REPORT

CLIMATE CHANGE AND IMPLICATIONS FOR WATER RESOURCES & NUTRITION SECURITY

International Life Sciences Institute (ILSI-India)
&
Center for Integrated Modeling of Sustainable Agriculture and Nutrition Security (CIMSANS)

INTERNATIONAL CONFERENCE ON CLIMATE CHANGE AND IMPLICATIONS FOR WATER RESOURCES & NUTRITION SECURITY

November 15-16, 2013
Bengaluru

REPORT

Sponsored By

International Life Sciences Institute (ILSI-India)
&
Center for Integrated Modeling of Sustainable Agriculture and Nutrition Security (CIMSANS), Washington D.C.

Co-Sponsored By

Indian Council of Agricultural Research (ICAR)
Ministry of Agriculture, GOI
Ministry Earth Sciences, GOI
and
Ministry of Environment and Forest, GOI

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About This Report

The Report begins with the 'Statement of Conclusions and recommendations' which is followed by two Sections viz. 'Climate Change Science' and 'Adaptation to Climate Change' which together comprise the contributed abstracts of presentations of Conference speakers. Some of these abstracts have been shortened without losing their main content

ILSI-India and CIMSANS gratefully acknowledge the valuable contributions containing useful information, ideas and concepts which the speakers and participants shared with the Conference delegates.

It is important to note that the 'recommended actions' are the collective views of the speakers and participants and do not in any way reflect the views of the institutions they represent or the individual views of any speaker or participant.

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Abbreviations

AGMIP	Agricultural Model Intercomparison and Improvement Project
AVHRR	Advanced Very High Resolution Radiometer
AWD	Alternate Wetting and Drying
BMP	Best Management Practices
CCI	Climate Change Initiative
CDWR	California Department of Water Resources
CGWB	Central Ground Water Board
CaLSim	Central Valley Project (California Simulation of Insurance Markets (CalSim))
CRIDA	Central Research Institute for Dryland Agriculture
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DBP	Disinfection Bio Products
DSM2	Sacramento-San Joaquin Delta
DSSAT	Decision Support System for Agro-Technology Transfer
ECV	Essential Climate Variable
EFAS	The European Flood Management System
ENSO	El Nino, La Nina and Southern Oscillation
EQUINOO	Equational Indian Ocean Oscillation
GCMs	Global Climate Model
GHG	Green House Gas
GIMMS	Global Inventory Modeling and Mapping Studies
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid-Tropics
IFPRI	International Food Policy Research Institute
IISc	Indian Institute of Science
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IPCC	Intergovernmental Panel on Climate Change
IUWM	Integrated Urban Water Management
LP	Linear Programing
MOWR	Ministry of Water Resources
MRV	Measurement, Reporting, Verification
NAMA	Nationally Appropriate Mitigation Action
NAQUIM	National Project on Aquifer Management
NASA	National Aeronautics and Space Administration
NICES	National Information System for Climate and Environmental Studies
NICRA	National Initiative on Climate Resilient Agriculture
NIH	National Institute of Hydrology
NMSA	National Mission on Sustainable Agriculture
NRM	Natural resource Management
PWD	Public Works Department
SA	South Asia
SASM	South Asian Summer Monsoon
SPUR	Temporary Barrier like structure
SVA	Source Water Vulnerability Assessment
SWMM	Storm Water and Waste Water Management Model
SWPP	Source Water Protection Plan
USBR	US Bureau of Reclamation
WHO	World Health Organization
WRA	Water Resources Assessment

Statement Of Conclusions And Recommendations

The Conference was held on Nov 15-16 in Bangalore, organized by ILSI-India and CIMSANS and cosponsored by the Ministry of Earth Sciences, Indian Council of Agriculture Research (ICAR), Ministry of Agriculture, and Ministry of Environment and Forest. The Conference was addressed by experts from India and overseas.

1. Background

1.1) Climate change is a defining challenge of the present century. In its state of the science report, the Inter-governmental Panel on Climate Change (IPCC) confirmed with 95% confidence that this challenge is created by the excessive generation of Green Home Gases (GHG) – such as CO_2, CH_4, and N_2O – by human activities, particularly the combustion of fossil fuels. Recognizing this problem the world community committed itself at Kyoto in 1997 to initiate measures to reduce GHGs and slow down global warming. However, past GHG accumulations have reached a level which, in spite of efforts to adopt a low carbon development path, will unequivocally bring about additional climate change well into the present century.

1.2) Climate change has begun to have limited adverse effect due to increases in temperature, rise in sea levels and extreme events like floods, droughts and tropical cyclones. But these adverse effects will intensify in the future, severely damaging urban and rural hydrology and making it difficult to ensure food and nutrition security. The impact will be worst in developing countries located in tropics, principally in Africa and South Asia.

1.3) It has been estimated that global agricultural production will decline 2% (relative to a scenario without climate change) while demand for food will increase 14% every decade. Initially, the gains in production in the temperate regions will more than offset losses in the tropical regions.

2. The Indian Scenario

2.1) Among all the nations of the world, India is likely to be one of the worst affected by climate change, mainly because 60% of the crop area is rain-fed. Monsoons by all accounts will change behavior, apart from increases in temperature and CO_2 levels. The predicted changes in rainfall are therefore a critical national issue because about fifteen percent of national GDP is derived from agriculture, and – perhaps even more importantly – this sector provides the primary means of livelihood to 55% of the population.

2.2) The climate change effect will be reflected in the following:-

I. The monsoon is predicted to be stretched over a longer period with earlier onset. Total precipitation amounts will be higher, but will also exhibit more annual variability.

II. Mean temperature is projected to increase 0.1-0.3°C in the monsoon season (June-October) and 0.3-0.7°C during winter (November-April) by 2050 and 0.4-2°C during summer and 1.1-4.5°C in winter by 2070.

III. CO_2 levels will be elevated.

IV. Wet areas will become wetter and dry areas will become drier.

V. Weeds and pests will show strong response to changes in water, radiation, CO_2 levels after climate change

VI. Vulnerability to tropical cyclones in coastal areas, floods in Northern States and droughts in Northeastern and Southern India will increase.

3. Impact Of Climate Change On Water Resources

3.1) Water resources are finite and fragile. Water is required as a source for both agriculture (irrigation) and human consumption (drinking water). The major sources of water are (1) the monsoon which provides about 60 per cent of the water resources, and (2) snowmelts which feed the Himalayan Rivers.

3.2) IPCC has projected that the monsoon in India will be prolonged with an earlier onset. Total precipitation will be seasonally higher, but irregular, with periods of heavy rainfall intercepted by dry periods. Hence runoff will be high.

3.3) India is the largest user of ground water. Use of surface water has declined from 60% to 30% of all water use due to pollution of rivers and other water sources. The high extraction rate of ground water is unsustainable with extraction exceeding recharge in Haryana and Punjab. There is also deterioration of many aquifers.

3.4) Climate change will have profound effects on the hydrological cycle. Evapotranspiration is a major component of the hydrological cycle and will affect crop water requirements. By 2050, 10% increases in both the amount and intensity of rainfall are likely. Hence, there will be considerable erosion and loss of soil from croplands.

3.5) Climate change, with increases in rainfall and CO2 will result in plant diseases from fungi, bacteria and viruses. The response from invasive weeds and pests will be high.

4. Impact Of Climate Change On Agriculture

4.1) A number of mathematical and simulation models have been developed and employed by ICAR to assess the impact of climate change. It is found that the yields of rice, wheat and maize will decline with the increase in temperature, despite the positive fertilizer effect of CO2. The same trends are predicted for both potatoes and milk. On the contrary, climate change impacts in India are expected to be favorable or neutral on millets, soybean, chickpeas and groundnut – at least in the short- to medium-term (i.e. through 2050).

4.2) According to available simulation modeling, in Northern India a 1°C rise in mean temperature would have no predicted effect on potential yields, though an increase of 2°C will reduce potential grain yields at most places.

4.3) A number of institutions like National Initiative on Climate Resilient Agriculture (NICRA), Central Research Institute for Dryland Agriculture (CRIDA), ICRISAT, Central and State Universities, etc. are engaged in agriculture research to better understand the likely impact of climate change.

4.4) The current research priority is to develop regional application models to investigate spatio temporal variability in various biotic and abiotic stresses and to link this with crop simulation, remote sensing and management options for yield optimization.

5. Blueprint For Action

5.1) In order to not only survive but hopefully continue to thrive amidst the predicted impacts of climate change, it is urgent for all nations, especially India, to take action now to counteract, adapt and mitigate the most adverse impacts.

5.2) It is true that not even the most sophisticated mathematical models can indicate the precise time when climate change will become overwhelming to water availability and agricultural productivity. However, any advance action in any case cannot be premature since the prospect of intensifying climate change is unequivocal. The sooner the government and people act, the better. This is essential to ensure that progress is not halted or reversed by climate change.

5.3) It is appreciated that the GOI (Government of India) has been aware and active in initiating action to reduce GHGs and to adapt to climate change. Many institutions have developed simulation and mathematical models to predict the impact on monsoons, snowmelt and the possibility of floods and droughts. The action program must focus on improvement in models for prediction of climate change with great spatial precision (at the regional scale) and with finer temporal resolution (current through 2030). It is also necessary to invest in both:

(1) **Adaptation** – in response to the anticipated climate change effect on water sources and agriculture; and

(2) **Mitigation** – adopting measures to reduce GHGs. More specifically, integrated action is necessary for effective conservation of resources, precision agriculture, minimum tillage, crop protection, soil fertility, pest management and reduction of postharvest losses. The following specific steps can be extremely helpful.

Water Resources

1. Direct accounting for the real, total economic value of water use is vital and hence appropriate pricing of water for irrigation and civic uses should be adopted nationally, following a full socio-economic analysis of the consequences of such a policy.
2. Check dams should be constructed to conserve water, which will also enable higher ground water recharge.
3. Technologies should be developed for reducing water losses in reservoirs, conservation of rain water, and crop management with less water. Crop varieties requiring less water should be developed.
4. To ensure access to safe water continuous surveillance from catchment to consumer is vital and technologies should be developed and policies evolved to keep water free from bacterial and chemical contamination.
5. Simplify and improve efficiency of current water utilization systems to cope with the challenges that lie ahead. Novel ideas, technologies, practices, and systems are urgently needed as part of an overall adaptation strategy. Exploratory, cross-disciplinary research and collaborations should be immediately initiated in order to identify the truly innovative approaches that are required. These will help to address particular climate change impacts on the future provision of basic services in various environmental and socio-cultural settings, such as

exploring completely novel methods for crop irrigation, especially for crops like rice which presently require large water resources.

6. Improve management of water resources. This includes water conservation, augmentation and preservation practices with a view to promoting overall water security. A comprehensive program must be assembled to evaluate projects, policies and programs for capacity building for water management professionals.

7. Comprehensive studies should be taken up about the impact of climate change in water quality, ground water and ecosystems.

8. Decision support systems (DSS) needs to be developed and implemented to analyze various developmental and climate change scenarios in an integrated manner. It would assist decision makers for the rational planning and sustainable development and management of available water resources.

9. Implement integrated water resources management – decision support systems across all scales that are useful for water resource management and agricultural production systems. Natural Calamities including Drought and Floods

10. Drought is inevitable but scientifically designed strategies can bring much desired change from crisis management to disaster preparedness through substantial support for monitoring.

11. Early warning systems have to be in place to be prepared for flash floods in urban areas with provision of sufficient storm water drains. Hydrological models for better management of storm water have to be designed.

12. The occurrence of intensified hydrological extremes needs to be minimized by adopting the better water resources system operation and management policies.

13. High resolution numerical models and meso-scale observations, high performance computers and Doppler Weather Radars are required for monitoring and predicting cloud bursts.

14. There is a need for paradigm shift of the traditional, fragmented and localized approach of flood management. An integrated flood management which encourages use of resources of the river basin as a whole need to be considered. Such approaches would employ strategies to maintain the protective capacity of the flood plains while providing the protective measures against losses due to floods. Agricultural technologies such as crop varieties tolerant to submergence and water logging should be promoted.

15. There is a need for regular mapping and monitoring of glaciers and glacial lakes so that changes in these two can be linked to disaster.

Agriculture And Nutrition Security

16. Climate change, water scarcity, and shifts in composition of diet and crop demand will undoubtedly lead to changes in cropping pattern geographically. Planning ahead for these changes will enable much more efficient and effective adaptation. New crop varieties in rice and wheat have to be developed to withstand the expected increase in temperature and irregular monsoons using all available and new technologies.

