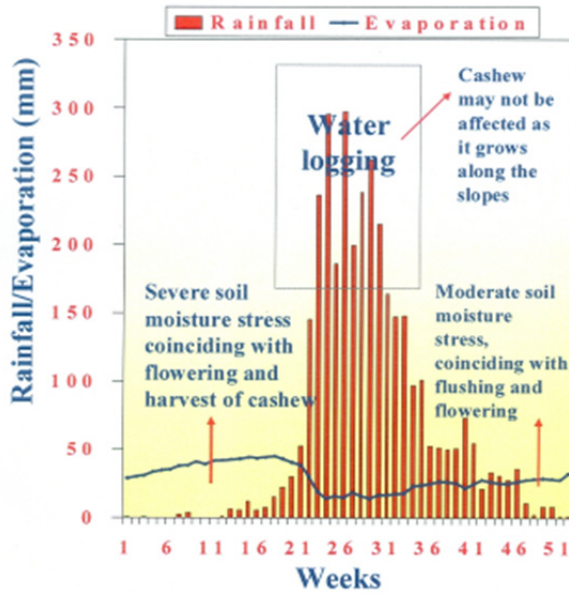


Figure 7. Mean weekly rainfall and pan evaporation at RARS, Pilicode, Kasaragod District, Northern Kerala, India.

Class	Region	Temperature conditions	Altitude (amsl)	Crops
Mega-therms	Low land	High to Moderate temperature throughout the year	0 -10 m	Coconut, arecanut and cashew
Meso-therms	Mid land	Moderate temperature throughout the year, winter temperature relatively low	10 -100 m	Coconut, cocoa arecanut, rubber, cashew and black pepper
Micro-therms I	High land	Moderate to Low temperature throughout the year, winter temperature low	100 -500 m	Rubber, coconut, cashew, arecanut and black pepper
Micro-therms II	High land	Low temperature throughout the year	500-1000 m	Coffee (arabica), rubber, arecanut and black pepper
Micro-therms III	High ranges	Low temperature throughout the year, winter temperature is occasionally goes below 0°C	1000-2500 m	Tea, Coffee (arabica) and Cardamom

Table 3. Altitudinal sequence of crops in Kerala.

Since rainfall is abundant during the monsoon season, surplus water during the first crop season leads to waterlogging which is detrimental to crop growth. In comparison, the second and third crops often suffer from soil moisture stress, and crop failure is a common phenomenon if irrigation is not assured. Erratic rainfall distribution during the monsoon, coupled with failure of the northeast monsoon, may result in drying up of surface reservoirs during summer, which are the major water resources in the region. In recent years, meteorological droughts during the monsoon and summer droughts are not uncommon across Kerala, with the summers of 1983 and 2004 particularly prominent (Fig. 8).

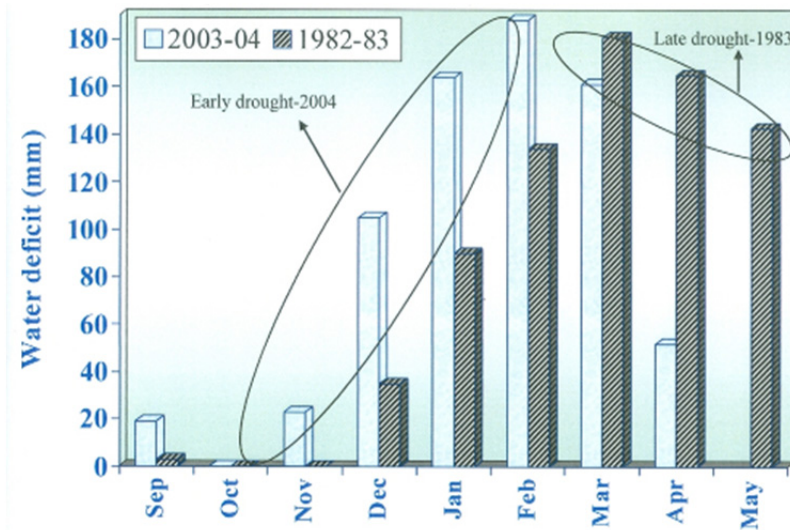


Figure 8. Water deficit in Kerala from Sept to May 1982-83 and 2003-04.

4.2.2. Impact of summer drought on plantations

The prolonged summer droughts, coupled with high temperature and low atmospheric humidity, in Kerala during 1983 and 2004 adversely affected production of many plantation crops, particularly rainfed coconut palms, arecanut, cardamom, coffee and black pepper and as a result the economy of the state was impacted. For example, monthly nut yield declined by up to 50 per cent (depending on management practices) in the year following drought, cardamom yield reduced by 30 per cent in Idukki district and several black pepper gardens were wiped out in Wayanad district. Cocoa yield was also adversely affected due to high temperature in the absence of soil moisture. The impacts of these droughts on the agriculture and economy of Kerala highlighted the need to manage the risks posed by climate variability and change in this region, including other climate hazards such as floods, cold temperatures and heat waves). Various measures are now in place and being developed to pro-actively manage these risks, particularly at local levels. In the next section two of these measures are highlighted: 1) Scarce water resource management specifically through effective management of irrigation; and 2) Weather forewarning and dissemination.

4.2.3. Climate risk management

Scarce water resource management – irrigation: Management of irrigation during the summer months under scarce water resources is one of the key tools available for managing the adverse impacts of summer drought on crops. Various methods can be used to assess the irrigation requirements for different crops and time periods throughout a season, e.g. estimate weekly water deficit/surplus by taking the difference between weekly rainfall and open pan evaporation, or through calculations of potential evapotranspiration.

In the RARS, Pilicode location of Kerala, the irrigation requirement for coconut was estimated using the FAO's CROPWAT decision support tool for estimating crop irrigation water requirements based on soil, climate and crop data (see: http://www.fao.org/nr/water/infores_databases_cropwat.html). According to CROPWAT, the monthly average irrigation requirement for coconut in this region varied from 1106 litres/palm/month in December to 1488 litres/palm/month in April. The total irrigation requirement from December to May was estimated as 7807 litres/palm (Table 4). These values have provided guidance to coconut growers in the region on the general amount of irrigation water required to improve yield during average summer months.

Month	ET _o (mm)	Water requirement (mm) (ET _o × 0.75)	Irrigation requirement (l) (πr ² h)
December	3.79	2.84	1106
January	3.95	2.96	1154
February	4.56	3.42	1204
March	5.01	3.76	1464
April	5.26	3.95	1488
May	4.76	3.57	1391
Total			7807

ET_o-Reference evapotranspiration; 0.75-Crop coefficient; r-Radius of coconut basin in m²

Table 4. Estimated irrigation requirements for coconut in the RARS, Pilicode location of Kerala.

More detailed seasonal irrigation advice to coconut growers has been provided by field experiments in which coconut palms were either irrigated at a rate 450 litres/palm/week for differing periods between December and May, or irrigated according to a climatic water balance approach, or not irrigated (Table 5). Results showed that the yield improved in all the irrigated treatments when compared to that of pre-treatments yield or no irrigation, as a result of reduction in the duration of water stress. Irrigation applied as per the climatic water balance approach (T6) showed one of the largest percentage yield increases, indicating that the preferred irrigation treatment for coconut yield is as required during the whole summer.

Treatment	Pre-treatment yield (1976-89) (A)	Post-treatment yield (1991-97) (B)	Difference in yield (A – B)	% increase over pre-treatment yield	Whether significant over pre-treatment yield
T1	103	122	19	18.4	S
T2	103	112	9	8.7	S
T3	94	107	13	13.8	S
T4	87	120	33	37.9	S
T5	92	115	23	25.0	S
T7	91	95	04	4.4	S
T6	60	82	22	36.7	S

T1- Irrigating the palms @450l/palm/week during December and January
 T2- Irrigating the palms @ 450l/palm/week from December to February
 T3 – Irrigating the palms @450l/palm/week from December to March
 T4 – Irrigating the palms @ 450l/palm/week from December to April
 T5 – Irrigating the palms @ 450l/palm/week from December to May
 T6 – Irrigating the palms as per climatic water balance procedure (150 l/palm/week in December, 200 l/palm/week in January, 300 l/palm/week in February, 350 l/palm/week in March, 400 l/palm/week in April, 450 l/palm/week in May)

Table 5. Duration of soil moisture stress on coconut yield of WCT.

