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APEC Climate Symposium (APCS) 2012

Harnessing and Using Climate Information for Decision Making

An In-Depth Look at the Agriculture Sector

St. Petersburg, Russia
October 8-11, 2012

APEC
Asia-Pacific Economic Cooperation

APCC

VOEIKOV MAIN GEOPHYSICAL OBSERVATORY

APEC Climate Symposium (APCS) 2012

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Contents

03_ Welcome Message

04_ APCS 2012 Organizers

05_ APCS 2012 Speakers

09_ APCS 2012 Program

13_ Session Ⅰ

21_ Session Ⅱ

43_ Session Ⅲ

61_ Session Ⅳ

Welcome Message

On behalf of the organizers, the APEC Climate Center (APCC) is delighted to welcome you to St. Petersburg, Russia, for the APEC Climate Symposium (APCS) 2012. Through close collaboration with the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet), the APEC Climate Center has developed this conference to promote the use of timely and well-designed climate information for decision-making in the agriculture sector.

With various participants from over 20 different developed and developing countries coming together to share their experiences, this event provides a unique opportunity for meteorologists and climatologists to interface with representatives from the agriculture sector. It is our hope that participants will return to their home countries enriched by the information and case studies shared over the next couple days and can apply their learning to building the adaptive capacity of the agriculture sector, an area that is especially critical to the Asia-Pacific region.

APCS 2012 would not have been possible without the strong support of our valuable partners, so we would like to offer our sincere thanks to the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) and the Voeikov Main Geophysical Observatory, as well as to all the speakers and participants.

We hope that you enjoy the symposium. Thank you.

Chin-Seung Chung
Director, APEC Climate Center

APCS 2012 Organizers

APEC Climate Center (APCC), Republic of Korea

The APEC Climate Center (APCC) is a leading regional organization that produces climate information products and services for APEC economies. APCC was established in 2005 with the endorsement and warm welcome of all APEC senior officials and leaders. Our mission is to enhance the socioeconomic well-being of member economies by providing high-quality climate information, which will allow them to better anticipate and manage extreme climate and weather events and face the adverse impacts of climate change. The Center produces climate information products and services based on a proprietary Multi-Model Ensemble prediction system. We organize the annual APEC Climate Symposium which allows various scientists, academics, policy-makers and other stakeholders to share the latest science and technology in climate prediction and explore climate information applications. APCC also facilitates regional cooperation through capacity building programs and data exchange.

Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet)

Roshydromet is the authority that operates hydrometeorological services, environmental pollution monitoring, and other meteorological and geophysical services for the Russian Federation.
The first strategic goal of Roshydromet is to provide timely warnings of hazardous hydrometeorological events and high levels of pollution in the environment in order to enhance hydrometeorological safety, thereby protecting the vital interests of individuals, society, and the state from the impacts of natural hazards and climate change. Roshydromet also conducts international exchange of hydrometeorological and other environmental information at the global level. Several of Roshydromet's research institutions - the Voeikov Main Geophysical Observatory and the Hydrometeocenter of Russia - have been important partners to APCC in conducting international research activities and supporting APCC's Multi-Model Ensemble prediction. We are delighted to be working together to host the 2012 APCC Symposium.

Voeikov Main Geophysical Observatory (MGO)

Founded in 1849, the Voeikov Main Geophysical Observatory (MGO) is the oldest meteorological institution in Russia. MGO is Russia's research pioneer in climatology, dynamic meteorology,aerology, actinometry, a number of atmospheric physics disciplines (cloud physics, atmospheric electricity, and boundary layer physics), atmospheric diffusion, and air pollution. MGO's objectives are research and development in the fields of long-range weather forecasting, climate theory, general and applied climatology, cloud physics and weather control , monitoring of atmospheric conditions, air pollution and precipitation chemistry; methods development for creation and operation of weather observation networks, atmospheric conditions, air pollution and precipitation chemistry monitoring networks; the development of methods, instruments, measurement data systems, and information technologies for meteorology; metrological support, standardization, and certification for meteorology; aviation weather support; and assessment of the efficiency of hydrometeorological data use in economic applications.

APCS 2012 Speakers

» Opening Remarks & Congratulatory Address

Chin-Seung Chung

Dr. Chin-Seung Chung joined the APEC Climate Center as the Director in April 2010 after four decades of professional experiencein government services. Since his arrival, Dr. Chung has steered APCC toward becomingone of the leading research centers providing climate information to the Asia-Pacific region. APCC contributes to prediction and monitoring activities of weather and climate in the Asia-Pacific region and supports capacity-building by providing climate information services and technical support for the reduction of economic losses due to adverse climate conditions.

Prior to his position at APCC, Dr. Chung was a Dean and Professor at the Korea Development Institute (KDI) School of Public Policy Management. He received his Ph.D. in Economics from the University of Georgia in 1983 and commenced a career in government service at different institutions. Dr. Chung served as the Deputy and Vice Minister at the Korean Ministry of Environment. While he was working at the Ministry, he was a Head Negotiator for the Korean Delegation for the COP3 meeting of the UN Framework Convention on Climate Change, at which the Kyoto Protocol was adopted in 1997. He has also served as a member and advisor to various national committees, including the Presidential Commission on Sustainable Development in 2003, the National Economic Advisory Council from 2004 to 2006 and the Regulatory Reform Committee from 2004 to 2008. He was also the President of the Korea Environmental Economic Research Association, as well as a Senior Research Fellow at the Korea Development Institute for twenty-two years from 1972-94. He has lectured at Stanford University, the Korea Advanced Institute of Science and Technology (KAIST) and Sogang University. He has conducted research and published books and numerous articles related to industrial trade and environmental issues. He is the author of Economic Development and Economic Policy in Korea (2006) and Environmental Policy at the Age of Decentralization in Korea (1993).

Igor Shumakov

Mr. Igor Shumakov is the Deputy Head of the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). He graduated from the Moscow Institute for Economics and Statistics with a concentration in Economical Informatics and Automated Systems of Management. Since 1992, he has held different positions in governmental and non-governmental organizations. In 2008 he was named the Deputy Director of the Department of International Cooperation in the Russian Federal Ministry of Natural Resources. Since 2009 he has been an Advisor to the Federal Minister on Technological and Nuclear Security. He was named the Deputy Head of Roshydromet in 2010.

Vladimir Dmitrievich Popov

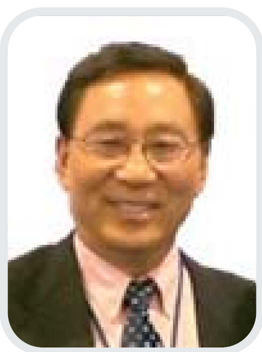
Prof. Vladimir Dmitrievich Popov is the Chairman of the North-West Regional Science Centre and Director of the North-West Research Institute of Agricultural Engineering and Electrification at the Russian Academy of Agricultural Sciences. He has a PhD in Agriculture Mechanization from the Vologda Dairy Institute. His areas of the expertise cover current agro-engineering issues including the development and implementation of adaptable farming technologies, machinery and equipment for resource saving farming; energy conservation practices for farms, including renewable energy sources application; and improving the environmental safety of agricultural production. The findings and results of his scientific research have been presented in 150 various scientific publications.

APCS 2012 Speakers

» Opening Remarks & Congratulatory Address

Vladimir Kattsov

Dr. Vladimir Kattsov, Doctor of Sciences (physics and mathematics), Director of Voeikov Main Geophysical Observatory in St. Petersburg, Russian Federal Service for Hydrometeorology and Environment Monitoring (Roshydromet). Scientific field and expertise: global climate 3D modelling; high-latitude climate dynamics, model evaluation and discrimination, climate impacts. National activities: Coordinating Lead Author, the Draft of the Climate Doctrine of Russian Federation (signed by the RF President D. Medvedev on 17 December 2009); Coordinating Lead Author, the Draft of the Russian Comprehensive Plan of Weather and Climate Scientific Research(at the request of the Security Council of Russian Federation of 17 March 2010). International activities: Vice Chair Elect, Joint Steering Committee (JSC) of the World Climate Research Programme (WCRP) Member at large, International Association of Meteorology and Atmospheric Sciences (IAMAS) of the International Union of Geodesy and Geophysics (IUGG); Member, Scientific Advisory Committee, Asia-Pacific Economic Cooperation Climate Center (APCC). Publications: more than 80 publications in peer-reviewed scientific journals and books. Lead author of the IPCC Working Group I Third (2001), Fourth (2007) and Fifth (under preparation) Assessment Reports Core Writing team member of the IPCC Forth (2007) and Fifth (under preparation) Synthesis Reports Lead author and member of scientific-coordination committee of Roshydromet's First assessment report «Climate Changes and Their Impacts over the Territory of Russian Federation» (2008); Lead author of the Arctic Climate Impact Assessment (ACIA, 2005).



Bin Wang

Prof. Bin Wang is a Professor and Chair of the Department of Meteorology, University of Hawaii. He serves as the Co-Chair of APCC Science Advisory Committee. His research fields includeClimate Science, Tropical Meteorology and Geophysical Fluid Dynamics. Wang has published more than 240 refereed papers which have inspired numerous studies on climate as evidenced by his h-index (60) and citation rate of over 5,000 times since 2008.Wang was awarded the American Meteorological Society Fellow and received the "Scientist of the Year" Award from the ARCS (Achievement Awards for College Scientists) foundation.

Keynote

Gerrit Hoogenboom

Dr. Gerrit Hoogenboom is Professor of Agrometeorologyat Washington State University, USA, and the Director of AgWeatherNet, a network of over 140 weather stations in the states of Washington and Oregon and one of the largest automated weather monitoring networks in the USA. He has over 25 years of experience in agricultural and environmental research, including studying the impact of weather and climate on crops. He has specialized in the development and application of computer simulation models and decision support systems and he currently coordinates the development of DSSAT, an agricultural modeling and decision supportsystem that is being used world-wide. He frequently organizes and facilitates international training workshops on crop modeling. He has published more than 200scientific papers in refereed journals as well as numerous book chapters and proceedings. He is an Editor for Agricultural Systems, Journal of Agricultural Science, Climate Research, and the Brazilian Journal of Agrometeorology.

Mark Howden

Dr. Mark Howdenis a Chief Research Scientist with CSIRO Ecosystem Sciences, Canberra, Australia. He is also the Theme Leader of the 'Adaptive primary industries, enterprises and communities'theme in the CSIRO Climate Adaptation Flagship and is an Honorary Professor at Melbourne University, School of Land and Food. Mark's work has focussed on how climate impacts on, and innovative adaptation options for systems we value: agriculture and food security, the natural resource base, ecosystems and biodiversity, energy, water and urban systems. He has also developed the national (NGGI) and international (IPCC/OECD) greenhouse gas inventories for the agricultural sector and assessed sustainable methods of reducing net greenhouse gas emissions from agriculture. Mark has worked onclimate change issues for over 24 years in partnership with farmers, farmer groups, catchment groups, industry bodies, agribusiness, urban utilities and various policy agencies. He has been a major contributor to the Intergovernmental Panel on Climate Change (IPCC) Second, Third, Fourth and Fifth Assessment reports and various IPCC Special Reports sharing the 2007 Peace Prize with other IPCC participants and Al Gore. He sits on the US Federal Advisory Committee for the National Climate Assessment and several other science and policy advisory bodies.

Selvaraju Ramasamy

Dr. Selvaraju Ramasamy is a Natural Resources Officer in the Climate, Energy and Tenure Division of the Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. He is currently focusing on the provision of technical advisory services on climate change adaptation and disaster risk reduction in agriculture to FAO member countries. His responsibilities includes the development of tools and methods for climate impact assessment, adaptation planning and strengthening institutional and technical capacity to improve climate information services for food and agriculture. He supports the development and implementation of investment projects on early warning systems and provides technical advice for the preparation of national and sub-national level framework programmes and action plans on climate change adaptation and disaster risk reduction in agriculture. Dr Selvaraju has over 19 years of experience in applied climate risk management research and development, mainly in the areas of natural resource management, sustainable agriculture, cropping system modelling and climate forecast applications.

APCS 2012 Speakers

Keynote

Kees Stigter

Dr. Kees Stigter, born in 1940, studied physics at the University of Amsterdam(1958-1966) and obtained his doctorate in Agricultural Sciences in 1974 at the (then Agricultural) University of Wageningen, The Netherlands. After an absence of 10 years for a professorship at the University of Dar es Salaam, Tanzania, he returned to Wageningen in 1985 and retired from the Department of Meteorology and Air Quality of that University in 2005. He then continued what he had done since 1975, but now for Agromet Vision (Bondowoso, Indonesia and Bruchem, The Netherlands): to work as a (visiting) professor in agrometeorology and agroclimatology in Asia and Africa. The representative of the Netherlands in the Commission for Agricultural Meteorology (CAgM) of the World Meteorological Organization (1985 2006), he became vice president (1986-1991) and president (1991-1999) of this Commission. He is since 2001 the founding president of the web-based International Society forAgricultural Meteorology. Author and co-author of more than 800 publications; co-author of a book on agrometeorology of multiple cropping (1993-French; 1997-English); since 1994 leader of the CAgM Expert Team and Editor-in-Chief on writing the third edition of the WMO Guide to Agricultural Meteorology Practices (GAMP, WMO 134), that appeared in 2007 (and internally edited by WMO in 2010). His book "Applied Agrometeorology" appeared in 2010. He works these days particularly on connecting agricultural sciences, environmental sciences, social sciences and extension services.

Roger Christopher Stone

Prof. Stone has lengthy career in meteorological and climatological research extending over 35 years, particularly in regards to research and development in climate forecast modelling as applied to agricultural production systems. Roger Stone received his PhD from the University of Queensland in 1992 in applied climate science and is currently the Director of the Australian Centre for Sustainable Catchments and Professor in Climatology at the University of Southern Queensland. Professor Stone also currently occupies the position of Open Program Chair within the WMO Commission for Agricultural Meteorology to provide research leadership, globally, in the field of climate change, climate variability and natural disasters in agriculture. Professor Stone is also an Expert Team leader within the UN Commission for Climatology on User Interface requirements in Climate Services and also a member of a WMO Expert Team in relation to the Global Framework for Climate Services. Professor Stone provides frequent science policy input to national and state and local organisations, government and industry and has also personally addressed over 30,000 farmers, agricultural managers and global agricultural commodity traders, globally.

APCS 2012 Program

October 8, 2012 (Monday)		Red room (A+B+C)
8:00-9:00	Registration	
9:00-9:25	**Opening Ceremony**	MC: Dr. Jin Ho Yoo
9:00-9:05	Opening Remarks	Dr. Chin-Seung Chung (Director, APCC/Korea)
9:05-9:10	Opening Remarks	Mr. Igor Shumakov (Deputy Head, Roshydromet/Russia)
9:10-9:15	Congratulatory Address	Dr. Vladimir Popov (Chair, Presidium of the North-West Regional Science Centre, Russian Academy of Agricultural Sciences/Russia)
9:15-9:20	Congratulatory Address	Dr. Vladimir Kattsov (Vice Chair Elect, WCRP JSC/Russia)
9:20-9:25	Congratulatory Address	Prof. Bin Wang (Chair, Department of Meteorology, UH/USA)
9:25-9:45	Photo Session	
9:45-10:00	Coffee Break	
10:00-12:00	**Session I** Keynote Presentations (Plenary Session)	Chair: Dr. Vladimir Kattsov Rapporteur: Dr. Flaviana Hilario
10:00-10:40	Coping with climate change: an active agrometeorological learning approach to response farming	Keynote - Prof. Kees Stigter (Agromet Vision/Netherlands and Indonesia)
10:40-11:20	The changing role of science in climate adaptation in the agriculture sector	Keynote - Dr. Mark Howden (CSIRO/Australia)
11:20-12:00	Climate forecast information For agriculture has no value unless it changes a management decision	Keynote - Dr. Roger Stone (Univ. Southern Queensland/Australia)
12:00-13:30	Lunch	
13:30-18:00	**Session II** Climate and Agriculture: Bridging the Information Gap	Chair: Prof. Kees Stigter Rapporteur: Dr. June-Yi Lee
13:30-14:00	Climate and Agriculture: Bridging the Information Gap	Keynote - Dr. Gerrit Hoogenboom (Washington State Univ./USA)
14:00-14:20	Rice and climate variability: A point of interest from the context of food security, agro-biodiversity, and socioeconomics	Dr. Nidhi Nagabahatla (Gottfried Wilhelm Leibniz/Germany)
14:20-14:40	Seasonal climate forecast as a decision support tool in Philippine agriculture and water resources management	Ms. Daisy Ortega (PAGASA/Philippines)
14:40-15:00	A decision support framework for flood risk assessment: An application to the Brahmaputra River in Bangladesh	Dr. SM Fakhruddin (RIMES/Thailand)
15:00-15:20	Coffee break	
15:20-15:40	Targeted seasonal climate information delivery in the Southeast USA	Dr. Jim O'Brien (Florida State Univ./USA)
15:40-16:00	Use and communication of climate data: Experience sharing based on the ACCC (Adapting to Climate Change in China) program	Ms. Hongmei Xu (CMA/China)
16:00-16:20	Cropping pattern planning for a flood prone area: A study using remote sensing and GIS to reduce the losses of climate change impact	Dr. Md. Rejaur Rahman (Rajshahi Univ./Bangladesh)
16:20-16:40	Effect of climate change on winter wheat Yield in North China	Dr. Yanling Song (CMA/China)
16:40-17:00	Coffee break	
17:00-17:20	Climate change and agriculture: Strategies for answering the challenges with biotechnology	Dr. Julian Adams (Univ. of Michigan/USA)
17:20-17:40	Impact of climate change on the agricultural sector of Russian economy	Prof. Oleg Sirotenko (All-Russia Scientific Research Institute for Agricultural Meteorology/Russia)
17:40-18:00	Using climate change information in ecosystems services for poverty alleviation research in China	Dr. Wei Xiong (IEDA, CAAS/China)
18:00-18:30	Wrapping-up and Discussion	
19:00-20:30	Welcoming Reception hosted by Roshydromet Place: Restaurant "Park Inn" in the Pulkovskaya hotel	

APCS 2012 Program

October 9, 2012 (Tuesday)		Red room (A+B+C)
9:00-12:00	**Session III** Climate and Agriculture: Case studies and User Experiences	Chair: Dr. Mark Howden Rapporteur: Dr. Nidhi Nagabhatla
9:00-9:30	Climate information services for food and agriculture: Opportunities and constraints for information providers and users	Keynote - Dr. Selvaraju Ramasamy(FAO/Italy)
9:30-9:50	Forecasting global crop failures to prepare for climate-induced food security	Dr. Toschicika Iizumi (NIAES/Japan)
9:50-10:10	Impact of monsoon rains on the total food grain production over India	Dr. Prasanna Venkatraman (APCC/Korea)
10:10-10:30	Coffee Break	
10:30-10:50	The use of climate information and prediction in cropping patterns for agricultural field extension officers as an anticipation and mitigation of climate variability and change in Indonesia	Mr. Antoyo Setyadipratikto (BMKG/Indonesia)
10:50-11:10	Determinants of post-cyclone household food insecurity under changing climate in Coastal Bangladesh: A case study of the cyclone 'Sidr'	Dr. Shitangsu Kumar Paul (Rajshahi Univ./Bangladesh)
11:10-11:30	The role of weather information on carrot yield performance - An empirical evidence from field data in Chinese Taipei	Dr. Ching-Cheng Chang (APTS/Chinese Taipei)
11:30-11:50	Effect of climate change on agro-ecosystem and rice production in coastal region of Bangladesh	Dr. Abiar Rahman (Bangabandhu Sheikh Mujibur Rahman Agricultural Univ./Bangladesh)
11:50-12:10	Public awareness for agricultural extension through training of trainers (TOT) on climate change	Ms. Vyta W. Hanifah (ICATAD/Indonesia)
12:10-13:30	Lunch	
13:30-18:00	**Session IV** State-of-the-art Climate Prediction for Agriculture	Chair: Prof. Jagadish Shukla Rapporteur: Dr. Michael Tippett
13:30-14:00	Subtropical high predictability establishes a promising way for monsoon and tropical storm predictions	Prof. Bin Wang (IPRC/USA)
14:00-14:30	Multidecadal trends of tropical cyclone and China summer monsoon extreme rainfall	Dr. Chih-Pei Chang (NPGS/USA)
14:30-15:00	Dynamical seasonal forecasting for agriculture in Australia	Dr. Oscar Alves (BoM/Australia)
15:00-15:30	Agroclimatic zoning for winter barley in Korea under the RCP8.5 projected climatic condition	Prof. Jin-Il Yun (Kyung Hee Univ./Korea)
15:30-15:50	Coffee break	
15:50-16:10	Multi-model ensemble prediction for the Boreal Summer Intraseasonal Oscillation	Dr. June-Yi Lee (IPRC/USA)
16:10-16:30	A time-scale decomposition statistical downscaling model	Dr. Jianping Li (IAP/China)
16:30-16:50	Applications of seasonal climate forecast to crop yield prediction: International & domestic collaborations	Dr. Hirofumi Sakuma (JAMSTEC/Japan)
16:50-17:10	Prediction of the first frost dates in Northern China	Dr. Lijuan Chen (CMA/China)
17:10-17:30	Coffee break	
17:30-17:50	Outlook on freeze risk in major peach growing regions in Korea under the RCP8.5 projected climate condition	Dr. Soo-ock Kim (Kyung Hee Univ./Korea)
17:50-18:10	Climate change impact on Typhoon affecting Taiwan Using MRI-20km Mesh AGCM time slice simulations	Prof. Cheng-Ta Chen (National Taiwan Normal Univ./Chinese Taipei)
18:10-18:30	Climate change: risks for Russian Agriculture	Prof. Mikhail Sall (MGO/Russia)
18:30-19:00	Wrapping-up and Discussion	
19:30-21:00	City tour	

October 10, 2012 (Wednesday)		Red room (A+B+C)
9:00-10:40	**Session V** Climate Information Services for agricultural application	Facilitator: Dr. Prasanna Venkatraman, Ms. Hye-Jin Park Rapporteur: Dr. Qingguo Wang
9:00-10:40	Introduction of APCC Climate Information Services (Climate Information Tool Kit : CLIK) and discussion on further development for agricultural application	
10:40-11:00	Coffee Break	
11:00-12:00	**Session VI** Wrap-up Discussion	Chair: Prof. Bin Wang Rapporteur: Dr. Julian Adams
11:00-12:00	Panel discussion and wrapping-up	
12:00-13:30	Lunch	
15:30-18:30	**Session VII** (SAC meeting: Closed meeting)	Chair: Prof. Jagadish Shukla and Prof. Bin Wang Rapporteur: Ms. Nina Dewi Horstmann
15:30-18:30	Open discussion & recommendations • APCC-SAC relationship (Contribution of SAC to APCC) • Strategic goals & future planning	
18:30-20:00	Farewell Reception hosted by APEC Climate Center Place: Restaurant "Paulaner" in the Pulkovskaya hotel	

APEC Climate Symposium 2012

Session I

COPING WITH CLIMATE CHANGE:
AN ACTIVE AGROMETEOROLOGICAL LEARNING APPROACH
TO RESPONSE FARMING
C. (Kees) J. Stigter and Yunita T. Winarto

THE CHANGING ROLE OF SCIENCE IN CLIMATE
ADAPTATION IN THE AGRICULTURE SECTOR
S.M. Howden

CLIMATE FORECAST INFORMATION FOR
AGRICULTURE HAS NO VALUE UNLESS IT CHANGES A
MANAGEMENT DECISION
Stone, R and Everingham, Y.L.