17. It is desirable to increase biodiversity, optimize pesticide use, follow crop rotation and minimize environmental pollution to counter emergence and proliferation of new weeds and pests.

18. Agricultural systems should be diversified to enhance climate resilience and nutrition-oriented to ensure sufficient availability of both macronutrients as well as micronutrients at the household and individual level.

19. Strategic program to include development of heat tolerant varieties, changes in crop management practices, particularly water saving technologies, weather forecasting and risk management need to be adopted and vigorously pursued.

20. Long term strategies should be evolved for germplasm evaluation for widening genetic base and pre-breeding and development of climate resilient varieties with increased utilization of plant genetic resource.

21. There is wide variability in gene pool for heat tolerance and other agronomic traits which can be used for wheat improvement.

22. In rice cultivation Alternate-Wetting-and-Drying irrigation practice which has a proven record should be used as mitigation option.

23. Rainwater harvesting systems through farm ponds which conserve soil, water and nutrients, have good potential of adaptation to climate risk.

24. Site specific and integrated system (crops+ livestock+ vegetables) based technological management options will reduce climate risk and enhance livelihood security of small and marginal farmers.

25. There is need to link the crop growth models with

the relational data base layers through remote sensing and GIS platforms to subsequently understand the agricultural production on regional scale.

26. The National Initiative on Climate Resilient Agriculture (NICRA) covering crops, livestock, fisheries has made significant progress and can be resource for future planning and action program.
27. Greatly enhanced monitoring of climate, its impacts on water resources and nutrition security, and the progress of adaptation initiatives will be essential. Such monitoring must include novel mechanisms for tracking the nutritional status of all socio-economic groups.
28. Millets which are rich in iron and phosphorous, proteins and fiber, should be widely introduced in Indian diets and since their digestibility is low, research should be undertaken to improve the digestibility. Nutrition should be the centerpiece of development program.

R&D

29. Develop and outline plans and specific opportunities to pursue high priority and high impact research projects, such as village rehabilitation and the reversal of soil degradation.

Capacity Building

30. Professional competency is required for application of modern sustainable agricultural production systems. Hence there is need to invest in human resource development for developing professional competencies including knowledge, skills, attitude and values.
31. Programs to further capacity building and human resource development on climate adaptation must be initiated, including such topics as the greater use of geo-spatial data, real time advisory and building farmer skills on water resource management.

Information Generation & Information Exchange

32. There is an urgent need to identify and prioritize key data and knowledge gaps in climate change adaptation (e.g. soil characteristics, land use, water use, etc.) according to their degree of adverse impact on effective policymaking and decision-taking.
33. There is an urgent need for greater exchange of information on climate/water/agricultural issues related to adaptation and mitigation. A centralized clearing-house for climate related data, studies, and information should be stored in a systematic fashion and exchanged with all stakeholders, including international researchers.
34. Successful adaptation to climate change will only be possible if all stakeholders are kept fully informed on the nature of the challenge, the adaptation plans that have been developed, and the progress that is being made over time across the entire country. Accordingly, a robust communication strategy on these topics should be developed and implemented.

5.4) Climate change encompasses every sector of the economy and every section of society. The approach for mitigation and adaptation will require cooperation and integrated action on the part of the people and the authorities at all levels. The time to act is now.

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Part I: Climate Change Science

Overview Of Climate Change: Causes Consequences And Their Mitigation

By Dr. Dave Gustafson

The possibility that climate might be affected by man-made greenhouse gas (GHG) emissions, particularly those related to the combustion of coal and other fossil fuels, appears to have first been proposed in 1896. Another Swede, Arvid Högboom, refined Arrhenius' calculations. The numbers Högboom derived for the impact of doubling atmospheric CO2 on global temperatures were in the range of 10p F, a bit higher than most of the values accepted today. However, given the rather low amounts of fossil fuel burning at that time, neither Arrhenius nor Högboom was particularly alarmed by the results, as a little warming seemed welcome in Sweden. However, the main reason for their lack of concern was that they incorrectly assumed it would take many millennia for human activities to double the amount of carbon dioxide in the air. This now appears to be a level that will be reached by about the year 2060, without some form of global regulatory intervention.

During the 1970s, scientists increasingly raised concerns over the question of rising carbon dioxide levels atmosphere. At the end of the decade a World Climate Conference was held in Geneva in 1979, convening 300 experts from 50 countries. They issued a consensus statement recognizing the "clear possibility" that an increase in carbon dioxide "may result in significant and possibly major long-term changes of the global-scale climate". The 1980s saw the development of the first true Global Climate Models (GCMs) by independent teams of researchers from around the world. Among the key advances in the development of these models were the addition of a true oceanic circulation model, representation of land topography, and several feedback processes, such as the melting of snow or ice mentioned previously. James Hansen, a scientist with NASA, has argued for strong positive feedback, and has asserted that 350 ppm should be the highest tolerable concentration for atmospheric carbon dioxide, well below the current level of approximately 400 ppm.

While some scientists question whether the 350 ppm figure is the right target, the vast majority of the scientific community has embraced the fundamental idea that continued GHG emissions will accelerate climate change and have major negative consequences for water resources and nutrition security, the primary subjects of this Conference. Indeed, it is clear that climate change is already affecting the world. Certain types of weather events have become more frequent and/or intense, including heat waves, heavy downpours, and, in some regions, floods and droughts. Sea level is rising, oceans are becoming more acidic, and glaciers and arctic sea ice are melting. These changes are part of the pattern of global climate change, which is now primarily driven by human activity.

Many climate change impacts are important to human health and livelihoods and the ecosystems that sustain us. The impacts are often most significant for communities that already face economic or health-related challenges, and for species and habitats that are already facing other pressures. While some changes will bring potential benefits, such as longer growing seasons, many will be disruptive to society because our institutions and infrastructure have been designed for the relatively stable climate of the past several thousand years, not the changing one of the present and future.

The Impact Of Intensified Irrigation On The Indian Monsoon And Moisture Transport

By Dr. Sonali McDermid

Agricultural intensification in India has resulted in the expansion and intensification of surface irrigation over the 20th century. This enabled a steady rise in agricultural production, such that India is now a major contributor to global wheat and rice stores. Some of the highest producing and most intensively irrigated areas are found in northwest India and along the Indo-Gangetic Basin, a region that plays an important role in the development of the South Asian Summer Monsoon (SASM). The SASM is responsible for a significant amount of moisture transport onto the Indian continent, and its circulation is, in part, driven by the land-sea temperature contrast between the pre-monsoon heating of northern India and the relatively cooler equatorial Indian Ocean. Introducing large quantities of irrigation water to the land-surface in northern India can facilitate increased evaporation, which effectively regulates the land-surface heating during the critical pre-monsoon period. The resulting changes to the surface energy balance could decrease the temperature contrasts between the north Indian land surface and the equatorial Indian Ocean, potentially altering the South Asian Summer Monsoon (SASM) circulation. Prior studies have noted apparent declines in the monsoon intensity over the twentieth century and have focused on how altered surface energy balances impact the SASM rainfall distribution. Among these findings, the changes to the surface energy balance brought about by intense irrigation were found to potentially alter the regional rainfall distribution both outside of and within the SASM season.

The results from the coupled NASA Goddard Institute for Space Studies ModelE-R global climate model that investigate the impact of intensifying irrigation on the large-scale SASM circulation over the 20th century was presented. Irrigation rates were estimated as part of a reconstruction of twentieth century global hydrography, and by using the University of Frankfurt/Food and Agriculture Organization Global Map of Irrigated Areas to identify the areas equipped for irrigation (spatial resolution of 5 arc minutes at the year 2000). Estimates of monthly irrigation rates extending back to 1900 were obtained using a water balance and transport model (WBMplus). In ModelE, these timevarying, historical estimates of irrigation water are added to the top of the soil column in the vegetated fraction of the grid cell (beneath the vegetation canopy) for our irrigated simulations. The effects of irrigation to the impact of increasing greenhouse gas (GHG) concentrations by running irrigated simulations both with and without the inclusion of 20th century GHGs was compared. Simulations that included the GHG forcing also displayed the resulting warmer Indian Ocean surface temperatures. In the irrigation-only experiment, irrigation rates anti-correlate strongly with lower and upper level temperature contrasts between the Indian sub-continent and the Indian Ocean (Pearson's $r = -0.66$ and $r = -0.46$, respectively) – these are important quantities that indicate the strength of the SASM circulation. When GHG forcing is included, these anti-correlations strengthen: $r = -0.72$ and $r = -0.47$ for lower and upper level temperature contrasts, respectively. Simulations that include both the irrigation and GHG forcing show attenuation of the SASM circulation and decreases in the inter-annual variability by 40%, which is consistent with trends shown in various reanalysis products. Irrigation also weakened the lower-level wind fields that converge moisture over the Indian subcontinent, which lead to widespread decreases in moisture transport from the Indian Ocean and Arabian Sea. This effect was even more pronounced when increasing GHG forcing was included for more realistic representation. We conclude that the inclusion of irrigation may be necessary to accurately simulate the historical trends and variability of the SASM system over the last 50 years. Currently, however, irrigation is not generally included as a regional, or global, forcing in most climate model simulations. As such, knowledge of how intensive irrigation practices (such as those in India) could impact regional and local climates is not widespread and, thus, is not frequently included in climate change analyses and national adaptation plans. These findings suggest that intensifying irrigation, in concert with increased GHG forcing, is capable of altering both the SASM circulation and the regional moisture transport by limiting north Indian surface warming and reducing important land–sea temperature gradients.

In north/northwest India's most heavily irrigated areas, utilizing groundwater stores may cease to be economically viable towards the middle of the 21st century. The rapid decline of groundwater stores and decreased amounts of surface irrigation water (due to decreases in snow-melt and heightened evaporation with global warming) could make for substantial changes to the regional hydrological cycle and SASM circulation. Adequate regulation of groundwater stores; application of precision irrigation and conservation water techniques; development of drought tolerant/resistant and adapted crops; and purposeful watershed management could allow for extended use of existing water resources and a more resilient national agricultural system, as dryland farmers also stand to benefit if human-made forcings (like intensive irrigation) on the SASM circulation are limited. Many efforts are underway to gauge the impact of appropriate water resource management under climate change conditions, including those being conducted in the Agricultural Model Intercomparison and Improvement Project (AgMIP, www.agmip.org). The new AgMIP Water Resources Initiative and how such studies can also inform Indian water resources management for agricultural uses at both the national and state levels was mentioned.

Importantly, in addition to intensive irrigation, the SASM system displays sensitivity to several other regional forcings and feedbacks, which could further impact its water transport, strength and variability under future climate conditions. These forcings include: atmospheric pollutants, particulate matter and black carbon; fluctuations in snow accumulation on the Himalaya; land-use and land-cover changes (such as deforestation and expansion of agriculture into marginal lands); and changes to ENSO variability, Indian Ocean Dipole events, and

Indian Ocean warming. Further research should examine the effects of each of these forcings, both in isolation and combined, to gain a comprehensive understanding of how India's water resources may be impacted. In addition, downscaling methods that have accurate local representation should be developed and employed to understand how these regional forcings vary spatially and what their impacts are to small farms holder across the subcontinent.

Modeling Climate Change Impacts On Regional Water Resources

By Dr. P. P. Mujumdar

Climate change results in regional hydrologic change. The three prominent signals of global climate change are: increase in global average temperatures, rise in sea levels and change in precipitation patterns which convert into signals of regional hydrologic change in terms of modifications in water availability, evaporative water demand, hydrologic extremes of floods and droughts, water quality, salinity intrusion in coastal aquifers, groundwater recharge and other related phenomena.

A major research focus in hydrologic sciences in recent years has been assessment of impacts of climate change at regional scales. An important research issue addressed in this context is related to the responses of water fluxes on a catchment scale to the global climatic variations. A commonly adopted methodology for assessing the regional hydrologic impacts of climate change is to use the climate projections provided by the General Circulation Models (GCMs) for specified emission scenarios in conjunction with the process-based hydrologic models to generate the corresponding hydrologic projections. The scaling problem arising because of the large spatial scales at which the GCMs operate compared to those required in distributed hydrologic models, is addressed by downscaling the GCM simulations to hydrologic scales. Projections obtained with this procedure are burdened with a large amount of uncertainty introduced by the choice of GCMs and emission scenarios, small samples of historical data against which the models are calibrated, downscaling methods used and other sources. Development of methodologies to quantify such uncertainties is a current area of research in hydrology.