Agro climatic zonation: Based on climate variables such as precipitation and potential evapotranspiration, the agro climatic zonation can be delineated using the water balance techniques. Such agro-climatic zonation if delineated on crop wise, climatic risks can be mitigated to a considerable extent. In the case of cardamom across the Western Ghats, Zone I & II are superior when compared to that of Zone III, where climate risk is high in terms of high temperature, prolonged dry spells and less length of crop growing season (Fig. 9). Similarly, cashew can be extended from northern districts of Kerala to south of Maharastra along the West Coast and North of Tamil Nadu to Orissa along the East Coast and inland areas away from the Coast. However, tea mosquito bug incidence along the West Coast and cyclones along the East Coast are the constraints for obtaining better cashew production. Similarly, simulation models can very well be used to simulate production potential of various crops in a given watershed area through which the climate risk can be minimized with proper crop management practices. In addition, agroadvisory service based on weather forecasting will go a long way in sustenance of crop production. Another multidisciplinary project launched by the Government of India, that is FASAL, is a classical example to help in GIS based watershed planning in Agriculture as a part of climate risk management.

Weather forewarning and dissemination: A reliable and clearly disseminated weather forecast is a very important tool for forewarning crop managers of potential

weather hazards. The India Meteorological Department is constantly working to improve forecast skill and help disseminate the forecast in a suitable form to aid farm level decisions.

To improve dissemination of weather forecasts in a timely manner to agricultural villages, Village Resource Centres that are linked online to an Agro Advisory Service (AAS) have been established (under the ISRO programme) across the Kerala region. AAS' base their advice on the latest weather forecasts and agricultural expertise. The economic impact of a weekly AAS based on medium range weather forecasting has been assessed for different crops and regions (Table 6). This showed that the percentage increase in yield varied from 6.4 – 19 per cent depending upon the crop in the case of AAS farmers compared to the non-AAS farmers. Furthermore, it indicated that seasonal crops need intensive advisory, followed by less intensive for biennials and perennials.

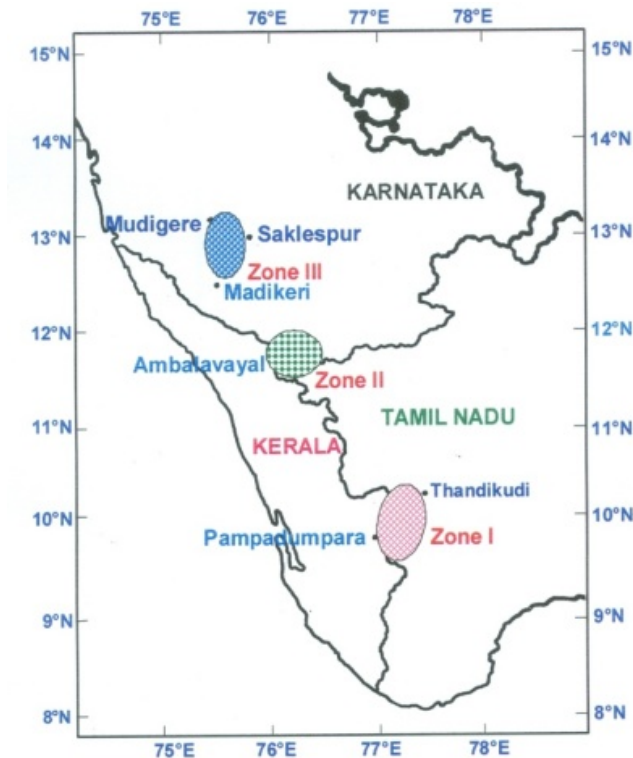


Figure 9. Agroclimatic zones of cardamom across the Western Ghats.

Season	Crop	Yield (t/ha)		% increase over in yield over non-AAS farmers	% increase in net return over non-AAS farmers
Rabi 2003-04	Paddy	3.7	3.0	19.0	30.0
	Banana	31.8	27.9	12.2	11.5
	Coconut*	13460	11025	18.1	13.2
Kharif 2004	Paddy	2.8	2.6	7.1	31.6
	Banana	22.8	20.5	10.1	7.9
Rabi 2004-05	Paddy	3.0	2.7	7.5	34.1
	Banana	31.3	29.3	6.4	11.9
Kharif 2005	Paddy	2.7	2.5	6.5	38.5
	Banana	25.3	22.4	11.2	7.1
Rabi 2005-06	Paddy	3.3	2.9	13.6	36.0
	Banana	27.8	24.5	11.8	12.3
Kharif 2006	Paddy	2.8	2.5	9.0	29.4
	Banana	24.5	21.6	11.9	10.0
Rabi 2006-07	Paddy	3.2	2.9	9.4	34.7

* nuts/ha in the case of coconut

Table 6. Impact of AAS on crop yields from 2003-04 to 2006-07.

4.2.4. Lessons learned

Adaptation strategies and awareness raising are particularly important for managing the risks posed by climate variability and change, not only on crops but also across all sectors that are sensitive to weather and climate. Various agroclimatic techniques have been used in the Kerala region of India to effectively manage some of the risks posed by climate to crop productivity. Expansion and further development of such techniques will be vital for the continued sustenance of agricultural production in humid tropical regions and particularly monsoonal regions. As pointed out by Prof. M.S. Swaminathan “India’s strength lies in its ability to manage monsoons” instead of saying “Indian agriculture is a gamble of the monsoon”.

4.3. CASE STUDY 3: Climate risk management through structural adjustment and regional relocation: A case of rice industry in Australia (S. Mushtaq, G. Cockfield, N. White, and G. Jakeman)

Climate change poses significant challenges to the Australian agricultural sector due to likely increased climate variability and increased frequency of extreme events. Climate change projections suggest that the southern part of Australia will generally become drier, while there is a likelihood of increased rainfall and the frequency and intensity of extreme

events in parts of the north⁵⁸. The possibility of climate change leading to less rainfall in southern mainland Australia, and as a result on-going water policy reforms, has triggered robust CRM strategies by agriculture sector, particularly in the rice industry. The success of any CRM strategy depends on risk management systems that reflect a more detailed understanding of the complexity inherent within human-environment interactions with more reliable future climate information and associated risks. This case study evaluates climate risks strategies employed by the rice industry in Australia.

4.3.1. Climate risk management in rice industry: Challenges and opportunities

The Australian rice industry has a relatively small number of producers, mostly within the Riverina (southern New South Wales), generating considerable export income. The rice industry and rice growers have adopted a risk-averse approach. CRM in the rice industry is based on a systematic process of managing climate and water availability risks to take advantage of opportunities to improve financial, economic, social and environmental systems. The rice processor has a global supply-chain that ensures continuous rice supplies. During years of low water availability, growers trade water and shift to low water intensive or dry land farming. This has resulted in highly variable domestic rice production. Water will probably become more expensive, less available and allocations will be less secure. The production capacity of the domestic rice industry will be significantly influenced by droughts and environmental water buy-backs. One strategy for Australian growers is to increase production in areas like the Burdekin (north Queensland) that have a sustainable water supply.

4.3.2. Evaluating structural adjustment as a CRM in Rice Farming System

Rice farmers are continually faced with pressures to adjust to changing environmental, climatic and economic conditions. Structural adjustments reflect the decisions by rice growers to adjust the size and farming operations to manage climate, environmental and economic risks⁵⁹. The following sections provide empirical evidence of structural change in rice farming.

Farm sizes, irrigated area and rice area: Rice farmers have greater flexibility in farm adjustment and structural change than dryland farmers. This allows them to reduce rice area and maintain farm income from dryland crops. It is hypothesised that increased water scarcity in the Riverina has resulted in an increase in farm size while total rice and irrigated area have reduced. Fig. 10 shows that water availability has a significant impact on rice production and irrigated area and that the total operated farm area is increasing significantly. The increase in farm area can be attributed to the decreasing number of farms and temporary and permanent water trading.

Crop shifting: An assessment of the Riverina (Fig. 11) indicates that farmers are continuously adapting to climate variability and climate change by changing crop mixes and farm restructuring. Rice area per farm is generally declining and being replaced by winter

dryland wheat. Some farmers have adjusted their farming operation by shifting from rice to wheat along with a larger area of dryland wheat. The reduction in rice and the increase in wheat area will have an industry-wide impact, e.g. rice mills and storage depots were closed as a result of the lower level of rice supply during 2007-08.