COPING WITH CLIMATE CHANGE: AN ACTIVE AGROMETEOROLOGICAL LEARNING APPROACH TO RESPONSE FARMING

C. (Kees) J. Stigter[1] and Yunita T. Winarto[2]

[1]*Visiting professor in developing countries, Agromet Vision, Bondowoso (Indonesia) and Bruchem (Netherlands) (cjstigter@usa.net),*
[2]*Academy Professorship Indonesia (KNAW-AIPI) & Professor, Department of Anthropology, Faculty of Social & Political Sciences, Universitas Indonesia, Depok, Indonesia (yunita.winarto@gmail.com)*

Abstract Summary: Farmers are confused by the consequences of climate change and want answers on an array of questions that go much beyond local climate issues. Giving and discussing answers and predictions, demand real dialogues in an agrometeorological learning approach to response farming. We use a new extension approach with "Science Field Shops" to temporarily bridge the gap in availability and training of extension intermediaries (EIs) and farmer facilitators (FFs). In these "Shops", farmers and scientists/scholars meet to discuss and solve vulnerabilities expressed by farmers in real dialogues, with these EIs and FFs participating. To make this approach participatory and in the end largely independent, there must be trust between the parties. We are on our way to have a group of rice farmers believe in their attempts to understand and reduce yield differences with the past and between them, by actively learning about consequences of climate change and how we can jointly fight them. In upscaling, this must create a rural response with permanent agrometeorological learning patterns and climate field services in farmers' fields. The latter will be established by better trained extension intermediaries.

Keywords: farmers, climate, extension, dialogues, Science Field Shops

"Dialogic means are born from integrity and care.
These are properties implying modesty".
[From: "The number Fu", by Ayu Utami, 2008.
Dutch translation from Indonesian, De Geus, 2012, p. 95]

1. INTRODUCTION

Farmers in Indonesia are confused by the consequences of climate change (e.g. Stigter, 2008a). For a long time, there was nowhere to go (Stigter and Winarto, 2012a). Extensive experience with agrometeorological extension in Asia/Africa (Stigter, 2010) has shown us that giving and discussing answers and predictions related to climate does demand real dialogues between bearers of new knowledge and farmers (e.g. Winarto et al., 2011).

We found that this must be organized in villages by frequently bringing together farmers and scholars/scientists, in question and answer sessions and discussions, also used for training a new generation of extension workers. But this must be based on farmers' own daily measurements of rainfall and observations of their own agro-ecosystems in rice (Stigter et al., 2009; Winarto et al., 2010). This will lead to active learning of farmers (Stigter and Winarto, 2012b).

This is a temporary new extension approach developed for the often found condition that no well trained extension is able to interact with farmers under conditions of a changing climate. We have called it "Science Field Shops" and experimented with it since 2007 in Gunungkidul (Yogyakarta) (Winarto et al., 2008) and then Indramayu (NW coastal Java) (Winarto et al., 2010).

We use this new approach with "Science Field Shops" to temporarily bridge the gap in availability and training of extension intermediaries (EIs) and farmer facilitators (FFs). In these "Shops", farmers and scientists/scholars meet to discuss and solve vulnerabilities expressed by farmers in real dialogues, with these EIs and FFs participating. And where necessary the scientists/scholars follow this up at their institutes with supportive (literature) research and teaching with and to their students (e.g. Stigter and Winarto, 2012b).

2. HOW DO "SCIENCE FIELD SHOPS" OPERATE?

The basic idea was based on Dutch so called "Law Shops", which came into existence, in the Netherlands, particularly from the very early 1970s onwards, where defenceless people could consult lawyers free of charge about their rights and how to defend them. This gave lawyers and law students the opportunity to see (and discuss) where ordinary people got stuck in the process and what is needed to get them their rights. Both sides learn from this procedure.

We are convinced that "Science Field Shop" sessions are also suitable to get material for improved curricula of CFSs for the future training of Extension Intermediaries. We believe that such curricula should be created together with farmers, discussing their vulnerabilities and other questions, noting the difficulties experienced in the ongoing and recent growing seasons. That is why we see "Science Field Shops" as a start for improved agricultural extension that fits a rural response to climate change (Winarto and Stigter, in prep.). For the basics of this response, see Stigter (2011a).

3. THE USE OF RESPONSE FARMING

Now we have the advantage that in agrometeorology, response farming has been developed decades ago (e.g. Stigter, 2008b; 2010; 2011b). Response farming as a set of agrometeorological services was created by Stewart from the eighties onwards (Stewart, undated; Weiss et al., 2000; Gommes, 2004). The principle was widened by Stigter (2008b; 2008c; 2010) and also further developed into a Farm Adaptive Decision Optimization (Gommes et al., 2010), by widening its fields of operation but keeping the village farmers as focus.

Response farming is a method of identifying and quantifying, statistically or otherwise, seasonal rainfall variability and (un)predictability and related risks, addressing these risks at the farm level. Originally, response farming was limited to rainfall events, but coping with weather and climate (and often soil) disasters as well as using windows of weather and climate (and often soil) opportunities are other forms of responding to weather and climate (and often soil) realities.

Services such as in advices on design rules on above and below ground microclimate management or manipulation, with respect to any appreciable microclimatic improvement: shading, wind protection, mulching, other surface modification, drying, storage, frost protection etc. belong to such "response farming" agrometeorological services (Stigter, 2008b; 2008c). Climate change complicates but does not alter this.

REFERENCES

Gommes, R., 2004: Applications of FAO agrometeorological software in response farming. WMO/Commission for Agricultural Meteorology expert meeting on weather, climate and farmers. http://www.wamis.org/agm/meetings/etwcf/Gommes/pps

Gommes, R., M. Acunzo, S. Baas, M. Bernardi, S. Jost, E. Mukhala and S. Ramasamy, 2010: Communication approaches in applied agrometeorology. Ch. II.D in K. Stigter (Ed.) Applied Agrometeorology, Springer, Berlin , pp. 263- 286.

Stewart, J.I. (undated): WHARF, World Hunger Alleviation through Response Farming. http://www.responsefarming.org/welcome.html (accessed September 2012).

Stigter, K., 2008a: Climate change is confusing Indonesian farmers. A visit to another Climate Field School in Indonesia, that of Gunungkidul near Yogyakarta. Available on the INSAM website under: http://www.agrometeorology.org/topics/accounts-of-operational-agrometeorology/climate-change-is-confusing-indonesian-farmers-a-visit-to-another-climate-field-school-in-indonesia-that-of-gunungkidul-near-yogyakarta

Stigter, K., 2008b: Agrometeorological services under a changing climate: old wine in new bags. *WMO Bull*. **57**(4):114-117.

Stigter, K., 2008c: Coping with climate risks in agriculture needs farmer oriented research and extension policies. *Scientia Agricola* (Piracicaba, Brazil), **65** (special issue), 108-115. http://www.scielo.br/pdf/sa/v65nspe/a16v65nsp.pdf

Stigter, K. (Ed.), 2010: Applied Agrometeorology. Springer, Berlin etc., xxxviii + 1101 pp.

Stigter, C.J., 2011a: Agrometeorological services: Reaching all Farmers with Operational Information Products in New Educational Commitments. CAgM Report 104, WMO, Geneva, 37 pp.

Stigter C.J. (K.), 2011b: Rural response to climate change in poor countries. Ethics, policies and scientific support systems in their agricultural environment. Ch. 5 in T.J. Sauer and J.M. Norman (Eds.), "Sustaining Soil Productivity in Response to Global Climate Change: Science, Policies and Ethics". Wiley & Sons Inc., Ames (Iowa, USA) and Chichester (UK), pp. 67 – 77.

Stigter, C.(K.)J. and Y.T. Winarto, 2012a: Considerations of climate and society in Asia (I). What climate change means for farmers in Asia. Earthzine, 4 April, http://www.earthzine.org/2012/04/04/what-climate-change-means-for-farmers-in-asia/

Stigter, C.(K.)J. and Y.T. Winarto, 2012:. Considerations of climate and society in Asia. (II). Farmers in Indonesia. http://www.earthzine.org/2012/04/17/considerations-of-climate-and-society-in-asia-farmers-in-indonesia/

Stigter, K. and Y.T. Winarto, 2012c: Approaches to active learning for farmers on the consequences of climate change in Indonesian rice fields. Climate Asia blog on the BBC site "Research and communication helping people respond to climate change in Asia". http://climateasiablog.wordpress.com/2012/08/03/approaches-to-active- learning-for-farmers-on-the-consequences-of-climate-change-in-indonesian-rice-fields

Stigter, K., Y.T. Winarto and T. Stathers, 2009: Rainfall measurements by farmers in their fields. Available on the INSAM website under: http://www.agrometeorology.org/topics/accounts-of-operational-agrometeorology/rainfall measurements-by-farmers-in-their-fields

Weiss, A., L. Van Crowder and M. Bernardi, 2000: Communicating agrometeorological information to farming communities. *Agric. For. Meteorol.* **103**:185-196.

Winarto, Y.T., and K. Stigter (Eds.), in prep.: Science Field Shops: The Beginning of Agrometeorological Learning in Indramayu.

Winarto, Y.T., K. Stigter, E. Anantasari and S.N. Hidayah, 2008: Climate Field Schools in Indonesia: coping with climate change and beyond. *LEISA Mag.* **24**(4), 16-18.

Winarto, Y.T., K. Stigter, E. Anantasari, H. Prahara and Kristyanto, 2010: "We'll continue with our observations": Agro-meteorological learning in Indonesia. *Farming Matters* (formerly *LEISA Mag.*) **26**(4), 12-15.

Winarto, Y.T., K. Stigter, E. Anantasari, H. Prahara and Kristyanto, 2011: Collaborating on establishing an agrometeorological learning situation among farmers in Java. *Anthropol. Forum* **21**(2), 175-197.

THE CHANGING ROLE OF SCIENCE IN CLIMATE ADAPTATION IN THE AGRICULTURE SECTOR

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Abstract Summary: Adaptation of food systems to climate variability and change will likely increase in importance but may require progressive changes in the type of science that is undertaken and how it is integrated into decision-making domains. This involves a move from a climate-centered to a decision-centered approach and moving from problem definition to co-developing solutions. New partnerships (especially with industry and policy), new agendas (from a science-gap model to an economic policy focus) and new institutions (especially boundary spanning) may be needed.

Keywords: *climate, agriculture, adaptation, policy, participatory*

1. INTRODUCTION

The challenges for agriculture and for food security over the next decades have been raised repeatedly: population growth, dietary change, energy demand combined with growing constraints in undegraded arable land, water and some inputs along with desires to reduce net greenhouse gas emissions and enhance landscape biodiversity. These multi-factor pressures on food supply, distribution and accessibility will likely be happening concurrently and interacting with substantial climate variability and change. Under such scenarios, adapting agricultural systems becomes a more immediate and critical concern. This has generated substantial research and associated literature. However, there appears to be a growing disjunction between the scale of this science activity and the very limited adoption of the research results by decision-makers (e.g. Meyer 2011). The existence of differences in the supply of versus demand for research is not new (e.g. Sarewitz and Pielke 2007) For climate adaptation research to deliver outcomes, it must *inter alia* change an action by a decision-maker in a climate-affected system (i.e. be adopted) and have some subsequent impact on some attribute or process which has societal value. It has been understood for decades that publication of scientific progress by itself does not guarantee adoption and even delivery of science in sophisticated, contextual technologies such as Decision Support Systems is a fraught process (e.g. Matthews et al. 2008). Consequently, progress in the science related to climate does not necessarily equate to progress in climate adaptation. This paper explores briefly a few of the issues and possible pathways forward.

2. FROM CLIMATE CENTRED TO DECISION CENTRED

Climate adaptation research always involves stakeholders if it is to be implemented. A critical aspect of this is the integration of the engagement process and the science focus. Participatory approaches to science-user engagement are widely acknowledged to be best practice by researchers in many fields (although typically resource-intensive). Participatory action research for climate adaptation focuses on co-design, co-production of knowledge, co-ownership of the results and strongly preferences the knowledge held by stakeholders (e.g Buizer et al. 2010). Experience with this approach has led to a core set of operating principles that include the need to start with the values, aspirations and decision-context of stakeholders (including the institutional environment); then to assess the decisions that are within their existing decision-horizon, the sensitivity of these decisions and their systems of interest to possible climate impacts; the stakeholders' existing capacity to deal with these impacts and how this capacity can be built; the array of adaptation options and their consequences, risks and costs; the implementation path for selected adaptations (including facilitating factors, barriers and limits); and monitoring to determine what works, what does not work, and why, for active adaptive management (e.g. Howden et al. 2012, Fig 1). This contrasts with the 'linear model' of research which places climate at the centre of the analysis, implicitly (and sometimes explicitly) preferencing climate information above other knowledge and biophysical components above socio-economic and policy ones (Sarewitz and Pielke 2007, Meyer 2011; Fig 1). This framing of science often focuses on delivering climate information at ever finer temporal and spatial scales and with ongoing reductions in uncertainty regardless of whether these are either desired or feasible (Wilby and Dessai 2010). Nevertheless, decision support tools that draw from this heritage can be used to translate climate knowledge into forms useful for decision makers. To be successful, however, there is mounting evidence that decision support systems need to be embedded into the social and institutional processes through which decisions are made (e.g. Matthews et al. 2008).

3. EVOLUTION OF THE SCIENCE INVOLVED

Responding to the interacting challenges of climate change and food security will require increasingly complex socioeconomic decisions: they are ultimately about human choice. Consequently, as we progress from the initial 'discovery' phase to generating adaptation outcomes, the questions need to change progressively, requiring a progressive change in the groups taking key actions (Fig 1) and the type of science and its relative contribution (Howden et al. 2012). The initial climate science was instrumental in raising the issue of climate change but needed to be integrated with applications science and economics to demonstrate its importance and to establish the rationale for a mitigation response and development of adaptation options. Implementation paths and public policy responses will involve relative less science which will be largely in the socio-economic and political science domains. An outcomes-focused and decision-centered approach will progressively move through these questions (Fig 1) with iterative loops bringing in the science from further up the sequence. This implicitly means that there will over time be *relatively* less investment in the climate science as the issue evolves (although the absolute investment might grow if the issue increases in importance). This evolution will likely be seen by broader society as a healthy and desirable transition. A climate-centered perspective in contrast will tend to push enquiry back to the top of the sequence, focusing on reduction in uncertainty and delivery of information at finer temporal and spatial scales. Similar arguments apply to research on managing climate variability.

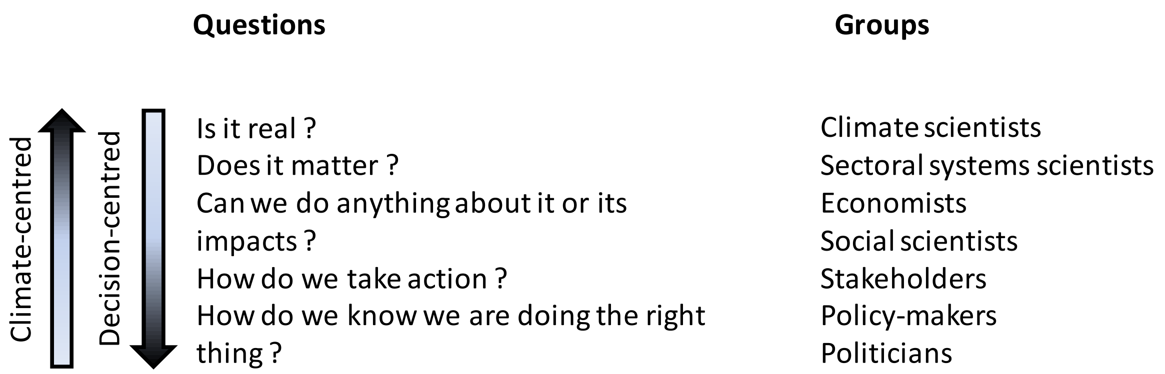

Figure 1. Suggested evolution of questions relating to climate change adaptation and the changing groups needed to address these. The shading of the arrows reflects the direction that climate-centric and decision-centric approaches tend to emphasise (Howden et al. 2012)

4. NEW PARTNERSHIPS AND NEW AGENDAS

Much of the climate research to date on agricultural systems has been linked with productivity metrics and with farmers as the key actors and has not fully addressed the value-chain or policy perspectives. There is a need to change the policy discussion from a science-gap model (knowledge will lead to action) and establish an economic policy agenda with a clear rationale for government intervention including through addressing market and public values failures (e.g. Meyer 2011) and other barriers to adaptation including institutional inertia. This will mean overcoming the focus on defining the problem to participating in developing the solutions. 'Boundary spanning' institutions are likely to grow in importance: those that work to transform scientific knowledge into forms that can be used to support decision making, and to feed back design criteria to help direct science towards outcome relevance (e.g. Buizer et al. 2010).

5. CONCLUSIONS

The key step forward is that scientists, science and related policy agencies need to see themselves as integral parts of community efforts to adapt to climate, and that in this process they need to adapt themselves.

REFERENCES

Buizer, J., Jacobs, K. & Cash, D. (2010) Making short-term climate forecasts useful: linking science and action. *Proc. of the National Academy of Sciences* **10**, 1071/pnas.0900518107.
Howden, SM, Nelson, R and Crimp, SJ (2012) Food security under a changing climate: Frontiers of science or adaptation frontiers ? In Palutikof, J, Boulter, S. Ash, A., Stafford Smith, M., Parry, M., Washka, M., Guitart, D. (eds) Climate Adaptation Futures. Wiley Publishing. pp 107-140.
Matthews, K., Schwarz, G., Rivington, M. & Miller, D. (2008) Wither agricultural DSS? *Computers and electronics in agriculture* **61**, 149-159.
Meyer, R. (2011) The public values failures of climate science in the US. *Minerva* **49**, 47-70
Sarewitz, D. & Pielke, R. (2007) The neglected heart of science policy: reconciling supply of and demand for science. *Environmental Science & Policy* **10**, 5-16.
Wilby, R. L. and Dessai, S. (2010) Robust adaptation to climate change. *Weather* **65**, 180–185.

CLIMATE FORECAST INFORMATION FOR AGRICULTURE HAS NO VALUE UNLESS IT CHANGES A MANAGEMENT DECISION

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Abstract Summary: Climate forecasting can be highly effective in assisting risk management in agricultural production systems in many world regions. To achieve success in integrating climate forecasting into 'real-world' decision making required careful targeting of the climate forecast output to the key decision-points in farm management and also to other important aspects of the whole value chain in agricultural production. Participatory approaches, involving 'discussion-support systems', have been demonstrated to be highly effective.

Keywords: *Climate forecasting, agricultural production, decisions.*

1. INTRODUCTION

Many agricultural production regions are exposed to high levels of seasonal climate variability. It can be demonstrated there are reasonably strong relationships between agricultural production and key climate drivers at various temporal and spatial scales, especially in regards to relationships between the El Niño/Southern Oscillation and agricultural production in many world regions. Knowledge of these types of relationships has led to the dissemination and utilization of seasonal forecast systems that are suitable for agricultural purposes. Both statistically-derived, seasonal forecast systems and the more complex fully coupled ocean-atmosphere systems are now being utilised in the development of seasonal forecast output which may have high relevance for agricultural producers. Yet, it may not be the case that routinely issued climate forecast output is necessarily of a relevant scale or sufficiently targeted to adequately affect management decisions in agriculture. This paper addresses key aspects associated with suggested approaches that may facilitate agricultural production and related decision making associated with seasonal climate forecasting developments.

2. DISCUSSION

The first requirement for an agricultural industry decision maker is that seasonal climate forecasting output needs to be relevant, timely and sufficiently accurate in order to assist in the decision making process (Meinke and Stone, 2005). The approach of utilising agricultural production simulation models/systems may also permit more careful examination of various 'real-world' scenarios which could include: assessing the value of planting a crop earlier or later than may be normal practice given the likely (forecast) in-crop growing rainfall, assessing the value of applying increased levels of nitrogen fertilizer given climate forecast input, assessing the cost or benefit of changing crop type, and so on. Indeed, there are countless levels and types of decisions that may be relevant to the input of climate forecasting information and these types of decisions are often peculiar to each type of farming system, thus requiring a large amount of effort ('targeting') if seasonal and other climate forecasts are to be effective in assisting 'real-world' decision making across many types of agricultural production (Figure1).

A further complexity in agricultural management associated with climate forecasting is the need to consider the whole value chain in many agricultural production systems where aspects related to farmer decisions are also linked to harvesting management and then across the value chain to mill level decisions, which are then also related to transport and logistical decisions at the industry scale. These sets of decisions are also intricately linked to such industry decision systems as marketing, forward selling, and aspects related to global markets. Seasonal forecast systems at varying scales can be applied to all the aforementioned 'decision points' but require careful targeting in terms of their spatial and temporal scales of output together with a recognition that impacts on decisions at one section of the value chain can also produce major flow-on impacts through other sections of the value chain (Everingham et al., 2002; Stone and Meinke, 2005).

Hammer *et al.,* (2001) stressed the most useful opportunities in assisting effective utilisation of climate forecast systems lie in the value of an interdisciplinary systems approach in connecting knowledge from the particular disciplines involved in this process in a manner most suited to decision-makers engaged in the particular agricultural production. This can be referred to as an (affective) end-to-end system involving utilisation of seasonal climate forecasting. Decision-support systems have been widely regarded as a potential panacea in terms of linking the many issues in the decision making frameworks in agricultural production with aspects of seasonal climate forecasting. Yet, in Australia and elsewhere, experience in use of these systems suggests they may have failed to adequately connect to the actual decision processes, especially when considering the many varying levels of activities in the agricultural value chains. To overcome this problem, it is suggested a more participatory approach referred to as a ‘discussion-support system’, can be highly beneficial (eg: Nelson et al.2000).

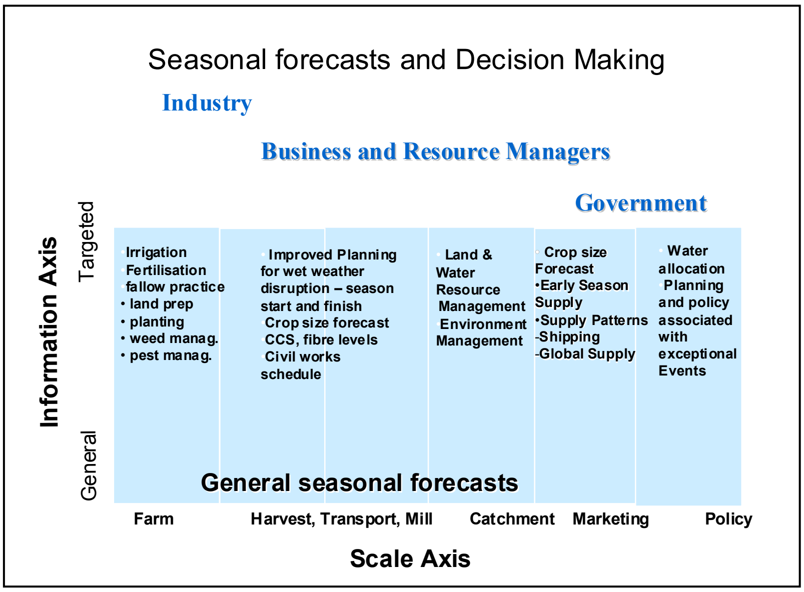

Figure 1. The relationships between scale, information content, and decision-makers in defining relevant systems and the systems approach to applying seasonal forecasts in agricultural systems – example for the sugar industry (after Hammer, 2000; Everingham *et al*., 2002; Stone and Meinke, 2005).

