Asia-Pacific Network for Global Change Research

Applying Climate Information to Enhance the Resilience of Farming Systems Exposed to Climatic Risk in South and Southeast Asia

Final report for APN project 2004-01-CMY-Meinke

Dr. Holger Meinke, Qld Dept of Primary Industries, Australia.
holger.meinke@dpi.qld.gov.au

Dr. James W. Hansen, International Research Institute, USA.
jhansen@iri.columbia.edu

Dr. Muhammad Aslam Gill, Ministry of Food, Agriculture and Livestock, Pakistan. aslamgill@hotmail.com

Prof. Sulochana Gadgil, Indian Institute of Science, India.
sulo@caos.iisc.ernet.in

Dr. Ramasamy Selvaraju, Tamil Nadu Agricultural University, India.
selvaraju_r@hotmail.com

Dr. K. Krishna Kumar, Indian Institute of Tropical Meteorology, India.
krishna@tropmet.res.in

Dr. Rizaldi Boer, Bogor Agricultural University, Indonesia.
rboer@fmipa.ipb.ac.id

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Final Report submitted to APN

Overview of project work and outcomes

Non-technical summary

This project builds on previous work in India and Pakistan (APN2000-017), which established a network of research teams with capacity to apply agricultural systems analysis to evaluate options for managing climatic risk. Building on that foundation, this project documented and delivered benefits from climate information to agricultural decision makers, and plotted a course for large-scale, sustained operational support of seasonal climate information and prediction within the target countries (India, Indonesia and Pakistan).

The final year culminated in a stakeholder workshop, during which an organisational ‘consortium’ approach was adopted by participants. This consortium approach builds on the existing network and maintains the momentum generated by this project. Directors of CRIDA and NCMRWF agreed to jointly take the lead in the development and set-up of such a consortium. The consortium will address the gaps in knowledge, institutions, and policy that obstruct change at the ground level.

The stakeholders considered the project to have had a major impact on the conduct of cross-disciplinary research, highlighting the importance of simulation modelling being the glue that connects several disciplines, providing a focus on outcomes relevant to end users and not ‘science for science’s sake’. This aspect was highlighted in a presentation by one of the Indian farmers at the stakeholder workshop. In addition, the project had achieved considerable capacity building via staff training and the development of post-graduate scholarship opportunities. The science conducted by the team was highly regarded and considered an excellent example of the value of international, cross-disciplinary research, as evident by the publications arising from this project.

Objectives

The main objectives of the project were:

1. Enhance the capacity of local research to apply a set of quantitative, systems analytical tools and methods.
2. Engage agricultural stakeholders at each pilot location in a participatory research process.
3. Address information and communication needs of stakeholders.
4. Evaluate and tailor seasonal climate forecasts to the needs of decision makers
5. Demonstrate effective use, and evaluate benefits, of climate prediction information for improved decision-making by targeted groups of agricultural stakeholders at pilot sites.
6. Propose a strategy to enhance sustained operational support of agricultural use of seasonal climate prediction in each host country.

Amount received for each year supported and number of years supported

US$ 85,000, 3 Years

Participating Countries

Australia, USA, India, Pakistan, Indonesia

Work undertaken

Project year 1 (2002):

- Project team meeting and workshop, Bangkok, May.
- Crop simulation workshops at project sites in Bangalore and Tamil Nadu, May-June.
- PI's (Hansen, Selvaraju, Boer and Meinke) contributed to the Advanced Training Institute on Climate Variability and Food Security, Palisades, NY, July.
- Hansen, Meinke contributions to the START-CLIMAG SG meeting, D.C., July.
- Systems analysis and modelling workshop, Queensland, for scientists from Pakistan, India, Indonesia, Argentina (funding from APN & NOAA-OGP), August-September.
- Visit by Mr. Shafqat Ezdi Shah (Secretary of Agriculture, Pakistan) to Queensland to establish an MOU with DPI, September.
- Hansen visited India to discuss an expanded effort with potential partners, September.
- Meinke presented an invited paper at a WMO/FAO workshop on vulnerability; this visit also included interaction with CLIMAG W Africa project, October.
- Meinke brief visit to START to update on project activities, October.
- Krishna Kumar project visit to IRI, November.

Project year 2 (2003):

- Workshop on Seasonal Climate and Crop Forecasting Methods for South Indian Rainfed Agriculture, Pune, India, 12-16 May.
- Strategic Planning Workshop: Seasonal Rainfall Prediction to Enhance Smallholder Farmer Livelihoods in Semi-Arid Peninsular India, Pune, India, 19-20 May.Concept note and donor contacts for upscaled operational support of agricultural use of seasonal climate prediction in India.
- Visit of Bandung District Agriculture Officers to Indramayu Climate Field School Program, 2-3 October.
- Project Mid-term Meeting, Hanoi, Vietnam, 8-9 December.
- Capacity Building Workshop, Hanoi, Vietnam, 10-11 December.
- Model installation and initiation of dynamic downscaling runs over India.
- Statistical downscaling of GCM hindcasts and associated diagnostics.
- Analysis of the influence of El Niño characteristics on Indian monsoon rainfall.
- Pre- and post-season farmer workshops, Tamil Nadu.
- Survey of diffusion of understanding and use of climate information, Tamil Nadu.
- Participatory evaluation of groundnut varieties, Tamil Nadu.
- Training of extension personnel in climate applications, Tamil Nadu.
- Analysis of ENSO influence on historic floods and drought, Bandung District.

- APSIM validation and simulation data base, Bandung District.
- Economic evaluation of cropping system responses to ENSO forecasts, Bandung.
- Continuation of cropping system analyses, Pakistan.
- Expanded crop simulation knowledge base and validation, Karnataka.
- Project visit (deVoil) to Tamil Nadu and Karnataka.

Project year 3 (2004/5):

- MJO related activities in Australia, India & Indonesia.
- Develop Simulation Scenarios and Evaluate Economic Benefits of Crop Management Responses, Indonesia
- Farm-Level Analysis of Responses to Forecasts, Indonesia
- Visit of Indonesian project staff (Mr Faqih and Mr Perdinan) to APSRU, Toowoomba in October 2004. Mr Perdinan has since commenced his AUSAID scholarship at the University of Queensland, Brisbane.
- Visit of Mr Asim (Pakistan) to APSRU, Toowoomba in October 2004 & Sept 2005.
- Construction of an APSIM wheat scenario data base, Pakistan.
- Collected, organized and initiated analysis of district crop statistics for Andhra Pradesh, Karnataka and Tamil Nadu.
- Enhanced utility of the stochastic disaggregation tool (APSIM file format, use of frequency and intensity targets, stand-alone parameter estimation).
- Stochastic disaggregation of GCM hindcasts, South India.
- Evaluation of the value of Seasonal Climate Forecasts, South India.
- Construction of a Whole-farm optimisation model for climate applications, South India.
- Development of a Multi-lingual, computer-based Risk Management Tool for Extension at TNAU and QDPI.
- Visit of Krishna Kumar to APSRU, Toowoomba & BMRC, Melbourne.
- Scholarship granted to Perdinan for UQ study, negotiations regarding scholarship opportunities for Asim are in progress.
- Final Project Team Meeting held at IITM, Pune.
- Stakeholder workshop held at ICRISAT, Hyderabad.
- several publications submitted or at final draft stage (see publication list)

Main Outcomes

- An international, multi-disciplinary network of systems scientists who are committed to the creation of ‘actionable climate knowledge’ by building partnerships with stakeholders.
- Better understanding of climate variability impacts and climate-related vulnerabilities.
- A consortium of partners to build and extend the existing nodes and pilot studies.