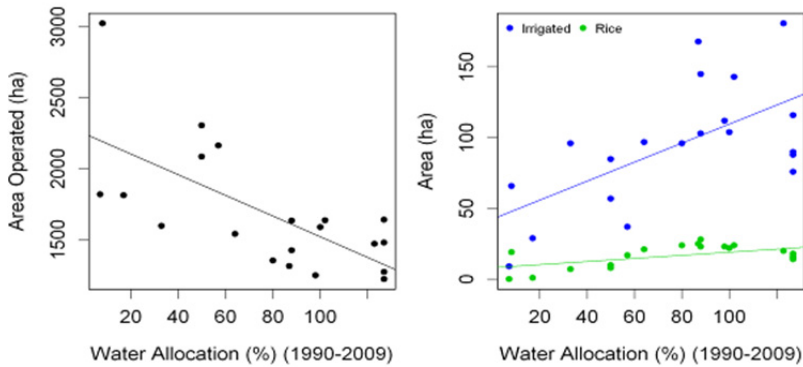


Figure 10. Area operated per farm, $p=0.001$, (left); rice area, $p=0.003$, and total irrigated area, $p=0.01$, (right) as a function of water availability and in Riverina, NSW, Australia; Source: ABARE Farm Survey.

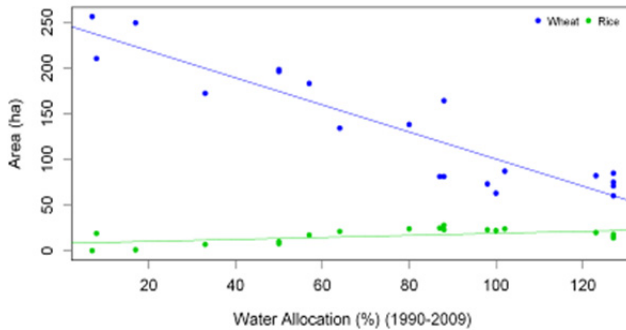


Figure 11. Wheat, $p<0.001$, and rice, $p=0.01$, production by area per farm as a function of water allocation in Riverina from 1992-2009, NSW, Australia; Source: ABARE Farm Survey.

Water trading: Water movement to more efficient and higher value commodities results in a consolidation of farms without showing evidence of a corporate takeover of the industry⁶⁰ showed that water markets facilitate the process of farm adjustment and structural change within the irrigation industry. To maintain a liveable income during drought periods some farmers adjust their operations by temporarily trading water to other growers to take advantage of higher water prices. Fig. 12 shows the relationship of water trading to rice area in the Coleambally Irrigation Area (CIA), Riverina (NSW). However, over the last 5 years the CIA is trading-out water to satisfy the demand of high value crops such as rice. In some instances rice farmers have had to purchase temporary groundwater in order to satisfy forward contracts⁶¹.

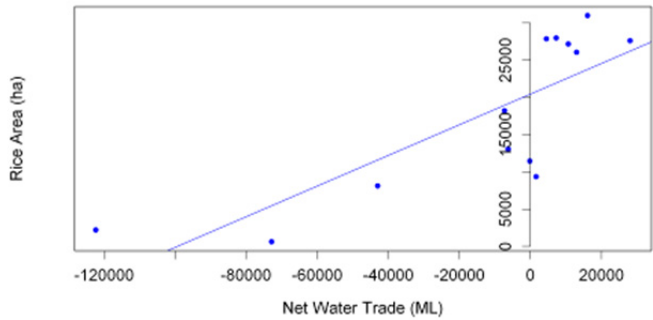


Figure 12. Relationship of net water trading and rice area in the Coleambally Irrigation Area, Riverina, NSW, Australia, $p < 0.001$; Source: Source: ABARE Farm Survey; Coleambally Irrigation, 2009⁶².

Financial impact: The reductions in available water have significantly influenced farm business profit and overall family income (Fig. 13) and income is sustained through off-farm activities. During 2007-2008 (<10 per cent water allocation) overall average family income per farm and farm business profit was $-\$27,893$ and $-\$109,536$, respectively. Clearly, this is not sustainable in the long-run. Under the anticipated climate change considerable adjustment in terms of cropping pattern or off-farm activities will be required to sustain a reasonable family income. Alternatively, relocation of farms or some of the production could be an option.

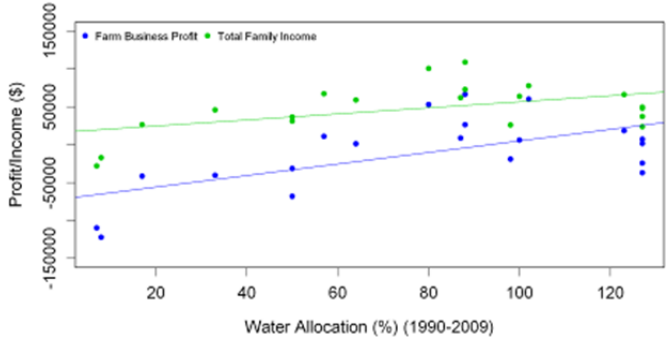


Figure 13. Relationship of water availability and farm business profit, $p = 0.003$, and total family income, $p = 0.03$, Riverina, NSW, Australia; Source: ABARE Farm Survey; Where: Farm business profit (\$): Farm business profit equals farm cash income plus build-up in trading stocks, less depreciation expense, less the imputed value of the owner manager, partner(s) and family labour. Total family income (\$): Family share of farm cash income less family share of depreciation plus all off-farm income of owner manager and spouse.

4.3.3. CRM Potential from regional relocation

A potential CRM strategy under climate change is to relocate rice production to regions with plenty of water such as the Burdekin. The CGE model was used to estimate the regional

economic impact of such strategy. The model compared the net impact of shifting rice production from Riverina to Burdekin on fallow sugarcane land, assuming with no competition and displacement of sugarcane land, under 2030 and 2070 future time periods.

4.3.4. Economic impact regional relocation CRM strategy

The macroeconomic impact of relocating rice production from the Riverina to the Burdekin is presented in terms of changes in real output and real income. Relocation also affects a range of other variables (notably employment) but these are not presented here.

Table 7 summarises the projected changes in real output and real income for each region. The loss of water and consequent switching from rice to wheat is projected to reduce the real economic output and income of the Riverina. Using a 4 per cent real discount rate a cumulative decrease of -\$915 million over the 59 years to 2069-70 has been estimated. The decrease in 2069-70 represents an average decrease in real economic output of around \$550 per person projected to be living in the Riverina at this time (295,000 people).

As a result of rice relocation on fallow sugarcane land, real economic output increases in Burdekin. A cumulative increase of total of \$759 million is projected over the 59 years to 2069-70. The increase in 2069-70 represents an increase in real economic output of around \$7,000 per person projected to be living in the Burdekin at this time (18,500 people). The net movement of labour is primarily between the Riverina and Burdekin with minimal net movement of labour to/from the Rest of Australia. Consequently it is projected that there will be minimal impacts (a cumulative total of -\$211 million) on the Rest of Australia.

	Real economic output (\$m)			Real income (\$m)		
	2029-30	2069-70	NPV (2010-11 to 2069-70)	2029-30	2069-70	NPV (2010-11 to 2069-70)
	2010-11	2010-11	2010-11	2010-11	2010-11	2010-11
Southern Rice	-45	-139	-915	-72	-161	-1,298
Burdekin LGA	35	131	759	58	178	1,149
Rest of Australia	-1	-21	-54	6	-26	9
Total Australia	-11	-29	-211	-8	-9	-140

Table 7. Cumulative change in real economic output and real income under scenario 1, relative to reference case for 2010-11.

4.3.5. Lessons learned and implications for CRM

With the expected reduction in water allocation, losses in rice production cannot be wholly offset by productivity gains given current production techniques and increasing temperatures and rainfall variability. The reduction in output will reduce net exports and have some impact on Gross Domestic Product (GDP), especially because of the extensive value-adding that occurs in Australia. Relocation to Burdekin is one potential risk

management option, but limited agronomic knowledge and uncertainty associated with the future climate and associated financial risk pose barriers to relocation. The displacement of an existing intensively-produced crop, such as sugar would result in a much larger net national loss, also meaning that there would be a net reduction in regional income and outputs. It is concluded that there is unlikely to be a rapid increase in rice production in the north without more reliable future climate assessment to build confidence for making informed relocation decisions, infrastructure support, and R&D and extension support to enhance rice productivity and better communication.