3. CONCLUSIONS

Considerable advances have been made in the development of seasonal climate forecasting systems and output over recent years. However, it is argued seasonal climate forecasting systems must be relevant, timely and accurate in order to be utilised on-farm and in decision-making along the agricultural production value chain. Agricultural production simulation models/systems can greatly assist in the development and output of ‘real-world’ on-farm scenarios which can be utilised by farmers and others in agriculture to consider their various decision options. Decision-support systems may assist in integrating the many complexities involved in linking seasonal climate forecasting to agronomic systems. However, in order to be effective for the actual decision-maker, it is suggested ‘discussion-support’ systems, involving a participatory approach with groups of users, is a more effective approach.

4. ACKNOWLEDGEMENTS

We acknowledge funding provided by key research development agencies in Australia that have greatly contributed to enhancing knowledge in climate forecasting and in agronomic systems, including supporting research into integrated decision-systems. These agencies include (but are not restricted to) the Grains Research Development Corporation, the Sugar Research Development Corporation and the Federal Managing Climate Variability Program.

5. REFERENCES

Everingham, Y.L., Muchow, R.C., Stone, R.C., Inman-Bamber, G., Singels, A., and Bezuidenhout, C.N. 2002 Enhanced risk management and decision-making capability across the sugarcane industry value chain based on seasonal climate forecasts. *Agric. Systems* **74**, 3, 459-477.

Hammer, G.L., Hansen, J.W., Phillips, J.G., Mjelde, J.W., Hill, H., Love, A., and Potgieter, A. 2001 Advances in application of climate prediction in agriculture. *Agric. Systems* **70**, 2-3, 515-553.

Meinke, H. and 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. *Clim. Change* **70**, 221-253.

Nelson, R.A., Holzworth, D.P., Hammer, G.L., and Hayman, P.T. 2002 Infusing the use of seasonal climate forecasting into crop management practice in north east Australia using discussion support software. *Agric. Systems* **74**, 3, 393-414.

Stone, R. C., and Meinke, H. (2005) ‘Operational seasonal forecasting of crop performance’. *Phil. Trans.Royal Soc. B* 360, 2109-2124.

Session II

CLIMATE AND AGRICULTURE: BRIDGING THE INFORMATION GAP

Gerrit Hoogenboom

RICE AND CLIMATE VARIABILITY: A POINT OF INTEREST FROM THE CONTEXT OF FOOD SECURITY, AGRO BIODIVERSITY, AND SOCIO-ECONOMICS

Nidhi Nagabahatla and Alla Yurova

SEASONAL CLIMATE FORECAST AS A DECISION SUPPORT TOOL IN PHILIPPINE AGRICULTURE AND WATER RESOURCES MANAGEMENT

Daisy Ortega ※Abstract not included in this publication

A DECISION SUPPORT FRAMEWORK FOR FLOOD RISK ASSESSMENT: AN APPLICATION TO THE BRAHMAPUTRA RIVER IN BANGLADESH

S.H.M. Fakhruddin, Mukand S. Babel, Akiyuki Kawasaki

TARGETED SEASONAL CLIMATE INFORMATION DELIVERY INTHE SOUTHEAST USA

James J O'Brien

USE AND COMMUNICATION OF CLIMATE DATA : EXPERIENCE SHARING BASED ON ACCC (ADAPTING TO CLIMATE CHANGE IN CHINA) PROGRAM

Hongmei Xu, Roger B. Street

CROPPING PATTERN PLANNING FOR A FLOOD PRONE AREA -A STUDY USING REMOTE SENSING AND GIS TO REDUCE THE LOSSES OF CLIMATE CHANGE IMPACT
Md. Rejaur Rahman

EFFECT OF CLIMATE CHANGE ON WINTER WHEAT YIELD IN NORTH CHINA
Song Yanling

CLIMATE CHANGE AND AGRICULTURE: STEGETGIES FOR ANSWRING THE CHALLENGES WITH BIOTECHNOLOGY
Julian Adams

IMPACT OF CLIMATE CHANGE ON AGRICULTURAL SECTOR OF RUSSIAN ECONOMY
Oleg Sirotenko

USING CLIMATE CHANGE INFORMATION IN ECOSYSTEMS SERVICES FOR POVERTY ALLEVIATION RESEARCH IN CHINA
Erda Lin, Tim Wheeler, Xue Han, Wei Xiong

CLIMATE AND AGRICULTURE: BRIDGING THE INFORMATION GAP

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Abstract Summary: Weather is the single most important factor that controls agriculture including both crop production and livestock. Growers and producers will be the first ones to acknowledge the importance of weather but integrating this knowledge in their daily decisions is a challenge. For climate information and forecasts to be useful in agriculture, it is important to understand how farmers make decisions and if weather and climate play a role in this decision making process. Translating this into information that is economically useful,timely and reliable is a challenge. However, with the rapid changes in information and communication technologies there are new opportunities. At the same time interest in yield predictions at a larger spatial scale are also increasing, both by the private sector as well as by policy makers. Integrating climate forecasts and associated information into the agricultural sector will require new scientific approaches in which atmospheric scientists will have to collaborate with social scientists and application scientists and engineers in concert with stakeholders.

Keywords:*Climate, Agriculture, Decision Making, Impact*

1. AGRICULTURE

Most people associate agriculture with food, but in reality agriculture is very broad. In addition to providing food, it is the livelihood of many people, especially in developing countries, it covers a major portion of land on the globe, it is very dynamic, and it continues to change especially with respect to applications and uses. Currently we can differentiate agriculture into crop production for food, such as vegetables, fruits, grains and legumes, crop production for feed, such as corn (maize) and soybean, crop production for fuels, such as corn and a range of new crops, and crop production for fiber, such as cotton. In parallel to crop production we have livestock production, including meat, dairy products, eggs, fisheries and others. The agricultural production system includes not only growers and producers as stakeholders, but also suppliers, food processers and ultimately the consumers. The overall goal of a produceris to maximize income: balancing productions costs on one hand and product prices on the other hand. However, the goal of consumers, in general, is to purchase food at a relatively low cost. In between the producer and the consumer you can find the supply and processing chains, which provide jobs to a large group of the population.Finally, governments play a role through regulation and price support.Why is this information so important? Ultimately weather and thus climate has a major impact on production and thus prices, affecting the livelihoods of many people across the globe.

2. WEATHER AND CLIMATE

Weather is always in the news, especially when weather extremes are predicted or occur. In many cases this affects agriculture as many extreme events are associated with either high and low temperatures and lack of rainfall resulting in drought. Recent examples include the current 2012 drought in the Midwestern USA, the Russian heat wave that occurred in 2010 or the heat wave in Europe that happed during the summer of 2003. In all cases world food prices were affected by these extreme weather and climate events. When an extreme event occurs, such as a drought, flood, an extreme low temperature or a heat wave, there is not really much a farmer can do to mitigate the potential impact of these extreme events. However, at a policy level the potential impact of these events is extremely important for proper planning. Governments have the option to provide price or other support to farmers who might face a complete loss of their production, or they could purchase agricultural products to guarantee a sustained supply of food. Unfortunately most of the policy responses are reactive rather than strategic based on sound scientific information. Options exist to improve this if climate information is provided that can be used by other disciplines, including agriculture.

3. AGRICULTURE AND FORECASTS

Luckily extreme events are not common for most regions. How useful is weather and climate information for stakeholders, including farmers, producers, and policy makers? Most countries now have some type of agricultural statistics service that is being used to provide seasonal yield predictions or forecasts. This information can be based on local reports from scouts who actually visit individual fields to sophisticated computer such as those employed by the Joint Research Center of the European Commission in which long-term climate forecasts are integrated with agricultural model simulations.

Providing useful information for producers is more challenging. Most farmers will accept local weather reports and one- or two-day forecasts, but longer term weather forecasts or climate outlooks are normally not well received. In addition, what options does a farmer have to translate his information into some type practical application that ultimately leads to an increase in yield and a reduction in production costs that ultimately lead to an increase in income?

4. VALUEOF CLIMATE INFORMATION

The usefulness of weather and climate information seems to be directly related to the value of the crop. High value crops such as flowers and in some cases vegetables are sometimes grown in greenhouses or glasshouses where the atmospheric conditions are completely controlled. This type of climate control is only feasible because a producer can grow a crop that has a high yield and associated high quality and thus a high income to offset the high production costs. On the low input end are the rainfed production systems where crops are grown every alternate year and water is stored during the fallow year in order to guarantee sufficient soil moisture to grow a crop or the zai system in Sub-Saharan Africa for growing sorghum and millet. In between are many different production systems, ranging from rainfed to irrigated, corn and soybeans, continuous rice to fruits and vegetables. In order for the weather and forecast information to be useful, it is not only important to understand the different production systems, but to understand how farmers make decisions. Even for these low input systems climate information could be useful, such as predicting when the beginning of the rainy season in Sub-Saharan Africa or total expected rainfall during a growing season for rainfed crops.

5. AGRICULTURAL DECISION MAKING

Farming is a risky business as ultimately the livelihood of the farmer and his family is at stake, especially for smallholder production systems. Farmers make decisions on a daily basis, ranging from which crop and variety to plant, when to plant, when to apply chemicals including fertilizers and pesticides, when to till the soil or to prune the crop, when to harvest, and when to sell his crop and associated byproducts. For many of these decisions weather and climate play a direct or indirect role. Therefore, there is an opportunity to introduce weather and climate information and associated forecasts so that farmers can make better decisions. This may sound easy, but in the real-world this is a challenge to implement and requires special methodologies with a need of collaboration among different types of scientists. Rather than providing farmers with weather and climate forecasts and telling them that they should use it, a much more stakeholder friendly approach is needed, keeping in mind that the end users are really the experts as they deal with weather on a daily basis.

Scientists and especially modelers have had a tendency to produce model predictions and outcomes that are not necessarily equivalent to the needs of the stakeholders. Therefore, it is important to interact with the stakeholders to try to understand how they make decisions and how weather and climate plays a role in these decisions. Timing of these decisions sometime is also critical. As an example, in most countries seeds are planted during the spring when the soils are favorable for planting. However, in some cases the seeds are ordered in the fall several months prior to planting. Therefore, changing a variety or even a crop might not be possible at planting due to a change in the weather or climate forecast. In other cases growers might not have an option to change a variety or a crop immediately, such as for perennial crops like fruits and forage crops.

5. TRANSDISCIPLINARY SCIENCE

This type of research requires a new scientific approach, sometime referred as trans-disciplinary science, where meteorologists and atmospheric scientists collaborate in concert work with agronomists and agricultural engineers as well with anthropologists, sociologists, and economists. This requires patience and a willingness to accept different ideas, as well as a non-traditional approach. This approach might work successfully in a research environment, but making it operational could be more challenging due to the associated costs. Several private companies have tried to develop these types of products and it seems that only a few so far have been able to make it profitable for both the company and the stakeholders. For instance, recent activities related to weather insurance and yield forecasting for the commodities market seem to have resulted in a successful integration of climate forecasts with agricultural models.

As producers are becoming more familiar with information and communication technologies, they might also be more receptive to this type of approach and information. Even in developing countries most farmers now have a cell phone. Therefore, delivering a text message that includes climate forecast information is relatively easy. However, key to the success of agricultural forecast information will be providing a product that is timely, that is useful, that is user friendly and can be easily obtained and delivered, that is reliable, and that ultimately provides some type of economic advantage for the stakeholders. Making this sustainable will also be a challenge and will require innovative approaches for generating revenue.

RICE AND CLIMATE VARIABILITY: A POINT OF INTEREST FROM THE CONTEXT OF FOOD SECURITY, AGRO BIODIVERSITY, AND SOCIO-ECONOMICS

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Abstract Summary: This script illustrates multi-level impact of climate variability on rice. Rice is crucial for food security, agro-biodiversity and socioeconomics (source of income and livelihoods). On one side, scientific valuations support the fact that long-term climatic variability (and change) can lead to concerns of food (security) production and raise questions on the future of livelihoods practices in agriculture based economies. On the other side, conventional research synthesis or development interventions in context of climate change mitigation and adaptation are typically designed with specific objectives limiting the opportunity for interaction between multi-sectoral experts. Moreover, existing uncertainty in simulation scenarios augmented with a notion that local level climate variability is not just a physiological determinant of crop productivity but to a major extent a defining factor for crop selection or even for change in land use pattern/practice. This article displays an inter-disciplinary effort that takes regional (South and South East Asia) and local (Wayanad-Kerela, India) level settings of rice crop and employs a mix of modeling, projections, seasonality, assessment and observation. The aim is to put forth science-based evidence for planning adaptation strategies to cope with and respond to change.

Keywords: *Climate, Agriculture, South Asia, India, Rice*

1. INTRODUCTION

Asia-Pacific region is witnessing major challenges posed by short-term climate variations, whilst long-term impact of climate change predicted as apparent, particularly for (agro) ecological systems. While host of research studies explain the possible impact of climate variability on agriculture systems concluding that even a small gradient of variation can cause quite a toll for agro-production mainly rain-fed, it is witnessed that socioeconomic dimension of climate impact often remains under addressed (Nagabhatla and Padmanabhan, 2012). Livelihoods are the main vein of a socioeconomic system. In many Asian countries livelihoods are largely agrarian, and in majority of the cases, subsistence. Rice is backbone of food security and to a fair extent determinant of the socio-economic stability particularly in South and Southeast Asia. This article will present key findings from an inter-disciplinary and multi-scalar effort to comprehend multi-level complexity in a social-(agro) ecological-climate nexus. The study has two components that skillfully combine the inter-disciplinary interest for better understanding the plausible influence of climate variability on rice production at a regional and local level.

The first component illustrates the change in rice production at regional level in last 50 years linking the rainfall pattern. It further explains the climate related potential rice yield for the future for this region in-view of the projected climate change scenarios (crop modeling with ORYZA driven by coupled GCM predictions). Simulations at regional (South and South East Asia) and national (India) level showed a general trend shifting the monsoon start and the favorable date of rice planting. Interannual variability in potential rice yield related to weather patterns is significant and exceeds any climate-change induced variation. It means if two average numbers and the amplitude of the potential yield are compared, first for historical and the second for future time slice.

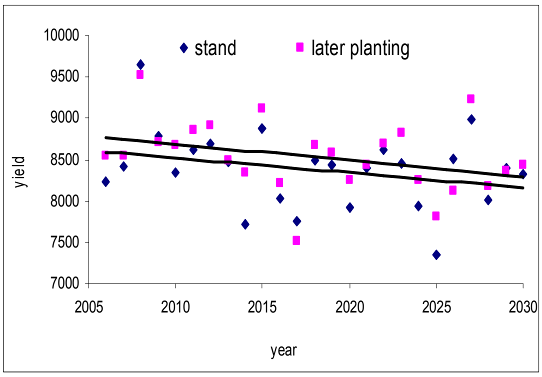

Figure 1. Projected rice yield with conventional planting date and while shifting planting date 15 days ahead the current planning date. Simulations with ORYZA2000 model driven by the GFDL climate projections for South and South East Asia.

Second component relates local level climatic (rainfall pattern and atmospheric temperature) with temporal trends of rice (area and production) in Wayanad District, Kerela- South India. We employed DTR (Diurnal Temperature Range) anomaly to comment on the effect of changing pattern of maximum and minimum temperature *vis-à-vis* environment suitability for rice in two seasons [summer (MAM) and winter (DJF)]. Positive DTR value viewed as a reflection of warming effect and to some extent considered fair for crop production. The condition is that the warming should not cross the threshold viz. optical/thermal kinetic range for that crop (or rice). In summer, mainly in May, DTR is tending to a negative trends possibly affecting the productivity, while in March and April the trend is positive, resulting in a balanced effect. One notes positive anomaly during winter, however the value at times may be relatively higher than the threshold. Area under rice cultivation and rice production proportion is higher in this season compared to summer rice due to favoring factor of temperature and rainfall, despite some sporadic irregularities. Concomitantly, other climatic (rainfall) factors govern the crop productivity, similar co-relation is observed with inter-annual and inter-seasonal rainfall distribution (not shown). Furthermore, remote sensing images (1970's to recent times, Landsat and Aster) are employed to derive the land use cover for visual expression of change in area cultivated with rice.

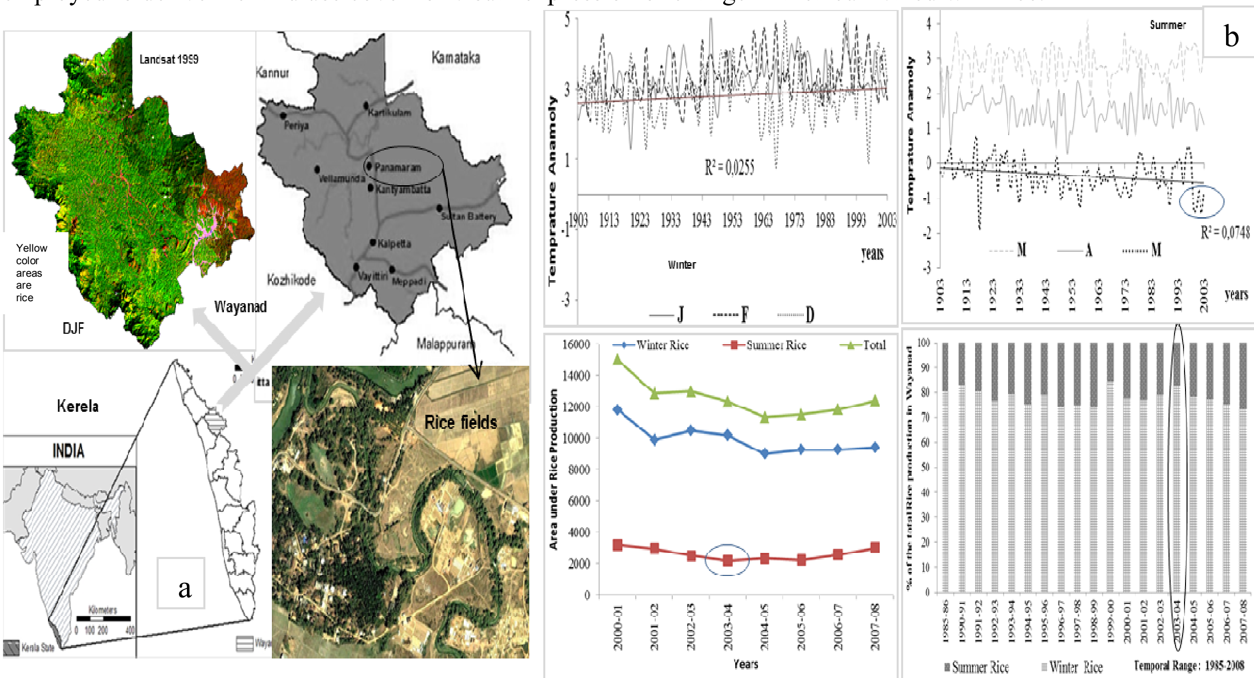

Figure 2. Wayanad: location and landscape features highlighted using remote sensing and Google Earth image (a); also seen is DTR Anomaly related with area under rice production and production or rice for winter and summer season (b)

4. DISCUSSION AND CONCLUSION

Two observations (a) According to model prediction no drastic change is expected in rice yield and water usage (relative to river runoff) in Asia on a regional scale in the next 20 years, but local scale variations can be significant, however course-resolution model is not a robust tool to study the effect of climate variability at specific locations. One can note that rice fields have a specific heat balance partitioning that leads to two-way coupling between the land-use change and local climate that in turn may influence the yield. (b) At local level, one can presume temporal variation in rainfall and surface temperature is a key determinant for change in land use practices (especially in context of small-scale agriculture). Data analysis supported by the discussions with the farmers reveal that rice fields in Wayanad are transformed to other land use or cash crops from the pressure of economic security, influence of agriculture intensification and to an extent impact of climate variation. Bearing in mind that deficiency of detailed research on varied levels of influences between climatic variability and crop production is a key barrier towards clear understanding of factors that drive land use change (including biodiversity), affects (food) yield and upset associated livelihoods. Above and beyond social, cultural, policy and management dimensions will undoubtedly influence the future of rice and rice producers.

Acknowledgements: *The authors thank BioDIVA team members for useful discussions on this topic and for their contribution in any form. The authors also thank APCC-Korea for the invitation to present this work.*

REFERENCES

Nagabhatla Nidhi and Padmanabhan Martina, 2012: Socializing the Pixels: demonstrating application of geospatial tools for socio-ecological research: The case of Wayanad. In NCCR North South. 2012-*International Conference on Research for Development (ICRD): Research for Global Transformation. Pre-Conference Proceedings*, 20-22nd August 2012, NCCR-North-South Dialogue 44 Bern, Switzerland: NCCR- North-South. 69pp

Yurova A, 2012. *Model investigation of the rice growth in Asia driven by future climate projections*. Research report of the YSSP program- Asia Pacific Climate Centre (APCC), Busan, South Korea, 27pp

A DECISION SUPPORT FRAMEWORK FOR FLOOD RISK ASSESSMENT: AN APPLICATION TO THE BRAHMAPUTRA RIVER IN BANGLADESH

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Abstract Summary: Early warning is a key element for disaster risk reduction. However, the advances in generating hazard risk information have not yet been incorporated into operational forecast systems and consequently, operational forecasts have not been integrated into decision making processes in order to reduce disaster risks. This paper describes a decision support framework (DSS) for flood risk management using one to ten days multiple weather ensemble (EPS) forecasts of the European Center for Medium Range Forecasts (ECMWF), integrating hydrological models, and combining GIS and user needs. It designed to interpret, translate, and communicate science-based risk information into user-friendly early warning information products to assist emergency managers and decision makers. The DSS interface allows users to interactively specify the objectives and criteria that are germane to a particular situation, and obtain the management options (strategies) that are possible, and the exogenous influences (scenarios) that should be taken into account before policy planning and decision making. The lumped and semi-distributed hydrological model was used in the multi-model discharge forecasting scheme. The modelling technique employs multiple linear regressions of observed discharge and observed and forecasted precipitation along with a non-linear "effective rainfall" filter based on the idea of linear storage reservoirs and a model structure similar to Unit Hydrograph theory's model. The semi-distributed model employed with a simple nine-parameter, two-layer representative area soil model, parameterizing most of the physical processes of water storage and transport with a slow and a fast time-scale response. It provides 51 set of discharge ensembles forecasts of one to ten days with significant persistence and high certainty (80-84%). Community assessment was conducted for risk and vulnerability assessment. The forecast lead time requirement, users' needs, impact and management options for crops, livestock and fisheries sectors were identified through focus group discussions, informal interviews and questionnaire survey. It was assessed that the existing two day lead-time for early warnings is too narrow and in most cases, is not effective. A ten day lead-time is more effective in order to prepare for harvesting crops irrespective of whether they are ripening or already matured. In this lead time period, cultivators can also store seeds for emergency seedbed preparations. The DSS for an early warning of an impending flood is useful and helps the community to interpret and translate scientific information into risk information. The usage of increased understanding of probabilistic long lead flood forecasting is valuable for society.