Relevance to APN scientific research framework and objectives

The project was alinged with APN’s mission to ‘foster global change research in the Asia-Pacific region’. By engaging with scientists and institutions from India, Pakistan and Indonesia the project team increased developing country participation in climate variability research. This report also contains evidence how interactions between the science community and policy makers were strengthend. In addition to the scientific achievements (see publication list), the project concentrated strongly on capacity building activities via staff exchanges, workshops and through the facilitation of scholarships.

Self evaluation

The project has made a significant contriubtion the global change debate and advanced APNs goals. The final stakeholder workshop provided a venue to openly discuss this assessment. The unedited, concluding remarks from this workshop support our self evaluation. The project team considers that all specific objectives have been met:

- Enhance the capacity of local research to apply a set of quantitative, systems analytical tools and methods.
- Engage agricultural stakeholders at each pilot location in a participatory research process.
- Address information and communication needs of stakeholders.
- Evaluate and tailor seasonal climate forecasts to the needs of decision makers.
- Demonstrate effective use, and evaluate benefits, of climate prediction information for improved decision-making by targeted groups of agricultural stakeholders at pilot sites.
- Propose a strategy to enhance sustained operational support of agricultural use of seasonal climate prediction in each host country.

The project was not without challenges: the international environment (security), institutional barriers (many) and natural disasters (earthquakes and Tsunami) all impacted on the project teams ability to perform their tasks. However, in spite of these issues, we consider the overall outcome to be highly successful.

Potential for further work

See recommendations from stakeholder workshop

Publications

Peer reviewed journal papers

Selvaraju, R., Meinke, H., Hansen, J.W. 2006. *Management responses to seasonal climate forecasts in southern India's dryland cropping systems*. Submitted to Agric. Syst.

Kumar, K.K., Rupa Kumar, K., Ashrit, R.G., Deshpande, N.R. and Hansen, J.W. 2004. *Climate impacts on Indian agriculture*. Int. J. Climatol. 24:1375-1393.

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Meinke, H., Nelson, R., Stone, R.C., Selvaraju, R. and Baethgen, W., 2006. *Actionable climate knowledge – from analysis to synthesis*. Climate Research, accepted subject to revision

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Meinke, H., Stone, R.C., 2005. *Seasonal and inter-annual climate forecasting: the new tool for increasing preparedness to climate variability and change in agricultural planning and operations*. Climatic Change, 70, 221-253.

Donald, A., Meinke, H., Power, B., Wheeler, M., Maia, A.H.N., Stone, R.C., Ribbe, J. and White, N., 2006. *Near-global impact of the Madden Julian Oscillation on rainfall*. Geophysical Res. Letters, in press.

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Selvaraju, R. and Kumar, K.K.. *Climate Change Impacts on Irrigated Rice Production Systems in Southern Peninsular India.* Int. Journal of Climatology, 2004. (provisionally accepted)

Singhrattna, N., Rajagopalan, B., Kumar, K.K. and Clark, M. 2005. *Interannual and Interdecadal Variability of Thailand Summer Monsoon.* Journal of Climate, 18, 1697-1708.

Singhrattna, N., Rajagopalan, B., Clark, M. and Kumar, K.K. 2005. *Forecasting Thailand Summer Monsoon Rainfall*. International Journal of Climatology, 25, 649-664.

Gadgil, S. Srinivasan, J. Nanjundiah, R.S.,, Kumar, K.K., Munot, A.A., and Rupa Kumar K. 2005. *On Forecasting the Indian Summer Monsoon : the Intriguing Season of 2002*. Current Science, 83(4), 394-403.

Peer reviewed conference papers

Aslam, M., Asim, M., Meinke, H. and Nafees, S.K., 2004. *Applying climate information to enhance wheat based farming in rain-fed areas of Pakistan.* Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia, published on CDROM and www.cropscience.org.au/icsc2004.

Boer, R., Wahab, I., Perdinan and Meinke, H., 2004. *The Use of Global Climate Forcing for Rainfall and Yield Prediction in Indonesia: Case Study at Bandung District.* Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia, published on CDROM and www.cropscience.org.au/icsc2004.

Donald, A., Meinke, H., Power, B., Wheeler, M. Ribbe, J., 2004. *Forecasting with the Madden-Julian Oscillation and the applications for risk management*. Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia, published on CDROM and www.cropscience.org.au/icsc2004.

Meinke, H., Hammer, G.L. and Stone, R.C., Hayman, P. and Rodriguez, D., 2004. *Climate variability, change and seasonal forecasting in Australia - global lessons from two decades of local effort*. Invited Symposium Paper, Impact of Climate Variability on Agricultural and Natural Resource Management, Annual Meetings Abstracts, American Society of Agronomy, 31 Oct – 4Nov 2004, Seattle, WA, USA, published on CD, paper 3738.pdf.

Rao, P.R.S., Rao, K.N., Sridhara, S., Byregowda, M., Shankarlingappa, B.C., Meinke, H., deVoil, P. and Gadgil, S., 2004. *Exploring cropping options with crop models: a case study of pigeonpea versus peanut in rainfed tracts of semiarid southern India.* Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia, published on CDROM and

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Other publications

Selvaraju, R. and Meinke, H. 2003. Climate Variability and Agriculture (CLIMAG): *Applying climate forecasts in smallholder farming systems.* Conference on monsoon environments: Agricultural and Hydrological impacts of seasonal variability and climate change, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy, March 25-29, 2003.

Meinke, H., Abawi, Y., Stone, R.C., Hammer, G.L., Potgieter, A.B., Nelson, R.A., Howden, S.M, Baethgen, W., Selvaraju, R., 2003. *Climate risk management and agriculture in Australia and beyond: Linking research to practical outcomes.* Invited paper, Asian International Conference on Total Disaster Risk Management, Kobe, Japan, 2-4 December 2003.

Meinke, H., Howden, S.M., Baethgen, W., Hammer, G.L., Selvaraju, R. and Stone, R.C., 2003. *Can climate knowledge lead to better rural policies and risk management practices?* Proceedings, NOAA Office of Global Programs Workshop, Insights and Tools for Adaptation: Learning from Climate Variability, November 2003.