4.4. CASE STUDY 4: Climate risk management and health: A call for user friendly climate information (Alexander von Hildebrand)

Climate change poses significant threats to climate-sensitive health outcomes, for example, through increasing the risk of malnutrition due to reduced access to food, waterborne diseases resulting from flood- or drought-related contamination of food and water, and physical and psychological from trauma following more frequent and harsher extreme events.

The appearance of infectious diseases in new geographical areas in response to warmer temperatures, increases in precipitation, and/or other climatologically-related changes, will increase the burden of malaria and dengue, and the *“combination of increasing vulnerability and risk of weather-related hazards are expected to result in more extreme events and disasters”*⁶³. Children, the elderly, the poor – and amongst them, women – are expected to suffer most.

To assess the risks to human health posed by climate change and take appropriate actions to reduce their impacts, national health authorities need to know the current and potential future burden of climate-sensitive health outcomes, in order to adapt to the resulting demand for more and climate resilient health services. For this purpose, WHO has developed a Vulnerability and Adaptation Assessment Tool⁶³. In order to implement it, user friendly climate and meteorological information is vital. This section will therefore discuss the importance and the urgent need for the availability of science-based climate and meteorological information as a pre-condition for managing climate risks to protect health from climate change.

4.4.1. Role of CRM in health

While the effects of climate on health are becoming better known, more needs to be done to achieve stronger engagement of the health sector and health professionals in climate-change action⁶⁶. One key issue is managing uncertainty in climate and health sensitivity information, which poses significant problems for the health community in decision making processes. *“Climate and meteorological information are a major component of climate adaptation. Tools and knowledge systems which clarify and reduce uncertainty about the climate sensitivity of diseases, will be essential inputs to disease control policies such as malaria elimination, as well as preventing health risks from extreme weather events and climate variability.”*⁶⁷. Therefore, to adapt

well to predicted changes of the climate system, *“climate and meteorological information must be taken into greater consideration in health science, practice, and policymaking”*⁶⁶. To this end, the World Health Organisation (WHO) works with partners and collaborating Centres to develop tools, information resources, and dialogs which facilitate climate informed management of health risks.

4.4.2. CRM in the World Health Organization

*“Each year, about 3.5 million people die from malnutrition, 2.2 million from diarrhoea, 800 000 from causes attributable to urban air pollution, and 60 000 in climate-related disasters, mostly in low resource settings and also frequently in humanitarian emergency situations. Climate change brings new challenges and costs to the control of infectious diseases as some are highly sensitive to temperature and rainfall, including cholera and the diarrhoeal diseases, as well as vector borne diseases including malaria, dengue and schistosomiasis. Climate change threatens to reverse the progress that the global public health community has been making against many diseases, and increase the challenges for the humanitarian community to respond to natural, biological and social emergencies.”*⁶⁴.

It is clear that climate factors play an important role in the definition of some human diseases. For other diseases where climate is only considered as one of many determinants, WHO have stated that it is also important to understand the various causal pathways from climate change through to health outcomes, in order to identify opportunities to address the environmental determinants of poor health outcomes.

WHO promotes *“measures to reduce the health impacts from climate risks and associated climate change, such as strengthening public health systems based on partnerships with multi-sectoral actors, enhancing capacity of health systems to reduce risks and respond to public health emergencies, protecting hospitals and other health infrastructure from climate risks and effects of climate change, strengthening surveillance and control of infectious disease against climate risk, improving the use of early warning systems by the health sector and building public health interventions at local level to increase community resilience.”*⁶⁵. Climate information is needed and should be available in ways that users in each country can understand, especially at the local level. This would facilitate the development of, for example, *“health action plans to enhance early warning and effective response over a range of time scales: from hours or days (for flood or heat wave warnings), to weeks (for seasonal epidemics of vector-borne disease), to months (seasonal forecasts of precipitation anomalies allowing planning for flooding or drought), to years (for drought and associated food insecurity).”*⁶³.

4.4.3. The WHO’s Vulnerability and Adaptation Assessment Tool

The Vulnerability and Adaptation Assessment Tool was developed by WHO to help manage climate risks to health (Fig. 14). It departs from gathering information on the extent and magnitude of current and future importance of climate dependent health outcomes, in order to identify policies and programmes that can prevent or reduce the severity of future health impacts.

A basic premise for the effective definition and, more importantly, implementation of a CRM process is to ensure the involvement and empowerment of the various stakeholders who will be responsible for implementing and assessing the results of the various actions to be undertaken is to establish an iterative process for monitoring and managing the health risks of climate change. Furthermore, to establish plans for communicating the CRM process “The credibility and legitimacy of the assessment results will be increased if stakeholders and the intended end-users have been informed of and included in discussions throughout.”⁶³.

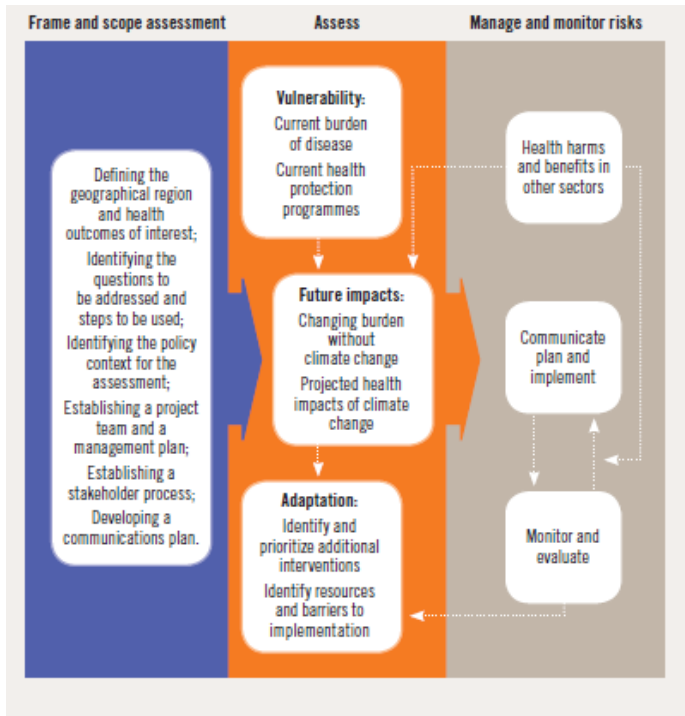


Figure 14. WHO Vulnerability and adaptation assessment tool

The three steps conducted in a particular assessment using the Vulnerability and Adaptation Assessment Tool will start with a description of the current burden of climate-sensitive health outcomes and of the most vulnerable populations and region. It is important at this step to address the question: What factors other than weather and climate determine vulnerability of populations and health systems? The second step involves description of the current capacity of the health sector and other sectors to address these risks to climate-sensitive health outcomes. The analysis of results from steps 1 and 2 will demonstrate gaps in the existing health system response. The third step tries to define how the burden of climate-sensitive health outcomes is likely to change over the coming decades, in order to assess the climate change vulnerabilities and their key drivers. This is done firstly irrespective of climate change, and then secondly taking into account the likely health

impacts of climate change, including the most vulnerable populations and regions, over the next decades and in the longer term. The analysis of results will help determine how well the health system is, or is not, prepared for example to changes in demand due to changes in the geographical distribution, and incidence or timing of climate-sensitive health outcomes. Gaps in health system response identified earlier, in steps 1 and 2, may be expanded upon during this step.

The information provided from implementation of the Vulnerability and Adaptation Assessment Tool enables the appropriate health experts to define the nature of additional public health policies and programmes that will likely be needed for effective health management, in order to address possible additional burden of adverse health outcomes due to climate change, and to define what policies and programmes are needed in other sectors to protect health.

Throughout the assessments, it is important to take into account that *“Future vulnerabilities may be different from current vulnerabilities because of changes in public health and health-care policies, governance and institutions, socioeconomic development, availability of human and financial resources, and other factors. Impacts can change with both changing vulnerabilities and environmental changes. Public health policies, programmes and interventions to address vulnerabilities and impacts will need to be revisited regularly to ensure continuing effectiveness in a changing climate”*⁶³.