Keywords: *Ensembles probabilistic forecasts, Flood risk, Decision support system, Community response.*

1. INTRODUCTION

To enhance the lead time of flood forecasts nowadays, ensembles' probabilistic flood forecasting technique is applied (Demeritt et al. 2007). Operational medium range flood forecasting systems are increasingly moving towards the adoption of ensembles of numerical weather predictions (NWP) known as ensemble prediction systems (EPS) (Cloke & Pappenberger 2009). One major subset of challenges in developing ensemble flood forecasting capacities is the communication of data uncertainty to professionals down the line who are responsible for flood forecasting, warnings and emergency responses. How flood forecasters and emergency service responders might deal with and utilize such uncertainty information is also an issue to which scant attention has been paid so far. A second major subset of challenges is the timely dissemination of forecast and warning information to relevant stakeholders and communities (Tapsell et al. 2004). Another significant challenge is changing warning response behaviours. A crucial purpose behind flood forecasting and warning is to change people's behaviour to increase adaptations, save lives, and reduce damages (Lawrence et al. 2011). However, people do not respond to warnings unless they internalize them or wholly trust them. Research indicates that people's images of the future are shaped by their experiences of the past, and a major constraint on the ability to use hazard information, such as a flood warning, is too much reliance upon experience (Drobota & Parker 2007). Nonetheless, little is known about how these psychological and sociological factors combine with warnings to predict who may be at maximum risk for negative outcomes. Yet, such studies are critically needed so that warning messages which are more effective can be designed for a greater chance of reducing loss. A decision support system integrating science and social information can enable users to interpret and translate scientific knowledge into user-friendly language to respond to an emergency.

2. CONCEPTUAL FRAMEWORKS

The DSS provides a clear visual presentation of where certain communities may be affected by a natural disaster and to what extent. The overall conceptual framework for the development of a DSS is shown in Figure below. The DSS has been defined in three major steps (a.) Initial Data Processing; (b.). Hydrological

Modelling; and (c.) Decision Support System. While data preparation for the hydrological model and flood risk maps are gathered in the initial data process, hydrological models run in the second phase. Based on the flow forecasts, the discharge ensembles' thresholds and impact outlook are designed based on risk assessment frameworks.

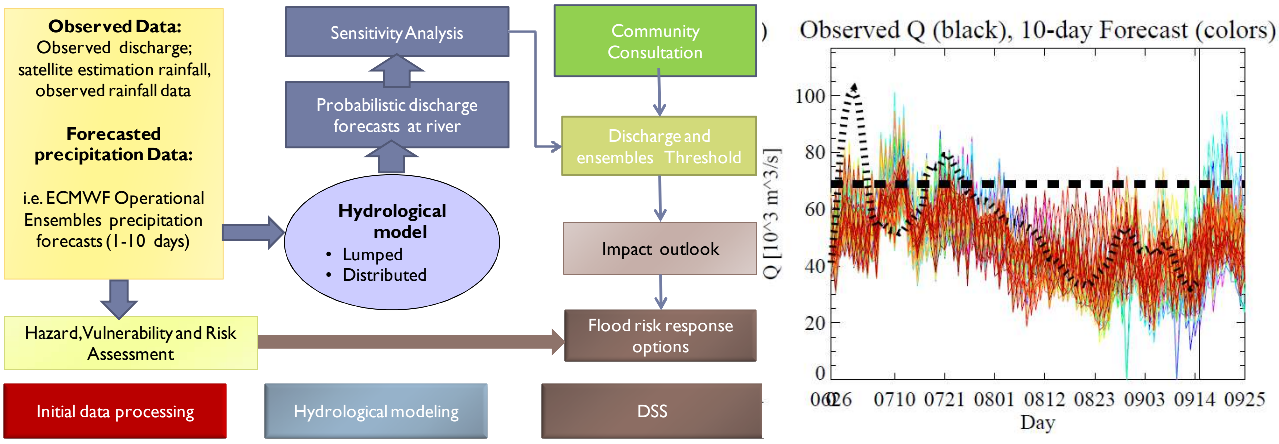
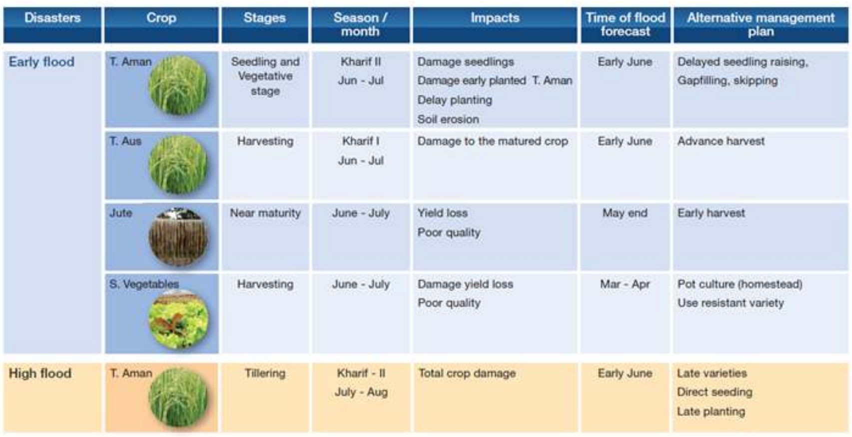


Figure 1. Left: Conceptual framework for flood risk DSS; Right: 10 days ensembles flood forecasts for 2012 in Brahmaputra River.



Disasters	Crop	Stages	Season / month	Impacts	Time of flood forecast	Alternative management plan
Early flood	T. Aman	Seedling and Vegetative stage	Kharif II Jun - Jul	Damage seedlings Damage early planted T. Aman Delay planting Soil erosion	Early June	Delayed seedling raising, Gapfilling, skipping
	T. Aus	Harvesting	Kharif I Jun - Jul	Damage to the matured crop	Early June	Advance harvest
	Jute	Near maturity	June - July	Yield loss Poor quality	May end	Early harvest
	S. Vegetables	Harvesting	June - July	Damage yield loss Poor quality	Mar - Apr	Pot culture (homestead) Use resistant variety
High flood	T. Aman	Tillering	Kharif - II July - Aug	Total crop damage	Early June	Late varieties Direct seeding Late planting

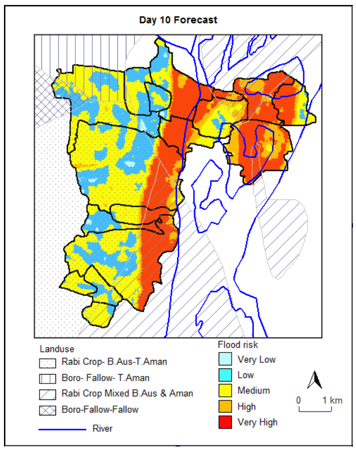


Figure 2. Left: Community response plan based on flood forecasts; Right: Flood risk map for 10 days

3. CONCLUSIONS

The Decision Support System for an early warning of an impending flood is useful and helps the community interpret and translate scientific information into risk information. The usage of increased understanding of probabilistic long lead flood forecasting is valuable for society and for the protection of agriculture in flood-prone areas. In order to receive value-added benefits from flood information, requirements of different users should be considered very carefully and met sensibly.

REFERENCES

Drobota, S. and Parker J. D., 2007: Advances and challenges in flash flood warnings, *Environmental Hazards 7* (2007), 173–178.

Demeritt, D., Cloke, H., Pappenberger, F., Thielen, J., Bartholmes, J. and Ramos, M-H.2007: Ensemble predictions and perceptions of risk, uncertainty ,and error in flood forecasting, *Environmental Hazards 7* (2007) 115–127.

Cloke, H.L., Pappenberger, F. (2009) Ensemble Flood Forecasting: a review, *Journal of Hydrology,* 375(3-4), 613-626.

Lawrence, J., Simon T., Andy R. and Dorothee Q. (2011) Vulnerability and adaptation to increased flood risk with climate change—Hutt Valley summary, The New Zealand Climate Change Research Institute, Victoria University of Wellington

Tapsell, S.M., Burton, R., Parker, D.J., Oakes, S., (2004). The social performance of flood warning communication technologies. Technical Report to the Environment Agency, Flood Hazard Research Centre, Middlesex University, Enfield.

TARGETED SEASONAL CLIMATE INFORMATION DELIVERY INTHE SOUTHEAST USA

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Abstract Summary: In the South East USA we have been learning to communicate with stakeholders for over 15 years. Our principle clients are the entire agricultural community in our footprint. We have a large ENSO impact. Thus our "signal" is dependable. From the beginning social scientists have been a backbone to our approach. Extension specialists are our boundary organization. We have developed very advanced rules for information delivery.

Keywords:*Climate, Agriculture, ENSO, Boundary Organization*

1. INTRODUCTION

First: only probability forecasts are allowed-no matter how insistent the users are. Second: information needs to be delivered in time to influence decisions. If the information cannot be reliable in time, we do not extrapolate. Third: trust will only be built over a long time. Fourth: A climate person always goes with a social scientist on each field encounter. Stakeholders always ask questions that only a specialist can answer.

Farmers are best prepared for CLIMATE VARIABILITY AND CHANGE by adopting best practices NOW which improve their productivity. There are no reliable climate forecasts for more than a year

There are many more. The SOUTHEAST CLIMATE CONSORTIUM has demonstrated a real new way to provide our users pertinent and timely information to save farmers monies.

2. FARMERS REACH INTO NEW 'TOOL BOX' TO SAVE MONEY AND CROPS

Climate variability has long been the bane of farmers, with droughts, floods, freezes and other uncontrollable factors resulting in significant crop losses and higher prices at the checkout lane. Now, thanks to efforts by researchers at seven universities, a new set of tools is helping to provide better long-term forecasts for the agricultural industry.

The Southeast Climate Consortium (SECC) has announced the development of AgroClimate, a new, improved decision support site for managing climate risks to agriculture. In the fall of 2004, the Southeast Climate Consortium launched AgClimate, its first decision support site for managing climate risks to agriculture. Since that time, Southeast Climate Consortium scientists have been working in partnership with Agricultural Extension Services to get information from farmers, extension agents, and forest managers to develop new tools and outlooks that help farmers and foresters to understand and manage climate risks. The new site, AgroClimate, is managed by the Florida Extension Services in conjunction with the Florida Agricultural Weather Network.

"AgroClimate aims to translate state-of-the-art science and climate forecasts from the fields of climatology, economics, agriculture, and forestry, into understandable information that farmers can use to manage risks caused by climate variability¸ " according to Dr. Clyde Fraisse, Climate Extension Specialist for the UF Institute of Food and Agricultural Sciences. " This web site provides simple displays of how temperatures and rainfall in the Southeast US are affected by sea surface temperatures in the Pacific Ocean and how they affect agriculture. In addition, SECC scientists work with extension specialists for different commodities to develop outlooks for specific crops and seasons."

Lawton Professor Emeritus James O'Brien at Florida State University has led the effort in developing the climate science base on which AgroClimate has been established. He points to the "strong cooperation among scientists and extension specialists from diverse disciplines to combine advanced computer models climate and agriculture" as the linchpin of success for developing this decision support system.

According to Dr. James Jones, a distinguished professor in the Agricultural and Biological Engineering Department at the University of Florida, "The development of first AgClimate and now the improved AgroClimate would not have been possible without strong support from the SECC states and from three federal agencies, the National Oceanic and Atmospheric Administration, the US Department of Agriculture Risk Management Agency, and the USDA Cooperative State Research, Education, and Extension Services." He also points to the partnership between the SECC and Extension Services in the SECC states as key to the success of AgroClimate.

The Southeast Climate Consortium includes Auburn University, Florida State University, North Carolina State University, University of Alabama-Huntsville, University of Florida, University of Georgia, and University of Miami. Probabilities from AgroClimate tools are based on over 100 years of data. For more information refer to the website at http://agroclimate.org.

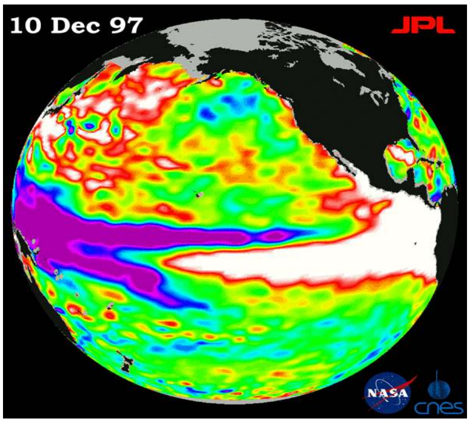

Figure 1.The SECC approach.

3. CONCLUSIONS

Use advances in climate sciences, including:improved capabilities to forecast seasonal climate and long-term climate change, to provide scientifically sound information and decision support tools for agricultural ecosystems, forests and other terrestrial ecosystems, and coastal ecosystems of the Southeastern USA.

USE AND COMMUNICATION OF CLIMATE DATA：EXPERIENCE SHARING BASED ON ACCC (ADAPTING TO CLIMATE CHANGE IN CHINA) PROGRAM

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Abstract Summary: Climate data and information is essential in case of supporting adaptation decision-making, but there are big challenges and gaps during using and communication of climate data supporting decision-making processes. We have some some experiences from ACCC (Adapting to Climate Change in China) project by building user-friendly climate scenarios. Experience has shown that climate data and information needed is that to support decision and policy making. Descriptions of the current and future climate and impacts are necessary, but often insufficient. The data and information need to be relevant, interpreted in the context of the decision required and able to be integrated with other relevant information within the decision or policy making processes. Both the access to the data and information and user-provider support are necessary. Experience has also shown that sustained engagement of users and providers, supporting continuous learning and sharing, offers the potential for effectively addressing the limitations.

Keywords: *Decision-making; User-friendly climate scenarios; Communication; climate data; ACCC*

1. INTRODUCTION

Climate data and information is traditionally targeted to describe the past, present and, in the case of scenarios and projections, the future climates. These are essential, but in the case of supporting adaptation decision-making, these descriptions can fall short of meeting the requirements and lead to inaction. The challenge is to develop and deliver this decision-relevant data and information based on sound science and an understanding of user needs and capacities. The challenge is to develop and deliver this decision-relevant data and information based on sound science and an understanding of user needs and capacities.

We have some lessons based on experience from ACCC (Adapting to Climate Change in China) project on which we need to build. These experiences related to the understanding of what climate data and information is needed, how the climate data or information could be adapted or extended to meet user requirements during the decision-making and policy development processes.

2. ACCC ACTIVITIES IN TERMS OF SUPPORTING USERS' NEEDS FOR USER-FRIENDLY CLIMATE INFORMATION

The Adapting to Climate Change in China (ACCC) project aims to improve international knowledge on the assessment of climate impacts and risks, and develop practical approaches to climate change adaptation, by helping China integrate climate adaptation into the development process to reduce its vulnerability to climate change, and by sharing this experience with other countries.

First and foremost, ACCC will focus on improving development of, and access to, climate change science in China. China has achieved a good level of regional climate modelling capacity and experiences. Under the ACCC project these have been built on with the intent to provide climate scenarios that can better inform vulnerability, risk and adaptation assessments. Efforts have been made to enhance the user-friendliness of the climate scenarios to be delivered. These efforts have included ongoing engagement with end-users to inform scenario development and their dissemination, development of user guidance and case studies, and training of end users. The interaction with end users and communication of the scientific issues and outputs has been a focus of efforts at all stages.

Figure 1. Homepage of ACCC climate change scenarios website

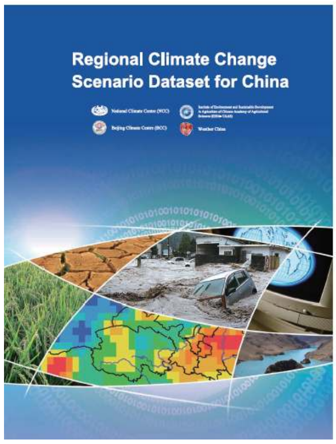

Figure 2. ACCC climate change scenarios brochure

The most important activity that ACCC has delivered was to develop user-friendly climate scenarios and a preliminary set of guidance available on the ACCC website. The ACCC climate change scenarios website (http://www.climatechange-data.cn/) (Fig. 1) classifies its users into different levels based on our understanding of their different needs, and provides them with various forms of customized climate scenario products (e.g., datasets, maps and graphics). User Guidance has been compiled to provide effective support to the intended users. The User Guidance introduces the available climate scenarios information, and how to use the climate scenarios, as well as specific issues that users of the climate scenarios should be aware of when accessing and using the information available. As case studies play a very important role in assisting the users' application of climate scenarios, the User Guidance also includes relevant case studies (Tab.1).

The user-friendly brochure has been prepared and circulates for highlighting the available scenarios to the impacts and risks assessment community and broader (Fig.2). This brochure provides information on the available ACCC climate change scenarios and their potential use, and highlights the nature of climate change within China using maps and images derived from the available scenarios. Also included is information on the application of the scenarios, including example applications in impact assessment for agriculture and for water resources.

Dedicated training has been carried out on the application of climate change scenarios that targeted users at different levels. Training provided involved two aspects: first, instructing users on access to the climate change scenarios; second, enhancing awareness on how to use the available climate information.

3. EXPERIENCES AND REMAINING CHALLENGES

Experience has shown that climate data and information needed is that to support decision and policy making. Descriptions of the current and future climate and impacts are necessary, but often insufficient. The data and information need to be relevant, interpreted in the context of the decision required and able to be integrated with other relevant information within the decision or policy making processes. Both the access to the data and information and user-provider support are necessary. Experience has also shown that sustained engagement of users and providers, supporting continuous learning and sharing, offers the potential for effectively addressing the limitations.

There is limited understanding of the nature and capacities of the evolving, diverse and growing user communities, especially the decision- and policy-making communities. Need for improving the understanding of what climate data and information is needed and how they can inform decision-making and policy development processes, especially when faced with the associated uncertainties and complexities of climate vulnerabilities and risks, and adaptation responses. There is limited understanding of the real needs of the user communities as they strive to understand vulnerabilities and risks, and assess, implement and evaluate adaptation responses. Need for sustained engagement of users and providers of climate information reflecting the evolving nature and scope of users and their needs and the updating of climate information available.

REFERENCES

Gawith M., Street R., Westaway R., and Steynor A., 2009: Application of the UKCIP02 climate change scenarios: Reflections and lessons learnt. *Global Environ Change,* 19(1):113–121.

Romsdahl J. R., 2010: Decision support for climate change adaptation planning in the US: why it needs a coordinated internet-based practitioners' network. *Climatic Change,* DOI 10.1007/s10584-010-9947-x.

CROPPING PATTERN PLANNING FOR A FLOOD PRONE AREA -A STUDY USING REMOTE SENSING AND GIS TO REDUCE THE LOSSES OF CLIMATE CHANGE IMPACT

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Abstract: A remote sensing, geographic information system and spatial multi criteria evaluation based land suitability analysis for crops was described in this study and used to suggest suitable cropping patterns to combat the adverse effects of flood due to climate change. IRS P6: LISS III optical satellite data and object-oriented digital classification procedure was used to generate flood and post flood land use/land cover maps of the area. To generate the necessary factors, constraints and standardization of the factors for the SMCE approach, remote sensing and GIS integrated techniques, models and analytical hierarchy process (AHP) were applied. The results depict that the land was highly to moderately suitable for the crops. Due to the flood hazard in Kharif season, some areas were found marginally suitable for Rice (*Aman*). The Rice-Wheat/Potato, Rice (Late sowing)-Potato, Rice-Potato and Rice-Mustard combinations were found the most suitable suggested pattern. About 19 percent of the total area was additionally suggested for rice, and 23.36 and 23.05 percent of the total area were suggested for mustard and potato, respectively, which can increase the total crop production and can minimize the loss of production of rice or rice crop failure due to climate change impact.

Key Words: *Climate Change, Crop Land Suitability, Cropping Pattern Planning, Remote Sensing, GIS, SMCE.*

1. INTRODUCTION

Due to the global environment change, the climate in Bangladesh is also changing and it is becoming more unpredictable recent years. Like many other countries, Bangladesh will face a tremendous challenge from the climate change. Among other sectors, its agriculture and water will face the deadliest experience from the impact of climate change such as floods, droughts, tornados, cyclones, tidal surges and soil salinities. Flood in the study area, Bogra district of Bangladesh is a common phenomena and it affects the area to a varying extent almost every year mainly due to the climate change. This district has experienced many severe floods that have devastated the area like other parts of Bangladesh in the past (Rahman, 2006). Since Bangladesh is a primarily an agrarian and highly populated country, the development and planning works should be related to the climate change to minimize the adverse effects. Planning is a decision-making method that analyses the problems, identifies the opportunities for change and appraises the alternatives taking into consideration environment, economic and social conditions that lead to the transformation of a current situation to the best option in order to minimize costs and maximize benefits. Land evaluation (i.e. suitability analysis) is a prerequisite for land use planning. Thus, this study was an attempt to suggest optimum cropping patterns for flood (*Kharif*) and post flood (*Rabi*) seasons based on selected crop suitability derived by spatial multi criteria evaluation (SMCE) technique with suitability prioritization, existing land use patterns, flood impact and expert knowledge.

2. DATA USED AND METHOD

Daily maximum and minimum temperature and rainfall data recorded at 35 meteorological stations of Bangladesh over the time period 1971-2010 were used and analyzed. Land use/land cover maps were prepared using IRS P6: LISS III satellite images (summer and winter seasons) and object based digital classification procedure (Baatz and Schape, 2000). *Thana* Soil Series Map of Bogra District (11 *Thanas*) of Bangladesh at 1:50,000 scale was used (SRDI, 2005) to create several layers of soil properties (i.e. texture, drainage, depth, moisture holding capacity, pH and organic matter). Shuttle Radar Topography Mission (SRTM) derived Digital Elevation Model (DEM) of the area was used to create a slope map. The flood hazard zonation map prepared by Rahman and Saha (2007) using GIS aided multi-criteria evaluation approach with selected criteria, was used. Crop land suitability was derived by spatial multi-criteria evaluation (SMCE) and analytical hierarchy process (AHP). Finally, crop suitability maps were used to cropping pattern suitability analysis and to suggest most favorable cropping pattern of the area so that minimize the losses due to flood.

3. RESULT AND DISCUSSION

Data analysis shows that in Bangladesh temperature is increasing and the rate of increasing was more during the last 30 years and the annual rainfall shows an increasing trend during the period of last 40 years (1971-2010). Pre and post monsoon rainfall decreased in the country during this period (Table 1). Due to climate change, flood is a common devastating phenomenon and a major cause of crop loss or failure almost every year in Bangladesh. Therefore, an optimum cropping pattern is needed for the flood prone area and this study provides a methodology to suggest optimal cropping patterns of the study area.

Temperature (^{0}C/yr)	1971-2010 (40 yr)	81-2010 (30 yr)	91-2010 (20 yr)	2001-2010 (10 yr)	**Rainfall (mm/yr)**	1971-2010 (40 yr)	81-2010 (30 yr)	91-2010 (20 yr)	2001-2010 (10 yr)
Mean	0.020	0.024	0.031	0.048	Annual Average	7.130	-5.616	0.005	-34.64
Mean Maximum	0.022	0.028	0.034	0.051	Pre-Monsoon	-0.750	-4.769	-2.567	-11.79
Mean Minimum	0.018	0.021	0.028	0.045	Post-Monsoon	-0.550	-1.296	-4.025	-1.283

Table 1. Trends of mean, mean maximum, mean minimum temperature and annual, pre and post monsoon rainfall of Bangladesh

The suggested cropping patterns depicted that by overall examination of suitability combinations, rice in *Kharif* followed by wheat/potato in *Rabi* season, would be the most suitable pattern which covers 22.13 percent of the cultivated area (Figure 1). Rice (late sowing, early mature)/deep water paddy in *Kharif* and potato in *Rabi* season could be taken up as a second most suitable pattern which covers around 22 percent of the total cultivated area. The cultivation of rice in *Kharif* followed by mustard in *Rabi* season would be a suitable pattern for 15.56 percent of the total cultivated area and another 15.72 percent of the cultivated area would be a suitable pattern for rice in *Kharif* and potato in *Rabi* season. It may be noted here that in very high and high flood hazard zones, late sowing and early maturing varieties of rice crop/deep water paddy have been suggested. Comparison statistics between existing cropping patterns and suggested cropping patterns further showed that 18.99 percent of the total area was additionally suggested for rice, and 23.36 and 23.05 percent of the total area were suggested for mustard and potato respectively, which can increase the total crop production of the area (Table 2).