Meinke, H., Howden, S.M., and Selvaraju, R., 2003. *Australia's experience in the development and application of climate information to reduce vulnerability to extreme events*. Invited paper, Pacific Science Congress, Bangkok, 17-21 March 2003.

Selvaraju,R., Meinke, H., and Hansen, J.W., 2005. *Climate forecast applications for better water management in agriculture: a case study for southern peninsular India.* In: Sivakumar, M.V, Hansen, J.W. (Eds.), Proceedings of the International Workshop on CLIMAG. Springer, New York.

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Baethgen, W., Meinke, H. And Gimenez, A., 2003*. Adaptation of agricultural production systems to climate variability and climate change: lessons learned and proposed research approach*. Proceedings, NOAA Office of Global Programs Workshop. Insights and Tools for Adaptation: Learning from Climate Variability, November 2003, http://www.climateadaptation.net/papers.html.

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Acknowledgments

Home institutions, START, ICRISAT

Technical Report

Preface

To assist (rural) communities, business and policy makers to better cope with climate-related risks, this project created 'actionable climate knowledge' by synthesising information across disciplines and including stakeholders in the process. The project team found that such synthesis generates desired outcomes, but it is much harder than traditional component research that fills specific, existing scientific knowledge gaps (analysis). Reasons for these difficulties are historical, institutional and societal. Hence, we argue for an overt attempt to move towards targeted climate syntheses and integration of our scientific understanding into applied risk management frameworks. This will require new institutional arrangements and multidisciplinary partnerships.

1.0 Introduction

Improvements in our understanding of interactions between the atmosphere and sea and land surfaces, advances in modelling the global climate, and substantial investment in monitoring the tropical oceans now provide some degree of predictability of climate fluctuations months in advance in many parts of the world. The emerging ability to translate timely, skilful climate forecasts into impact assessment at the field or farm level can improve agricultural decision making by either preparing for adverse conditions or taking advantage of favourable conditions.

2.0 Methodology

Dr Hansen proposed 3 phases of an evolutionary strategy to improve agricultural decision making through climate prediction: (1) an exploratory phase (basic capacity building, gaining understanding of the system), (2) a pilot phase (co-learning through intensive interactions between researchers and decision makers) and, conditional on a successful pilot phase, (3) an operational phase that focuses on engaging, equipping and transferring ownership to those groups and institutions that will provide forecast information and support to a larger target audience on a sustained basis. Using a holistic approach, the project team established a process whereby systems simulation capability in conjunction with the latest climate science was used as an 'engagement model' with decision-makers at field, farm and policy level. This process translates often abstract, scientific information into well-quantified outcomes of alternative decision options, thereby providing users with tangible information that immediately results in better decisions. This project has led to "phase 3" in India, and at least into 'phase 2' in Indonesia and Pakistan.

3.0 Results & Discussion

While the projects results are documented in the publication list above, many activities did not result in 'publishable' outcomes and are therefore listed below.

Project year 1 (2002):

A *systems analysis and modelling workshop*, Queensland, trained young project staff from India, Indonesia and Pakistan in cropping systems simulation tools.

Seasonal prediction strategy. Investigators at IITM and IRI developed a collaborative strategy to advance seasonal prediction in the Indian region, including statistical and dynamic downscaling of GCM simulations. The IRI completed preliminary evaluation of statistically-transfored output of several GCMs over India for the SW monsoon and northern Pakistan for winter and early spring, and provided GCM boundary conditions and guided Regional Spectral Model set-up and use for dynamic downscaling experiments at IITM. An MOU formalized collaboration between the IRI and IITM.

Systems analysis and farmer participation, Tamil Nadu, India. Work at TNAU focused on the knowledge base for cropping system analysis, farm-level analysis of forecast responses, and ex-post impacts of farmer responses. We validated APSIM for groundnut, horsegram, sorghum and cotton using experimental data. An on-farm groundnut variety selection experiment and characterisation of horsegram genotypes for model validation supported APSIM simulations. A survey of 79 farmers provided data to support whole-farm economic analysis for forecast responses. We recorded two collaborating farmers' activities and cash flow as input to a whole-farm budgeting model. By reducing cotton area in response to the May forecast, one gained Rs 5,400 by December. We discussed a forecast favoring low rainfall, and model-based analyses of response options with ~30 farmers in workshops. Most (~70%) farmers in Thamaraikulam changed from cotton to early sorghum. Some reduced planting densities of groundnut. The ~20% of farmers who planted cotton abandoned their crops by August, loosing all input costs.

Crop simulation, Pavagada region, India. Pigeonpea, often interplanted with groundnut, is growing in importance as increasing competition from imported oils is suppressing the price of groundnut. To estimate the impact of rainfall variability, we used data from Univ. Agric. Sci., Bangalore, to validate APSIM-Pigeonpea. The model captured response to rainfall well in the Pavgada region. Simulation results served as a basis for discussiing alternative cropping options with farmer groups in the district. Dr. S. Sridhara, Asst. Prof. Agron., Bangalore, trained to run, and guide other staff members, in project simulations.

Climate applications, Bandung district, Indonesia. An MOU formalized collaboration between our project, Bogor Agric. Univ., Bureau of Meteorology and Geophysics, and the Directorate of Plant Protection and Local Government. Based on synthesis of past results for the Citarum watershed, and to take advantage of other synergistic activities, we shifted project activities from Indramayu to Bandung, and collected rainfall and streamflow data for the Citarum watershed. Two research assistants (Perdinan and Maris K. Rahadian) who received training are equipped to run APSIM to evaluate cropping system performance under different climate and management scenarios.

Resilient cropping systems, Pakistan. An MOU formalized collaboration between the Pakistan Ministry of Food, Agriculture & Livestock and Queensland DPI. Farmer discussions enabled us to characterise the system to support systems analyses to address farmer concerns about (a) summer fallow to conserve moisture for winter crops, (b) risk of reduced wheat yields following mungbean, and (c) sowing time for mungbean and for wheat following mungbean, in response to climate conditions. Despite skepticism, some farmers conducted on-farm trials based on simulations. Gill arranged lectures on project activities and simulation results for policy makers, crop scientists and extension workers.

Project year 2 (2003):

Workshop on Seasonal Climate and Crop Forecasting Methods for South Indian Rainfed Agriculture. The workshop, co-sponsored by IRI and IITM, provided training and advanced analyses at project locations in Tamil Nadu and Andhra Pradesh for Selvaraju and five scientists associated with the ATI. Using statistically-corrected, cross-validated GCM predictors, participants evaluated rainfall prediction skill, analyzed historic crop data, tested stochastic disaggregation and k-nearest-neighbour methods for linking climate prediction to crop simulation, and derived and discussed communication of probabilistic forecasts. We also analysed empirical predictors for each project site. Lectures gave an overview of Indian monsoon forecasting approaches and activities.