4.4.4. The need to improve integration of baseline health and climate data for CRM

To implement well the Vulnerability and Adaptation Assessment Tool climate and weather data resources are required that are appropriate for health sector applications. This information is key to enable adequate answers to be established for the following questions:

- Which regions and populations in a country are the most vulnerable to climate and climate change?
- What are the health risks posed by climate change over the next decades and the longer term?
- How well is the health system prepared for changes in demand due to changes in the geographical distribution, incidence or timing of climate-sensitive health outcomes?

To enable the analysis of relationships between current and past weather/climate conditions and health outcomes, relevant data is required both on health and climate. To date there have been only a few studies which have combined the most appropriate health and weather/climate data available, for example, from ministries of health and national meteorological and hydrological services, respectively. Improved integration of these data and the expertise that their host organizations provide would significantly improve the analyses necessary for CRM.

The Vulnerability and Adaptation Assessment Tool invites the use of spatial mapping to describe the geographical distribution of current or projected future vulnerabilities and

hazards. *“A geographical perspective and the use of geographical information systems (GIS) offer opportunities to show current distributions of, for example, vulnerable populations and the spatial relationship to disease vectors, river basins prone to flooding, health facilities, and other important variables of interest to public health officials”*⁶³.

It is important to keep in mind the following caution when models are used to project the health risks of climate change. *“Modeling can be a complex undertaking requiring highly technical expertise and specific data inputs that take time and effort to acquire. The capacity to design and run models to project health impacts can be developed through training courses and other mechanisms. A goal of the assessment could be to build research capacity and increase the availability of models to project health impacts in future studies”*⁶³.

It is all about what happens locally. *“Risk management works best when tailored to local circumstances. Combining local knowledge with additional scientific and technical expertise helps communities reduce their risk and adapt to climate change (robust evidence, high agreement)”*⁶³.

The health impacts that may occur in a particular location will depend on the actual climate and climate changes experienced and the vulnerability of the community and region. Qualitative data may allow changes to be assessed over short time periods, but, it is clear that *“Models are generally used to quantitatively estimate how the health risks of climate change could increase or decrease over time, particularly for longer time periods”*⁷⁰. Indeed, *“models can explore the range of potential impacts of a changing climate in the context of other drivers of population health to better understand where, when and in what population groups’ negative health outcomes could occur.”*⁶³.

For decision-makers, it is important to have certainty that their decisions are “climate-proof”. The availability and use of locally specific climate and meteorological information relevant to health outcomes is vital for these decisions⁶³.

4.4.5. Examples of good practice in CRM for health

WHO developed a Technical Document on Vulnerability and Adaptation Assessment Tool with input from over 20 countries that designed to provide basic and flexible guidance on conducting national or sub-national vulnerability and adaptation assessments. The document provides examples and references for users⁶³. Some examples of practice provided in this document that would benefit from better access to climate information are the following:

Exercise to plot climate-sensitive diseases in geographically defined populations:

Motivated by concerns about health vulnerabilities related to climate change, a joint WHO/WMO/UNEP/UNDP workshop was conducted in the Hindu Kush–Himalaya regions⁶⁶. Only crude estimates of the current burden of climate-sensitive diseases were available because of the lack of health surveillance data at the local level. Therefore, a

qualitative assessment was conducted as a first step to generate this information. Expert judgment was used to determine the extent to which climate-sensitive diseases could be a concern in populations in mountainous and non-mountainous regions of six countries (Table 8).

Country	Afghanistan	Bangladesh	Bhutan	China	Nepal	India
Heatwaves	M-P	P	-	P	P	P
Flood deaths/morbidity	P	P	P	P	P	P
Glacial lake floods	M-P	-	M-P	M-P	M-P	M-P
Flash floods	M-P	P	M-P	M-P	M-P	M-P
Riverine floods	P	P	-	P	P	P
Vector-borne disease	P	P	P	P	P	P
Malaria	P	P	P	P	M-P	P
Japanese encephalitis	-	P	-	P	P	P
Kala-azar	P	-	-	-	P	P
Dengue – P P P – P						
Waterborne diseases	M-P	M-P	M-P	M-P	M-P	M-P
Water scarcity, quality	M-P	P	P	M-P	M-P	M-P
Drought-related food insecurity	M-P	P	-	M-P	-	M-P

M-P health determinant or outcome occurs in mountainous and non-mountainous (i.e. plains) areas;

P health determinant or outcome occurs only in non-mountainous areas;

- health determinant or outcome is not present in the country (WHO/SEARO, 2006).

Source: Kristie L. Ebi, Rosalie Woodruff, Alexander von Hildebrand and Carlos Corvalan (2007). Climate change-related health impacts in the Hindu Kush-Himalayas. *Ecohealth*, 4:264–270⁶⁷

Table 8. Current climate-related health determinants and outcomes in the Hindu Kush–Himalaya regions

Qualitative estimates of future health impacts of climate change using expert judgment:

During the assessment of health risks and responses in the first Portuguese national assessment, a qualitative assessment was conducted of the possible impacts of climate change on vector-borne diseases, including malaria, West Nile virus, schistosomiasis, Mediterranean spotted fever and leishmaniasis; the latter two are endemic to Portugal.

Although human cases of vector-borne diseases have generally decreased over recent decades, many competent vectors are still present in Portugal. Disease transmission risk was categorized qualitatively based on vector distribution and abundance and pathogen prevalence. Four brief storylines of plausible future conditions were constructed based on current climate and projected climate change, and assuming either the current distribution and prevalence of vectors and parasites, or the introduction of focal populations of parasite infected vectors. These storylines were discussed with experts to estimate transmission risk levels. For Mediterranean spotted fever, the risk of transmission was high under all

storylines, suggesting that climate change is likely to have a limited impact. For the other diseases, the risk level varied across the storylines. For example, the risk of leishmaniasis varied from medium under current climate to high under both climate change storylines. The risk of schistosomiasis varied from very low (current climate and current vector distributions) to medium (climate change and focal introduction).⁶⁸

Climate and health observatory: Innovations in data sharing, communications and partnership building in Brazil, by Christovam Barcellos, FIOCRUZ Brazil:

Given the complexity of processes that drive climate change impacts on human health, it is necessary to gather data from different institutions in order to understand monitor and project these outcomes. These data include not only climatic and human health variables but also trends in socio-demographic and environmental factors and institutional capacity. The experience of the Brazilian Climate and Health Observatory demonstrates how to bring multiple institutions and stakeholders together to support actions to decrease human health vulnerability to climate change. The observatory has the following functions: gathering available data on climate, environment, society and health; conducting situation analyses and identifying trends and patterns related to climate change impacts on health (e.g. semi-qualitative graphs and maps); providing information to national alert systems and for monitoring health emergencies associated with extreme weather events; supporting research and development on climate and environmental changes and associated health impacts; promoting the active participation of civil society and citizens on issues related to climate change, environmental degradation and health impacts (e.g. news reports, commentaries, photographs).

The observatory project is supported by the Brazilian Ministry of Health and PAHO and is coordinated by the Oswaldo Cruz Foundation. Through workshops, participants developed institutional agreements for sharing data and identified specific data formats, timescales and spatial resolution to be used at the observatory.

Climate change and health impacts to be addressed first include direct impacts from heatwaves, floods and droughts; the expansion of vector-borne diseases; the vulnerability of water supply and sanitation systems, and the increasing risk of water-related diseases; and the interaction between climate change and impacts on air pollutants that increase the risks of respiratory diseases.

City of Quito, Ecuador Climate change mitigation and adaptation plan:

In 2012, the Municipal Council of the city of Quito, Ecuador developed a climate change mitigation and adaptation plan. It aims at reducing GHG emissions by 15 per cent relative to projected growth, and social environmental and economic climate vulnerability by 20 per cent. The plan will create innovative mechanisms for reducing the carbon footprint of the private sector. The municipal plan strengthens the generation and management of climate information and knowledge in close collaboration with the national climate institution, National Institute of Meteorology e Hydrology (INAHMI). Source: <http://www.quitoambiente.gob.ec/home/noticia.php?idNoticia=108>

Capacity building: Climate Information for Public Health:

In collaboration with the Pan-American Health Organization (PAHO), the International Research Institute for Climate and Society, in partnership with the Center for International Earth Science Information Network (CIESIN) and the Mailman School of Public Health initiated a two-week course on Climate information for Public Health in 2008⁶⁹. It is held annually and *“provides a balance of concepts and methods from the health and climate communities using an approach deeply oriented toward methodology, gathering and using evidence for decision-making in order for the participants to get in-depth knowledge and skills in decision-making for health-care planning of climate sensitive diseases”*⁷⁰.