In this presentation, an overview of research carried out at IISc on assessment of hydrologic impacts of climate change addressing scale issues and quantification of uncertainties, were provided. Specific applications on impact assessment for water availability, agricultural water demands, river water quality and urban flooding were discussed. Information on currently ongoing research on detection and attribution of hydrologic change was provided and research issues that need immediate attention were highlighted.

Variability Of Precipitation And Precipitation Effectiveness Over India

By Prof. Sulochna Gadgil

The skill of models in simulating the present day monsoon variability is rather poor and the predictions for climate change vary considerably from model to model. While several models predict an increase in monsoon rainfall, a large number of the models predict a decrease. The only robust conclusion is that the frequency of the extremes (droughts, excess rainfall seasons) will increase.

There has been considerable progress in our understanding the year-to year variation of the Indian summer monsoon since the discovery of a strong link to the El Nino, La Nina and Southern Oscillation (ENSO) over the Pacific (Sikka, 1980; Rasmusson *et al*; 1983). The phenomenal progress in prediction of ENSO since the 90s facilitated monsoon prediction, particularly the extremes on which El Nino and La Nina have a large impact. However, it turned out that during the strongest El Nino of the century in 1997 the monsoon was above average (instead of being a severe drought as expected from the link with ENSO). Studies since then have shown that the Equatorial Indian Ocean Oscillation (EQUINOO) also plays an important role in determining the year to year variation of the monsoon (Gadgil *et. al.* 2004).In fact, all the extremes of the monsoon can be explained in terms of ENSO and EQUINOO. However, most of the climate models are not able to simulate the link of the monsoon with EQUINOO. Improvement of the predictions of the monsoon will occur only when this challenge is met.

To identify the farming strategies which can ensure food and nutrition security in the face of climate variability and change, advances in atmospheric and agricultural sciences have to be harnessed in a genuinely interdisciplinary approach involving farmers as well.

Snow And Glacial Influences On Water Resources And Stream Flow

By Dr. Sanjay K. Jain

Runoff from melting of snow and glaciers contributes significantly to water resources and stream flow in many parts of the world. Many rivers, streams, springs and lakes in the mountain regions are fed by the release of water from the frozen snow and ice reservoirs. In the Himalayan region, majority of rivers have their upper catchment in the snow covered areas. The solid precipitation results in temporary storage and the melt water reach the river in the melt season. Snow and glacier runoff play a vital role in making all these rivers perennial, whereas the rainfall contribution during the monsoon period is critical for storages in various reservoirs. The snow accumulation in Himalayas is generally from November to March, while snowmelt is from April to June. During April to June, snowmelt is the predominant source of runoff and during July to September it forms a significant constituent of melt.

Reliable prediction of quantity, timing and variability from mountains is essential for the livelihoods of many millions of people around the world. Estimation of the snow and glacier contribution in the annual runoff of various Himalayan rivers is necessary for the development and efficient management of water resources, which include flood forecasting, reservoir operation, design of hydraulic structures, etc. The planning of new multi-purpose projects on the Himalayan Rivers further emphasizes the need for reliable estimates of snow and glacier runoff. Despite their well-recognized importance and potential, not many attempts have been made to assess the snow and glacier contributions in these rivers, although a few hydrological studies have been carried out for glacierized river basins in the western Himalayan region. The conversion of snow and ice into water is called snowmelt, which needs input of energy (heat). Hence the process of snowmelt is linked to the flow and storage of energy into and through the snowpack (USACE, 1998).

Snowmelt models have two basic approaches towards calculating the amount of snowmelt occurring from a snowpack: energy budget method and temperature index method. The energy budget approach attempts to make the process as physically based as possible. The goal is to simulate all energy fluxes occurring within the snowpack to give an accurate account of total snowmelt in response to each of these energy fluxes over time and space. This approach is extremely data intensive, requiring vast amounts of input data either to force an initial run of a model, or to calibrate it based on historical data before running a forecast. Too often, this approach suffers from inadequate data supply or simply that the level of data is unwarranted for the purpose at hand. In light of the intensive data requirements necessary for the energy budget approach, an alternative method known as the temperature index or degree day approach allows for snowmelt calculation with much less data input. The basis of the temperature index approach is that there is a high correlation between snowmelt and air temperature due to the high correlation of air temperature with the energy balance components which make up the energy budget equation (Semádeni- Davies, 1997; Ohmura, 2001; Hock, 2003).

For assessment of snow and glacier melt runoff a model (SNOWMOD) has been developed at NIH (Jain, 2001, Singh and Jain 2003). The snowmelt model is designed to simulate daily stream flow in mountainous basin where snowmelt is major runoff component. The process of generation of stream flow from snow covered areas involves primarily the determination of the amount of basin input derived from snowmelt along with some contribution from glacier melt and rain. Most of the Himalayan basins experience runoff from the snowmelt as well as rain. The contribution of rain comes from the lower part of the basin having elevation less than 2000m, the middle part between 2000m to 4000m contributes runoff from the combination of rain and snowmelt while in the high altitude region having elevation more than 4000m, runoff computation comes from the glacier melt. The contribution from snow and glacier is controlled by the climatic conditions and therefore, varies from year to year.

Climate Change And Its Impact On Water Resources Of A River Basin In India

By Dr. Nagesh Kumar

There is growth in scientific evidence about global climate change. Since, hydrological processes are sensitive to climate variability and change, understanding linkages between the climate and the hydrological processes and their feedbacks becomes critical for sustainable management of water resources, environmental quality, economic development and social well-being. Understanding the aforementioned linkages will not only increase the awareness of how the hydrological systems may change over the coming century, but also prepare us for adapting to the impacts of climate change on water resources. So any holistic integrated and environmentally sound sustainable management of the available water resources in climate change scenario is intimately linked to the ability to adequately assess them.

Water resources assessment (WRA) involves determination of the sources, extent, dependability and quality of water resources for their proper utilization and control. General Circulation Model (GCM) data obtained at global scale for four different climate change scenarios viz., A1B, A2, B1 and COMMIT are downscaled to river basin scale using Support Vector Machine (SVM). Six Cardinal variables viz., precipitation, maximum temperature, minimum temperature, wind speed, relative humidity and solar radiation are downscaled at monthly time scale from CGCM3 output. Geographical Information System (GIS), remote sensing and Digital Elevation Model (DEM) are used along with GCM downscaled data in assessing the impact of climate change on water resources using ArcView Soil and Water Resources Assessment Tool (AV-SWAT). Catchment of Malaprabha reservoir in Karnataka state of India is chosen for demonstration.

Soil And Water Conservation Vis-À-Vis Climate Change For Sustainable Food Production

By Dr. P.K. Mishra

Evapotranspiration, the major component of the hydrological cycle will affect crop water requirement and future planning and management of water resources to a great extent. An analysis in Rajasthan shows that even as small as 1% increase in temperature could result in an increase in evapotranspiration by 15mm, which means an additional water requirement of about 313 million cubic meter for the whole arid zone of Rajasthan. Climate change will also increase risk and unpredictability for farmers (especially of small and marginal categories, which are most vulnerable and least able to adapt to the changes) by warming and related aridity, shifts in rainfall patterns and intensities resulting into growing incidence of extreme weather events. Projections of monsoon rainfall pattern over the Indian subcontinent indicate that by 2050, a 10% increase in the amount and 10% increase in the intensity of rainfall are very likely due to climate change, leading to increase in erosive power of rainfall. Studies have indicated that 1% increase in rainfall intensity may increase soil loss from croplands by 1.5%. Hence by 2050, about 66 M ha area in India under the erosion class of 5-10 t ha-1 yr-1 covering mostly croplands will be additionally affected by higher rates of erosion due to climate induced changes in rainfall. This will result in significant increase in water erosion affected land degradation area from the current level unless ameliorative measures are taken.

Soil and water conservation practices can play a major role in the mitigation of agriculture's contribution to greenhouse gas emissions and adaptation to changes in seasonal precipitation and temperature patterns. Over the last three decades several technologies have been developed, evaluated, tested and disseminated by various R&D agencies and line departments in the country. The choice and effectiveness of the technology is however dependent on the soil type, rainfall characteristics and land features in the changing climatic scenarios. Watershed is the right unit for undertaking NRM based interventions and development with proper quantification of resources to counter the negative effect of climate change.

Experiences show that efficient management of natural resources following watershed approach not only enhance agricultural productivity on sustainable basis but also help in moderating floods in downstream reaches and mitigate the impact of droughts during rain deficit years. As an adaptive measures, the water resources if restored and managed properly along with appropriate soil and water conservation measures, no doubt supplement a robust, natural resource friendly and climate resilient agricultural production system.

PART II: Adaptation To Climate Change

Increased Flood And Flood Management
By Dr. R. D. Singh

There could be several causes of floods like intense precipitation, inadequate capacity within riverbanks to contain high flows as well as silting of riverbeds, landslides leading to obstruction of flow and change in the river course, retardation of flow due to tidal and backwater effects, poor natural drainage, drainage congestion, cyclone, heavy rainstorms/cloud bursts, snowmelt and glacial outbursts, dam break flow etc. For the mitigation and management of floods, two types of measures, i.e., structural and non-structural measures are adopted. The structural measures of flood mitigation and management are dams and reservoirs, detention basins, embankments, channel improvement, drainage improvement, watershed management etc. While the non-structural measures of flood mitigation and management are flood forecasting and warning, flood hazard assessment, mapping and risk zoning, disaster mitigation system and preparedness, flood insurance etc. Nearly 40 million hectares of our country is flood-prone, of which about eight million hectares are flooded annually. The annual average area affected by floods in India is 7.563 Mha.

Prediction of cloudbursts is a challenging task and requires high-resolution numerical models with mesoscale observations, high-performance computers and Doppler weather radars. The radar can measure the size of raindrops in the clouds on the basis of which, conditions such as a cloud burst and unexpected rainfall can be predicted. The recent occurrence of cloud burst and flash floods in Uttarakhand is explained. The concept of Integrated Flood Management has led to a paradigm shift. Absolute protection from floods is a myth, and we should aim at maximizing net benefits from the use of flood plains, rather than trying to fully control floods. A proactive approach towards the management of floods over a traditionally reactive approach is rapidly gaining recognition among flood managers. The proactive approach does not treat floods only as an emergency or an engineering problem, but as an issue with social, economic, environmental legal and institutional aspects. The proactive approach is not limited to a post-event reaction, but includes preparedness, including flood risk awareness and response measures to flood management at different stakeholders' levels.

Drought And Drought Management
By Dr. Jagdish Rane

Future climate predictions points at change in rainfall pattern that may enhance amount of rains in dryland, but distribution of rains will be a big concern and challenge. While the limited precipitation, the primary cause of drought, is beyond the control of institutions involved in drought management, scientifically designed strategies can bring much desired change from crisis management to disaster preparedness through substantial support for monitoring, preparing and mitigating the stress. The livelihood of farmers in dryland can be substantially improved if strategies are focused on cycles of years and combination of efficient enterprises rather than only on drought year and single or a couple of enterprises. Win-win situation for environment and farmer can prevail if we successfully identify the best combination of technologies suited to a particular agro-eco system in annual, biennial or perennial cycles taking into consideration the massive adoption of water harvesting and watershed programs in pipeline.

Early Flood Warning Systems
By Dr. Thomas Pagano

Accurate and timely stream flow forecasts are critically important to water managers and emergency protection services. These forecasts cover a range of timescales from flash flooding (e.g. minutes to hours ahead) to seasonal (e.g. months ahead) and are generated by a range of statistical (e.g. regression-based) and dynamical (e.g. rainfall-runoff) model based techniques. The extent of human control over the forecasts, such as by adjusting model inputs and outputs, varies from nearly completely automated systems to those where forecasts are generated after discussion among a group of experts. Hydrologists predict complex coupled human-natural systems using incomplete and uncertain information and imperfect models. Such operational predictions are produced while integrating anecdotal information and un-modeled factors. Historical and real-time data availability, the complexity of hydrologic processes, forecast user needs, and forecasting institution support/resource availability (e.g. computing power, money for model maintenance) influence the character and effectiveness of operational forecasting systems.

Although it is an active research topic, nearly all operational forecasting systems struggle to make quantitative use of Numerical Weather Prediction model-based precipitation forecasts. Similarly, global-scale and spatially distributed hydrologic information from remotely sensed measurements are biased and have limitations. Forecast uncertainty is commonly estimated operationally by using an ensemble of future precipitation scenarios and/or a measure of historical model error. However, probabilistic forecast communication and use remains a stumbling block for many. The flexibility of the water manager's operating procedures and the size of the reservoir relative to incoming stream flow determine the relevance of forecasts to hydropower operations; moderately-sized reservoirs that can draw down in anticipation of high flows or slow releases in anticipation of drought stand to benefit the most. An open question is whether and how operational forecast skill may change as watershed hydro climate patterns evolve due to climate change.