Vietnam Capacity Building Workshop. We met with about a dozen representatives from Vietnam's agricultural, meteorological and disaster management agencies to brief them on the project and discuss their needs and priorities. They see a need to expand use of forecasts for the benefit of farmers, with immediate emphasis on (a) assessing climate information needs and (b) training intermediaries. Participants presented insights from pilot projects in central and southern Vietnam. The workshop raised a range of scientific issues, some of which have been addressed during the final year of the project (eg. the feasibility of MJO-based forecasting at time scales of 2 weeks to 2 months for tactical decision making). The workshop also highlighted some of the insitutional challenges likely to be encountered when working across many countries and with a wide variety of institutional partners. Our project team (Selvaraju and Rizaldi) and experience have an opportunity to contribute particularly in capacity building.

Strategic Planning Workshop: Seasonal Rainfall Prediction to Enhance Smallholder Farmer Livelihoods in Semi-Arid Peninsular India. Representatives from 6 Indian institutions (IITM, NCMRWF, MSSRF, ICRISAT, CRIDA, IISc) and the IRI, including 3 project investigators, met to develop a consensus strategy to expand operational support of forecast applications for rainfed agriculture in India. The meeting achieved a consensus strategy articulated in a concept note for donors, and established an institutional consortium. Although the consortium approached several donors, there are no immediate prospects for funding at the scope outlined in the concept note.

The meeting achieved a consensus strategy, produced a report, articulated the strategy in a concept note for donors, and established an institutional consortium. The consortium approached several donors (USAID, Ford Foundation, DFID, CIDA), but did not succeed in securing funding for the scale of effort outlined in the concept note. Other circumstances prevented the project team from further pursuing an upscaled operational project.

Dynamic Downscaling for India. We installed the Regional Spectral Model (RSM) at IITM, and conducted trial verification runs in preparation for long integrations using first reanalysis then GCM simulations as boundary conditions. We organized and transferred to IITM output from five-member ECHAM 4.5 simulations for 10 years as input to planned RSM runs.

Statistical GCM Correction for India. Although monthly ECHAM 4.5 hindcast rainfall is poorly correlated with observed Indian monsoon rainfall, our analyses show strong correlation with both GCM rainfall in the western Pacific and GCM circulation indices over a region from India to East Africa. These indices offer promise of improving skill and supporting downscaling. We initiated similar diagnostics for retrospective forecasts from NCAR using the CAM2 GCM coupled with a simple slab ocean model.

El Niño Characteristics. Examination of spatial SST patterns in different El Niño events shows that events with warm anomalies centred on the International Dateline have much stronger impact on the Indian and Australian rainfall, while those with anomalies displaced to the east have stronger impact in Indonesia and NE Brazil. We plan GCM experiments to corroborate these observations, and to examine the ability of GCMs to capture these differences and the ability of a coupled GCM to predict such differences in the location of SST anomalies and their time evolution.

Extending Climate Applications within Tamil Nadu. Lectures on climate forecasts and risk management were organized for about 1200 state agricultural extension staff. The initiative was linked to the state's ongoing hi-tech agriculture capacity building activities. Seasonal forecasts and management recommendations were also issued to 80 farmers' discussion group conveners, each of whom is responsible for disseminating the technology to at least twenty other farmers.

Diffusion of Understanding and Adoption, Tamil Nadu. At 3 communities, we conducted 12 pre- and post-season workshops designed to improve farmers' understanding and competence at applying probabilistic forecasts and systems analysis to decisions. Results of a qualitative and quantitative evaluation show that 31% of farmers improved their decision skill to a "good" level from an initial "low" level. The proportion of farmers modifying decisions based on climate information increased over the study period. Each collaborating farmer extended climate knowledge to an average of five other farmers.

Participatory Evaluation of Groundnut Varieties, Tamil Nadu. An on-farm participatory experiment supports modeling and provides insight to criteria for variety selection in a variable climate. Farmers (30) ranked varieties considering factors including climate variability. Farmer rankings were not consistent with yields, and considered use of own seed, ease of harvest, "bold seeded," market preference, complete fill, shorter duration and familiarity. Farmers value runner-type varieties for climate risk management.

Extending the Indramayu Climate Field School (CFS) to Bandung. The Bandung Agriculture Office has expressed interest in implementing the CFS – part of a NOAA-OGP/ADPC project – within the district. As a first step, agriculture extension workers from Bandung visited Indramayu to observe the CFS.

ENSO Influence on Floods and Drought, Bandung. Analysis of 1961-2002 data shows strong negative impact of El Niño on June-October rainfall that translates into reduced rice production in most sub-districts. Increased rainfall in La Niña years has caused floods in some sub-districts where drainage systems are inadequate.

Economics of Forecast Response, Bandung. Drought cost the district ~US$14 million in 1989-2001, mostly during El Niños (91, 94, 97). Results show that farmers could have saved an average of $235 ha^{-1} had they not planted a second rice crop in El Niño years. Aggregate savings would have been $5.6 million if 1/2 the farmers adopted this practice. Replacing second rice with soybean during El Niño would further increase benefits.

Project year 3 (2004/5):

The use of reanalysis data to extend meteorological time series and deal with data availability problems is researched in Indonesia: statistical downscaling methods are applied to GCM outputs and evaluated with independent data over several regions. The same technique is applied to crop simulation models, and combined with statistical forecasting techniques provides a useful tool for creating production and economic scenarios.

Lessons learned from *farmer field schools* have developed increasing confidence in seasonal forecast products throughout Indonesia. Several workshop & seminars have been presented:
A seminar “Method for the use of climate forecast information for making decisions at policy and farmer level” presented at Ministry of Agriculture workshop, Jakarta.
A seminar “Characteristics of El-Nino and its relationship with drought events in rice growing areas” presented at a meeting of National Plant Protection Working Group, Mataram, Indonesia.
A training workshop seminar “Reducing climate risk by improving farmers’ capacity in using climate forecast information” presented at Semarang, Indonesia. This was also communicated to policy makers through national working group meetings (National Working Group on Plant Protection and National Working Group on Climate Anomaly).

Linking Seasonal Forecasts with Crop Production. Demonstrated utility of crop models linked to seasonal forecasts through historic analogs, and ongoing progress in dynamic climate forecast models has stimulated work at the IRI on additional approaches. The ongoing work has led to enhancements and distribution of a stochastic disaggregation tool and several methodology publications, and is influencing applied projects in Africa. Results have been encouraging, but have not been widely compared against the standard analog method.

The topic of *Risk Management across levels* has been studied at both IRI and DPI&F. Outcomes of this work highlight the need to achieve true integration of disciplinary knowledge, rather than focusing on certain aspects of the system at the exclusion of others. The capacity to think and act beyond disciplinary boundaries is rare and difficult to nurture in the established institutional context. Existing institutional arrangements often act as a disincentive to true integration.