The course helps participants to recognize the role climate plays in driving the infectious disease burden and public health outcomes, understand management and data integration as an opportunity to improve the decision making process in Public Health and realize the benefits and limitations of different climate and environmental data sources including remotely sensed data, meteorological data and climate predictions.

4.4.6. Lessons learned and the way forward

As pointed out by the United Nations Task Team on Social Dimensions of Climate Change, *“Global and regional one-size-fits-all climate analysis may not reflect the reality of a particular community or country and can under- or over-emphasize risks relevant to certain communities. The outcomes of downscaling should be incorporated where relevant and feasible, and combined with complementary mappings that may include social impact assessments and vulnerability maps, in order to identify social climate-induced hotspots (places where particularly severe problems may need to be addressed) and their intersection with other kinds of vulnerabilities such as lack of access to preventive and curative health services, that can reduce health vulnerability to climate change”*⁷¹.

Health sectors in countries need to possess tools to conduct climate change vulnerability and adaptation assessments. *“The goal remains to better understand how climate variability and climate change can and do affect health risks today and in the future, in order to better inform policies and programmes that can protect public health”*⁷⁰. However, once there is motivation for action, *“decision makers need to know the magnitude of potential risks and identify a range of options (including their feasibility, benefits, acceptability, effectiveness and costs); the availability of resources and their distribution across the population; and the structure of critical institutions, including the allocation of decision-making authority”*⁷².

The call for the production, availability, delivery and application of locally specific, science-based climate and meteorological information is a fundamental requirement for improving the application of CRM to address health risks. Integration of this information with appropriate health information and data will provide an opportunity, but also a challenge, to health authorities to demonstrate leadership within and outside the sector on mitigation and adaptation to climate change in order to protect health.

5. Conclusions and recommendations

From global to local levels, public and private sector institutions are seeking the tools and knowledge for CRM (including capacity building and adaptation). People require climate information over wide ranges of time and space scales for planning and operational purposes. It is imperative, therefore, to ensure that they have the highest quality and widest possible range of products, information (including about uncertainties), and guidance on how the information can be used to provide optimal results and ensure appropriate decisions are made.

Effective CRM must be founded on scientifically sound risk assessment techniques that develop understanding, and where possible, quantification of the risks associated with natural hazards, socio-economic vulnerabilities and their impacts. Climate risk assessment, in turn, requires quality assured historical, real-time and future-projected data on climate-related hazards and socio-economic vulnerabilities, with reliable regional detail. Changing patterns of climate hazards make those data needs even more imperative. Understanding the challenges posed by climate change to longer-term strategic planning and investments (e.g. infrastructure planning and retrofitting based on building codes as a 100 year flood may become a 30 year flood), would help providers frame future products and services, and users build resilience to future as well as current climate. To be effective, processes adopted for CRM must be perceived by individuals, communities and governments as providing real possibilities of improving their living standards through awareness, adaptation, prevention and increased resilience to climate impacts. If authorities set up sustainable, coherent and participative CRM plans that are ‘owned’ at local level, these will provide strong foundations for the development of successful adaptation strategies.

5.1. Common constraints to Climate Risk Management

A number of constraints limiting the use of climate information for decision-making by sectors have been discussed throughout this chapter. Some of the most common constraints to be addressed before implementation of sustainable CRM systems are:

- Limited national capabilities for climate data processing, analysis, modeling and the generation of information and forecast services including sectoral applications in strategic sectors such as agriculture, health, water resources and others.
- Lack of capacity to communicate information between NMHS and national agencies and authorities.
- Limited capability of governmental institutions and sectoral institutions to identify their climate information requirements.
- Limited coordination between local institutions and agencies.
- Weak or non-existent planning of the investment budget for actions aimed at prevention of and preparedness for national disasters at the level of national and subnational governments.

- Weak or non-existent accountability system for encouraging and mandating use of available scientific information for appropriate risk reduction measures.
- Limited involvement of the private sector to engage with stakeholders in the development of risk management measures.
- Limited knowledge of climate and limited training in application and use of climate information and products by users in many sectors;
- Problems in identifying threats to carry out works on risk reduction because of limited use of the necessary tools for assessment.
- Limited synergy among national institutions to share climate and climate-relevant information at national level.
- The absence of an efficient communication system on extreme climate events to disseminate information such as warnings and advisories.
- Overly technical language in some climate information and products, making them difficult to understand by lay people.
- The lack of a culture of prevention of damage and proper maintenance, supported by finances, for the vulnerable physical and social infrastructure.

Even though climate scientific knowledge and probability modelling have advanced significantly over the last few past decades, especially with respect to the understanding of climate variability and change, the level of uncertainty inherent in probabilistic climate products has tended to make their communication by scientists for integration and understanding by users of the information more challenging. While the scientific community regards uncertainty as an inherent property of the climate system, which can be assessed through probability analysis, decision makers may consider uncertainty as a barrier to decision making, especially when other socio-economic and political variables also need to be considered. The result is a complex and confused integration situation among actors which requires careful communication to ensure the complex information is understood by all and appropriate decisions are made. To overcome this limitation, it is recommended that the climate scientific and stakeholder communities create an agenda sustained by the transfer of requirements, knowledge, tools and instruments allowing the formation of a community of practitioners with analytical skills and sharing basic agreements for action. To improve disaster and climate risk governance, it is proposed that decision-makers should also assume responsibilities concerning the understanding of risks within their sectors and regions, and consider the need to integrate DRR management and CRM using the wide range of currently available instruments and development mechanisms.

The role of the NMHS is decisive within the national efforts to cope with the opportunities and impacts of climate variability and change and to encourage effective CRM. The activities of NMHS regarding climate observations, data management, analysis maintaining a 'climate watch' and forecasting are strictly necessary to estimate the "near climate change", estimate indexes and provide local trends to be applied for risk management and development of adaptation plans. The nature of climate risks, including climate change implies accurate monitoring efforts under a rigorous methodology and standards that only NMHSs can

provide in a sustainable way. The current efforts of NMHSs in weather and climate forecasts, the analysis of extremes and other prediction services are valuable for CRM and consequently a solid basis to work on climate change estimations at local level where global projections are not necessary applicable. To encourage communities to engage with such climate services and to enhance the relationship with the vulnerable local populations, a number of recommendations, that will underpin a “new business model” for conducting effective CRM at local levels, are proposed for the operations of the NMHSs of the WMO.

5.2. Recommendations for NMHSs for improving CRM at local level

For improving CRM at local levels, it is recommended that NMHSs:

1. Focus on users, and enhance collaborations with CRM communities in order to assess their needs and address these through provision of high quality and opportune climate services, including through organizing or participating in both face-to-face and on-line Regional and National Climate Outlook Forums which offer direct interaction with users including sectors and the media, and participate in capacity development of users through training in climate matters, adaptation and in the use of climate products.
2. Tailor climate products for CRM end users, including planning departments, local authorities, government agencies involved in environment and risk management, based on their requirements.
3. Monitor the climate and its evolution, conduct Climate Watch programmes, develop regular information for users on the past and current states of the climate, and couple these with reliable, user-friendly predictions for upcoming seasons, as part of a climate services culture.
4. Build and sustain observing networks to provide the data needed for a range of climate services for CRM; conduct data rescue exercises to enhance digital climate databases.
5. Promote training and development of their meteorological staff in diverse aspects of climatology and climate services and in CRM.
6. Enhance climate research, development of climate indexes and other analysis, within their operational activities.
7. Combine climate products with other geospatial information related to vulnerability derived from other institutions for development of more decision-ready, actionable products (this will require strategic alliances, in “win-win” relationships with co-benefits).
8. Enhance the liaison with local communities, communitarian networks and local media for efficient dissemination of tailored products applicable for CRM.
9. Seek and act on user’s feedback for product evolution and improvement.