Centralized forecasting systems having a national, transnational and even global extent are a new development. A number of systems are operational and seeking to evolve into mainstream sources of flood risk information. The European Flood Awareness System (EFAS) and its global equivalent (GloFAS) are nearly completely automated and are intended to serve global disaster relief organizations and the operational agencies of countries with trans boundary basins and/or relatively underdeveloped medium-range river forecasting systems. University of Oklahoma and the National Aeronautics and Space Administration also collaborate to provide global real-time predictions of floods and landslides based on satellite rainfall estimates. Converting these generalized forecasts into actionable warnings still requires local flood vulnerability information, thus they play a complementary role to national-scale flood warning services.

Addressing Climate Change In Long Term Water Resource Plans

By Dr. Francis Chung

Climate change is adding another layer of complexity to the already difficult water management challenge—providing a sustainable water supply for food, public health, energy, and industry while protecting and enhancing the human and natural environment. The warming climate is raising sea levels, melting snows earlier thereby depriving the natural storage capacity, shifting inflows to upstream reservoirs expanding flood flows and depleting conservation storage space, changing the plant physiology and phenology affecting the agricultural production, proliferation of pests and insects, just to list a few.

For water resources planners and managers, estimating the impact of potential climate change on the water resources poses a great challenge, especially in regions where hydrologic extremes are frequently experienced even in present conditions. Planning for the hydrologic extremes, either for droughts and floods, as well as forecasting the future population, economy, land use and corresponding water consumption and supply is already a complex and complicated task to water resources planners and managers. Climate change will add another layer of complexity to plan and manage future water supply and consumption.

California Department of Water Resources in coordination with the United States Bureau of Reclamation has formed an ad hoc work team to tackle this task of assessing the impact of climate change on the State's water resources. Various leading research institutions in California have made a great stride in many aspects of gauging future climate change, ranging from field monitoring to mathematical modeling of future climate conditions. The work team works closely with these leading research institutions in California. The work team also has in its possession various water resources management tools. The tools include a systems model that simulates the operation of the State Water Project and the Central Valley Project (CalSim), an estuarine hydrodynamics and water quality model that simulates the various management options of the Sacramento-San Joaquin Delta (DSM2), and a fine detailed groundwater simulation model that performs the water accounting in the surface and subsurface of the Central Valley (CVGSM). These models are serially connected to assess the effects of climate change on the State's water resources.

CalSim is a linear-programming (LP) based systems simulation model that is designed to simulate the operations of the State Water Project and the Central Valley Project. CalSim and its predecessors have been extensively used in California to analyze future water storage or conveyance facilities in California by both the California Department of Water Resources (CDWR) and the US Bureau of Reclamation (USBR). CalSim runs on a monthly time step although on a regional scale daily time steps are possible within CalSim. DSM2 has three modules: hydrodynamics, water quality, and particle tracking. Hydrodynamics module, based on four point finite difference solution technique, generates inputs to water quality and particle tracking modules. Water quality module employs a Lagrangian 'box-car' solution technique to eliminate numerical dispersions. Conservative as well as non-conservative constituents are modeled in water quality module. Particle tracking module was developed with the eventual goal of simulating the fish behavior in water column. CVGSM is a quasi-three dimensional finite element model designed to simulate the movement of water in the Central Valley aquifer. All three major models, CalSim, DSM2, and CVGSM, have their generic versions that can be applied elsewhere than in California. In order to assess the impacts of climate change on water resources in California these three models are connected both internally and externally.

There exist a number of Global Climate (circulation) Models (GCM's) and Regional Climate Models (RCM's) today. These models, when coupled with many possible future emission scenarios, generate a great number of possible future scenarios. A new approach is being developed to assess risks to future water resources management. Probability of each future prediction, if and when available, will be used in generating risks. Risks, expressed as a function of events and associated probabilities, will be useful information in developing and managing water management policies. Several climate research teams in California at the urging of the CDWR and USBR work team are leading the effort of identifying probability density functions (PDF's) of these various climate predictions. Cumulative density functions (CDF's) of these predictions will be used as inputs to CalSim and DSM2. Various management alternatives can then be generated and evaluated in view of associated risks.

Storm Water Flood Modeling In The Sub Basin Of Chennai Corporation, Chennai, Tamil Nadu, India

By Dr. YRS Rao

The study demonstrates the application of hydrological model for better management of storm water in urban watersheds. Mean annual rainfall in Chennai metropolitan is about 1200 mm and mean rainy days are about 52 days. The storm water drains and sewer lines are separate in the study area. Entire Chennai Corporation drains the storm into Bay of Bengal mainly through two major rivers namely Cooum and Adyar Rivers. The entire Chennai Corporation is divided into 12 watersheds based on the natural barriers like rivers, channels, drains, roads, railway lines and contours. Among these watersheds the Otteri Nullah sub basin has been chosen for micro level urban storm water modeling in consultation with Tamil Nadu State Government. This sub basin is the largest sub basin among the sub basins of Chennai Corporation. The total catchment area of Otteri nullah is 30.63 Sq.Km. Major objectives of the study are: evaluation of existing storm water drainage network efficiency using mathematical model, computation of inflowoutflow hydrograph at various outlets, water surface profile along the drains, feasibility of improvement of the existing drainage network and additional network if possible to mitigate urban storm water flooding.

The application of Storm Water and Waste Water Management Model (SWMM) model with different return period storms has indicated that the present networks of storm water drains are not adequate to drain off the runoff generated from the sub basin. The PWD has proposed to modify the longitudinal profile of Otteri Nullah drain as a part of flood mitigation measures in the sub basin. The proposed longitudinal profile is incorporated in the model and tested the adequacy for storm water drainage network for different return period of storms. It has been observed that the proposed longitudinal profile is adequate to drain off only 2- years return period storm in the basin. The existing drainage system without any blockage is verified with 2, 5, and 10 and 25 years return period storm and corresponding flood peaks at basin outfall are 54.43, 64.82, 70.89 and 77.13 m3/s respectively. It has been found that the existing storm water drainage network in the basin is inadequate even to dispose off 2 years return period design storm runoff. The hydrographs at outfall of the sub basin has been developed for various return period design storms and this information is very useful for best management practices (BMP). The data monitored in the sub basin may act as benchmark dataset for further research and to explore other flood mitigation measures in the study area.

Adapting Urban Water Supplies To Climate Change: An Australian Experience

By Dr. Shiroma Maheepala

The world's populations has predominantly become urban, nearly 50% of the world's population currently lives in cities and it is expected to increase to about 70% by 2050. In Australia, nearly 90% of the population now resides in urban areas, it is where 95% of the total population work, and where over 80% of the nation Gross Domestic Product (GDP) is is generated. If this trend to live in urban areas is increasing, it is expected that by 2030, about 92% of Australia's population will reside in urban areas, and about 94% by 2050, which means that Australian cities will need to accommodate an extra 7 million people by 2030 and an extra 13.9 million by 2050. Supplying adequate and secure water supplies to growing urban population is a challenge, particularly in the face of climate change. Australia is the driest continent in the world and its climate is highly vulnerable to climate change. Australian average temperatures are projected to rise by 0.6° to 1.5°C by 2030 and by 1 to 5°C by 2070. Overall, the climate change projections for Australia indicate warm and dry future climatic conditions throughout the continent, which along with the expected population growth in urban areas, is expected to cause a significant shortfall in urban water supply.

The prolonged drought conditions occurring since late 1990s has given the taste of such a climate to both urban and rural communities. Many Australian major cities experienced an unprecedented shortage of available water with each city's unrestricted water consumption getting closer to or over, their sustainable yield. Water restrictions are in place in all Australian major cities and towns, allowing the use of reticulated water for indoor uses only. Water supply shortfall and the potential to exacerbate water shortage under changed climatic condition are not the only issues of concern to Australian cities, since late 1990s. The need to protect urban ecosystems from storm water and wastewater discharges, rising costs of maintaining ageing water infrastructure, understanding expectations of the community living in urban areas and minimizing greenhouse gas emissions from water projects are also considered as critical challenges. Solutions have been sought to address these changes. It is in this context that 'integrated urban water management' (IUWM) had been seen as a potential solution for most of these challenges.

IUWM is an approach to plan and manage urban water systems (i.e. water supply, wastewater and storm water systems) to minimize their impact on the natural environment, and to maximize their contribution to economic vitality and overall community improvement using less resources and producing less wastes and harmful emissions. IUWM approach promotes diversification of water supplies by considering fit-for-purpose use in a manner that produces less waste and harmful emissions, to reduce greenhouse gas emission loading to the environment. This approach has now been embraced by all the Australian major cities and towns, as a potential adaptation measure for climate change and a potential solution for growing urban water demand. All major cities and towns now adopt IUWM principles for long-term water supply planning and are in the process of securing water supplies through source diversification, which involves the use of non-conventional sources such as recycled wastewater, storm water, rainwater and desalinated water. Integrating these non-conventional sources with the conventional surface water and groundwater sources is a challenge, which is being addressed through research, and the implementation of demonstration projects throughout the continent.

Water Availability And Traditional Knowledge Based Adaptation To Climate Change

By Dr. Pradip Dey

Climate change is a defining moment of our time with major negative implications on ecology, human culture, livelihoods and food security. The IPCC advocates to search local solutions for climate change adaptations; however, its report does not recognize the breadth and strength of century tested traditional knowledge in combating climate change. Major water concerns are: (1) most critical resource for Indian agriculture; (2) the resource is shrinking; (3) increased competition from other sectors; (4) decline in water table; (5) water-logging and salinity; (6) increased pollution; (7) environmental change to affect availability; and (8) reduction in river flow. The emerging scenario from different parts of the globe suggests that neither the scientific technologies alone nor the traditional knowledge exclusively can completely solve the threats of food and nutritional security challenges emanating from climate change, however, a fusion of the two can. Traditional Knowledge can be defined as the collectively owned non-formal intellectual property comprising wisdom, knowledge and teaching developed by local and indigenous communities over time in response to the needs of their specific local environment and integral to the cultural or spiritual identity of the social group in which it operates, preserved and many-a-time orally transmitted for generations.

Traditional water management practices include Stone Bunding, Stones-cum-Earthen Bunding, Stone-cum-Vegetative Bunding, Brushwood Waste Weir, Grassed Waterways and SPUR Structure. The planners and policy makers have yet another tool and dimension to initiate participatory action plan involving tribal farmers and their rich reserve of traditional knowledge in order to develop adoptable technology that will enable mitigation of water scarcity and problem of climate change for financial inclusion and mainstreaming of indigenous population. The study conclusively proved that planners and policy makers have yet another tool and dimension to initiate participatory action plan involving tribal farmers and their rich reserve of traditional knowledge in order to develop adoptable technology that will enable mitigation of water scarcity and problem of climate change for financial inclusion and mainstreaming of indigenous population. Moreover, region-specific amalgamated technological prescriptions refined with targeted policy analysis are required for effective implementation and obtaining positive outcomes within a finite time horizon.

Emergence Of New Pathogens And Viruses And Algae

By Dr. D. Rathnamma

Changes in the environment may increase the frequency of contact with a natural host carrying an infection, and therefore increase the chances of encountering microorganisms previously unknown to humans. The ecological changes including agricultural activities, food-handling practices, changes in water ecosystems, deforestation and also climate changes provide new opportunities for pathogens to emerge and gain access to human populations. A pathogen may emerge as an important public health problem because of changes in itself or its transmission pathways. A recent example of an emerging disease is the severe fever with thrombocytopenia syndrome (SFTS) that was discovered in China in 2010. The causative agent is a bunyavirus, a new member of the Phlebovirus genus in the family Bunyaviridae (Dexin Li, 2013). Ticks are suspected to be the vector that transmits the virus to human. In early 2013, a new H7N9 avian influenza virus became epizootic in Eastern China, causing 132 spills over infections of humans with 28 percent case fatality (Li Q et al., 2013).

Notably, 60 to 80 percent of new human infections are likely to originate in animals, disproportionately rodents and bats, as shown by the examples of Hantavirus pulmonary syndrome, Lassa fever and Nipah virus encephalitis.