Strong leadership is required to induce cultural change in established institutional arrangements. This thinking is reflected in a “gap analysis” underway that is meant to guide investment in climate information systems for development in Africa.

Modelling the Indian Summer Monsoon, IITM, Pune Dynamical modeling of the Indian Monsoon remains a challenge. Examination of 50 year (1950-99) long simulations in 10 different GCMs with large ensembles showed near zero skills for the Indian summer monsoon rainfall. However, this analysis brings out that there is much higher potential predictability for the Indian monsoon which is sea surface temperature (SST) driven. It was shown that the specification of SSTs in the warm pool region (Western Pacific and the Indian Ocean) is responsible for such low predictive skills of monsoon in atmosphere only GCMs. However, skills showed subtaintial improvement when air-sea interations in the warm pool are treated as a coupled system. This prompted comparison of fully coupled ocean-atmosphere model hindcasts made under an European Union project called DEMETER. This analysis reveals that, while they appear to perform better than uncoupled models, they are still not more skillful than current statistical models.

In the light of the above,the IRI is evaluating a new set of model runs that uses prescribed SST predictions in the eastern tropical Pacific (ENSO region), and a coupled mixed-layer ocean model elsewhere, but preliminary results show only modest improvement. The main avenues for further improving dynamic prediction of the South Asia monsoon system are improvements in atmospheric model physical parameterization to correct the existing oversensitivity, better understanding of the implications of coupling for ocean-atmosphere dynamics and ocean prediction, and enhanced spatial resolution of the atmospheric component. Further work in the area is being undertaken at IITM and the IRI.

The MJO phenomenon as a useful mid-range forecasting tool. A near-global analysis has demonstrated that the MJO (a large-scale, tropical atmospheric anomaly that originates in the Indian Ocean and propagates eastward at intervals between 30 to 60 days) is a significant phenomenon that can influence daily rainfall patterns, even at higher latitudes. The MJO has dicernable impacts throughout Asia, Australian and parts of Africa. The development of an MJO-based forecasting capacity bridges the weather-climate divide, providing improved tactical management of climate-sensitive systems such as agriculture. The MJO is. The MJO sits at the interface between synoptic weather forecasting and seasonal, ENSO-based climate forecasting (3-monthly to seasonal forecasting). The passage of the MJO also influence the onset and break activity of the Asian–Australian monsoon system. The ability to forecast the next MJO passage significantly improves tactical climate risk management by influencing decisions in relation to sowing opportunity prediction, disease management, harvest scheduling, irrigation scheduling, product quality management and marketing. This research has established the basis for such a capability (Donald et al., 2006).

On-farm trials and simulation studies in Pakistan have contributed material to highly regarded “Travelling Wheat Seminars” that bring together scientists, extension specialists and policy makers on local farms prior to the commencement of each wheat growing season. Simulated yield data is now routinely used as a key input into these seminars and forms critically important information for farmers' decision making.

Climate / Simulation applications, Pakistan. A software package in the style of WhopperCropper was developed to aid extension officers in the rainfed wheat zone of Pakistan in understanding the dynamics of crop rotations & climate interactions.

Farm level responses to climate forecasts in South India. A case study of climate forecast applications for improved water management practices was published in the CLIMAG proceedings, highlighting the opportunities that exist to better manage water resources through appropriate use of climate information, resulting in improved economic performance within a more sustainable production system. Regional and village-level stakeholder meetings are an effective vehicle for extending and coordinating the application of climate information for sustainable water management, however, there remains a need to develop effective extension programs to support the stakeholders.

Stochastic disaggregation of GCM hindcasts at Tamil Nadu Agricultural University. Statistical approaches to climate forecasting are approaching the limits of predictability and future advances in climate forecasting might arise from dynamic General Climate Modelling (GCM) approaches. The GCM output must be 'downscaled' in some form before it can be used for field level decision making. In an effort to apply the GCMs downscaled forecasts, we linked GCM based climate forecast with crop models for yield prediction. We used a statistical transformation of seasonal rainfall output fields from ECHAM4 to identify optimal predictors. Simulated peanut yield results are based on monthly rainfall hindcasts that were disaggregated to daily values using a stochastic weather generator. The results showed a promising level of predictability and the approach should be further investigated. However, our understanding on downscaling from GCMs raises most important questions related to (i) spatial coherence in skill levels with in a smaller region and (ii) the amount of efforts (eg. capacity building) needed before and after implementing the approach for the benefit of smallholder farmers. This activity overlaps several other activities and issues of interest at the IRI. The IRI's Climate Predictability Tool (CPT) makes the method accessible and provides easier access to GCM output.

A Whole-farm optimisation model for climate applications, TNAU. A linear programming model was constructed to maximize farm gross margin by allocation of land area based on the land and water availability constraints under each of the ENSO phases. Data collected from 37 farmers in the region was used to estimate fixed and variable costs of production, crop water requirements and water availability. It is shown that in a ordinary linear programming formulation of a farm plan, non-embedded risk can be at least partly accommodated by the use of expected activity net returns calculated across possible states of nature. However, the linear risk programming model does not account for any non-neutral risk attitude of the farmer.

An examination of the Value of Climate Forecasts conducted at TNAU compared the value of climate forecasts and other management decisions (crop choice, fertilizer management, and planting density). The value of forecasts in smallholder system depends on prediction skill, SOI phase types, and types of decisions and their responsiveness to climate forecasts. Though the forecast skill for summer monsoon is concurrent and moderate, the value is greater for groundnut and cotton management. Winter monsoon rainfall forecasts are reasonably 'skilful' (i.e. they show a fair degree of separation between forecast categories) with sufficient lead-time but have low value for sorghum management.

The average value of forecasts across all years ranged from Rs.34 ha^{-1} for groundnut fertilizer management to Rs.504 ha^{-1} for groundnut stand density adjustment. The crop choice decisions following negative and falling April/May SOI phases would improve the average annual net income to a greater magnitude. The plant density decision would also improve the gross margin but to a lesser extend than altering crop choice decision. Though the value of crop choice decision was greater for negative and falling SOI phases, the all year average value was lesser than the stand density adjustment.

A Multi-lingual, computer-based Risk Management Tool for Extension has been developed for use by extension workers in Tamil Nadu. The tools facilitate a simple climate data analysis and serve a purpose of providing first hand information for taking farm and regional level decisions based on climatology and forecasts. The tool also serves as a data base management kit for agricultural extension officers. The tool can provide rainfall averages and probabilities on seasonal, monthly and weekly basis. The tool also helps to understand the crop production risks in a given season.