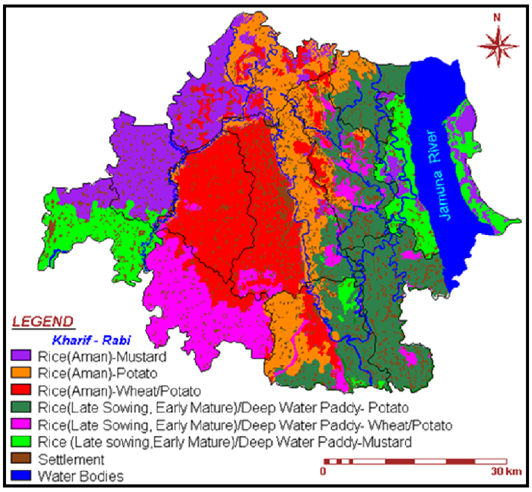

Figure 1. Suggested Cropping Pattern (Kharif-Rabi)

Crop Season	Observed Area		Suggested Area		Crop Suitability	Increased Suggested Area (%)
	(% of the Total Area)					
	Crops	%	Crops			
Kharif (Flood)	Rice	62.75	Rice	43.64	S1+S2	18.99
			Rice (Late Sowing, Early Mature)/Deep Water Paddy	38.10	S3+S2	
			Total	81.74	-	
Rabi (Post Flood)	Mustard	7.27	Mustard	30.63	S1+S2	23.36
			Wheat/Potato	1.25	S2/S2	1.25
			Total	31.88	-	24.61
	Potato	26.81	Potato	23.47	S1+S2	-3.34
			Wheat/Potato	26.39	S2/S2	26.39
			Total	49.86	-	23.05
	Total	34.08		81.74	-	47.66

Table 2. Existing and Suggested Cropped Area

4. CONCLUSION

Due the climate variability and change, flood is the major problem of Bangladesh. Since Bangladesh is an agrarian country, flood has a great impact on agriculture and a major cause of crop loss or failure in the flood prone area. Natural disaster like flood cannot be stopped but can control some extend of it impact through proper planning. This study was an attempt to suggest suitable cropping patterns to reduce the adverse impact of floods in the area. The Rice-Wheat/Potato, Rice (Late sowing)-Potato, Rice-Potato and Rice-Mustard combinations were suggested as the most suitable cropping patterns for flood and post flood seasons and18.99, 23.36 and 23.05 percent of the total area were additionally suggested for rice, mustard and potato, respectively. This study depicted that remote sensing and GIS data in a range of formats and from a variety of sources can be used effectively in land evaluation for crops. It is also demonstrated that the SMCE technique, along with expert knowledge, can be utilized in an effective way for land suitability analysis for crops and cropping pattern planning for a flood prone area. It is expected that land-evaluation for crops will be useful for identifying areas suitable for crops in terms of efficient income generation and sustainable land management to overcome the climate change, particularly the natural hazard problem of the area.

REFERENCES

Baatz, M. and Schape, A. 2000: Multiresolution segmentation-an optimization approach for high quality multi-scale image segmentation. In J. Strobl and T. Blaschke (Eds.), *Angewandte Geographische Informationsverarbeitung XII. Beitrage zum AGIT- Symposium Salzburg 2000*, Karhlsruhe, Herbert Wichmann Verlag, 12-23.

Rahman, Md. R. 2006: Flood inundation mapping and damage assessment using multi-temporal RADARSAT and IRS 1C LISS III Image. *Asian Journal of Geoinformatics,* vol. 6, no. 2, pp. 11-21.

Rahman, Md. R. and Saha, S. K. 2007: Flood hazard zonation-a GIS aided multicriteria evaluation approach (MCE) with remotely sensed data. *International Journal of Geoinformatics*, vol. 3, no.3, pp. 25-37.

SRDI 2005: Soil Resource Development Institute, Dhaka.

EFFECT OF CLIMATE CHANGE ON WINTER WHEAT YIELD IN NORTH CHINA

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Abstract Summary: The crop model World Food Studies (WOFOST) was tuned and validated with meteorological as well as winter wheat growth and yield data at 24 stations in 5 provinces of North China from 1997 to 2003. The parameterization obtained by the tuning was then used to model the impacts of climate change on winter wheat growth for all stations using long-term weather data from 1950 to 2000. Two simulations were made, one with all meteorological data (rainfed) and the other without water stress (potential). The results indicate that the flowering and maturity dates occurred 3.3 and 3 days earlier in the 1990s than that in the 1960s due to a 0.65° C temperature increase. The simulated rainfed yields show that the average drought induced yields (potential minus rainfed yields) have decreased by 9.7% over the last 50 years. This is to be compared with a 0.02% decrease in yield if the precipitation limit is lifted. Although the precipitation during the growing season has decreased over the last 50 years, the drought effects on the rainfed yields remained to be practically unchanged as the spring precipitation did not decrease markedly. Then by assuming constant winter wheat varieties and agricultural practices, the influence of drought induced by short rain on winter wheat yields was simulated using crop model WOFOST and the projections of future climate for the scenario A2 and A1B in North China. The results showed that drought index seemed to decrease by 9.7% and 10.3% with the projected increasing rain and temperature at the same period for A2 and A1B scenarios during 2012-2100, which indicated the drought influence on winter wheat yields would be relieved considering the projected more rain and increasing temperature as well as the growth stage of winter wheat at the same period over North China from 2012-2100. Whereas it seemed that the drought can't be alleviated or more severe in the following 10-30 years.

Keywords: *rought, climate change, winter wheat, North China*

1. INTRODUCTION

Winter wheat is one of China's most important staple food crops, and its productivity is strongly influenced by climate, especially droughts. As a result, the impact of climate change on its production is associated with food security of China. Using observed climate data and the projections of future climate, the influence of climate change was simulated using crop model WOFOST in North China.

The inter-annual, monthly and daily distribution of climate variables (e.g., temperature, precipitation) affects a number of physical, chemical and biological processes that drive the productivity of agriculture. The latitudinal distribution of crop is a function of the current climatic and atmospheric conditions, as well as of photoperiod (e.g., Leff et al., 2004). The total seasonal precipitation as well as its pattern of variability are both of major important for agriculture (Olessen and Bindi, 2002). Short-term natural extremes, such as droughts and floods, inter-annual and decade climate variations, as well as large-scale circulation changes, such as the El Nino Southern Oscillation (ENSO), all have important effects on crop (Tubiello, 2005). In North China, drought becomes a most serious disaster which can strongly influence on agriculture production.

2. TABLE AND FIGURE

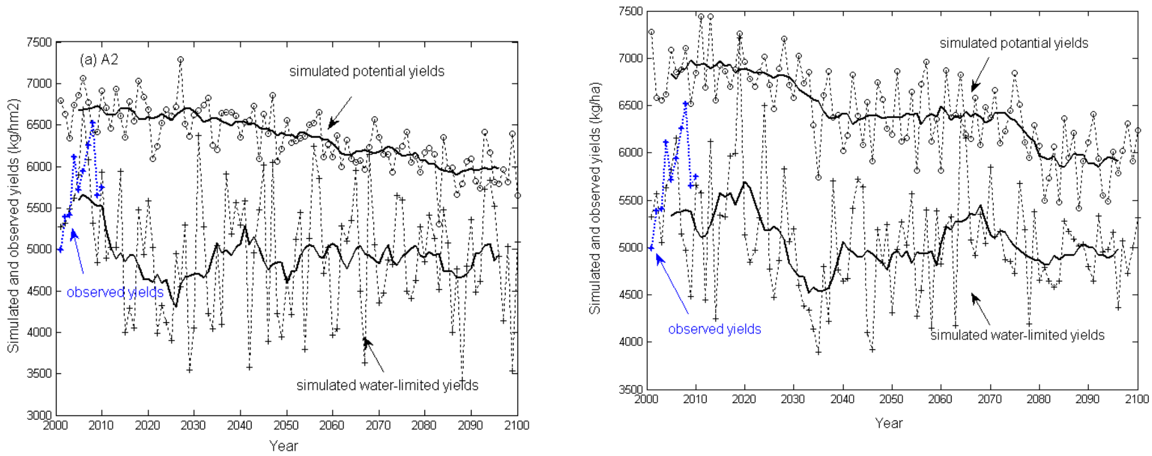

Figure 1. Simulated mean potential and rainfed yields of winter wheat for 22 stations in North China from 2001 to 2100 for A2 (a) and A1B (b) scenarios

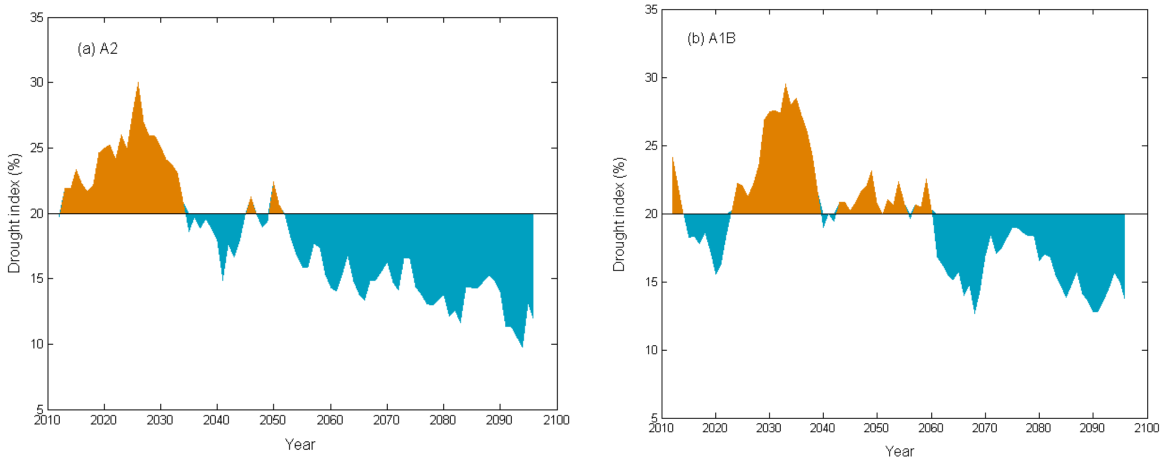

Figure 2. Drought index change of winter wheat in North China from 2001 to 2100 for A2 (a) and A1B (b) scenarios

3. CONCLUSIONS

By assuming constant winter wheat varieties and agricultural practices, the influence of drought on winter wheat yield was simulated from 2012 to 2100. The results showed that drought index seemed to decrease by 9.7% and 10.3% with projected increasing rain and temperature at the same time for A2 and A1B scenarios during 2012-2100. While, the most serious drought was simulated during about 2016-2030 more than 20% loss of the potential yield for A2 scenario, and the serious drought was projected during about 2025-2040 for A1B scenario. Over all, the results indicated the drought influence on winter wheat yields would be relieved considering the projected more rain and increasing temperature as well as the growth stage of winter wheat at the same time over North China from 2012-2100. Whereas it seemed that the drought can't be alleviated or more severe in near 10-30 years.

All of these indicated the water resources are facing shortage in North China, which threatened firstly the irrigation of agriculture. Because the irrigation water for agriculture mainly comes from groundwater and reservoirs in North China. As a result the decreasing water resource becomes a restricting factor of agriculture over North China. Furthermore, it seemed that the agriculture drought can't be alleviated or more severe in near 10-30 years depending on above research. As a result, the water resource would be a restricting factor of agriculture and the influence of drought on agriculture can't be alleviated or more severe considering both the precipitation objected by GCMs and irrigation from groundwater and reservoirs at the same time.

REFERENCES

Leff, B., N. Ramankutty and J.A. Foley, 2004: Geographic distribution of major crops across the world. Global Biogeochem, Cy, 18, GB1009

Olesen, J.E., M. Bindi, 2002: Consequences of climate change for European agriculture productivity, land use and policy. Eur.J.Agron, 16: 239-262.

Tubiello, F.N, 2005: Climate variability and agriculture: perspectives on current and future challenges. Impact of Climate Change, Variability and Weather Fluctuations o Crops and Produce Markets, B. K night, Ed., Impact Reports, Cambridge, UK, 45-63

CLIMATE CHANGE AND AGRICULTURE: STRATEGIES FOR ANSWERING THE CHALLENGES WITH BIOTECHNOLOGY

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Abstract Summary: Developments occurring in Agricultural Biotechnology over the last twenty years have provided technology providers with powerful tools to develop new crops which specifically address present and future changes in world climate. A brief introduction to the technology, including differences and similarities to conventional plant breeding will be presented. Much research in both the private as well as the public sector is being carried with a goal to develop new crops which will serve to both mitigate as well as to adapt to climate change. In some cases such crops are in advanced stages of development with commercialization expected in the near future. Regulation of agricultural biotechnology in APEC as well as in the rest of the world can challenge the development of such new crops. Most recent biotechnology developments may offer new opportunities in terms of the development of new crops as well as the possibility of the easing of the regulatory hurdles that such new crops face.

Keywords: *Climate, Agricultural Biotechnology, Cost of Regulation, Nitrogen Use Efficiency Abiotic Stress*

1. INTRODUCTION

The application of biotechnology to development of new crops varieties allows *i)* the faster development of new crop varieties, *ii)* the facilitation of the incorporation of novel traits, and *iii)* the more accurate modification of crop plant genomes. Since they were first commercialized in 1996, Biotech crops are now grown in 29 countries, and on ~160 million hectares. In 2012, 75% of the soybeans and 82% of cotton grown worldwide, are biotech. The first generation of Biotech crops were developed with improved agronomic traits; tolerance to herbicide and resistance to insect pests. The new generation of biotech crops now being developed possess a much wider range of traits such as, improved nutritional characteristics, improved traits relevant to industrial applications, and traits addressing present and future predicted changes in climate. This new generation of crops presently under development have the potential to mitigate climate changes as well as to adapt to climate changes.

2. AGRICULTURAL BIOTECHNOLOGY AND MITIGATON OF CLIMATE CHANGE

17% of greenhouse gas emissions can be ascribed to the (conventional) agricultural sector, exceeded only by the electricity and heating sector. The synthesis and use of nitrogenous fertilizers principally in the industrialized world is the principal source of the emissions by the agricultural sector. A new generation of nitrogen use efficient (NUE) crops is under development. Nitrogen use efficiency is determined by more than one pathway, thus allowing for different and alternative strategies in the development of NUE crops. NUE wheat, barley maize and canola varieties are in advanced stages of development and commercialization by the private sector is expected shortly.

Other traits relevant to the mitigation climate change which are the focus of research around the world are increased photosynthetic efficiency and increased utilization of carbon dioxide levels. Crops with such traits have the potential to mitigate climate change by utilization of increased carbon dioxide as well as by reducing pressure to convert forest and other natural areas into cultivated lands. Development of such crops is presently in the very early stages.

3. AGRICULTURAL BIOTECHNOLOGY AND ADAPTATION TO CLIMATE CHANGE; DEALING WITH UNPREDICTABILITY

A consequence of climate change is the increased unpredictability of rainfall patterns. Thus, crops that are resistant to drought and flooding can play an important role in adaptation to climate change. Drought tolerance has so far received the most attention, with commercialization expected within the next year of new Biotech drought tolerant varieties of maize and sugar cane. As before with NUE, drought tolerance is determined by a number of genes operating in a number of different pathways. This presents both challenges and opportunities in the development of new drought tolerant varieties. Although the private sector is principally responsible for the development of these new varieties, the public sector has been extensively involved in the development in drought tolerant sugar cane in Indonesia. A public/private consortium is driving the development of drought tolerant maize for Africa – the so called WEMA (*W*ater *E*fficient *M*aize for *A*frica) project. Members of this consortium include Monsanto from the private sector, non-government donors such as the Gates Foundation, and National Government research Organizations in several African countries.

Biotechnological tools are also playing an important role in the development of new crop varieties that are resistant to flooding, though this work is at an earlier stage of development compared with work on drought tolerance. Traits that are associated with flood tolerance are energy maintenance while flooded, as well as protection (efficient active oxygen scavenging, and low ethylene synthesis or sensitivity). The public sector is playing in the development of flood tolerant rice. Among the institutions working in this area are the International Rice Research Institute in the Philippines.

3. AGRICULTURAL BIOTECHNOLOGY AND ADAPTATION TO CLIMATE CHANGE; RISES IN SEA LEVEL.

Sea-level rises that are predicted through the end of the century will severely reduce the significant losses of arable land as well as the salinization coastal regions under cultivation of low areas of land under cultivation. In the APEC region, the Economy that will be the most severely affected is Vietnam, which could lose as much as 50% of land under cultivation to Rice by the end of the century. The tools of biotechnology are being used to develop salt-tolerant varieties of several important crops, most notably rice. Two mechanisms for salt tolerance are *i)* restriction of salt uptake and *ii)* sequestration in subcellular compartments of the salt that is taken up. This latter mechanism for salt tolerance is particularly intriguing as it could play and role in bio-remediation of salinized areas. In addition plants, which are used for animal forage, and which are tolerant to salt mediated by such a mechanism could reduce the necessity to add salt to animal feed. Initiatives under way to develop salt tolerant crops will be briefly described.

4. AGRICULTURAL BIOTECHNOLOGY AND ADAPTATION TO CLIMATE CHANGE; NEW CROPS IN EARLY STAGES OF DEVELOPMENT.

In one study, an increase of 1 °C in night-time minimum temperatures was associated with a loss in yield of 10% in rice. The development of heat tolerant varieties is in the very early stages, but nevertheless could prove to be extremely important in adaptation to climate change. Discussion of research underway in this area will be presented.

5. AGRICULTURAL BIOTECHNOLOGY AND CLIMATE CHANGE; REGULATORY CHALLENGES

It is generally agreed that the lack of effective and science based regulatory policies as well as overly stringent regulation hinders the development and access to biotechnologies, and furthermore restricts the development of new crops to the private sector. The special challenges inherent in the regulation of new crops which can mitigate and adapt to climate change will be discussed. In particular it will be suggested that such crops could serve as the catalyst in the development of new effective and enabling national biotechnology policies which could facilitate the development and appropriate use of biotechnologies particularly in APEC economies.

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IMPACT OF CLIMATE CHANGE ON AGRICULTURAL SECTOR OF RUSSIAN ECONOMY

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Keywords: *climate change, agriculture, crop capacity, modeling.*

1. Introduction

Russian climate is the most harsh for agriculture. Bioclimatic potential (BCP) of Russian territories is 20-30 % lower than that of the EU countries, but exceeds it by 2 or 3 times in unrealized BCP. According to Climatic doctrine anticipatory adaptation for global climate change is one of Russia's priority policies. To research the coevolution of climate and agrosphere we have devised an imitational model which includes:
- models of agroecosystems productivity;
- models of water-heat regime and moisture of agrosphere;
- models of carbon cycle for arable soils;
- models of climate risks for agriculture;
- models of optimizing crops allocation.

On this basis we realized a system of continuous monitoring of agroclimatic indicators, carbon balance components and crops productivity, which operates with a month step in 20th and 21st centuries (up to 2011 in retrospective, then up to 2100 in prognostic regime).

2. Substance

The layout of soil water reserves reproduces about 55-60% of low season dispersion of soil water reserves during the frost-free season in European parts of Russia. The explained productivity dispersion – integral indicator of monitoring system – is about 70%, which allows to estimate imitation system as adequate.

Let us present the results of agrosphere and climate modeling in retrospective regime. Table 1 presents refreshed estimations of most important agroclimatic indicators trends for the period of modern global warming. Comparing these estimations with similar figures for the period of 1976-2004 shows us that summer and autumn temperature trends are on the rise and winter temperature trend falls. For the last decade almost in all Russian territories January temperature trends became negative. The growth of winter and spring rainfall witnessed before has stopped. Table 2 presents the reaction of agriculture to modern climate change.

Positive trends of productivity, which are most important to winter crops, remain. Yet in central federal district and several other regions witness the domination of negative trends of climate-based productivity due to climate aridisation.

Table 3 presents expected productivity change if multimodel (ensemble) scenario works. More arid climate based on warming leads to lowering of productivity of a lot of crops, except for the most heat-loving and drought-resisting plants. The lowering of labile organic mass content aggravates the negative effect of the warming

Table 1. Refreshed estimations of agroclimatic indicators trends for the period of modern global warming since 1976 to 2010.

Federal district	Changes in heat and moisture provision (figure/ 10 years)											
	winter		spring		summer		autumn		GTK index	Budyko's aridity index	Number of days with temperature >10°C	Temperature total > 10° C
	T, °C	R, mm	T, °C	R, mm	T, °C	R, mm	T, °C	R, mm				
Center	0,74	-3	0,47	-1	0,73	-14	0,57	0	-0,115	0,064	3	131
Northwest	0,90	6	0,36	6	0,57	-1	0,47	-3	-0,032	0,026	3	106
Volga region	0,53	0	0,47	6	0,57	-12	0,65	-5	-0,081	0,056	2	93
South	0,34	1	0,27	9	0,64	-4	0,53	12	-0,019	-0,015	4	134
Urals	0,27	1	0,45	8	0,25	-4	0,65	0	-0,023	0,015	2	62
Syberia	0,06	2	0,64	3	0,25	7	0,23	2	0,011	-0,003	3	55
Far East	0,46	5	0,3	8	0,26	6	0,44	-4	0,022	0,011	3	68
Russia	**0,41**	**2**	**0,45**	**5**	**0,42**	**-2**	**0,46**	**0**	**-0,033**	**0,021**	**3**	**84**

Table 2. Adjusted estimations of changes in climate-based crop productivity in Russia's regions since 1975 to 2009.

Federal district	Crops and leguminous plants	Winter wheat	Summer barley	Crops and leguminous plants	Winter wheat	Summer barley
	quintale/hectar for 10 years			% for 10 years		
Volga region	0,33	1,28	0,41	2,3	7,1	3,1
South	0,27	0,99	0,09	1,2	3,7	0,5
Center	-0,09	0,38	-0,03	-0,5	1,9	-0,2

Table 3. Estimations of possible changes in crop productivity by 2020 and 2040 in the realization of ensemble climate scenario in Voronezh region with (1) and without (2) taking into account changes in content of labile organic mass.

Crop	Crop productivity change							
	years 2011-2030				years 2041-2060			
	quintale/hectar		%		quintale/hectar		%	
	1	2	1	2	1	2	1	2
Crops	-0,8	-1,0	-4,7	-5,9	-1,9	-2,5	-11,2	-14.7
Winter wheat	-0,2	-0,6	-1,0	-2,9	-0,7	-1,5	-3,4	-7,3
Summer barley	-1,3	-1,4	-7,5	-8,0	-3,0	-3,4	-17,2	-19,5
Sunflower	+0,2	+0,2	+1,9	+1,9	+0,6	+0,5	+5,8	+4,8
Sugar beet	-4,6	-5,0	-2,9	-3,2	-7,8	-8,9	-4,9	-5,7

3. Conclusion

The most important field in application of this monitoring system is predicting crop productivity on short term, long term and strategic scale. We have shown that involving data on dynamics of content and rate of decomposition of four main modeled fractions of organic part of soil as predicates we can significantly increase the advance time and accuracy of crops productivity prognoses. We present the results of prognosis accuracy estimation for crops productivity in Central Russia, Volga region and Southern federal district.

We have also presented the reaction of crop productivity to possible climate change for humid and arid scenarios of global warming. The expected growth of crop productivity if most possible scenarios work is linked to a vast unused adaptation potential of Russia's agrosphere.