Newly emerging and reemerging infectious diseases are the two major categories of emerging infections. The diseases that are recognized in the human host for the first time; and diseases that have historically infected humans, but continue to appear in new locations or in drug-resistant forms, or that reappear after apparent control or elimination. An important example of an emerging infectious disease is HIV/AIDS; the virus was first isolated in 1983. However, it is estimated that, since the start of the epidemic, 30.6 million people worldwide have become HIV infected and nearly 12 million have died from AIDS or AIDS-related diseases (WHO, 1998: Morens and Fauci, 2012.)

Other emerging diseases include Ebola virus, first outbreaks occurred in 1976. Indigenous cases have been confirmed in four countries in Africa (Côte d'Ivoire, Democratic Republic of Congo, Gabon and Sudan). Through June 1997, 1054 cases had been reported to WHO, 754 of which proved fatal. Sin nombre virus, a new world Hantavirus was isolated from cases of a local outbreak of a highly fatal respiratory disease 'hantavirus pulmonary syndrome' in the southern United States in 1993. It has subsequently been diagnosed in sporadic cases across the country and in Canada and several South American countries. In 2002, a new coronavirus emerged in China, associated with a severe acute respiratory syndrome (SARS) and substantial mortality in humans. The disease quickly spread globally before the epidemic was contained, in 2003, after more than 8000 cases and some 800 deaths in 29 countries. The disease emerged from bats and spread into humans first by person-to-person transmission in confined spaces, then within hospitals, and finally by human movement between international air hubs. The related MERS (Middle East Respiratory Syndrome) caused by another coronavirus which appeared in Saudi Arabia in late 2012 (van Boheeman et al., 2012).

In 1994, an outbreak of severe respiratory disease with high mortality occurred in thoroughbred horses in Australia. Two persons at the stable developed severe influenza-like disease and one died. A new virus called Hendra virus was isolated from both affected horses and human. This virus is maintained by enzootic, asymptomatic infection in certain species of fruit bat. Nipah virus also emerged from bats and caused an epizootic in herds of intensively bred pigs, which in turn served as the animal reservoir from which the virus was passed on to humans. There was an outbreak of acute encephalitis with high mortality in workers handling pigs in Malaysia during 1998–1999. The virus was antigenically related to Hendra virus, but subsequent sequence analysis identified as new species and designated as Nipah virus. Epidemiological investigations identified the source of the virus as fruit bats.

The influenza virus, H5N1 is a well-known pathogen in birds but was isolated from human cases for the first time in 1997. This virus emerged from wild birds to cause epizootics that amplified virus transmission in domestic poultry, precipitating dead-end viral transmission to poultry-exposed humans. The 2009 H1N1 pandemic influenza virus emerged from pigs as well, but only after complex exchanges of human, swine, and avian influenza genes.

The reemerging pathogens first appeared long ago, but have survived and persisted by adapting to changing human populations and to environments that have been altered by humans. Dengue virus and West Nile virus (WNV), distantly related flaviviruses, serve as good examples. They have been spread by geographic movement of humans in association with the mosquito vectors for the diseases. For example, Dengue came to the Americas in association with the slave trade of earlier centuries. In this regard, slaves infected by mosquitoes in Africa presumably brought the infection to the Americas by seeding the mosquito population upon arrival. Dengue has become the most important arthropod transmitted viral disease of humans in the world today, with more than two billion people at risk and tens of millions of cases annually. During the 1990s, a virulent strain of West Nile virus emerged in the Middle East and invaded portions of Eastern Europe and subsequently the United States, causing extensive mortality in birds and fatal encephalitis in humans and horses. The virus has since spread throughout North America and into Central and South America, and is now a leading cause of human arbovirus encephalitis in the New World.

The WNV has become adapted to multiple mosquito and avian species, a major factor in increasing its opportunity to infect humans. Rift valley fever (RVF) is a zoonotic disease typically affecting sheep and cattle in Africa. Mosquitoes are the principal means by which RVF virus is transmitted to animals and humans. Following abnormally heavy rainfall in Kenya and Somalia in late 1997 and early 1998, RVF occurred over vast areas, producing disease in livestock and causing haemorrhagic fever and death among the human population. The epidemics of Yellow fever (YF) continue to occur. The threat of YF is present in 33 countries in Africa and eight in South America. The virus is maintained in a mosquito–monkey–mosquito cycle. The Crimean-Congo hemorrhagic fever is an emerging problem, with increasingly more cases being reported each year from many parts of the world and is transmitted by ticks.

Surveillance, Monitoring, Water Quality Design: Safe Drinking Water Supply –WSP

By Dr. J.K Bassin

Per capita availability of water in the country is decreasing with time, thereby affecting the quality of water.
Management of safe drinking water includes risk analysis to identify priority hazardous scenarios. Pathogens are often considered to be a higher health risk issue for municipal water supplies than chemicals.

The key to microbiologically safe drinking water is exclusion of fecal contamination from supply. Outbreaks of cholera and typhoid in the 19th and the early 20th centuries led to the wide-spread use of filtration to treat water supplies followed by the gradual introduction of the use of chlorine, usually on an intermittent basis, from 1910 onwards. The Croydon typhoid outbreak in 1937, however, led to continuous chlorination of water being used almost universally in PWS. According to WHO, supplying all mankind with healthy water poses a continuous challenge. WHO has been issuing guidelines for drinking water quality from time to time based on which the national standards are set in many countries. In September 2004, WHO issued 3rd edition of 'Guidelines on Drinking-water Quality'. The emphasis of Recommendations is no longer on monitoring the quality at the tap but rather on a comprehensive analysis of supply systems as well as the guidance of processes according to a so-called water safety plan.

Water safety plans are developed mainly on the basis of risk management which necessitates assessment of public health concerns, assessment of risks affecting water quality and public health, and management of the identified risk factors.

WSPs are a risk management tool to prevent the contamination of drinking water before it occurs. WSPs utilize the following questions to build the management plan: i) What are the hazards to safe drinking water? ii) How will these hazards be controlled? iii) How will the control of hazards be monitored? iv) What actions must be taken to restore control? v) How can effectiveness of the system be verified?

Major risk associated with water supply is due to microbial contamination since a lapse here can cause large-scale infection through the consumption of contaminated water. The enhanced scientific knowledge has identified the pitfalls of large-scale disinfection using chlorination of water, it gives rise to the formation of more harmful chemicals called disinfection bio-products (DBP) some of which are carcinogens.

The risks associated with DBPs are high and serious but the risks associated with 'not disinfecting' the drinking water far outweigh these risks. Therefore, it is only appropriate to assign higher priority to disinfection despite the risks associated with DBPs owing to even higher and large-scale risks associated with microbial contamination.

Delivery of safe water necessitates assessment of risk associated with the water supply system based upon sound scientific evidence and supported by appropriate monitoring of water quality. This approach includes knowledge about the source of water, the quality of water received from this source, the necessary control measures required to treat the raw water, protection of distribution network, timely repair and maintenance, and safe handling of water by the consumers.

Impact Of Climate Change On Agricultural Systems And Adaptation Responses

By Dr. Mark Rosegrant

Research from IFPRI assesses the impacts of climate change on agricultural production, prices of major commodities, calorie availability and child malnutrition in 2050. The modeling methodology seeks to reconcile the limited spatial resolution of macro-level economic models that operate through equilibrium-driven relationships at a national level with detailed models of dynamic biophysical processes. The climate change modeling system combines a biophysical model, the Decision Support System for Agro-technology Transfer [DSSAT] crop modeling suite of yield responses of five important crops (rice, wheat, maize, soybeans, and groundnuts) to climate, soil and nutrients with the SPAM data set of crop location and management techniques . The biophysical production impacts are then aggregated and input into IFPRI's global agricultural supply and demand projections model, IMPACT.

For most countries and regions, crop production is projected to be reduced significantly due to climate change. Developing countries are projected to be especially hard hit, and agriculture in India and other parts of South Asia are particularly negatively affected by climate change. In some countries, such as China, some crops fare reasonably well, because higher future temperatures are favorable in locations where current temperatures are at the low end of the crop's optimal temperature. On a global basis, the yields of major food staples are projected to be 10-20 percent lower in 2050 under the IPCC A1B SRES climate change scenario, compared to a no-climate change scenario. By 2080, with continued worsening of climate change, the crop yield differential increases to between 15-35 percent, depending on crop and GCM utilized.

World prices are a useful single indicator of the effects of climate change on agriculture. Even with no climate change, world prices for the most important cereal crops, rice, wheat, and maize, will increase between 2000 and 2050, driven by population and income growth and growing water and land scarcity. Climate change results in still higher price increases in 2050 compared to the no-climate change case, pushing the prices of rice, wheat and maize 15-25 percent higher in 2050. Progress on improving food security is slow even under the baseline no-climate change case. The higher food prices due to climate change reduce projected food consumption and calorie consumption by 12 percent in developing countries in 2050 compared to the no-climate change scenario and causing projected child malnutrition to rise by 10 percent. These impacts would significantly worsen food security, especially for the poor and vulnerable groups in rural communities.

Private Sector Efforts To Manage Water Resources In Face Of Climate Change

By Mr. Deepak Jolly

Based on six risk categories the Coca-Cola company developed a companywide standard for Source Water Sustainability. The purpose of this standard is three fold. 1) Ensuring that source water is managed at the same level as other ingredients to protect product quality, and ensure the sustainability and supply continuity of water supplies to the Coca-Cola system manufacturing operations sufficient to support current and future production. This includes promoting and supporting the sustainability of local water resources in the communities where the Coca-Cola system manufactures. 2) Ensuring accurate identification, assessment and mitigation of risks to water supplies used by the Coca-Cola system manufacturing operations. These include, but are not limited to, environmental, social, political, economic and regulatory risks. 3) Identifying a practical way that manufacturing operations can respect and support the water rights of people, nature, business, government and formal rights holders.

The Source Water Sustainability standard is implemented through conducting Source Water Vulnerability Assessment (SVA). SVA is a formal identification and assessment of the social, environmental, economic, regulatory and political risks to all sources of process water. SVA's are prepared by a qualified Water Resource Expert. This activity involves a rigorous scientific study on watershed to understand water resources vulnerability in Quantity, Quality, and Community areas. Based on the identified vulnerabilities a Source Water Protection Plan (SWPP) is developed for each facility to work around and mitigate them.

This plan includes, 1) A comprehensive inventory and assessment of vulnerabilities to the facility's ability to reliably access sufficient, high quality freshwater supplies while avoiding reputation and brand damage; 2) Actions to mitigate any adverse effects the facility's water use has on the availability and quality of water for the people in the local community, and actions the facility will take, if any, to address the local community's source water risks; 3) A Monitoring and Mitigation Plan that lists actions to mitigate the identified vulnerabilities; and 4) A Stakeholder Engagement Plan that lists actions to reduce vulnerabilities through improved relations and to engage stakeholders in the facility's water resource sustainability and stewardship interests.

The WRA and SWP plans have provided an opportunity for the Company to understand impact of climate change on our business at facility level. As a result, the company has engaged with the local community on watershed scale and water partnerships. As a part of global commitment and Vision 2020 goals the Company is targeting to reduce specific water use by 25% from 2010 base line and also attain 100% water replenishment level on global level. In tune with the above Coca-Cola India has already achieved 36% reduction in specific water use over past five years and recorded 118% of water replenishment level by 2012.

Multi-Stakeholder Partnerships To Improve Nutrition Security

By Dr. Mohammed Oufattole

Numerous agriculture companies are involved in the first steps of food production, and they have become increasingly aware of the critical role they play in providing small-holder farmers with tools and services that promote a safe, affordable, and nutritious food supply. A three-part approach is taken to provide tools and options to small-holder farmers.

Traditional Markets: This approach fully leverages R&D commitments to improve commodity crops, such as progress to double the yields of a critical grains and oilseeds, and to provide better vegetable varieties with farmer and consumer appeal. Technologies are broadly licensed to multiple seed companies in order to support a competitive marketplace that provides the greatest seed choices for farmers.

Philanthropic Donations: This approach utilizes foundations, such as the Monsanto and Syngenta Funds, to bring benefits that do not directly involve or impact current commercial businesses. This includes sharing technology with public research institutions to improve crops that are important to food security but not core to our business such as cassava and cowpea.

Cooperative Development Partnerships: This approach combines traditional market approaches and philanthropic donations to provide unique solutions that improve choices for farmers. This includes technology sharing partnerships, such as the Grow Africa commitment in Tanzania.