***Stakeholder workshop, ICRISAT*.**

At the final stakeholder workshop, each PI presented a short description of the work undertaken at each node. These are summarised below:

Dr Meinke began with an **overview** of the project that described learning points:

- Farmers are usually targeted as the users of climate forecasts. However, they might not be the most responsive target group, depending on the policy framework within which they operate.
- Climate forecasting is only one of many instruments that aim to reduce uncertainty.
- Participatory systems analysis needs to establish the role of climate forecasting in relation to other tools.
- Quantitative systems analytical approaches initiate dialogue and can lead to valuable discussion support systems.

And outcomes that the project has delivered:

- A general process that shows how agricultural systems analysis and climate science and information can be combined with direct linkages to smallholder farmers to positively influence agricultural decisions;
- An agronomic and climatological systems analysis of cropping systems, including quantification of strategic management opportunities;
- A professional network spanning Pakistan, Indonesia, India (3 locations), USA and Australia;
- Succession planning and capacity building

Dr Kumar presented **An overview of seasonal climate prediction in India,** in which he states that:

- Statistical models still dominate seasonal prediction of Indian Monsoon rainfall – though with limited success in recent decades
- GCM based prediction systems are still evolving and the skills in fully coupled models appear to be better than uncoupled models
- The role of recent land and oceanic warming on the variability and global tele-connections of monsoon needs further understanding
- Downscaling methodologies offer some promise in generating seasonal prediction products for specific target sites

Prof. Gadgil described the links between monsoon, agricultural production and the domestic economy; the impact of recent failures in monsoon prediction; and recent IISc work in statistical prediction methods, in her talk **Impact of monsoon variability on Indian Agriculture and Economy: Can seasonal predictions help?**

She highlights several important steps to improving seasonal predictions:

- Understanding the links to events over the Pacific: ENSO
- Simulation and prediction of these links
- Understanding the links to events over the equatorial Indian Ocean
- Simulation and prediction of these links
- A need to ensure that models respond appropriately to ENSO as well as EQUINOO

Dr Meinke presented outcomes from work on the **Near-global impact of the Madden-Julian Oscillation on rainfall** that states:

- This near-global analysis demonstrates that the MJO is a significant phenomenon that can influence daily rainfall patterns, even at higher latitudes, via teleconnections with broadscale mean sea level pressure (MSLP) patterns.
- These weather states provide a mechanistic basis for an MJO-based forecasting capacity that bridges the weather-climate divide.
- Knowledge of these tropical and extra-tropical MJO-associated weather states can significantly improve the tactical management of climate-sensitive systems such as agriculture, particularly in Asia and Australia.

Dr Hansen gave a talk **Linking Seasonal Forecasts with Crop Simulation –** that presents both the advances made over recent years, and pathways forward:

- Six years ago, there was a
  - Dominance of historic analogs
  - Doubts about crop predictability
- Recent advances cover
  - Synthetic weather conditioned on climate forecasts
  - Use of daily climate model output
  - Statistical prediction of crop simulations
  - Downscaling and upscaling
- Opportunities and challenges remaining include
  - Embedding crop models within climate models
  - Enhanced use of remote sensing, spatial data bases
  - Robustness of alternative coupling approaches
  - Forecast assessment and uncertainty

    - Climate research questions

The technical challenges that still face us include:

- Nonlinearities. Crop response to environment can be nonlinear, non-monotonic.
- Dynamics. Crops respond not to mean conditions but to dynamic interactions, eg Soil water balance, Phenology.
- The scale mismatch problem.

And the opportunities presented by our current understanding allow us to answer such questions:

- Does predictability (climate and impacts) change from year to year?
    - Artifact of skewness?
    - Real impacts of climate state?
    - Captured by GCM ensembles?
- Interpretation of forecasts based on categorical vs. continuous predictors?
- Consistency of hindcast error vs. GCM ensemble distributions?

The progress has stimulated interest in "*weather within climate*", asking questions about:

- Skill at sub-seasonal time scales
- Higher-order rainfall statistics
- Shifts in timing, onset, cessation
- Methods to translate into weather realizations

Dr Selvaraju discussed **The value of Systems Science and Component Knowledge for Climate Risk Management,** which stated our aim to "utilize the ability to predict climate variability and change on range of scales to improve decision making using climatic risk management strategies in agriculture at farm, regional and national scales for enhancing resilience and sustainability". He summarised his findings:

- Climate information helps to to reduce production uncertainty and risk under smallholder farms; but may not be effective if it is out of context and less understanding on the system
- System analysis helps to generate quantified focused options understanding local systems and knowledge from a generic climate information
- Information (options) requirement varies greatly within a very small spatial domain – system science can link that gap
- Effective use information requires to identify the leverage points in the system – farmer's perception complements to system analysis

Dr. Boer talked of **Assessing the Vulnerability of Indonesian Rice-Based Farming System to Climate Variability** which described the farming system, its importance to Indonesia, and the relationships to the ENSO phenomenon. He also describes farmer perceptions of climate information and how that information has been applied.

Taking the definition of risk from (Jones et al., 2005), Climate Risk = Probability of climate hazard × Vulnerability:

- Risk will increase as the frequency and intensity of climate hazards increase over time and space, assuming that vulnerability is constant.
- Agricultural simulation approaches can assist to define technological options that can reduce the vulnerability

The remaining challenges are to

- Matching the options with socio-cultural and economic conditions of farmers
- Communicating climate (forecast) information
- Increasing ability to translate climate (forecast) information into crop management strategies
- Engaging policy makers and institutions to remove barriers facing by farmers in adopting and implement the options

Dr Meinke (representing Dr. Aslam who was unable to attend due to the earthquake in Pakistan) presented **Applying climate information to enhance the resilience of farming system in rainfed areas of Pakistan,** which described simulation studies that have lead to a range of outcomes in Pakistan:

- research into predictability of poor seasons
- large scale on-farm trial to quantify the potential for double cropping
- intensive research using simulation modelling to match varieties to local climatic conditions
- establishment of 'traveling wheat seminars' that bring together scientists, extension specialists and policy makers on local farms prior to the commencement of the wheat growing season

Dr Hansen presented- **Climate as a Key Driver of Risk - Can advance information mitigate impact?** presenting risk as hazards, variability and uncertainty, the impacts of climate variability, and consequent risk. He summarises with a table that describes whether advance information can mitigate impact:

• Variability of yields	NO
• Reduced mean yield	NO
• Sub-optimal management	YES
• Ex-post impacts of climate shocks	PARTIALLY
• Ex-ante impacts of uncertainty	YES
• Influence on chronic poverty	PARTIALLY

Dr Selvaraju presented **Research, Extension and Farmers Partnering to Manage Climate Risk**, that described participatory interactions with local farmer groups in South India. He describes how the local team:

- engaged with local farmer groups and extension officers to understand their agricultural system and their needs
- considered their practices and rules of thumb and considered those as part of our system analysis framework
- developed options and discussed risks, opportunities and consequences of management alternatives through simulation modelling
- encouraged farmers to make informed decisions after understanding the risk and consequences
- solicited feed back and responses from farmers and extension system and reconsidered options

To scale up these interactions to a regional level means

- Moving from research to implementation
    - Developing self sustaining groups to manage climate variability
- Developing capacity building efforts for
    - Farmers
    - Extension officers and information brokers

- And linking research to extension and farmers and feed-back
    - Social networks, CBO
    - Existing extension network

Mr PR Sheshagiri Rao presented the workshop with a “reality check” describing his project activities: **A farmers’ perspective on science of climate risk management** in which he describes farmer interactions from the study region at the semi-arid region around Pavgada. While reinforcing Dr Hansen’s concept that integrated climate & simulation technologies are adopted in a gradual manner, he highlights how far we have to go with modelling tools, eg. lack of dynamical assessments of climate impacts on pest & disease interactions, livestock, economic & regional models.
He presented a list of specific questions that the farmer groups in the regions have asked the project team, the answers provided, and an indication of acceptance.