REFERENCES

Sirotenko O.D., Kleshenko A.D., Pavlova V.N., Abashina E.V., Semendyaev A.K. 2011. Monitoring of climate change and estimation of the consequences of the global warming. *Agrophysics*. **3**, 31-39.

USING CLIMATE CHANGE INFORMATION IN ECOSYSTEMS SERVICES FOR POVERTY ALLEVIATION RESEARCH IN CHINA

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Abstract Summary: Climate change is a key driver of change in ecosystems, ecosystems services and their links with causes and alleviation of poverty. However, many research groups do not have the skills and tools to use climate change information (in current climates and future climates – from the coming season to many decades ahead) in ESPA research. Through a structured programme of knowledge exchange, our project is addressing the skills needs of two major stakeholder groups in China – potential ESPA researcher in Universities and research institutes and poor communities living in ecosystems vulnerable to climate change. The continued engagement of researchers will be encouraged by setting up an ESPA climate network.

Keywords: *Climate change information, ESPA*

1. INTRODUCTION

The project "Using climate change information in ecosystems services and poverty alleviation research in China" was one of 11 within the second phase of the Ecosystems Services and Poverty Alleviation programme (ESPA) funded by the UK Department for International Development (DFID), the National Environment Research Council (NERC) and the Economic and Social Research Council (ESRC). The project brings together for the first time a unique group of climate and climate impacts researchers from world-leading institutions concerned with climate in the UK and China, each with international reputations for excellence in research and training, in order to build capacity in using climate information within the expanding ecosystems services for poverty alleviation community in China.

The NERC/DFID/ESRC ESPA research programme recognises climate change as a key driver of change in ecosystems, ecosystem services and their links with the causes and alleviation of poverty. However, many of the potential participants in the ESPA programme will not have the skills and tools to use climate change information in ESPA research. This project addresses skills needs of two major stakeholder groups through a structured programme of knowledge exchange. For researchers across the sciences and social sciences in China, we build their capacity in using climate information (in current climates and future climate - from the coming season to many decades ahead) to enable them to better participate in the ESPA programme.

For poor communities living in ecosystems vulnerable to climate change, we explore how best to raise awareness of how climate change may affect them and the impacts of climate change on local ecosystems to enable this stakeholder group to create and communicate a demand for research in the ESPA programme. This will address the development needs of those poor communities whose livelihoods are particularly vulnerable to the impacts of climate change. Of strategic importance, this project engage researchers and the poor in China with the ESPA research programme.

2. OBJECTIVES OF THE PROJECT

Strengthen capacity of ESPA researcher through the development and delivery of a training programme on how to use climate information and climate change projections in research projects on ecosystems services and poverty alleviation in China.

Raise awareness of climate change issues and their impacts on ecosystems among poor communities in China, and those working with them and create a demand for research.

Deliver an agenda-setting documents on how to use climate change information in studies of ecosystems services for poverty alleviation in China and other ESPA programme regions.

3. METHODOLOGY AND APPROACH

Activity 1 - Building Capacity

A survey of a wide cross-section of academics and researchers in the sciences and social sciences in China who are possible participants in the ESPA programme determined the training and information needs concerned with climate change. We developed then training programmes tailored to these needs and delivered through four 2-day workshops in China;

Activity 2 - Raising Awareness

Two case studies were conducted to raise awareness of climate change issues and to explore how climate change issues can be better communicated between different stakeholders within the ESPA programme. We used one poverty county dominated by agricultural ecosystems (in Gansu Province) and another with a fragile natural grassland ecosystem (in Qinghai Province) where we have already established contacts with local leaders. Surveys of community knowledge of climate change and its impacts that were developed and used by CAAS in Ningxia Province was conducted in Gansu and Qinghai in order to understand more about local knowledge of climate change and its impacts on ecosystems and what needs should be addressed through research.

We developed two tools in community meeting settings. The first, based on community mapping techniques adapted to the social and institutional realities of rural China, identified sources and channels of communication on climate issues at community level. The second, based on causal diagram techniques, provided an understanding of people's current knowledge and attitudes regarding both climate change and ecosystems services. The output of these meetings was a revised version of the tools, validated by use in the field, for dissemination to other stakeholders and that contributed to the wider development agenda.

Activity 3 – Communication

The findings and lessons learned from the project were communicated to a variety of stakeholders - policymakers, donors, researchers, poor communities and NGOs using a range of media. A dual language English/ Chinese website (part of the successful http://www.espachina.org) website) was set up by CABI to promote the project to a wide audience, to facilitate interaction with workshop attendees using FAQs, and to manage the project itself (in a password protected part). We developed an ESAP Climate Network for workshop participants to encourage their on-going participation.

Video diaries were filmed during the workshops and case studies and edited to provide a range of short documentaries in English and Chinese for distribution to Chinese provincial and county TV stations. A set of guidelines and recommendations for using climate change information in studies of ecosystems services for poverty alleviation in China, and other ESPA regions, were formed from experience gained in activities 1 and 2. These were summarised in an agenda-setting document that be launched at the final consortium meeting at which a range of stakeholders will be invited.

4. NEW FINDINGS

The project brings together for the first time a unique group of climate and climate impacts researchers from world-leading institutions concerned with climate in the UK and China, each with international reputations for excellence in research and training, in order to build capacity in using climate information within the expanding ESPA community in China.

From the project, we recognized that there were gaps between climate services and ESPA research needs, particularly for the tools and methods for obtaining specific climate change information. Participatory tools were useful to gain insight into what farmers know and think and were able to bridge the gaps between climate servers and agricultural adaptation. Scientists gave useful suggestions for improving the tools, which they felt they could integrate into their future research. Farmers gave useful information on social and economic aspects of ecosystem change, complementing the biophysical understanding from the scientists' own research. Participatory research is a useful medium for communication among stakeholders, as well as a method for information gathering and analysis.

Acknowledgements:

The project was operated by a team of researchers from China (Chinese Academy of Agricultural Sciences, China Meteorological Authority and Gansu and Inner Mongolia Meteorological Bureau) and the UK (Walker Institute, University of Reading). The research was funded by NERC, ESRC and DFID under the Ecosystem Services for Poverty Alleviation programme.

Session III

CLIMATE INFORMATION SERVICES FOR FOOD AND AGRICULTURE: OPPORTUNITIES AND CONSTRAINTS FOR INFORMATION PROVIDERS AND USERS
Ramasamy Selvaraju

FORECASTING GLOBAL CROP FAILURES TO PREPARE CLIMATE-INDUCED FOOD INSECURITY
Toshichika Iizumi, Hirofumi Sakuma, Masayuki Yokozawa, Jing-Jia Luo, Andrew J. Challinor and Toshio Yamagata

IMPACT OF MONSOON RAINS ON THE TOTAL FOOD GRAIN PRODUCTION OVER INDIA
Venkatraman Prasanna

THE USE OF CLIMATE INFORMATION AND PREDICTION IN CROPPING PATTERNS FOR AGRICULTURAL FIELD EXTENSION OFFICERS AS AN ANTICIPATION AND MITIGATION OF CLIMATE VARIABILITY AND CHANGE IN INDONESIA
Antoyo Setyadipratikto,Fera Addrianita

DETERMINANTS OF POST-CYCLONE HOUSEHOLD FOOD INSECURITY UNDER CHANGING CLIMATE IN COASTAL BANGLADESH: A CASE STUDY OF CYCLONE 'SIDR'
Shitangsu Kumar Paul and Jayant K Routray

THE ROLE OF WEATHER INFORMATION ON CARROT YIELD PERFORMANCE AN EMPIRICAL EVIDENCE FROM FIELD DATA IN CHINESE TAIPEI
Ching-Cheng Chang, Shu-Hua Lin, Emma Huang

EFFECT OF CLIMATE CHANGE ON AGRO-ECOSYSTEM AND RICE PRODUCTION IN COASTAL REGION OF BANGLADESH
Md. Abiar RAHMAN and Su-Chel KANG

PUBLIC AWARENESS FOR AGRICULTURAL EXTENSIONS THROUGH TRAINING OF TRAINERS (TOT) ON CLIMATE CHANGE
Vyta W. Hanifah, E. Sirnawati, A. Yulianti,
U. Humaedah, and E. Jamal

CLIMATE INFORMATION SERVICES FOR FOOD AND AGRICULTURE: OPPORTUNITIES AND CONSTRAINTS FOR INFORMATION PROVIDERS AND USERS

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Abstract Summary: Recent advances in climate prediction have raised exciting opportunities for managing the climate risks and enhancing opportunities. Enabling institutions and policies, smart Information and Communication Technologies (ICTs) and vibrant local community networks complement this advancement, especially by connecting climate information providers, enablers and end-users. However, there are number of constraints that hold back the advancement of climate science, especially in developing countries. Promoting mechanisms for effective User Interface Platforms (UIPs) at the national level and strengthening formal institutions and informal networks at the local level are crucial to reach the most vulnerable livelihood systems in agriculture. An effective climate information service should aim at strengthening activities ranging from production, availability, delivery and application of science-based climate information services to users.

Keywords: *Climate information services, Food and Agriculture, User Interface Platforms (UIPs)*

1. INTRODUCTION

Climate is the main driver of agriculture and the dominant factor in the overall variability of food production. Small-scale farmers, herders and fishers have always been affected by climate variation and are often food insecure. FAO estimates that a total of 925 million people were undernourished in 2010. Achieving food security in a changing climate warrants a systemic and integrated approach, taking into account ecological, economic and social perspectives. The climate information services will be one of the tools that have the potential to meet the needs of the future. Achieving this potential depends on capability to offer diverse, location specific, timely and easily understandable climate information that match production, management, market systems and decision cycles conditioned on uncontrollable climatic factors (Fig. 1, modified from Brennan and McCown 2001).

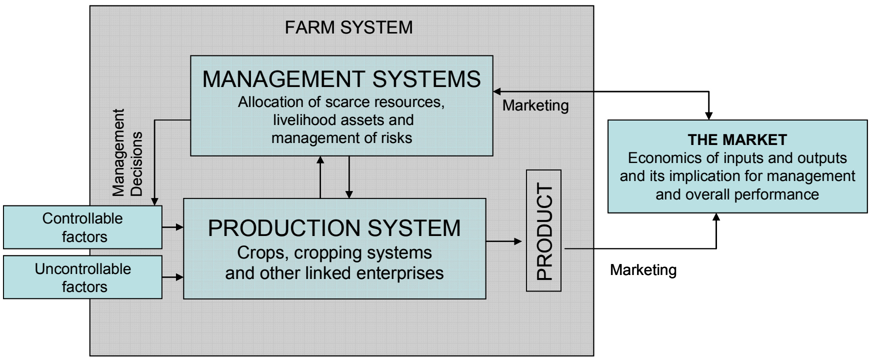

Figure 1. A simple model of the farm as systems of production and management and its interaction with market and controllable and uncontrollable factors

The climate information products should be customized to suite needs of users – food and agriculture policy makers, agriculture service providers, irrigation managers, input suppliers, market intermediaries, local cooperatives, micro-financing, farmers, fishers, livestock herders etc., Information providers are constrained by non-availability and/or insufficient data, while users often perceive that information is general, and highly technical. Providers often provide narrow, specific and precise aspects within the limits of available tools and methods. This paper focuses on two major areas: (i) reaching the most vulnerable end-users depending on agriculture, livestock and fisheries and (ii) strengthening institutional and technical capacity to facilitate production, availability, delivery and application of climate information services.

2. REACHING THE MOST VULNERABLE

Agriculture communities in mountainous, coastal eco-systems; arid and semi-arid regions are most vulnerable to climate risks due to remoteness, lack of resources, dependence on agriculture, prone to degradation, frequent occurrence of extreme climate events and non-availability of agricultural support services. The existing climate services seldom reach end-users in these areas due to lack of understanding about their needs, non-availability of data, gaps in available records, and inadequate communication and institutional mechanisms. There are opportunities to overcome these gaps - rescuing past data, digitizing paper records, use of model-based techniques, satellite observations and database management systems. Several recent initiatives aim to improve observation, monitoring and communication systems, but are usually donor-driven and highly fragmented. Promoting integrated National Meteorological and Hydrological Systems and connecting them with User Interface Platforms (UIPs) in agriculture can improve delivery of climate information services to end-users.

At the decentralized levels, localized climate information services need to provide a full range of advice regarding crops to be planted, time and optimal quantity of inputs and management practices, livestock stocking rates, fishing time and area and market outlooks to prevent/reduce risks (Selvaraju et al. 2011). The local advisories need to contain information on status of input availability with support services, cooperatives, private sector and community-based organizations (CBOs) to motivate locally relevant decision making. Climate information services are central to a range of interventions from local to national level (Fig. 2).

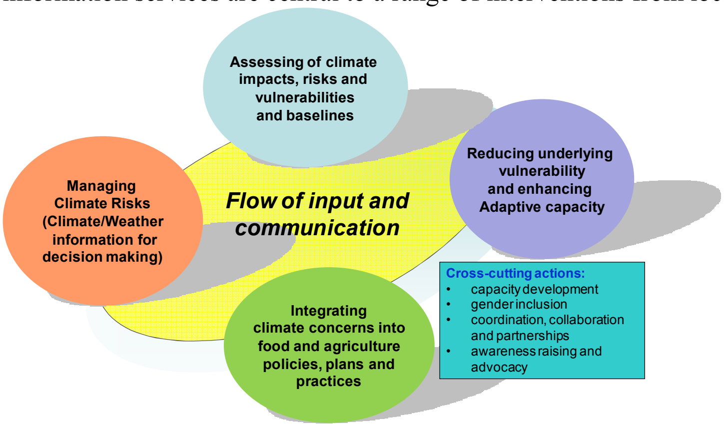

Figure 2. Climate services for risk management and adaptation planning in food and agriculture

3. STRENGTHENING INSTITUTIONAL AND TECHNICAL CAPACITY

The capacity to identify, collect and share data, use information and relevant methods for data analyses and develop information products is crucial. The priorities are: transfer of recent knowledge from climate science, as well as strengthening of the capacity for agro-meteorological observation, the development of customized forecasting products, the management of data and modelling for climate impact assessment and application of climate information at the farm level. Strengthening technical capacities of agriculture extension services in interpreting climate information, preparing impact outlooks and developing adaptation options is necessary to act as an efficient interface between policy-makers and the farming community.

Agricultural research, together with climate science needs to provide several new location-specific risk and opportunity management practices. The priority areas of research relevant to climate services are: improving automated data collection, dissemination and analysis; developing needs-based early warning and forecasting systems; and developing communication protocols. Significant public and private partnerships are required to advance weather index-based risk insurance. Participatory and practical learning (e.g Farmer Field Schools) and action research through institutional partnerships and networking need to be adopted for effective application of climate information in agricultural decision making.

4. CONCLUSIONS

The emerging ability of climate science to provide timely and accurate climate information, together with innovative tools and methods for analysis, presents opportunities for managing climate risks and for initiating strategic climate-resilient adaptation. However, to make effective use of these advancements, strong partnerships and collaboration among national hydro-meteorological services, agricultural extension agencies, national research institutions, community based organizations and social networks are a prerequisite. All of these efforts present key challenges, but offer immense opportunities for supporting sustainable agriculture and food security

REFERENCES

Brennan, L.E, and R.L. McCown, 2001: Back to the future - Reinventing farm management economics in farming systems research, 10th Australian Agronomy Conference. Australian Society of Agronomy. 2001.

Selvaraju, R., R. Gommes, M, and Bernardi, M, 2011: Climate science in support of sustainable agriculture and food security. Climate Research, Vol. **47**: 95–110.

FORECASTING GLOBAL CROP FAILURES TO PREPARE CLIMATE-INDUCED FOOD INSECURITY

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Abstract Summary: This study presents a global picture of the predictive skill of interannual crop yield variation at two lead times using an ensemble-mean seasonal temperature and soil moisture forecasts and statistical crop models. We found that the areas where the in-season prediction is statistically skillful account for 3.8% to 12.1% of the world harvested area.

Keywords: *Climate variability, Global crop prediction, Major cereal and legume crop, Predictive skills*

1. INTRODUCTION

High food prices worsen food access of the urban poor. Since 2007, food agencies in import-dependent countries have been paying the increased attention to crop prospects in both own country and major food-exporting countries. Given the increasing food demand and expected increase in climate extremes linked to climate change, tense food situation likely continues intermittently during the coming decades (FAO, 2009). Under these circumstances, global crop monitoring and prediction have been increasingly important.

Most countries operate crop prediction for specific crops or famine early warning (Verdin et al., 2005). Some of them use seasonal climate forecasts and provide successful predictions with a few months lead. So far, however, few studies have evaluated the crop prediction skill at the global scale. We therefore presented a global picture of the crop prediction skill for major cereal and legume crops, based on the state-of-the-art ensemble dynamic seasonal climate forecasts and statistical crop models.

We assessed the crop prediction skill at two lead times. First one is the "pre-season" prediction that predicts the interannual yield variation of this cropping year before planting month. The second one is the "in-season" prediction that is performed just before the coming of key growing season (reproductive growth period) of this crop year to predict the yield variation in this cropping year. The pre-season and in-season prediction uses mean climate information for key growth season derived from seasonal climate forecasts at 3- to 5-month lead and at 1- to 3-month lead, respectively.

2. DATA AND METHODS

Climate and crop data are arranged for the period 1982-2006 and 1.125 x 1.125 degree grid coordinate. Historical temperature and soil moisture were obtained from the Japanese reanalysis dataset. The data were temporally averaged over each key growing season and spatially according to the geographical distribution of crop harvested area from the global phonological dataset of Sacks et al. (2010). Nine-member seasonal temperature and soil moisture forecasts were generated from the SINTEX-F ocean-atmosphere coupled general circulation model (Luo et al. 2005). The ensemble-mean values were calculated for each forecast at various lead times from one month up to 12 months. Then the forecast averaged over each key growing season were generated in a similar manner as used for the reanalysis. Bias of climate forecasts was statistically removed.

Historical crop yields were obtained from the global gridded crop yield dataset (Iizumi et al. 2012), which aligns high-resolution yield statistics and yield proxy from the satellite remote sensing.

The crop and climate time series were combined to derive a statistical model as follows: (1) a first difference time series was computed for the yield and reanalysis data; (2) a percentage first difference of yield was computed by dividing first difference of yield by an average yield over three years (the same average yield was used for the first three years of the studied period); (3) multiple linear regression models were computed:

$$Y_{t,g} = \sum_{c=1}^{2} w_{g,c} Y_{t,g,c} \Big/ \sum_{c=1}^{2} w_{g,c}, \quad (1)$$

$$\Delta Y_{t,g,c} = \alpha_{g,c} \Delta T_{t,g,c} + \beta_{g,c} \Delta S_{t,g,c} + \gamma_{t,g,c} + \varepsilon, \quad (2)$$

where the suffix t, g, and c denotes year, grid cell, and cropping system, respectively. ΔY is the percentage first difference of yield (%), w is the production of each cropping system as the weight (t), ΔT and ΔS is the first difference of reanalysis temperature (^oC) and soil moisture (mm), respectively, α, β, and γ are the regression coefficients, and ε is the error term; (4) the regression coefficients were determined by using the Markov Chain

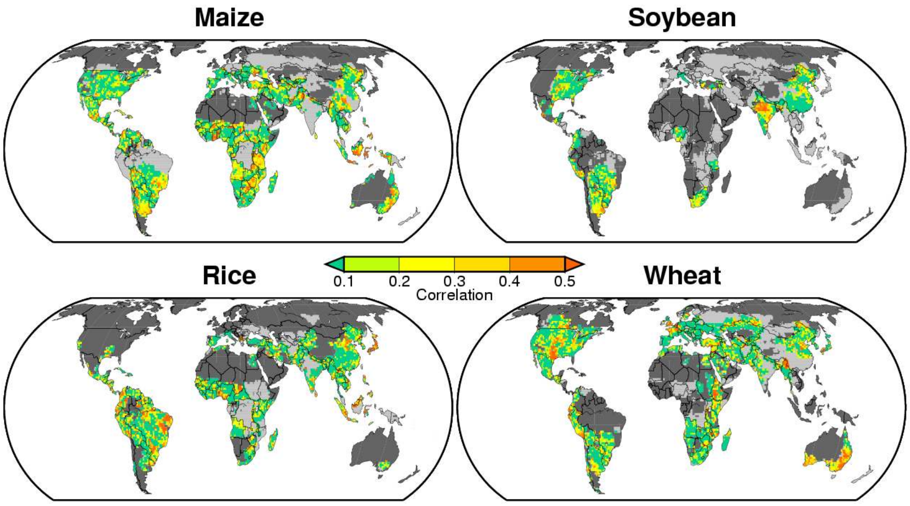

Figure 1. Geographical distribution of correlation coefficient for maize, soybean, rice, and wheat, calculated between the percentage first difference time series of reported yields and those of the in-season prediction for the period 1982-2006. A correlation value that is greater than 0.404 is statistically significant at the 5% level (i.e., prediction is skilful).

Monte Carlo method; and (5) the bias-corrected seasonal temperature and soil moisture forecasts at two lead times were input to the regression models to predict the interannual relative yield variation.

3. RESULTS AND DISCUSSION

In the in-season prediction, a good skill appeared in quite a few parts of the world, such as Australia, Southwest part of United States, West Europe, Ethiopia, northern part of Myanmar, and Pacific side of South America, if wheat was taken as the example (Fig. 1). Importantly, almost the similar geographical distribution of predictive skill was found even in the pre-season prediction although the correlation values in the pre-prediction were in general lower than those for the in-season prediction (figure not shown).

For wheat, the in-season prediction is skilful in 9% to 35% of wheat harvested area in the top four wheat-exporting countries (United States, France, Canada, and Australia). The in-season prediction explained 32% to 37% of the variance of the interannual relative yield variation foe the 25-year period in the skilful area. The pre-season prediction remains skilful in 1% to 32% of the harvested area in the countries and captures 19% to 34% of the variance of the interannual relative yield variation in that area.

4. CONCLUSIONS

Our evaluation shows that the areas where the in-season prediction is skillful account for 3.8% to 12.1% of the world harvested area. These percentages decrease as lead time elongates, but still remain 3.3% to7.2%. All predictions except maize and pre-season prediction for soybean are significantly skillful compared to the random forecasts. Particularly, wheat prediction is more promising than other crops. This suggests that seasonal climate forecasts-based crop prediction could provide scientifically-sound information on climate-induced decrease of global food supply that affects poor's food access through high food prices.

Acknowledgements:

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REFERENCES

FAO (Food and Agriculture Organization of the United Nations), 2009: Report of the FAO Expert Meeting on How to Feed the World in 2050, FAO, 23 pp.

Iizumi, T., M. Yokozawa, G. Sakurai, M. I. Travasso, V. Romanernkov, P. Oettli, T. Newby, Y. Ishigooka, and J. Furuya, 2012: Historical changes in global yields: Major cereal and legume crops from 1982 to 2006, *Global Ecol. Biogeogr.*, (in review).

Luo, J.-J., S. Masson, E. Roeckner, G. Madec, and T. Yamagata, 2005: Reducing climatology bias in an ocean–atmosphere CGCM with improved coupling physics, *J. Clim.*, 18, 2344-2360.

Sacks, W.J. D. Deryng, J.A. Foley, and N. Ramankutty, 2010: Crop planting dates: An analysis of global patterns, *Global Ecol. Biogeogr.*, 19, 607-620.

Verdin, J., C. Funk, G. Senay, and R. Choularton, 2005: Climate science and famine early warning, *Phil. Trans. R. Soc. B*, 360, 2155-2168.