Indirect Impacts: Pests And Diseases, Weeds And Others, Crop Improvement

By Dr. Vellingiri Geethalakshmi

Weeds have a greater genetic diversity than crops. Each crop is associated with more than 10 "troublesome" weed species and most of them are similar in growth habit or photosynthetic pathway (Bridges, 1992). If change of resources such as light, water, nutrients or carbon dioxide occurs within the environment, it is more likely that weeds will show a greater growth and reproductive response. Recent evidence indicates that, many of "noxious" or "invasive" weeds may show a strong response to increases in atmospheric CO2 (Ziska and George 2004). Elevated CO2 as a result of below ground carbon storage would benefit perennial weeds with increases in the growth of roots or rhizome (Rogers et al. 1994). Increasing temperatures may mean an expansion of weeds into higher latitudes or higher altitudes. Higher CO2 will stimulate photosynthesis and growth in C3 weeds and C3 crops, and reduce transpiration and increase water use efficiency in both C3 and C4 weeds and crops (Elmore and paul, 1983). Higher temperatures can possibly offset some of the benefits of elevated CO2 for both, weeds and crops. Stimulation of biomass accumulation from CO2 doubling was estimated by Patterson (1995) to be +31% in wheat, +30% in barley, +27% in rice, +39% in soybean, +57% in alfalfa, and +84% in cotton. In contrast, a survey of experimental results on 27 non-crop C3 species revealed that biomass accumulation increased from 79% to 272% compared to ambient CO2. Climate change may affect the effectiveness of the herbicide and studies have revealed reduction in herbicide Efficacy and requirement of more pesticides to kill weeds under warmer climate, this is likely to result in more trace chemicals in the environment.

Climate Change Vs. Insect Pests: Insects are ectothermic, very sensitive to temperature, and cannot sustain living below and above certain thresholds. Each insect species has a different optimum temperature for survival and reproduction. In colder regions (higher latitudes) with distinctive seasons insects have broader thermal tolerance and are living in climates that are currently cooler than their optima (Deutsch et al. 2008). Global warming might therefore benefit many insect species in the temperate regions as a result of change in geographical distribution, increased overwintering, changes in population growth rates, increases in the number of generations, extension of the development season, changes in crop-pest synchrony, changes in interspecific interactions and increased risk of invasion by migrant pests (Porter et al. 1991; Bale et al. 2002).

Climate Change Vs. Plant Diseases: Crops are damaged due to diseases caused by fungi (rust, blight, mildew, rot), bacteria/ phytoplasma (wilt) and viruses. The occurrence of plant fungal and bacterial pests depends mainly on climate and weather. Temperature, rainfall, humidity, radiation or dew can affect the growth and spread of fungi and bacteria (Patterson et al. 1999). In general, climate change has the potential to modify host physiology and resistance, and to alter stages and rates of development of the pathogen (Coakley et al. 1999). The relationship between climate change and associated weather events, and resulting changes in disease development will generally not be a simple one-to-one relationship. The impacts will tend to be most dramatic when climatic conditions shift above a threshold for pathogen reproduction, are amplified through interactions, or result in positive feedback loops that decrease the utility of disease management strategies (Gerrett et. al. 2008).

Elevated CO2 may increase C3 plant canopy size and density, resulting in a greater biomass with a much higher microclimate relative humidity. This is likely to promote plant diseases such as rusts, powdery mildews, leaf spots and blights (Manning and von Tiedemann 1995). In soybeans, elevated CO2 alone or in combination with ozone (O3) has significantly reduced downy mildew (Peronospora manshurica) disease severity by 39–66% and in contrast, increased the severity of brown spot (Septoria glycines) (Eastburn et al. 2009).

Climate Change Vs. Pest Control: The economic, social and environmental impacts of climate change can be positive, negative or neutral, since these changes can decrease, increase or have no impact on plant diseases, pests or weeds depending on each region or period of time considered. Any direct or indirect impacts from a changing climate will have a significant effect on herbicide/ pesticide management. For example, drought can result in thicker cuticle development or increased leaf pubescence, with subsequent reductions in herbicide / pesticide entry into the leaf (Ziska et al. 2004). Climate change could alter the efficacy of weed bio-control agents by potentially altering the development, morphology and reproduction of the target pest. Change in CO2 concentration would lead to changes in C: N ratio and alterations in the feeding habits and growth rate of herbivores and warming could result in increased overwintering of insect populations and changes in their potential range (Patterson,1995).

Economic Impacts Of Climate Change On Agriculture
By Dr. T Jayaraman

Issues to keep in mind while discussing the economic impact include**:** impacts of climate change as a change from the baseline; evolution of baseline must take into account development; development is not only growth – involves many kinds of structural changes; limitations of modelling of development ; characterising development; and macroeconomic issues; local factors are also important – biophysical, environmental, economic, social aspects; normative issues need to be considered putting people at the centre of the story and development as transforming the structure of economic, social and political inequalities (human development a part but not all).

While undertaking studies official statistics have to be referred to and they are important and significant but insufficient. There are many gaps also. They often underestimate inequalities and needs to be supplemented by detailed village level data and information but village level studies are difficult and time-consuming.

It may be noted that:

- Conditions of production and correspondingly output and incomes vary sharply across socio-economic categories.
- Consequences of climate or weather shock will be non-uniformly distributed across categories of farmers.
- Any spatial averaging will miss substantial aspects of inequalities and their consequences.
- Consequences of climate shock need to be studied similarly at the household level.

Climate Change And Indian Agriculture: Impacts, Adaptation And Mitigation
By Dr. B Venkateswarlu

Simulation modeling studies carried out by ICAR on several crops has revealed that climate change impacts in short term (2020 scenario) are in the range of 4-6% decline in yields with business as usual scenario. However, by adoption of the best-bet practices, based on the existing technology options, these yield declines can be overcome. The impacts of long term climate change (2050, 2080 scenarios) are more significant in the range of 15-25% reduction in yields which require strategic research on adaptation and mitigation.

Most studies have revealed that crops like wheat, rice and maize could be impacted negatively while the impacts on crops like soybean, chickpea and groundnut could be positive or neutral. The yields of potato are likely to increase in the North-West India while in Central and Eastern zones, the crop will be negatively impacted. Studies have clearly demonstrated that warming will exacerbate the heat-stress in dairy cattle leading to decline in milk yield.

Recognizing the importance of climate change on Indian agriculture, the Indian Council of Agricultural Research has initiated a comprehensive research programs on adaptation and mitigation. Preliminary research on crop simulation modeling was initiated nearly a decade ago which gave useful insights on the impacts and vulnerability. A mega program i.e. National Initiative on Climate Resilient Agriculture (NICRA) was initiated in 2011. Research is being carried out on adaptation and mitigation covering crops, livestock, fisheries and natural resource management. The project has made significant progress in the last two years. The first ever vulnerability atlas of India at district level for 572 Rural districts was completed.

The gene bank material of wheat was evaluated for terminal heat tolerance and a reference set of 3200 genotypes identified for further use. Field phenotyping of large number of germplasm lines in wheat, rice, maize, pigeon pea and tomato for heat, drought and water logging tolerance resulted in identification of 100 most promising genotypes so far. Feed supplements and appropriate shelter designs were made for reducing the impact of heat stress on large and small ruminants. A country wide GHG measurement net-work has been established to measure major greenhouse gases as influenced by the management practices under different crop/livestock production systems. Most importantly, the climate resilient agricultural practices are being demonstrated on farmers' fields in more than 100 vulnerable districts. This component has generated excellent response from the farmers and other stakeholders. The project is continuing in XII Five Year Plan with expanded mandate to cover other crops like cotton and sugarcane and an objective of reaching more number of farmers through on-farm participatory research and converging with National Mission on Sustainable Agriculture (NMSA).

Crop Genetic Diversity For Climate Resilient Agriculture

By Dr. K C Bansal

Climate change will pose agriculture with a number of challenges including: shrinking availability of natural resources (land and water), biotic and abiotic stress factors, malnutrition, and sustainability in agricultural production. Most climate change studies project significant decrease in crop yields in South Asia including India. As regards wheat an increases of 1-3°C in temperature may reduce yield up to 10% by 2020 in Asia (IPCC)–5-7 % decline in wheat yield for every degree increase in temperature.

Adaptation and mitigation strategy will include development of heat tolerant varieties; changes in crop management practices, including use of water saving technologies; weather forecasting and risk management measures.

Major constraints for wheat productivity enhancement in India include heat stress, shrinking water and land resources, breeding constraints, lack of screening and phenotyping methodologies, lack of pre-breeding efforts, and narrow genetic base. One of the major effects of increase in CO_2 will be on change in insect-pest dynamics.

Two pillar strategies will have to be adopted first by germplasm evaluation for widening genetic base and secondly pre-breeding and development of climate-resilient varieties.

India has a gene rich region. It is one of 12 world mega biodiversity centers, 17 mega diversity nations. The three of the 34 hot spots of biodiversity are in Himalayas, Indo-Burma region, Western Ghats and Srilanka. Western Ghats is the hottest spot with 68% endemic freshwater fish species. India has 162 breeds of domesticated animals, 10% of world's microbes, 6% of insects, 12% of birds and 20% of lower plants.

NBPGR, New Delhi, India maintains the National Gene Bank which includes 3, 97,829 varieties of 12 crop groups. The figure includes 3777 released varieties and 2024 genetic stocks.

The goal is to enhance agricultural production by enhanced utilization of plant genetic resources (PGR) through PGR utilization by breeders for crop improvement. Certain gaps will have to be addressed such as:

- **Over-reliance on own working collection**
- **Greater reliance on international nurseries / trials**
- **Reluctance to use PGR in the breeding programs**
- **Lack of long-term strategy for broadening genetic base**
- **Poor characterization and evaluation status of germplasm**

Wheat collections from different parts of the world are conserved in National Gene Bank of NBPGR. NBPGR has taken the initiative of identification of trait-specific germplasm for wheat improvement. NBPGR has characterized and evaluated entire set of about 22,000 wheat accessions at different locations in India. As regards reference set for terminal heat tolerance. 3,019 wheat accessions were selected based on 5 parameters (canopy temperature depression, leaf waxiness, days to maturity, grain yield per plant and 100 seed weight), and further validated at NBPGR, Issapur farm during Rabi 2012-13. A set of 3202 wheat accessions with wide variation for canopy temperature depression, leaf waxiness, days to maturity, grain yield per plant and 1000 seed weight were evaluated under terminal heat stress under two sowing dates during Rabi 2012-13 at NBPGR, Issapur.

The following may be noted:

- ***Wide variability was found in the gene pool heat tolerance and other agronomic traits that can be used for wheat improvement.***
- ***Heat stress under delayed sowing reduces grain yield due to reduction in biomass (due to reduced tillering), grains per spike and grain weight, while harvest index was unaffected.***
- ***Wheat germplasm showed very high variability for these traits and accessions with high stability for these component traits have been identified.***
- ***Canopy temperature has a negative effect on grains per spike and grain weight, and thus genotypes with very high CTD identified in this study will be useful in stabilizing these yield components under heat stress.***
- ***2000 germplasm lines showing less than 10% yield reduction have been identified. These lines will be greatly useful as donors as well as for identification of genes/ QTLs for heat tolerance in various component traits.***

The trait specific reference set for terminal heat tolerance is further being developed. This project will be utilized for association mapping and/or linkage mapping, and allele mining for target trait. Identified germplasm lines with higher level of heat tolerance can be included as a donor parent in breeding program for developing new promising heat tolerant wheat cultivars.

These are plans for utilization of *ex situ* collection using climate analogues for enhancing adaptive capacity to climate change in following crops: Wheat, Pearl millet, Sorghum, Chickpea, and Pigeon pea.

Potential of underutilized crops is being explosed. These include: Minor Cereal; Job's Tear; Seudo Cereals: Amaranth, Buckwheat, Chenopods; Legumes: Adzuki Bean, Faba Bean, Rice Bean and Winged Bean; Oilseeds: Perilla and Paradise Tree; Vegetables; Kankoda and Kalingada; Industrial Crops: Jatropha and Tumba.

A Global Consultation on "Use and Management of Agro Biodiversity for Sustainable Food Security" was held on 12- 14 February, 2013. Priority areas were identified for South-South cooperation and an operational roadmap for strengthening partnership in conservation and utilization of genetic resources was developed.

New Technologies For Crop Irrigation With Special Reference To Rice Cultivation

By Dr. Reiner Wassmann

The contribution of rice production to the overall GHG sources is about 1.5%, but at national scale this percentage can reach up to >20% within the GHG inventories of South East Asian countries. Considerable efforts have been directed towards identifying mitigation options by altered crop management. Various crop management strategies have been suggested, ranging from the selection of potentially low-emitting rice cultivars to proper post-harvest management.