Research issue	**Results**	**Acceptance**	**Reasons/ Benefits**
Pest and disease management	Simple model for risk assessment Benefit cost analysis of sprays	Yet to be provided	Further validation and refinement needed
Optimal sowing window	15-25 days later than current practice	Very small	Increase in pests and diseases High penalty- May not sow the crop
Planting density	50-75% of recommended seed rate	Partial	Poor crop establishment
Forecast rain prior to sowing	El-Nino and El-Nino + 1 years linked to seasonal total	Yet to be provided	Choice of crops, inter crops Invest in crop insurance
Alternative crops	Evaluation of potential crops	Yet to be provided	Needs further quantification
	Early sowing of Pigeon Pea better than groundnut	Yet to be provided	Pest impact to be considered
Enhance soil fertility in small farms	Add appropriate soils @ 150-200 t / ha	High	■ Partly subsidized, ■ Enhanced water holding capacity ■ Bench mark for further

adoption

As a case in point, he describes how obscure climate events (eg. 7-day Wet spells) can cause varying amount of benefits or problems to different sectors and users.
He describes 'traditional' adaptation and coping mechanisms identified in the region, and how these mechanisms failed in the severe 2001-04 drought, leading to more severe responses (migration to cities, shift from cattle to goats, entrepreneurial activities), and how the adoption of successful practices is very rapid during distress situations.
He also mentions how trade liberalisations over the last 5 years have allowed broader market access to (knowledgeable) farmers, allowing them to spread (even move) their risk away from traditional cropping systems.

Dr Boer presented a talk **Increasing Farmers Ability To Manage Cimate Risk Through Field School** which describes the how the Climate Field School program, initially developed and supported by NOAA-OGP through ADPC and conducted through collaboration with a number institutions (Bogor Agricultural University, Indramayu Agriculture Office, Bureau of Meteorology and Geophysics and Directorate of Plant Protection) has now been adopted by the Department of Agriculture and expanded into 30 vulnerable districts.
He describes how the next step entails:

- Development of modules which cover wider aspect of climate information application (not only for on-farm activities but also for off-farm activities)
- Development and Improvement of curriculum (initial, intermediate and advance phase of CFS program)
- Training of trainers (ToT)

Dr Hansen presented **Scaling Up Support for Climate Applications in India: a Consortium Approach**, aiming to

- Present our thinking and activity beyond more measurable project outcomes
- Elicit critique of our assumptions, approach
- Stimulate continued dialog

It is proposed that the consortium's objectives be to

- Evaluate & demonstrate value of seasonal rainfall forecasts for smallholder farmers > Evidence
- Advance methods and institutional capacity to produce high-quality forecast information products that are timely, relevant to smallholder farmers > Prediction Capacity
- Enhance capacity of climate application leadership within NARES and relevant local institutions > Application leadership capacity
- Build on lessons to facilitate widespread adoption throughout semi-arid India > Institutional Upscaling

This project has largely completed the initial scoping phase – the Objectives and Strategy have already been described. The next phase would need to be largely designed and led by operational agricultural and climate institutions within the target country. Subsequent discussion finalized a consortium that will build on the foundations laid by this project(day 3).

Dr Meinke discussed **The policy relevance gap** – a talk that outlined how climate information is often irrelevant and fails to influence policy. He describes the conundrum that

1. There are no policy mechanisms for influencing rainfall, but this is the activity most (climate) scientist engage in
2. There are few policy options to affect crop or pasture yields, but crop and pasture yields are what most (agricultural) scientist are concerned about
3. but there is strong community demand for policies to anticipate and moderate the effects of climate variability on farm incomes, an area largely devoid of science input.

This irrelevance stems from that fact that

- Current scientific emphasis is on analysing and describing rainfall and production variability, which only informs policy makers of the exposure to drought, for which there is no policy solution.
- Analytical support for drought policy that focuses on exposure to climate risk is largely irrelevant because climate variability cannot be altered by policy in the short term.

And describes key lessons from experience:

- Climate knowledge needs to deliver **true societal benefits**.
- We need to expand the systems boundaries and fully explore the scientific and socio-economic tensions and interactions - **the system is bigger than most of us thought**.
- We need to include the socio-economic dimensions important to rural communities and policy makers, but **without abandoning science**.
- We need to achieve **true integration** of disciplinary knowledge, rather than focusing on certain aspects of the system at the exclusion of others.
- True integration without abandoning science takes **real resourcing**.
- The **capacity to think and act beyond disciplinary boundaries is rare** and difficult to nurture in the established institutional context.
- Existing institutional arrangements often act as a disincentive to true integration.
- **Strong leadership** is required to induce cultural change in established institutional arrangements.

The last day was devoted to synthesis and further development

Dr Roth from ACIAR presented perspectives of the Australian research funding agency ACIAR:

- In some areas climate variability is a significant determinant of farm profitability – hence likely that returns on R&D investment attractive
- Dealing with climate variability enables coping with climate change
- Funding of climate risk R&D *per se* is unattractive to an agency like ACIAR – this needs to be framed within a specific problem context and part of a systems approach; e.g. 'improving profitability of rainfed peanut farming systems in drought prone districts of Andhra Pradesh' or 'maximising water productivity in water shed development'.

During the final session the stakeholders agreed that an organisational ‘consortium’ approach was the best way forward. To this extent, the Directors of CRIDA and NCMRWF (Drs Ramakrishna and Rathore, respectively) agreed to jointly take the lead in the development and set-up of such a consortium. The consortium will address the gaps in knowledge, institutions, and policy that obstruct change at the ground level.

The stakeholders considered the project to have had a major impact on the conduct of cross-disciplinary research, highlighting the importance of simulation modelling being the glue that connects several disciplines, providing a focus on outcomes relevant to end users and not ‘science for science’s sake’. In addition, the project had achieved considerable capacity building via staff training and the development of post-graduate scholarship opportunities.