IMPACT OF MONSOON RAINS ON THE TOTAL FOOD GRAIN PRODUCTION OVER INDIA

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Abstract: The study focuses on understanding the variations of precipitation during summer monsoon season and its impact on Kharif (summer) and Rabi (post monsoon) food grain yield over India. For this, objectively defined indices of observed precipitation, in terms of seasonal and daily means have been computed for the period 1966–2010 using daily India meteorological department (IMD) gridded rainfall data of 1° latitude × 1° longitude resolution. Total food grain yield over India during Kharif season is directly affected by variations in summer monsoon precipitation (June through September). An increase (decrease) in rainfall is generally associated with an increase (decrease) in the food grain yield. A Similar correspondence during the Rabi food grain yield and post-monsoon (October through December) over India is not evident, indicating that the Rabi crop is not directly affected by variations in post monsoon precipitation alone, but the summer season precipitation also influences the Rabi crop through water availability and soil moisture availability over many parts of India.Though the reduction of rainfall activity during the entire summer monsoon season leads reduction in Kharif crop yields, the occurrence of prolonged rainfall breaks also causes adverse effect on the crop growth resulting in reduced crop yields.

Keywords: *Indian summer monsoon rainfall, Active/Break cycle, Soil moisture, Kharif and Rabi food grain yield.*

1. INTRODUCTION

Agriculture is the backbone of India's economy. Nearly 70% of the working population depends on agricultural activities for their livelihood. The majority of India's population depends on cereal and pulse production for sustenance. Rainfall occurring over India during summer monsoon season (the major rainy season generally starts in June and ends in September) significantly affects the agricultural production of the country by providing water for both the two main crop growing seasons, Kharif (summer) and Rabi (post monsoon). Variations in the summer monsoon rainfall affect the total food grain yield of India and also the country's economy, which largely depends on agriculture (Krishna Kumar et al., 2004).

2. CROP PRODUCTIVITY VS MONSOON RAINFALL

Rainfall during the end of summer monsoon season provides soil moisture for Rabi crops, while Kharif crops are directly affected by day-to-day variations in summer monsoon rainfall (Revadekar and Preethi 2010). Thus the rainfall in summer monsoon season is important for both Kharif and Rabi crops.

Year	Standardised RF anomaly (JJAS)	Crop productivity index in Kharif season	Corresponding crop productivity index in Rabi season	Corresponding Standardised RF anomaly (OND)
1970	1.33	94.91	56.87	-0.94
1975	1.61	35.68	-15.41	0.92
1983	1.52	28.71	-4.64	0.18
1988	1.59	23.49	102.09*	-1.42
1994	1.49	68.01	118.16*	0.11
2007	1.27	78.82	-29.34	-1.26

Table 1. WET Year Crop - Climate Relationship, where * indicates the strong relevance of summer monsoon precipitation during Rabi season irrespective of OND monsoon rainfall anomaly.

Year	Standardised RF anomaly (JJAS)	Crop productivity index in Kharif season	Corresponding crop productivity index in Rabi season	Corresponding Standardised RF anomaly (OND)
1972	-2.14	-37.58	-17.44	-0.46
1974	-0.99	-90.07	-41.75	-0.02
1979	-1.47	-159.3	-159.02*	0.81
1982	-1.14	-125.04	-15.98	-0.65
1986	-1.05	-113.02	-8.95	0.8
1987	-1.6	-124.27	-21.26	1.43
2002	-2.03	-181.96	-92.07*	-1.03
2004	-1.03	-68.45	-92.38*	-0.52

Table 2. Dry Year Crop - Climate Relationship, where * indicates the strong relevance of summer monsoon precipitation during Rabi season irrespective of OND monsoon rainfall anomaly.

Large-scale droughts and floods during summer monsoon season have a major impact on food grain production. The correlation coefficient between All India Kharif crop yield and All India Summer Monsoon (JJAS) rainfall is 0.71, which is highly significant (99.9% confidence level based on two-tailed students-t test) for a 45year period, where as the correlation coefficient between All India Rabi crop yield and post monsoon (OND) rainfall is –0.11, indicating that the Rabi crop yield is not directly affected by variations in the post monsoon rainfall. However, rainfall during the end of summer monsoon season provides soil moisture for Rabi. Analysis of Rabi crop yields during wet and dry summer monsoon years (Table-1, 2) indicates the strong relevance of summer monsoon precipitation during Rabi season irrespective of OND monsoon rainfall anomaly. Thus years with higher summer monsoon rainfall result in higher crop productivity and the years with lower rainfall results in lower crop productivity for both the Kharif and Rabi seasons.

3. COMPOSITE ANALYSIS OF HIGH YIELD (WET) AND LOW YIELD (DRY) YEARS

The composite analysis (Figure 1and 2) carried out based on JJAS wet and dry years clearly bring out the importance of summer monsoon over the entire India. The spatial extend of wetness or dryness for the high and low yield of Kharif and Rabi crop for high or low JJAS rainfall is evident from the analysis. Apart from the seasonal mean rainfall the daily variations in the rainfall amount and long breaks also significantly affect the crop yield over India. The impact of prolonged breaks on the crop yield is also being examined in this study; the long breaks tend to occur during weak monsoon years (Prasanna and Annamalai, 2012).

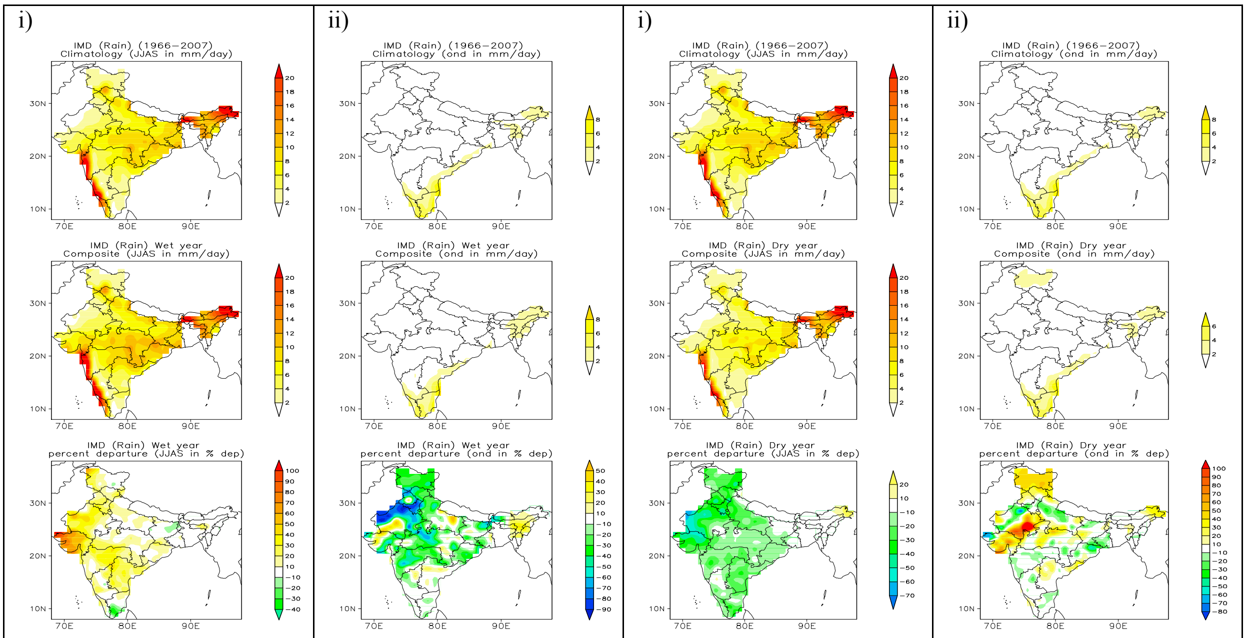

Figure 1. Precipitation composites for wet and dry years are shown here. i) Wet year JJAS, a) Climatology, b) composite and c) Percentage departure; ii) Wet year OND, a) Climatology, b) composite and c) Percentage departure.

Figure 2. Precipitation composites for wet and dry years are shown here. i) Dry year JJAS, a) Climatology, b) composite and c) Percentage departure; ii) Dry year OND, a) Climatology, b) composite and c) Percentage departure.

4. CONCLUSIONS

All-India crop yield index shows a strong relationship with all-India summer monsoon rainfall. Crops grown in both the summer monsoon (Kharif) and the post-monsoon (Rabi) seasons respond significantly to the summer monsoon. Understanding the observed spatial variability of crop-rainfall association will require further study using state-level crop production statistics and sub divisional monsoon rainfall.

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REFERENCES

1) Krishna Kumar, K., K, Rupa Kumar, R. Ashrit, N.R. Deshpande, and J.W. Hansen, 2004: Climate impacts on Indian Agriculture. *International Journal of Climatology* **24**, 1375-1393.
2) Prasanna, V., and H. Annamalai, 2012: Moist dynamics of extended monsoon breaks over south Asia. *J. Climate*, **25** (11), 3810-3831.
3) Revadekar, J.V., and B. Preethi, 2011: Statistical analysis of the relationship between summer monsoon precipitation extremes and foodgrain yield over India. *International Journal of Climatology*, DOI: **10.**1002/joc.2282.

THE USE OF CLIMATE INFORMATION AND PREDICTION IN CROPPING PATTERNS FOR AGRICULTURAL FIELD EXTENSION OFFICERS AS AN ANTICIPATION AND MITIGATION OF CLIMATE VARIABILITY AND CHANGE IN INDONESIA

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Abstract : Climatology Meteorology and Geophysics Agency (BMKG) of Indonesia has routinely prepares the information of forecast season (rainy and dry), monthly rain forecast, and water availability to plants, in order to support agricultural sector. The BMKG also forms Climate Field School (CFS) to improve the ability of anticipating the phenomenon of extreme climate and climate change. CFS program is addressed to the officers of the Provincial and District Agriculture, Agricultural Extension Field (PPL) and the group of farmers in sub-district or village level. The result of the progress of Farmers group CFS participants at the Kupang and Lombok (East of Indonesia Province) shows an increased understanding of information by 78% of CFS compared before following with only about 55% of climate understanding. In line with these results, in Lombok maize production reached 21 tons/ha and in Kupang 19 tons/ha of typically only about 16-17 tons/ha.

Keywords: *Climate, forecast, Climate Field Schools (CFS), Agriculture Extension Field (PPL) .*

1. INTRODUCTION

The Indonesia Government has formulated their National action plans in responding to mitigation and adaptation to climate change in agriculture sector. One of the action plans is adjusting the planting dates according to the onset and duration of wet (rainy) season. The seasonal and monthly rainfall prediction its uses HyBMG model and ensemble mean by statistical-dynamical forecast downscaling derived from many scientific and research institutions (e.i. NOAA/NCEP, IRI, BoM/POAMA, JMA/JAMSTEC, KMA/APCC, etc.). The purpose of this information is to provide materials for decision makers of various sectors including agriculture. By improving farmers understanding on climate information, it is expected that agriculture production can be maintained, irrigation can be optimized, and all activities related with climate factors can develop properly. In order to deliver the service for agriculture sector, BMKG conducted a method to transfer the knowledge of its product so that farmers could understand how to interpret climate information. Such method is called **Climate Field School (CFS)**.

2. OBJECTIVES OF CFS

The aim is to increase farmers knowledge on the application of climate information in their decision making. Trainers travel to districts around the country to provide education to farmers on how to use BMKG forecasts to guide land preparation activities and to decide which crop to plant and when to plant.

Figure 1. Field trip of the CFS's participant at farm land, BMKG's Climatological Station and practice learning for climate information.

III. The Climate Information and Prediction at CFS's location

The prediction at CFS's location for the onset of dry season 2011 at Lombok Barat (West Lombok) district was prepared by Kediri Climatological Station (BMKG office at NTB Province), the onset of dry season prediction will begin on ten-day 1st May 2011 with normal characteristic of rainfall during the dry season period in 2011. The onset of dry season prediction in 2011 at Kupang district was prepared by Lasiana Climatological Station (BMKG office at NTT Province), the onset of dry season prediction will begin on ten-day 1st April 2011. There's delayed ten-day from the normal with above normal for rainfall during the dry season period in 2011 (Fig. 2)

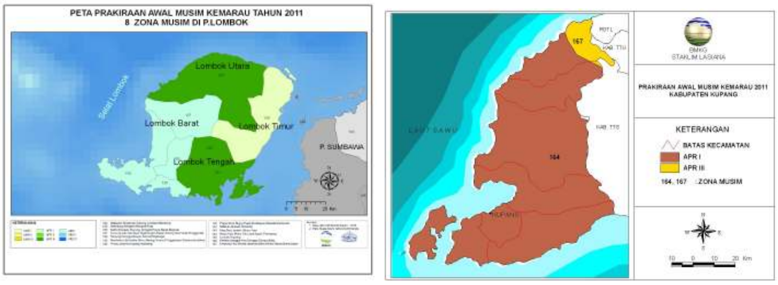

Figure 2. Prediction for the onset of dry season 2011 for Lombok Districts (left) and Kupang District (right).

CONCLUSION

The result of the progress of Farmers group CFS participants at the Kupang and Lombok (East of Indonesia Province) shows an increased understanding of information by 78% of CFS compared before following with only about 55% of climate understanding. In line with these results, after used the climate/rainfall information and prediction from BMKG in Lombok maize production reached 21 tons/ha and in Kupang 19 tons/ha of typically only about 16-17 tons/ha. This shows how important the benefits of CFS activities for the PPL and the farmers in the operations in the sector agriculture, especially in the management of cropping / planting calendar for food crops, as well as adaptation and mitigation of climate variability and change its region respectively. With the CFS program is indirectly able to improve the livelihoods of farmers.

REFERENCES

BMKG, 2011. *Forecast of Dry Season 2011 in Indonesia*. Jakarta, Indonesia.

Koesmaryono, Y., and Y. Apriyana, 2009: Impacts of Climate Variability on Agriculture: *Agriculture's Performance, Diversity and Uncertainties.* Workshop on Climate Field School And Validation Of Asean Regional Climate Model. BMKG, Surabaya, Indonesia 11-13 August 2009.

UNDP Indonesia, 2007. *The other half of climate change*. Jakarta, Indonesia.

DETERMINANTS OF POST-CYCLONE HOUSEHOLD FOOD INSECURITY UNDER CHANGING CLIMATE IN COASTAL BANGLADESH: A CASE STUDY OF CYCLONE 'SIDR'

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Abstract Summary:

This study examines the post-cyclone household food security status in coastal Bangladesh, and identifies the role of cyclone damage, livelihood capitals, various socio-demographic variables, household coping strategies and other relevant variables for achieving food security in terms of per day calorie consumption. Based on a questionnaire survey at household level with 331 out of 778 households in the central coast of Bangladesh, this study finds that about 26 percent of sampled households are hardcore food insecure and 19 percent are absolutely food insecure in terms of the consumption of 1805 Kcal and 2122 Kcal per day respectively. Multiple regression analysis shows that different socio-economic and demographic variables, livelihood capitals, cyclone damage, post cyclone income diversification and relief assistances are the significant predictors of post cyclone food insecurity. Hence, the present study argues that cyclones and storm surges are the main impediments to the development in coastal Bangladesh while livelihood capitals, household demography, post cyclone income diversification and relief aid play vital role to achieve food security.

Keywords: *Food Security, Cyclone, Livelihood Capitals, Coping Strategies, Bangladesh.*

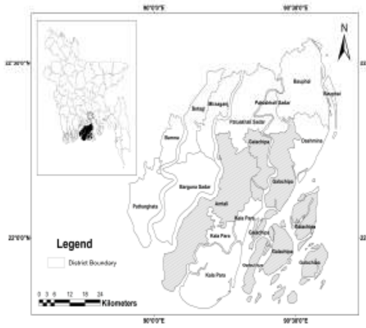
1. INTRODUCTION

Bangladesh is considered as one of the most vulnerable countries to climate change because of its location, and topographic and socio-economic characteristics, such as almost plain and low lying topography, over population, massive poverty level, and high dependency on climate sensitive sectors for livelihoods such as agriculture and fishery (Haq and Jessica, 2008). Besides, Bangladesh coast is well-known for severe cyclones and induced surges with 6-10 percent of world's tropical cyclones per year (Paul and Routray, 2011). Present increasing trend of global warming may escalate tropical cyclones and other natural disasters with the colossal damages in the twenty first century (Emanuel, 2005). In this present state of vulnerability to tropical cyclone, issues may arise what will be the pattern and intensity of cyclone in the Bay of Bengal under climate change condition in future? The IPCC third assessment concludes '……… *there is some evidences that regional frequencies of tropical cyclones may change but none that their locations will change. There is also evidence that the peak intensity may increase by 5% to 10% and precipitation rates may increase by 20% to 30%"*(IPCC, 2001). If this tentative assessment turns to be true, the fact that cyclone track will remain unchanged under climate change condition but with increased intensities will be alarming for Bangladesh (Ahmed, 2005). Moreover, situation will be further aggravated because; about 40 percent of total population is 'absolute poor', failing to acquire minimum level of food energy 2122 Kcal per day per person. Within which 20 percent and 8 percent are hard-core poor (below 1805 Kcal/day/person) and ultra-poor (below 1600 Kcal/day/person) respectively (FAO, 2008).

More recently three factors are identified which worsen the household food security such as devastating monsoon flood and catastrophic cyclone in 2007 and rising prices of food and other essential commodities (FAO, 2008). A number of studies have focused on macro level food production, supply and national food policies; disasters, vulnerability and food availability; poverty, welfare and nutrition measurement parameter and debates; and experiences of hunger, poverty, and disempowerment at individual level (World Food Programme, 2000, Del Ninno and Roy, 1999, Ravallion and Sen, 1996, Paul et al, 2012). Despite the availability of a number of literatures on food security issues in Bangladesh; the role of disaster damage, livelihood capitals and various coping strategies to define post disaster household food security are relatively unknown. Therefore, the present study explores post-cyclone household food security status; and identifies the role of cyclone damage, household demography, socio-economic variables, livelihood capitals and coping strategies that influence post cyclone household food security in coastal Bangladesh.

STUDY AREA AND METHODOLOGY

Angulkata and Tatulbaria villages of Bargona district and Charkashem village of Patuakhali district in the central coast of Bangladesh are purposively selected for household survey considering the vulnerability to tropical cyclone (Map 1). Total sample size is 331 out of 788 households; and samples have been drawn proportionately from the three villages. The primary data have been collected through key informant's interview, questionnaire survey and focus group discussions in the study villages. In the present study direct calorie intake such as total household food consumption is converted into calories and the calorie figure is divided by the number of adult household members is considered to assess household food security. For analysing data various descriptive and inferential statistics are used. A regression model is also employed to identify the significant predictors of post disaster household food security.



Map 1: Study Area

RESULTS AND DISCUSSION

The study finds that disasters such as cyclone and induced surge have devastating impacts on environmental, socio-economic conditions, and livelihoods of people that result in the post disaster food insecurity. In general, majority of people have experienced availability of food for 7-9 months in a year. The situation worsens during post-cyclone based on locational exposure, gender, income and occupation of households as well. In coastal Bangladesh, household food intake is highly centered on rice consumption that reveals less dietary diversity and lacking of all other types of nutrients. Such rice consumption declines 46.82 percent from normal time to post cyclone situation, which is directly related to the locational exposure, gender, income and occupation of household head. One quarter of respondents have found that the amount of food usually they consume is adequate, while only 23 percent have found quality of such food is adequate. Though majority of the respondents have shortage of food in terms of both quality and quantity but in general they are satisfied on quantity of food and moderately satisfied on quality of food they consume based on five point likert scale. Such satisfactory behaviour of coastal people is linked with fatalism. All the respondents are Muslim by religion with a strong belief of 'Allah (God) that He allocates food for each person and human being has very little to do'. Moreover, such fatalism also leads to more psychological strength to the victims to battle against cyclone especially in the remote places where no cyclone shelters or strong houses are available in which people can seek refugee during disaster. Similarly, more than 80 percent of respondents are worried with high level of anxiety (Five Point Likert scale) for future food consumption during post cyclone is also linked with location, gender, income, education and occupation. Such findings reaffirm that female headed households, lower income groups, illiterate and unstable occupational groups, and households in remote locations are the most vulnerable to post cyclone food insecurity (Paul and Routray, 2010).

The present study also finds that 19.34 percent of households are 'absolutely' food insecure based on a daily per capita caloric intake of 1805- 2122 Kcal, and 25.98 percent are hard-core food insecure with caloric intake of 1805 Kcal. Based on the regression model (n= 331, R= 0.825, R^2=0.681, Adjusted R^2=0.665, p<0.000), this study finds that the age and education level of housewife (mother), household income, food expenditure, gender of household head, human capital, natural capital, financial capital, social capital, post disaster income diversification, extent of damage due to cyclone, number of dependent members in the family and post disaster relief aid are all significant factors influencing food security. The analysis proves that the age and education of housewives play vital role in post disaster food security. It also implies that relatively higher aged and educated mothers can better understand family food quality and requirements. Gender of household head plays a significant role in post disaster household food security; where female headed households were found most destitute and food insecure. Number of dependent population in a household negatively influence post disaster food security due to the share of same food among household members and reduce per capita calorie consumption. This study confirms the role of household income, amount of land, and more expenditure on food items in achieving adequate calorie within the household. The present study confirms the negative role of cyclone damage which reduces per capita calorie consumption. Besides, post-cyclone income diversification appears as a significant predictor of post cyclone food insecurity. Relying on additional income sources rather than main income sources, most of lower income households avoid post disaster hardship and support family with at least minimum level of required food. As all types of livelihood capitals play vital positive role for achieving post-cyclone food security; households with more assets are less likely to be food insecure in post disaster situation.

CONCLUSION

Post-cyclone household food security varies according to location and socio-economic factors (gender, income, education etc.). Thus, it is important to identify exposed locations and vulnerable groups through scientific analysis of food security indicators and indices. Improving socio-economic status of targeted groups is prerequisite to minimize post-cyclone food insecurity. Maternal characteristics are important predictors of post disaster food security. Thus emphasize is needed to be given on girl's education, community based health and nutrition education and incorporation of disaster preparedness, calorie consumption and nutrition issues in the text books at school level in disaster prone areas. Likewise, intervention is needed for household's asset building as all types of livelihood capitals are significant predictors of food security. Relief aid has positive influence on post disaster food security; thus priority for relief and rehabilitation should be given to those groups who are at the bottom of the society. Post-cyclone income diversification appears as a significant predictor. Hence, safety net programs are needed to be emphasized and continued with specifically targeting the absolute poor and hardcore poor and made more effective through proper monitoring. Moreover, emphasize should be given on re-building livelihood such as assistance for producing food rather than providing food, and supports should be expanded for income generating activities for the rural poor in cyclone prone areas which can reduce the prevalence of post-cyclone food insecurity for longer period of time.

REFERENCES

Ahmed A.U. (2005) Adaptation Options for Managing Water Related Extreme Events Under Climate Change Regime: Bangladesh Perspectives, in M.M.Q. Mirza and Q.K. Ahmad (eds.), Climate Change and Water Resources in South Asia, Balkema Press, Leiden.

Del Ninno C. and Roy D. K. (1999) Impact of the 1998 Flood on Labor Markets and Food Security and the Effectiveness of Relief Operations in Bangladesh, Food Management and Research Support Project, Ministry of Food, Government of Bangladesh/International Food Policy Research Institute. Mimeo.

Emanuel K. (2005) Increasing destructiveness of tropical cyclones over the past 30 years, *Nature*, 436 (4), 686-688.