However, only modified irrigation practice, namely in form of Alternate-Wetting-and-Drying (AWD), has at present a proven track record as mitigation option. This water-saving technique can reduce methane emissions up to 50 %. Some field experiments showed higher nitrous oxide emissions with these techniques, but this risk can be minimized through proper fertilizer management. However, the challenge is to identify incentives for farmers in applying water-saving techniques. In most irrigation schemes farmers have no immediate revenue from lower water consumption, so that additional incentives from carbon credits could be a pivotal step for large-scale implementation.

The recently approved methodology "Methane emission reduction by adjusted water management in rice" allows the registration of CDM projects in rice through water saving techniques. As for other agricultural systems, however, the implementation of the CDM concept as well as other mitigation approaches, e.g. NAMA (Nationally Appropriate Mitigation Action) plans, still face severe challenges due to the involvement of many stakeholders. Moreover, land use systems show enormous variability in terms of space and time which is in part due to the natural factors (namely soil properties and climate) as well as distinct crop management practices, so that proper guidelines for MRV (Measurement, Reporting, Verification) will become critical for CDM projects in the land use sector.

Climate Change: Strategies Of Adaptation And Mitigation In Rainfed Agriculture In Relation To Water Management In Andhra Pradesh

By Dr. K. Sreenivas Reddy

Adaptation strategies in rainfed areas include: rainwater harvesting (in-situ and ex-situ), ground water recharge,

development of drought resistant crop varieties, and enhancing water productivity through efficient irrigation systems. Mitigation strategies should focus on conservation agriculture (mulching and low/ minimum tillage), carbon sequestration; in-situ conservation of rain water and contour cultivation, (tillage practices- deep, tied ridging, conservation furrows, broad bed and furrows, vertical mulching and compartmental bunding). Conservation furrows plus deep tillage in sunflower have given yield benefit of 25% over farmer's practice. Ridges and furrows system in cotton has given additional yield of 500 kg/ha over farmers practice. In situ moisture conservation has minimized drought effects across production systems: 270 on farm trials in 18 target districts. Pigeon pea in ridge and furrow system has recorded 13% yield increase over flat sowing at Mirzapur, UP, India.

It may be noted that rain water harvesting systems through farm ponds has good potential of adaptation to climate risk in both Kharif and Rabi rainfed crops. This system has advantage of conservation of soil, water and nutrients and promotes local water availability for agricultural operations. It can be made for multiple enterprise integrating agriculture, horticulture, fish, poultry etc.

Aqua crop has been found effective with reliable results for assessing the rain water productivity in rainfed areas. The Aqua Crop model was calibrated for maize under different supplemental irrigation and crop management practices. The maximum basal crop coefficient for maize varies from 0.75 to 1.05 and water productivity of 31 gm-2. Aqua crop model predicted well with the measured values in case of grain yield, biomass, WP, crop canopy and soil water content. The model efficiency varied from 0.98 to 0.99 for grain yield, biomass and water productivity.

Under well irrigation, CO2 foot print was found minimum with drip irrigation system as compared to other surface, rain gun and sprinkler. The crop water balance for both maize and cotton with Echam-5 and CSIRO models climate data indicated the reduction in the deficits because of shift in rainfall, reduced Crop ET in case of late sowing of the crops for Telanagana region.

While introducing the new technologies as a strategy to mitigate the climate change, both investments and incentives for the farmer must be considered for protecting the future agri environment.

Integrated Modeling Of Overall Productivity *By Dr. N Subash*

Climate change impacts are increasingly visible in South Asia (SA) with greater variability of the monsoon. There has also been an increase in the occurrence of extreme weather events such as heat waves and intense precipitation that affect agricultural production drastically and thereby the food security and livelihoods of many small and marginal farmers, particularly in the more stress-prone regions of the central and eastern Indo Gangetic Plan (IGP). It is reported that if the current trends continue until 2050, the yields of irrigated crops in South Asia are projected to decrease significantly – maize by 17 %, wheat by 12 % and rice by 10 % - as a result of climate change induced water stress. It has been predicted that a doubling of the current CO2 level in the atmosphere will cause an increase of 1.5-4.0oC in average global surface air temperature, and changes in rainfall patterns, by the end of 21st century and predictions for Asia are mean warming of about 3.1°C till 2050s and about 4.6°C till 2080. Mean temperature in South Asia was projected to increase by 0.1-0.3°C in the monsoon (kharif) season (June-Oct) and by 0.3-0.7°C during winter (rabi) (Nov. - April) and by 0.4-0.2°C during kharif and 1.1-4.5°C during rabi by 2070 (IPCC, 2007). Simulation models for rice production indicate a reduction in yield of about 5% per degree rise in mean temperature above 32°C. It is observed that a 2°C increase resulted in a 15–17% decrease in grain yield of rice and wheat but, beyond that, the decrease was very high in wheat. However, a 3°C rise in temperature cancelled out the positive effect of elevated CO2 on wheat.

Simulations of the impact of climate change on wheat yields for several locations in India using a modeling approach indicated that, in Northern India, a 1°C rise in the mean temperature had no significant effect on potential yields, though an increase of 2°C reduced potential grain yields at most places. Future climate change-induced shifts in ocean currents, the sea level, sea-water temperature, salinity, wind speed and direction, strength of upwelling, and predator response are all likely to alter fish-breeding habitats as well as their food supply, impacting fish abundance in Asian waters.

Site specific and integrated system(cropping + livestock + fisheries+ vegetables) based technological management options reduce the climatic risk and better utilization of available natural resources produce higher agricultural productivity and thereby enhance food and livelihood security of small and marginal farmers of the region. Integrated assessment of climate change impact on agricultural systems through modeling - combining offline and online approaches - provides meaningful estimates for helping the policy makers to develop constructive/ concrete national/regional plans for the future.

Simulating Agricultural Processes With Crop Models *By Dr. Naveen Kalra*

Growth of crops obeys certain physiological principles. These may be described in qualitative terms but to a certain extent, various growth processes can be quantified in response to the environment by mathematical formulae. By linking the equations to each other, a mathematical model is obtained that, for convenience, can be written as a computer program. Such a quantitative model of crop growth, enables predicting crop growth rates and yields under a variety of environmental and management conditions.

This may be used as a tool for the grower to assist in his decisions on management operations (e.g. in scheduling of irrigation, fertilizer application and crop protection), or to be used in process control (e.g. .in climate control in greenhouses). A crop model may also be used for yield forecasting, e.g. by the processing industry for predicting and planning the supply, or by the government planners. It may be applied in land use evaluation and planning e.g. to access the production potentials of new cropping areas in dependence of availability of water and fertilizer. At present, the physiological models have mainly been used as a research tool, especially as a framework in analysis of experimental results, and in studying the effect of individual processes on crop growth in relation to the environment.

The empirical or regression models describe the observed plant weight with some empirical function. So they describe the effect only at the level of observation. The physiological models on the other hand, explain the observed growth rates from the underlying physiological processes and in relation to the environmental factors. They describe the mechanism of crop growth in an explanatory way. These models are direct descriptions of observed data and are generally expressed as regression equations (with one or a few factors) and are used to estimate the final yield.

As soon as enough scientific knowledge about the growth pattern, the growth-controlling factors and the interactions that are dominant within a particular cropping system becomes available, model building can be initiated.

The various levels of crop models start with assessing crop growth under non-limiting conditions, and the main use of such models is to determine potential yields. Since potential growth conditions are not features in cropping system, additional relationship would be specified in order for the model to have an application value. The major limiting factor (e.g. water stress, nitrogen stress, competition from weeds or disease outburst) is then identified and its effects on leaf area development, radiation use efficiency and partitioning factors are then derived and expressed mathematically.

Inter-annual climate variability in Indian context is significant. The simulation results in literature clearly indicate the effects of inter-seasonal climatic variability at various locations on growth and yield of crops. The seasonal temperature has one-to-one correspondence with yield of major crops, which can aid in extrapolating the results for evaluating the impact of climate change and its variability on growth and yield of crops. Probability of occurrence of extreme climatic events has increased in recent past, and farmers have to learn to deal with them. There is a need to identify suitable resource and input management strategies to sustain crops yields under these extreme events, and these have to be conveyed to farmers well in advance. Simulation models play key role in this regard. Through simulation models, vulnerable regions with the climate change could be identified.

There is a need to link the crop growth models with the relational database layers through remote sensing and GIS platforms to subsequently understand the agricultural production on regional scale. The potential productivity centers and appropriate land use type and appropriate agronomic management options have to be identified for sustaining the crops' yields. We need to identify mitigation strategies for reducing GHG losses, sequester carbon, and evolve methods to enhance nutrients' use efficiency. There is also strong need to develop integrated assessment model for evaluating agri-sector impact of climate change.

Satellite Remote Sensing For Climate Variability / Change Studies Status & Scope

By Dr. M.V.R. Sesh Sai

Observational data and model simulations form the foundation for understanding the climate system. Satellite remote sensing allows for continuous monitoring on the global scale. It provides an independent source of observations to validate climate models and climate theories. It started with the Vanguard 2 satellite, launched following the Sputnik. Since then, several satellites in both polar sun synchronous and the geo-stationery orbits have been launched to monitor land, atmosphere and oceans towards understanding the complex climate variability and response. Data from these satellites vary in spatial and temporal resolutions and often serve as complementary sets and augment the scientific analyses.

Observations from satellites enable deriving information on land, ocean and atmosphere at various spatial and temporal scales. Spatio-temporal changes of land cover have been studied by the research community in a variety of situations to understand the drivers that are responsible for such changes and use such information towards developing mitigation measures to cope up with the adverse impacts, if any. Satellite data on land, water and atmosphere are integrated towards generating products for re-analysis of the data for studying a wide range of climate research towards better comprehension of the processes and their interactions. Some of the salient inferences drawn by the scientific community are briefly presented hereunder.

Among the characteristics of the terrestrial biosphere, vegetation and its phenology are the main characteristics. Phenology is highly sensitive to the climate change as the vegetation – climate feedbacks are mediated by phenology. While the trend of global average greenness is positive, the regional trends did exhibit considerable variations in direction and magnitude of change. Fortnightly Global Inventory Modeling and Mapping Studies (GIMMS) NDVI series derived from a suite of NOAA AVHRR satellites for the period of 1981 to 2010 have been extensively used by the researchers to detect land surface phenology, change in land cover, drought frequency, NPP dynamics, greening and browning trends, etc. The processed data has been corrected for sensor degradation, and calibration of inter-sensor differences. Though not fully corrected for the atmospheric effects, effects due to absorption of scattering due to ozone, water vapor, Rayleigh scattering and aerosols in the atmosphere were reduced.

SSMI provided information on the variations in the spatial extent of the sea ice. During 1979-2010, the analysis revealed, the Antarctic Sea Ice extent increased by 1.5+ 0.4 % per decade.ERS-1 and 2, Envisat and Cryosat data provided valuable information on the mass losses of the Antarctic and Greenland ice sheets. Ocean surface topography observations from the TOPEX/Poseidon and other such missions indicated a global mean sea level rise of 3.2+0.8 mm yr-1 between 1992-2006.

The Global Climate Observation system has listed 26 out of 50 essential climate variables as significantly dependent on satellite observations. A-train formation has been useful in collecting data for retrieval of several important climate parameters from a host of six sensors, four NASA missions (Aqua, Aura, CALIPSO and Cloudsat) and one each of JAXA (GCOM-W1) and of CNES mission (PARASOL), flying in close proximity to one another. This provided nearsimultaneous observations of a wide variety of climate science related parameters to aid the scientific community in advancing our knowledge of Earth-system science and applying this knowledge for the benefit of society. The satellites are in a polar orbit, crossing the equator northbound at about 1:30 P.M. local time, within seconds to minutes of each other.

Extended Path Finder datasets of Atmosphere and Oceans (PATMOS-x) aims to derive atmospheric and surface climate records from the roughly 25 years of data from NOAA's Advanced Very High Resolution Radiometer (AVHRR). PATMOS-x generates mapped and sampled results with a spatial resolution of 0.1° on a global longitude, latitude grid. This format avoids spatial or temporal averaging of data thus maintaining the flexibility to conduct multidimensional analysis.

In India, over the past 3 decades Indian Remote Sensing Satellite are being used to generate information on natural resources, including infrastructure, and disaster management support. In addition, with the availability of Global Earth Observation (EO) datasets and by participation in various global and national initiatives, geo-spatial information on various land, atmosphere and ocean parameters is being generated.