The science conducted by the team was highly regarded by stakeholders and considered an outstanding success and excellent example of the value of international, cross-disciplinary research. Stakeholders suggested that the project team consider a short, but high level, high impact publication of their activities (eg New Scientist) – to demonstrate the “4 continent effect” of the project – an essential component for donors (including NGOs) considering investment in the field.

The following key recommendations were taken from all participants (in no particular order - see audio record in supporting documents:

- The big question really is enterprise mix, percentages; the emphasis has been too much just on crops and production techniques; we need to be able do manage climate risk at the whole farm level.
- There is an urgent need for whole farm economic modeling.
- The integration of animals and crops to do a full cropping/livestock analysis is of highest priority.
- Climate schools will provide the opportunity to understand local climates.
- The next 3-4 yrs will be crucial for seasonal forecasting, around 6 GCM centric groups working in India on this issue. There is a dire need to bring agricultural scientists closer with these groups to stimulate interactions and foster relevancy. This is were the consortium needs to play an importanct role as facilitator and provider of linkages.
- The existing network of advisory service is a good vehicle but needs better focus. The matter needs needs discussion at a government level.
- There is a need for an intermediate agency that translates available climate information to information easily understood by the user community. We also need to train NGOs or similar groups so that they are better equipped to deal with climate information.
- There is a need for better tools for integration. These tools should start out with the simple question “What is the main problem faced by community?”.
- In meetings, there are always good interactions between scientists, but these interactions need institutional support to continue further. All project members have other (institutional) commitments, making it hard to maintain momentum. There is a need to identify people within the climate community in India to develop tools that are easily useable by farmers; have dedicated climate and agricultural scientists jointly working on this.
- Institutions should make ‘farming the rain’ a business proposition. Develop an inventory of what is already available then identify gaps – holistically.
- Need to bridge gap between climate and ag scientists; at present there is no coordination; farmers need to know what are consequences of Climate

Change and Climate Variability; we need to increase the confidence level, but also tell them the limitations; need an institutional arrangement for continuation.

- A need is evident for decision support tools to be tailored to different farming activities and enterprises.
- In India advances in monsoon forecasting will help markets – there should be an economic study by the Government in terms of price regulation; should aim at defining optimal storage etc based on climate scenarios
- In Indonesia, Field schools are a good way forward.
- Depending on rainfall patterns, seasonal planning needs to be tailored
- We have seasonal climate forecasts coming from IMD, but people can't act on it. Needs to be made available to all agro-climatologists at all universities.
- Relations between farmers, scientists etc should be facilitated by institutions
- We have soil maps, contingency plans, seasonal climate forecasts but all these are not transformed into farm-valuable information; fine-tune existing crops and cropping systems at village scale and incorporate scientific technologies to establish linkage between all stakeholders (multi-disciplinary approach); establish a training system, viable drought mgt strategies; develop a model for up-scaling.
- Need a stakeholder analysis in regards to climate and how this can be packaged; knowledge management strategy and how we can 'sell' the information; needs serious institutional capacity building and how we can share this; need to advertise our successes to show how people can develop communication strategies – within the next 6 months
- All climate info useless unless policy supports for eg seed availability is in place; we need teaching workshop for journalists.
- Go ahead and disseminate down-scaled seasonal forecast in probabilistic terms rather than hiding it; demonstrate how good they are and what their limitations are.
- Would be keen to see documentation of learnings failures and successes, documentation is an important stepping stone to see where the 'winners' are.
- Progress has been made in seasonal climate forecasts, but scepticism remains; we need to advertise what we have.
- Understanding Climate Change – there are indicators but these differ from place to place, which is confusing. Need to quantify Climate Change for small regions; for same region need projections for the next couple of decades.
- Understand farmers needs, what are the climate depended options; need to understand probabilistic forecasts of rainfall and production.
- Information by itself is useless without understanding to apply it. While capacity building is seen as a critical element in long-term uptake, scholarships to develop young scientists are difficult to obtain.
- Mitigation – adaptation CV vs CC and connection to policy using compatible approaches; needs whole farm simulation tools.

4.0 Conclusions

The main objectives of the project were:

- Enhance the capacity of local research to apply a set of quantitative, systems analytical tools and methods.
- Engage agricultural stakeholders at each pilot location in a participatory research process.
- Address information and communication needs of stakeholders.
- Evaluate and tailor seasonal climate forecasts to the needs of decision makers
- Demonstrate effective use, and evaluate benefits, of climate prediction information for improved decision-making by targeted groups of agricultural stakeholders at pilot sites.
- Propose a strategy to enhance sustained operational support of agricultural use of seasonal climate prediction in each host country.

Main Outcomes

- An international, multi-disciplinary network of systems scientists who are committed to the creation of 'actionable climate knowledge' by building partnerships with stakeholders.
- Better understanding of climate variability impacts and climate-related vulnerabilities.
- A consortium of partners to build and extend the existing nodes and pilot studies.

To assist (rural) communities, business and policy makers to better cope with climate-related risks, this project created 'actionable climate knowledge' by synthesising information across disciplines and including stakeholders in the process. The project team found that such synthesis generates desired outcomes, but it is much harder than traditional component research that fills specific, existing scientific knowledge gaps (analysis). Reasons for these difficulties are historical, institutional and societal. Hence, we argue for an overt attempt to move towards targeted climate syntheses and integration of our scientific understanding into applied risk management frameworks. This will require new institutional arrangements and multidisciplinary partnerships.

5.0 Future Directions

As a result of the final stakeholder workshop, an Indian-led consortium (the Directors of CRIDA and NCMRWF, Drs Ramakrishna and Rathore, respectively) is being formed that will address the gaps in knowledge, institutions, and policy that obstruct change at the ground level.

References

nil

Appendix

Conferences/Symposia/Workshops
Appendix 1: Bangkok Workshop, May 2002
Appendix 2: Hanoi Workshop, Nov 2003
Appendix 3: Final Stakeholder Workshop, ICRISAT
(On accompanying CD)

Funding sources outside the APN
Y3 In-kind contritions in $USD:

IRI,	*40,950*
QDPI&F,	*58,410*
MINFAL, Pakistan	*13,920*
IITM, Pune	*6,095*
IISc, Bangalore	*5,460*
TNAU, Coimbatore	*12,920*
BAU, Bogor	*12,920*

Glossary of Terms
Include list of acronyms and abbreviations
nil

The final project report must follow the template outlined in this document.

Please submit the report to Linda Stevenson < lstevenson@apn.gr.jp > by:
30 September 2005 (approved no-cost extension)

In the following formats:

Soft Copy version (CD-ROM about 30) and
Hard Copy version (about 30 bound copies) if within the available budget

Both hard and soft copies of the report should be addressed to:

Linda Stevenson
APN Programme Manager for Scientific Affairs
APN Secretariat
IHD Centre Building, 5F,
1-5-1 Wakinohama Kaigan Dori
Chuo-Ku, Kobe 651-0073 JAPAN