5.3. Moving forward with GFCS

As previously noted, the WMO, along with partnering organizations and with the support of Member countries, has embarked on a new era for climate services, with the decision to implement the Global Framework for Climate Services (GFCS). This decision was reached in the full understanding that GFCS success will require strengthening of observations and monitoring, research, modeling and prediction, the Climate Services Information System

(the operational ‘engine’ of the GFCS which includes the NMHSs of WMO’s 189 Member countries), and much improved interaction with users. A great deal of capacity development will be required to ensure the capability of climate providers to deliver quality information and the ability of the users to take up and apply the information. Indeed, in many places this is already underway, such as the provision of climate services in developing countries via the Regional Climate Outlook Forum supported by the WMO Climate Information and Prediction Services (CLIPS) project (Semazzi, 2011)⁷³.

The current effort of the CCI Task Team on CRM, which has provided the motivation for this chapter, marks the beginning of a new collaboration on CRM. As the GFCS is implemented and improves over time, much will be learned, and the concept of CRM, *inter alia*, will be tested and evolve, particularly with the cooperation of the organizations affiliating themselves with the GFCS. We hope this chapter provides techniques, case studies, good practices and guidelines that will be useful for this endeavour.

Author details

R. Martínez*

International Research Center on El Niño (CIIFEN), Guayaquil, Ecuador

D. Hemming*

Met Office Hadley Centre, UK Meteorological Office, Fitzroy Road, Exeter, UK

L. Malone*

World Meteorological Organization (WMO), Geneva, Switzerland

N. Bermudez

United Nations Development Programme (UNDP), Quito, Ecuador

G. Cockfield and S. Mushtaq

Australian Centre for Sustainable Catchment, University of Southern Queensland, Toowoomba QLD, Australia

A. Diongue

Agence Nationale de l’Aviation Civile et de la Météorologie (ANACIM), Senegal

J. Hansen

International Research Institute for Climate and Society (IRI), New York, USA

A. Hildebrand

Panamerican Health Organization (PAHO), Quito, Ecuador

K. Ingram

University of Florida, Gainesville, FL, USA

G. Jakeman

* Leading Authors

ACIL Tasman Pty Ltd. Canberra, Australia

M. Kadi

African Centre of Meteorological Application for Development (ACMAD), Niamey, Niger

G. R. McGregor

School of Environment, University of Auckland, New Zealand

P. Rao

Academy of Climate Change Education & Research, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala, India

R. Pulwarty

National Oceanic and Atmospheric Administration (NOAA), Boulder, CO, USA

O. Ndiaye

Service Départemental Du Développement Rural, Kaffrine, Sénégal

G. Srinivasan

Regional Integrated Multi-hazard Early warning System (RIMES), Bangkok, Thailand

Eh. Seck and N. White

AgriScience Qld, Department of Agriculture, Fisheries and Forestry, Toowoomba QLD, Australia

N. White

Dept. of Biological and Physical Sciences, University of Southern Queensland, Toowoomba QLD, Australia

R. Zougmore

Climate Change Agriculture and Food Security (CCAFS), West Africa, Bamako, Mali

6. References

- [1] Ritchey T. *Wicked Problems: Structuring Social Messes with Morphological Analysis*. Swedish Morphological Society; 2011.
- [2] World Meteorological Organization. *Climate knowledge for Action: A Global Framework for Climate Services – Empowering the most vulnerable*. WMO-No. 1065. 2010.
- [3] Jones R. *An Environmental Risk Assessment/Management Framework for Climate Change Impact Assessments*. *Natural Hazards*. 2001; 23: 197-230.
- [4] Taubenböck H, Post J, Roth A, Zosseder K, Strunz G, Dech S. *A conceptual vulnerability and risk framework as outline to identify capabilities of remote sensing*. *Nat. Hazards Earth Syst. Sci*. 2008; 8:409-420.
- [5] Wilby R, Troni J, Biot Y, Tedd L, Hewitson BC, Smith DM, Sutton RT. *A review of climate risk information for adaptation and development planning*. *International Journal of Climatology*. 2009; 29:1193-1215.
- [6] Hemming D, Boorman P, Hartley A, Kay G, McInnes R, McNeill D. *Identification of dangerous thresholds in regional climate and other biophysical quantities related to key impacts*. Report (Deliverable # D2.4.3) for the UK Department for Energy and Climate

- Change and Department for Environment, Food and Rural Affairs under the Hadley Centre Climate Programme. 2011; GA01101 2010-2012.
- [7] Johnson L, Weaver C. [Internet]. 2009. Available from: <http://www.utexas.edu/lbj/directory/faculty/catherine-weaver>.
- [8] Breuer NE, Fraisse CW, Hildebrand PE. Molding the pipeline into a loop: the participatory process of developing AgroClimate, a decision support system for climate risk reduction in agriculture. *Journal of Service Climatology*. 2009; 1: 1-12.
- [9] Bartels W, Arnold J, Breuer NE, Furman CA, Staal L, Irani TA, Jones JW. Supporting dialog and learning among stakeholders through climate working groups. Southeast Climate Consortium Technical Report Series. SECC Technical Report. 2011; 12-001:00-00.
- [10] Bartels W, Furman CA, Royce F, Ortiz B, Zierden D, Fraisse CW. Developing a learning community: Lessons from a climate working group for agriculture in the southeast USA. Southeast Climate Consortium Technical Report; 2012. Series: SECC Technical Report 12-002:00-00.
- [11] Crane T, Roncoli C, Breuer N, Broad K, Paz J, Fraisse C, Ingram KT, Zierden D, Hoogenboom G, and O'Brien JJ. Collaborative approaches to the development of climate-based decision support systems. Proceedings of the 88th AMS Annual Meeting, New Orleans, LA, January 20-24, 2008.
- [12] Fraisse CW, Breuer N, Bellow JG, Cabrera V, Hatch U, Hoogenboom G, Ingram KT, Jones JW, O'Brien JJ, Paz J, Zierden D. AgClimate: A climate forecast information system for agricultural risk management in the southeastern USA. *Computers and Electronics in Agriculture*. 2006; 53(1):13-27.
- [13] Hammond A, Adriaanse A, Rodenburg E, Bryant D, Wood R. Environmental indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development. World Resources Institute. 1995.
- [14] Hák, T., Moldan, B. & Dahl, A.L. (eds). (2007). Sustainability Indicators. A scientific assessment. *SCOPE 67*, Island Press. 2007.
- [15] OECD. Handbook on Constructing Composite Indicators: Methodology and User Guide OECD, European Commission, Joint Research Centre. OECD Publishing, 2010.
- [16] EEA-JRC-WHO. Impacts of Europe's changing climate. – 2008 indicator-based assessment. Joint EEA-JRC-WHO report. EEA Report No 4/2008.
- [17] Smeets E, Weterings R. Environmental indicators: Typology and overview. European Environment. Agency, Technical report No. 25, Copenhagen, 1990; 19.
- [18] Wascher D, Perez-Soba M. (eds.) Learning from European Transfrontier Landscapes – a project in support of the European Landscape Convention. Alterra report 964, LANDSCAPE EUROPE, Wageningen. 2004.
- [19] Rochet M, Rice J. Do explicit criteria help in selecting indicators for ecosystem-based fisheries management? 2005.
- [20] Marx S, Weber E. Decision making under climate uncertainty: The power of understanding judgment and decision processes. In: T. Dietz & D.C. Bidwell (Eds.), *Climate Change in the Great Lakes*. MSU Press. 2012; Chapter 5: 99-128.
- [21] IPCC. Special Report on Managing the Risks of Extreme Events (SREX) and Disasters to Advance Climate Change Adaptation. Cambridge Press. 2012.
- [22] Pulwarty R. Climate and water in the West: Science, information and decision-making. *Water Resources*. 2003; 124: 4-12.