The geo-portal of the Indian Space Research Organization, Bhuvan, showcases the Indian imaging capabilities in multi-sensor, multi-platform and multi-temporal domain. Bhuvan provides a range of services enabling visualization of various thematic data generated from the national missions and projects carried out by the National Remote Sensing Centre (NRSC). This Earth browser of Bhuvan gives a gateway to explore and discover virtual earth in 3D space with specific emphasis on Indian Region. An information system, called the NICES (National Information System for Climate and Environmental Studies) using Indian remote sensing and geostationary satellites data and others is being developed.

The European Space Agency has established the Climate Change Initiative (CCI) to create new climate data records for (currently) 13 essential climate variables (ECVs) and make these open and easily accessible to all. A climate modeling users' group provides a climate system perspective and a forum to bring the data and modeling communities together. Parameters in the CCI include clouds, aerosols, ozone, greenhouse gases, sea surface temperature, ocean color, sea level, sea ice, land cover, fire, glaciers, soil moisture and ice sheets.

Valuable spatio-temporal information on different climate science related parameters is being generated exploring the satellite data. Nevertheless, satellite data often contain uncertainties caused by biases in sensors and retrieval algorithms for capturing robust long term trends of climate variables. Further, short duration series of satellite data and calibration / validation issues are some of the important constraints. Currently, the studies are concentrated to circumvent these issues by integration of observations from multi-level platforms and simulation modeling to supplement the information needs and address the gaps through international cooperation.

Groundwater Issues, Remediation And Modeling And Wastewater Management

By Dr. N.C.Ghosh

Phenomenal growth of groundwater extraction structures over the last 50 years, from 3.9 million in year 1951 to 18.5 million in year 2001 (Minor Irrigation census, 2001; Singh and Singh, 2002), provides evidence of growing substantial dependence on uses of groundwater in India. With the present projected number of extraction structures of around 27 million (Shah, 2009) and estimated groundwater withdrawal of 243 BCM (CGWB, 2011), India is the largest groundwater user in the World (World Bank, 2010) meeting demands in more than 85% of rural domestic requirements, 50% of urban water and more than 60% of irrigation requirements.

Groundwater quality deterioration in many aquifers from sources of anthropogenic (Nitrate, Chromium, etc.) and geogenic (Arsenic, Fluoride, and Salinity) origin, a wide spread groundwater quality problem in many states in India, poses a serious threat to the available quantity of groundwater resources. Impact of projected climate change on groundwater resources is another emerging issue that can neither be overlooked nor be predicted with certainty about the aquifer responses to the climate change variables.

A review of the estimated total replenishable groundwater resource of the country (CGWB, 2011) of 431 BCM shows, net annual groundwater availability is 396 BCM (91.88% of annual replenishable quantity) and the annual groundwater draft (as of March 2009) for irrigation, domestic and industrial uses is 243 BCM (CGWB, 2011), leaving a scope of balance of 153 BCM (35.5%) for future development. An estimate and projection of annual groundwater requirements for various sectors indicated that if the business goes as usual, nearly 74% by 2025 and more than 100% by 2050 of the net annual groundwater availability will be required in various sectoral uses.

As a noteworthy step towards groundwater resource management, Ministry of Water Resources, Government of India under its 12th Five Year development plan has conceived the 'National Project on Aquifer Management (NAQUIM)' with objectives to: identify and map aquifers, quantify the available groundwater resources potential and propose plans appropriate to the scale of demand, characterize aquifer and identify institutional arrangements for management (MoWR, 2012). Some of the concerns are deep drilling of tube wells, over exploitation of aquifers, surface modifications, aquifer intrinsic salinity is another issue-need innovative method for management of aquifers under influence of salinity, etc.

Modeling Impact Of Agricultural Water Management Interventions On Watershed Hydrology And Various Ecosystem Services

By Dr. Kaushal K. Garg

Water resource is classified into two broad categories: green water and blue water resources. Blue water is portion of the rainfall which is available in water bodies, groundwater aquifers, which human directly can consume and could be transported from one to other locations. Green water is potion of rainfall which is stored in vadose zone and get available in form of soil moisture, which is utilized by plants and trees. It is estimated that 70-80% of global freshwater is available in form of green water and utilized by various biomes which generates number of ecosystem services. Blue water is the only a small fraction of total freshwater (Wani et al., 2012). With development of modern technology and excavation methods, blue water has been over-exploited globally.

Other than the blue water resources, there is large untapped potential for harnessing the green water resources in rain fed areas. A large number of on-station trails and modeling studies described that current crop yields in rain fed areas are two to five times lesser than their actual potential which could be harnessed through proper land, water and nutrient management practices. For example, long term field experiments (ranging from two to five ha range) conducted at ICRISAT showed that average crop yield with improved managed condition in rain fed areas is 5.1 ton/ha/year (together from monsoon and non-monsoon crops) compared to 1.1 ton/ha/year in farmers managed field (single crop in a year) clearly demonstrated huge untapped potential of rain fed areas.

In situ water management practices improved infiltration capacity and the water holding capacity of the soil, which resulted in higher crop water availability. This was particularly important during dry years when yields were low. The construction of check dams (ex situ structures) led to higher groundwater recharge, which enabled improved supplementary irrigation of the monsoon crop (in this case cotton). With higher groundwater levels the areas used to grow a second, fully irrigated cash crop (normally vegetables) during the dry season could be expanded, which makes an important financial contribution to the household budget (Garg and Wani, 2012). The ex situ systems also captured a large fraction of the sediments lost from the fields, which the farmers carried back again during the dry season.

Under a new climate with lower slightly reduced annual average rainfall amounts and higher rainfall intensities, interventions such as those implemented under the watershed development programs in India may be increasingly important for securing agricultural yields in upstream areas to achieve food security and improve livelihoods of small and marginal farmers through increase in green water use efficiency. It is important to clearly illustrate impacts and trade-offs in both upstream and downstream locations for different agricultural water interventions, accounting for changes in climate, water-related ecosystem services and the risk of ecosystems crossing thresholds into an undesirable state as well as the important goal of achieving sustainable development and reducing poverty in the developing tropical regions (Garg et al., 2012).

Adoption Of Climate Resillient Technologies In A Drought Prone Village In Tumkur District, Karnataka

By Dr. L.B. Naik

Climate change has become an important area of concern for India to ensure food and nutritional security for growing population. The impacts of climate change are global, but countries like India are more vulnerable in view of the high population depending on agriculture. In India, significant negative impacts have been implied with medium-term (2010-2039) climate change, predicted to reduce yields by 4.5 to 9 percent, depending on the magnitude and distribution of warming. Since, agriculture makes up roughly 16 percent of India's GDP, a 4.5 to 9 % negative impact on production implies a cost of climate change to be roughly up to 1.5 percent of GDP per year. Durgada Nagenahalli of Tumkur district has been identified by Krishi Vigyan Kendra (IIHR), Hirehalli, Tumkur for Technology Demonstration (Zone VIII) under National Initiative on Climate Resilient Agriculture (NICRA). The technology demonstration component deals with demonstrating proven technologies for adoption of crop and livestock production systems to climate variability. D.Nagenahalli village of Koratagere taluk was selected under this project, because it is relatively more vulnerable to climatic variability like drought, dry spells and extreme temperature. The village has acute shortage of water, soil degradation, preponderance of waste and common land, decreasing green cover and deforestation. The following technological interventions demonstrated that they enhanced resilience of farming systems to climatic variability.

- Soil management through land leveling and making compartments, trench cum bunding, tank silt application, contour bunding, deep ploughing, ploughing across the slope, live bunds, crop mulching and stubble mulching, soil health card as monitoring tool, compost production units.
- Water management through new farm ponds, percolation ponds, recharge of borewells and open wells, new check dams, water storage structures, desilting and widening of catchments channels, blocking leakage of D. Nagenahalli lake, desilting and widening of defunct farm ponds and check dams, micro irrigation systems.
- Crop interventions through field crops (drought resistant varieties of ragi, maize, red gram and ground nut), vegetable crops (high yielding varieties suited to rainfed areas of tomato and chilli), fruit crops (mango, amla, tamarind, lemon and cashew) and tree based farming system (around 34,000 mixed tree species) were tried in the farmers' fields.
- Farm mechanization through custom hiring centre, institutional arrangements, capacity building and awareness creation were promoted.
- Natural Resource Management (NRM) interventions to build resilience against climate variability.

Trench cum bunding, leveling, cover crops helped in arresting the soil erosion. Farm pond and check dam helped farmers for supportive irrigation to crops, recharge the underground water and increases the cropping intensity. Drip and sprinkler irrigation increased the irrigation efficiency in commercial crops. Performance of improved varieties like ragi, red gram, groundnut, paddy, maize etc., is significantly superior to local varieties. Tree *spp*. planted on the bunds increased the vegetative cover and meets the fodder requirement during drought. With custom hiring centre equipments farmers were benefited, labour efficiency has enhanced and efficient use water tank for watering tree promoted.

Human Resource Development For Sustainable Agriculture Under Present Climate Change

By Dr. B.K. Narayana Swamy

The development of human resource is becoming a matter of prime concern for increasing sustainable agricultural production. It is the professional who create circumstances that can help in making things happen. Human Resource Development (HRD) is the process of enabling people to make things happen. Hence, HRD is essential for adoption of emerging scientific revolutions in changing climate. The professional competencies include knowledge, skill, attitude and values. The professional competency is required for application of modern sustainable Agricultural Production system under current agrarian issues. The competencies could enable professional to act and improve for more alternatives and increase choices. Of all the factors of sustainable agricultural production man has the highest priority and is the most significant factor of production and plays a pivotal role in areas of productivity and quality. There is need for HRD to increase sustainable agricultural production under changing global climate.

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What is ILSI-India?

ILSI-India is a branch of International Life Sciences Institute (ILSI) with Head Quarters in Washington D.C. It works on issues relating to food safety, nutrition, toxicology, risk assessment, biotechnology and environment. It works very closely with industry, R&D organizations, and government departments, Ministry of Health, Department of Biotechnology, Ministry of Science and Technology, Ministry of Agriculture and Ministry of Food Processing Industries.

ILSI-India carries out its mission through sponsoring workshops, conferences, seminars, training programs and research. It also brings out publications and organizes educational programs. ILSI-India activities cover India and South Asian Region.

ILSI is a non-profit, worldwide organization whose mission is to provide science that improves human health and well-being and safeguards the environment. It achieves this mission by fostering collaboration among experts from public and private sectors of society on conducting, gathering, summarizing, and disseminating science.

ILSI strategy encourages global action on identifying and then resolving outstanding scientific questions in four thematic areas that capture the core of ILSI's work:

- food and water safety
- toxicology and risk science
- nutrition, health and well-being
- sustainable agriculture and nutrition security

ILSI branches include Argentina, Brazil, Europe, India, Japan, Korea, Mexico, North Africa and Gulf region, North America, North Andean, South Africa, South Andean, Southeast Asia Region, Taiwan, the Focal point in China, and the ILSI Health and Environmental science Institute. ILSI also accomplishes its work through the ILSI Research Foundation (composed of Center for Environmental Risk Assessment of Genetically Modified Crops (CERA), Center for Risk Science Innovation and Application (RSIA), Center for Nutrition and Health Promotion and Center for Integrated Modeling of Sustainable Agriculture & Nutrition Security (CIMSANS)

ILSI has a non-governmental status with World Health Organization and a special consultative status with Food and Agriculture Organization of the United Nation.

What is CIMSANS?

The world faces and escalating challenge to meet accelerating global demand for all staple food crops in the face of multiple constraints - climate change resource scarcity, and ecosystem preservation. Although agricultural production has increased significantly, it is not keeping pace with demand and this is especially true of non-commodity staple food crops, such as cassava and rice, where yield gains are comparatively lower. The emerging science of **integrated modeling** is being used to assess how crops and food security are being threatened. However, the underlying models being used in these assessments are often based on questionable assumptions and very limited or out-dated information.

It is against this backdrop that the International Life Sciences Institute Research Foundation (ILSI RF) has formed a new Center of Excellence, **the Center for Integrated Modeling of Sustainable Agriculture and Nutrition Security (CIMSANS)**. CIMSAN's immediate goal is to foster broad public/private collaboration in the development and application of sound science to integrated modeling of agriculture production systems and nutrition security. In so doing, CIMSANS willfill a sizable unmet need, completely distinct from other multi-collaborator initiatives in the sustainability space. The assessments produced by CIMSANS will ultimately make it possible for the world community to make properly informed decisions about the new adaptation imperatives that will be necessary to meet future nutrition needs (over the next few decades) in truly sustainable ways.

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