- [23] Weichselgartner J. Disaster mitigation: the concept of vulnerability revisited. *Disaster Prevention and Management*. 2001; 10(2): 85-94.
- [24] CIIFEN. Manual de buenas prácticas para adaptación al cambio climático en zonas costeras. Una guía para la formulación, diseño e implementación de medidas de adaptación al cambio climático en zonas costeras. Programa Costas y Bosques Sostenibles. 2011; 1 1:63
- [25] Ministerio del Ambiente del Ecuador. Second National Communication to the UNFCCC. 2010.
- [26] Lindell M, Perry R. *Communicating Environmental Risk in Multiethnic Communities*. Thousand Oaks, CA: Sage Publications. 2004.
- [27] Fischhoff B. Transaction analysis: A framework and an application to insurance decisions. *Journal of Risk and Uncertainty* 1993; 7: 53-69.
- [28] Cutter S, Mitchell T. Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina. *Annals of American Geographers*. 2000; 90(4): 713-737.
- [29] Pulwarty R. Communicating Agrometeorological Information, including Forecasts, for Agricultural decisions. WMO Guide to Agricultural Meteorological Practices (GAMP) 27 WMO Geneva. 2007.
- [30] Goddard L, Aitchellouche Y, Baethgen W, Dettinger M, Graham R, Hayman P, Kadi M, Martinez R, Meinke H. Providing Seasonal-to-Interannual Climate Information for Risk Management and Decision-making. *Procedia Environmental Sciences World Climate Conference - 3*. 2010; 1: 81-101.
- [31] CIIFEN. Implementación de un Sistema de Información multimodal de eventos climáticos extremos en el Ecuador. Quinto Plan de Acción DIPECHO Sudamérica del Departamento de Ayuda humanitaria de la Comisión Europea. 2008; 1: 1-48.
- [32] Campbell J. Modeling the performance prediction problem in industrial and organizational psychology. In: M. D. Dunnette & L. M. Hough (Eds.), *Handbook of Industrial and Organizational Psychology*. Palo Alto, CA: Consulting Psychologists Press, Inc. 1990; 1: 687-732.
- [33] Mileti, D.S. and C.Fitzpatrick. *The Great Earthquake Experiment: Risk Communication and Public Action*. Boulder, CO: Westview Press. 1990.
- [34] Dennis M, O'Brien P. Warnings During Disaster: Normalizing Communicated Risk. *Social Problems*. 1992; 39(1): 40-57.
- [35] Intergovernmental Panel on Climate Change. *Climate Change 2007 - Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge . 2007.
- [36] UNISDR Terminology. [Internet], 2009. Available from: http://www.unisdr.org/files/7817_UNISDRTerminologySpanish.pdf
- [37] Traore A, Rogers D. Towards a multi-hazard early warning and response system in West Africa. Bonn, Germany: EWC-III. 2006.
- [38] IFRC. *World Disasters Report 2009: Early warning, early action*. International Federation of the Red Cross. 2009; 68-93.
- [39] Wisner B, Blaikie P, Cannon T, Davis I. *At risk. natural hazards, people's vulnerability and disasters*. New York: Routledge. 2004.
- [40] Hewitt K. *Interpretation of Calamity: From the Viewpoint of Human Ecology*. Boston, Allen.1983.

- [41] Verver M. The East African food crisis: Did regional early warning systems function? *The Journal of Nutrition*. 2011 n.111.150342.
- [42] UNISDR. Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters. 2007.
- [43] UNEP. UNEP's activities in 2006. Year of Publication: 2007. ISBN No: 978-92-807-2801-9.
- [44] Pulwarty R, Verdin J. Crafting early warning information systems: the case of drought. In: *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*. 2012 (Birkmann, J, ed. (United Nations University Press, New York, forthcoming).
- [45] Glantz M. Usable Science 9: El Niño Early Warning for Sustainable Development in the Pacific Rim and Islands. Report of workshop held 13–16 September 2004 in the Galapagos Islands, Ecuador. Boulder, CO: ISSE/NCAR. 2005.
- [46] Webster P, Hopson T, Hoyos C, Subbiah A, Chang R, Grossman R. A three-tier overlapping prediction scheme: Tools for strategic and tactical decisions in the developing world. *Predictability of Weather and Climate*, Ed. T. N. Palmer and R. Hagerdorn, Cambridge University Press. 2006; 718: 645-673.
- [47] Hopson T. Operational Flood-Forecasting for Bangladesh, University of Colorado Ph.D. Dissertation, Department of Astrophysical, Planetary, and Atmospheric Science. 2005.
- [48] Subbiah A, Fakhruddin E. CFAB: Climate Forecast Applications for Communities. Asian Disaster Preparedness Centre (ADPC). Report, January, 2012; pp. 23.
- [49] Clark M, Olson J. *Nursing within a Faith Community: Promoting Health in Times of Transition*. Thousand Oaks, CA: Sage Publications, Inc. 2000.
- [50] Misselhorn A. What drives food insecurity in southern Africa? A meta-analysis of household economy studies. *Global Environmental Change*. 2005; 15: 33-43.
- [51] Morgan R. The development and applications of a drought early warning system in Botswana. *Disasters*. 2005; 9: 44-50.
- [52] Pulwarty R. Communicating Agrometeorological Information, including Forecasts, for agricultural decisions. *WMO Guide to Agricultural Meteorological Practices (GAMP)*. 2007; 27.
- [53] Birkmann J, Chang Seng S, Suarez D. *Adaptive Disaster Risk Reduction, Enhancing Methods and Tools of Disaster Risk Reduction in the Light of Climate Change*, DKKV Publication. 2011; 43.
- [54] UNISDR. *Global Assessment Report on Disaster Risk Reduction*. UN International Strategy for Disaster Reduction. 2011.
- [55] Bohle, H., Keck, M, and P. Sadakpolrak 2009: Adaptive Food Governance. In: *IHDP Update 3, Magazine of the International Human Dimensions Programme on Global Environmental Change*: 543-58.
- [56] Sakdapolrak P. Water Related Health Risks, Social Vulnerability and Pierre Bourdieu. In: *UNU-EHS*; 2007 (6): 50-60.
- [57] WMO, ACMAD. *Climate Forecast in Africa*. WMO/TDNo. 927, October 1998.
- [58] IPCC. Working Group II Impacts, Adaptation and Vulnerability-Chapter 17 Adaptation Practices; 2007 and Technical Report: *Climate Change and Water*; 2008.
- [59] Mc Coll J, Young C. *Managing Change: Australian structural adjustment lessons for water*. Policy and Economic Research Unit CSIRO Land and Water; 2005 (Report No. 16/05).
- [60] Bjornlund, H., McKay, J., 1999. Do Permanent Water Markets Facilitate Farm Adjustment and Structural Change Within Irrigation Communities? *Rural Society*.

- [61] Sanders F, Burt M. Subcritical Contraction for Improved Open-Channel Flow Measurement Accuracy with an Upward-Looking ADVN (with Charles M. Burt and Brett F. Sanders), *Journal of Irrigation and Drainage Engineering*; 2010.
- [62] Coleambally Irrigation [Internet]. Australia 2009. Available from: <http://new.colyirr.com.au/>
- [63] Health issues gain traction at UN Climate Conference [Internet] WHO; 2011. Available from: http://www.who.int/globalchange/mediacentre/events/2011/durban_conference_update/en/index.htm
- [64] Protecting health from climate change - World Health Day 2008 [Internet] WHO; 2008. Available from: http://www.who.int/world-health-day/toolkit/report_web.pdf.
- [65] Disaster Risk Management for Health Fact Sheet [Internet] WHO; 2011. Available from: http://www.who.int/hac/events/drm_fact_climate_risk_management.pdf
- [66] Confalonieri U, Menne B, Akhtar R, Ebi K, Hauengue M, Kovats R, Revich B, Woodward A. Human health. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK; 2007: 391-431.
- [67] Ebi K, Woodruff R, Hildebrand A, Corvalan C. Climate change-related health impacts in the Hindu Kush-Himalayas. *Ecohealth*; 2007(4): 264–270.
- [68] Casimiro E, Calheiros J, Duarte F, Kovats, S. National assessment of human health effects of climate change in Portugal: Approach and key findings. *Environmental Health Perspectives*; 2006 (114): 1950–1956.
- [69] Climate Risk Management Overview [Internet] WMO. Available from: http://www.wmo.int/pages/themes/climate/risk_management_overview.php
- [70] IRI Resources tools [Internet]. Available from: <http://portal.iri.columbia.edu/portal/server.pt?open=512&objID=1094&mode=2>
- [71] The Social Dimensions of Climate Change, Discussion draft [Internet] 2011. Available from: <http://www.who.int/globalchange/mediacentre/events/2011/social-dimensions-of-climate-change.pdf>
- [72] IPCC. *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*; 2010.
- [73] Samazzi F.H.M. Framework for climate services in developing countries. *Climate Research*; 2011 (47): 145-150.