FAO (2008) Special Report FAO/WFP Crop and Food Supply Assessment Mission to Bangladesh, http://www.fao.org/docrep/011/ai472e/ai472e00.htm

Haq S. and Jessica A. (2008) Climate Change Impacts and Responses in Bangladesh, International Institute for Environment and Development, 3 Endsleigh Street WC1H 0DD London.

IPCC (2001) Climate Change 2001: Impacts, Adaptation and Vulnerability, Contribution to Working Group-II to the Third Assessment Report, McCarthy et al (eds), Cambridge University Press.

Paul SK, Routray JK (2011) Household response to cyclone and induced surge in coastal Bangladesh: coping strategies and explanatory variables. Nat Hazards 57:477-499.

Paul S. K., Paul B. K. and Routray J. K. (2012) Post-Cyclone Sidr nutritional status of women and children in coastal Bangladesh: an empirical study, Natural Hazards, DOI: 10.1007/s11069-012-0223-4

Ravallion M. and Sen B. (1996) When methods matter: Monitoring poverty in Bangladesh, *Economic Development and Cultural Change,* 44(4), 761-792.

World Food Programme (WFP) (2001) Enabling Development: Food Assistance in South Asia, New Delhi, India: Oxford University Press.

THE ROLE OF WEATHER INFORMATION ON CARROT YIELD PERFORMANCE –AN EMPIRICAL EVIDENCE FROM FIELD DATA IN CHINESE TAIPEI

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Abstract Summary: Weather information is critical to all stages of planning, planting, pest control and harvest of vegetable production. The increasing occurrence of severe climate events in response to global warming has posed a particular risk for vegetable production under contract in recent decade. This study attempts to link the local weather data and crop yield performance and identify the linkage between key climate factors on yield. Field survey data of 275 contract farms from a carrot producer cooperative in Yunlin County in Taiwan and weather station data located in adjacent areas were used to identify the key weather factors and the tolerance levels of heat, precipitations and wind blows. We confirm that carrot growth has an optimal temperature zone between 9-21°C. The threshold level is an essential knowledge for farmer's field operations as well as for their income assurance. Based on the result of the study, not only low temperature but also heat stress would cause negative impact. Therefore, global warming may threaten the carrot production especially in tropical region where temperature rises above 21°C.

Keywords: *crop growth, warming, weather information*

1. INTRODUCTION

Plant growth is sensitive to temperatures at various tolerance levels (Welch et. al. 2010; Hussain et.al. 2008; 2010; Rosenfeld et. al. 1998). The increasing occurrence of severe climate events in response to global warming has posed a particular risk for vegetable production under contract in recent decade. As an innovative way to address this issue, this study attempts to link the local weather data and crop yield performance and identify the linkage between key climate factors on yield. Most of thresholds of temperature were determined by the experimental fields study. In this study, a statistical method is proposed to determine temperature thresholds by observed farm data and hourly temperature and rainfall data. Regression methods are also used to verify the key weather factors and the tolerance levels of heat and precipitations.

2. DISCUSSION

This study uses the contract farm record of a carrot cooperative to identify the key climate factors on yield. Field data of 275 carrot farms were collected in 2011 from a producer cooperative in Yunlin County whose export market includes the supermarket chains in Japan. The farms are located in two villages near the coastal region. The data includes each farm's location, plot size, soil type, dates of sowing and maturity, irrigation method, and yield. The soil type determines the irrigation methods including canal and spreading.

The weather data was obtained from the nearby air-quality monitoring stations operated by the Environmental Protection Administration. Temperatures are recorded as hourly average while precipitation is accumulated amount of rainfall in an hour. The thresholds of growing temperature and rainfall strength could be estimated by the maximum Pearson Correlation coefficients of observed yield growth and Hours of Growing Degree (HGD) and Hours of Growing Rainfall (HGR) respectively. The HGD was estimated from hourly temperature at each site as:

$$\mathrm{HGD}_{\min,\max} = \sum_{t=1}^{N} \mathrm{H}_t \,, \quad \mathrm{H} = \begin{cases} 0 \ \text{ if } \ \mathrm{T}_t < \mathrm{T}_{\min} \text{ or } \mathrm{T}_t > \mathrm{T}_{\max} \\ 1 \ \text{ if } \ \mathrm{T}_{\min} \le \mathrm{T}_t \le \mathrm{T}_{\max} \end{cases} \qquad (1)$$

where t is an individual time step (hour) within the growing season, T_t is observed average temperature during this time step and N is the number of hours between sowing and maturity, i.e. length to maturity. $HGD_{5,30}$ corresponds to equation (1) with $T_{min} = 5^oC$ and $T_{max} = 30^oC$. The same method applied in precipitation as Hours of Growing Rainfall (HGR), for example $HGR_{0,2.5}$ is the total hours of accumulated rainfall between 0mm and 2.5mm. Figure 1 indicates that mean growing-season temperature is negatively correlated with yields, i.e. cooler season with higher yield. From 5 to 25°C with 1°C intervals, the correlation coefficients between harvested yields of unit area and number of Growth Degree Hours (GDH) are calculated.

The results of the correlation analysis are shown in Figure 2. First, the correlation coefficients dramatically increase when temperatures exceed 10°C (i.e., when x=5 at $GDH_{5,x}$), and then decrease as temperatures drop below 17°C (i.e., when x=17 at $GDH_{x,25}$). This indicates that the most optimal growing temperature for carrot is between 10-17°C. Second, The GDH below 10 and above 21 could have negative impacts on carrot yield in this study. Previous studies agree that carrot growth is subject to a temperature range but different by locations, e.g., Bremer (1931) suggesting a soil temperature range from 12 to 28°C and the optimal at 20°C , while Rosenfeld et. al (1998) reporting the optimal range between 12-16°C.

The regression analysis results are presented in Table 1 where carrot yield is explained by $HGD_{10,21}$, $HGR_{0,2.5}$, and a dummy for irrigation method. We find that the cumulative temperature in the growing season is a positive contributor to yield. However, precipitation is harmful but it is statistically insignificant. This is related to the fact that all the contract farms have either canal or spraying irrigation system and thus the yield performance may not be affected by rainfall pattern. We also confirm the fact that canal irrigation method is negatively associated with yields significantly.

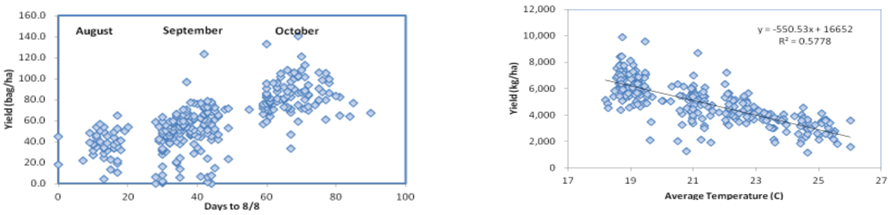
3.CONCLUSION

A field survey data from two villages in central Taiwan offers a chance to evaluate how weather conditions affect carrot yields beside irrigation system or soil type. We confirm that carrot growth has an optimal temperature zone between 9-21°C in central Taiwan. The threshold level is an essential knowledge for farmer's field operations as well as for their income assurance. Based on the result of the study, not only low temperature but also heat stress would cause negative impact. Therefore, global warming may threaten the carrot production especially in tropical region where temperature rises above 21°C. These results suggest that accurate weather forecasts can be instrumental in maintaining productivity and fulfill contract at the peak of quality. They can also be used to reduce potential losses from natural hazards and stabilize farm income which is beneficial to all stakeholders in the supply chains. Finally, the empirical results can assist in prioritizing researches on developing climate-resilient varieties and addressing the impact of climate change that are likely to occur over the next century.

4.TABLES AND FIGURES

Table 1. Regression analysis results

	Coefficien estimates	Standard Deviation	t -statistics	P-value
Intercept	92.11766	19.33655	4.76391	0.00000
$HGD_{10,21}$	0.02885	0.00509	5.67146	0.00000
$HGR_{0,2.5}$	-0.01231	0.00769	-1.59994	0.11078
Irrigation (Canal)	-11.30040	3.61583	-3.12526	0.00197



*one bag equal 60kg

Figure 2: Lef panel indicated the distribution of sowing date and yields. Right panel indicated the trend of yield and average temperature of growing season.

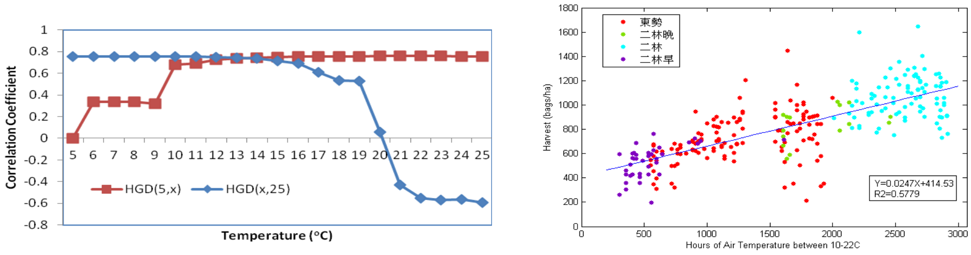


Figure 3: Left panel: Correlation coefficients of yield and growing degree hours ($GDH_{5,x}$ and $GDH_{x,25}$) under different daily temperatures. Right panel: scatter distribution of yield and $GDH_{10,21}$, which means that the carrot yield is positively related to the number of hours in the optimal temperature range (10-21°C).

5.REFERENCES

Hussain, S.I., P. Hadley, S. Pearson: 2008, A validated mechanistic model of carrot (Daucus carota L.) growth. Scientia Horticulturae 117: 26-31. Doi:10.1016/j.scienta.2008.03.021

Rosenfeld, H.J., R.T. Samuelsen, E. Lea: 1998 The effect of temperature on sensory quality, chemical composition and growth of carrots (Daucus carota L.) II Constant diurnal temperature under different seasonal light regimes. Journal of Horticultural Sciences and Biotechnology 73(5) 578-588.

Suojala, T.: 1999, Cessation of storage root growth of carrot in autumn. Journal of Horticultural Science & Biotechnology. 74(4): 475-483.

Welch, J.R., J.R. Vincent, M. Auffhammer, P.F. Moya, A. Dobermann: 2010, Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. PNAS 107(33):14562-14567.

EFFECT OF CLIMATE CHANGE ON AGRO-ECOSYSTEM AND RICE PRODUCTION IN COASTAL REGION OF BANGLADESH

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Abstract Summary: The coastal region of Bangladesh contributes to about one fifth of the country's landmass and one seventh of the total population. Over 30 million people live in the coastal region relying on agriculture, fishery, forestry, and other livelihood activities. Coastal region is the most vulnerable area to climate change in Bangladesh. The aim of this study is to understand the climate change and its impacts on agro-ecosystem and rice production in coastal region of Bangladesh. The long-term (1960-2009) data showed that most of the rainfall occurred during July to October followed by March to June and little rainfall occurred during November to February. Both maximum and minimum temperatures showed increasing trend. However, the increment rate was higher in case of minimum temperature than maximum. The SPI indicated that frequent dry and wet conditions were prevailed in the study area, while DTR showed decreasing tend. Sea level rise, high salinity, high intensity of cyclones and other natural hazards making the agro-ecosystems degraded. The soil salinity level was increased by 23.3% over 4 decades in the study area. The relationship showed that *aman* rice productivity index and seasonal SPI and DTR have strong multiple regression ($R^2 = 0.34$). The seasonal distribution of rainfall in terms of SPI and variation of temperature in terms of DTR during *aman* rice season accounted for 34% yield variability. It indicates that non-technological factors such as climate change, increase in salinity and natural hazards play a vital role in rice production despite technological development.

Keywords: *Climate change, Coastal region, Soil salinity, Rice productivity.*

1. INTRODUCTION

The coastal region of Bangladesh contributes to about one fifth of the country's landmass and one seventh of the total population (Miah et al. 2010). Out of 2.85 million hectares of the coastal and offshore areas about 0.83 millions hectares are arable lands, which cover over 30% of the total cultivable lands of Bangladesh (Haque 2006). Once, the coastal region was rich in natural resources with huge forest vegetation, fishes, crops, poultry, livestock and wildlife. The region, however, is at the verge of degradation largely due to climate change and human activities. The degradation of the coastal ecosystems started with the implementation of Coastal Embankment Project (CEP) during early 1960s (Mohit et al. 1998). Coastal embankments also made the areas inside the polders more vulnerable to cyclonic storms and intrusion of saline water (DoE 2006), thus turning agricultural lands to non-agricultural uses, and ultimately turned the areas unsuitable for agriculture.

The region is increasingly being affected by various natural hazards causing damages of lives, properties as well as economy in recent times than in the past. Climate change affecting the crop productivity and production related activities. Agricultural land use in these areas is very poor, which is roughly 50% of the country's average (Petersen and Shireen 2001). The soils are, in general, poor in organic matter content (varies from less than 1% to 1.5%). The low organic matter content in soils indicates poor physical condition of the coastal soils. In coastal region, rice, jute, sugarcane, pulses, oilseeds, spices, vegetables and fruits are grown in saline soil, but their contributions to cropping intensity is low. In salt affected highlands, local transplanted *aman* rice (July-November) is the dominant crop. The present study aims to identify the adverse impacts of climate change on the agro-ecosystems and rice productivity in the coastal region of Bangladesh.

2. METHODOLOGY

Study Area and Climate: Khulna is located in the southern part of the country. Khulna has a tropical monsoon-type climate, with a hot and rainy summer and a dry winter. The annual mean maximum and minimum temperatures are 35.1 and 12.1 °C, respectively. Most rains occur during the monsoon (June–September) and little in winter (November–February). The average annual rainfall is 1955 mm. This region is subject to devastating cyclones, originating over the Bay of Bengal, in the periods of April to May and September to November.

Dataset: The monthly temperature and rainfall data series for all three locations were collected from Climate Research Unit (CRU). The monthly data on rainfall, temperatures from July to October were considered as *aman* rice season in this study. Spatial distributions of annual and seasonal temperatures and rainfall were analyzed using NCAR Command Language (NCL) and MS-Excel computer software. Standardized precipitation index (SPI), diurnal temperature range (DTR) and rice productivity index were calculated followed standard methods. Rice production data was collected from the Department of Agricultural Extension (DAE), while soil salinity data were collected from Soil Resource Development Institute (SRDI).

3. RESULTS AND DISCUSSION

3.1Trends of Rainfall and Temperatures: The trend of annual rainfall anomalies shows increasing pattern. The increasing trend was not remarkable during March to June and November to February, but it was significant during July to October. Like rainfall, temperature also showed increasing trend. Corresponding the monthly normalized anomalies, the minimum temperature anomalies showed a remarkable positive trend in all the regions, while the trend was so distinct for maximum temperature anomalies (Fig. 1). In the recent years, SPI showed above the normal level indicating high frequency of drought. The anomalies of DTR (Tmax – Tmin) showed decreasing trend throughout the year.

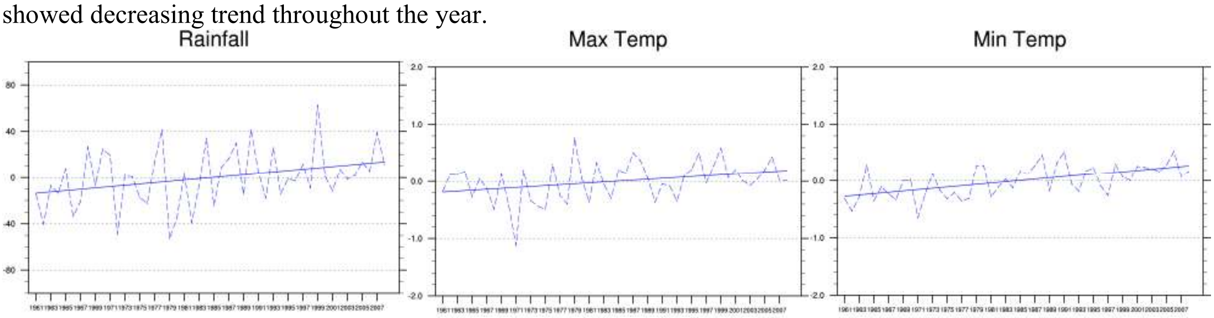

Fig. 1. Rainfall, maximum and minimum temperature anomalies over time. The straight line shows the linear trend of the rainfall anomalies over the period of 1960-2009.

3.2 Salinity level: The saline affected area in the study area increased by 23.3%, while salinity level rose from 9.8 to 30.57 dS/m over 4 decades (Fig. 2a). The relationships between soil salinity and rice seasonal rice yield were linear and negative. The coefficient of determination (R^2) was high in *aus* season and the relationship was weak during *aman* season (Fig. 2b). This might be due to decline in soil salinity due to monsoon rain.

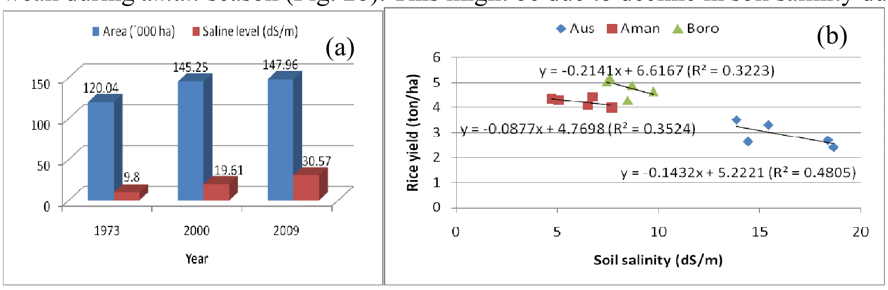

Fig. 2(a) Saline affected area and salinity levels over time; (b) relationships between soil salinity and rice yield.

3.3 Influence of SPI and DTR on RPI: The rice productivity index (RPI) and seasonal SPI and DTR have a significant (R^2 = 0.49) multiple regression during *aman* rice season. These indicate that anomalies of seasonal rainfall (SPI) and temperature (DTR) together accounted for 49% of the variability of *aman* rice (Table 1).

Table 1. Rice productivity index (RPI) and seasonal SPI and DTR relationship regression equations and statistics

Season	Regression equation	R^2	SE
Aus	RPI = 27.630 + SPIi(-8.532) + DTRi(-54.512)	0.19	4.697
Aman	RPI = 21.178 + SPIi(-20.172) + DTRi(-34.498)	0.34	4.643
Boro	RPI = 13.603 + SPIi(-10.803) + DTRi(-7.139)	0.04	4.66

4. CONCLUSIONS

Monsoon rainfall, maximum and minimum temperatures showed increasing trend. However, the increment rate was higher in case of minimum temperature than maximum. The SPI indicated frequent dry in recent years. Agro-ecosystem in coastal region has been degraded due to climate change along with sea level rise, high salinity, high intensity of cyclones and other natural hazards. The soil salinity level was increased by 23.3% over 4 decades. In recent years, rice productivity is not increasing over time as it was observed 5 years back. Negative relationships were found between rice yield and soil salinity and climate change. It indicates that non-technological factors such as climate change, increase in salinity and natural hazards play a vital role in rice production despite technological development.

REFERENCES

DoE. 2006. Bangladesh: National Programme of Action for Protection of the Coastal and Marine Environment from Land-Based Activities. Department of Environment, Ministry of Environment and Forest, Dhaka, Bangladesh.

Haque, S.A. 2006. Salinity problems and crop production in coastal regions of Bangladesh. *Pak. J. Bot.* **38(5)**: 1359-65.

Miah M.G., M.N. Bari and M.A. Rahman. 2010. Resource degradation and livelihood in the coastal region of Bangladesh. *Front. Earth Sci. China,* **4(4)**: 427-437.

Mohit, M.A., M.R. Karim, and G. Mustafa. 1998. Integrated Management of the Floodplains of Bangladesh: Physical Infrastructure Planning Perspective. Proc. National Seminar on Integrated Management of Ganges Floodplains and Sundarban Ecosystem, 16-18 July, 1994, Khulna, Bangladesh. Pp. 1-4.

PUBLIC AWARENESS FOR AGRICULTURAL EXTENSIONS THROUGH TRAINING OF TRAINERS (TOT) ON CLIMATE CHANGE

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Abstract Summary: Review of the impact of climate change on the agricultural sector is shelled out either in the news or in scientific writing. The purpose of this paper is to show that public awareness for farmers can be reached through optimizing the role of extensions, thus becomes important to increase the knowledge about climate change and its impact on the agricultural sector. Based on the results of questionnaires during the Training of Trainers (TOT) on Climate Change, it seems that extensions already known that climate change has taken place but did not know about local wisdom to deal with its impact. Furthermore, the extensions have also been responsive and disseminate information to farmers but still limited knowledge gained from various sources rather than information derived from a competent source or local climatological station. In addition, the frequency of delivery is still rare due to limited resources and lack of training facilities for the extensions to gain depth knowledge about climate change. Thus, the findings of the questionnaire are an important input to the preparation of the material in the TOT on Climate Change.

Keywords: *Climate change, impact, TOT, extension*

1. INTRODUCTION

The agricultural sector plays an important role for the people of Indonesia, one of the largest employers (45%) and be able to contribute around 17% to the national economy (Amin, 2012). Indonesia's population works in the agricultural sector in general is that farmers who had been reading the signs in nature to predict climate variability. Readings are then used as a guide in making decisions on the determination of cropping farming. Based on geography, topography and climate, Indonesia is vulnerable to the impacts of climate change. The impact is already being felt in the last century (Tumiwa, 2010). Farmer is one of the actors affected large enough for farming. Therefore, it needs to be increased awareness of the impacts of climate change and to anticipate and adapt so that farmers are able to adjust the pattern of farming with signs of recent climate change.

Increased awareness of farmers to the impacts of climate change can be achieved through the role of agricultural extension agents who are actively providing counseling. Training of Trainers (TOT) is one means to increase the capacity of extension gradually from the central to the local. It is motivated by a wide range of agricultural extension work in Indonesia that consists of 33 provinces. Hopefully, through this capacity extension can help farmers to determine the steps to anticipate and adapt to the impacts of climate change.

2. DISCUSSION

As mechanism of gradually training, this TOT is the training in level I (national) which then will be followed up in level II or province involving agricultural extension of the district. At the field level called level III training; the extension is more often associated with farmers. TOT level I was involved 39 people from 18 Assessment Institute for Agricultural Technology (AIAT) and the extension from the pilot project location of ICCTF. Variability of the participants can be described as follows. The average age was 45 years, with the youngest aged 26 and the oldest 59 years. Experience as an extension has lived for an average of 13 years, with a range of diversity between 2 years to 34 years. The participants are dominated by male extensions (77%).

Based on the results of the questionnaire, participants' perceptions of the phenomenon of climate change as showed in Table 1. Perception can be formed through a variety of activities, namely physical processes (sensing), physiological (sensing results delivery to the brain through sensory nerves) and psychological (memory, attention, information processing in the brain) (Mardijono, 2008). According to the entry, participants are aware that climate change is already happening. However, the change is not considered to have a major impact on the agricultural sector. The majority of the participants already know that the condition of existing farming practices require adjustment (adaptation) to the impacts of climate change. More than half of the participants do not make observations around in order to use local wisdom as a simple effort to identify the symptoms of climate change impacts that affect the planting and other farming activities.

Local wisdom shown by signs on nature or “pranata mangsa”-Indonesian lang.- introduced by Pakubuwana VII (King of Surakarta), came into use since June 22, 1856 (Pramudia, 2011). “Pranata mangsa” includes various aspects of phenology and other natural phenomena are used as guidance in farming activities and prepare for the disaster. In “pranata mangsa”, the determination of the behavior associated with animal, plant development, and the landscape around, is associated with an agrarian culture (Pramudia, 2011).

In order to disseminate and provide insight into the impact of climate change and strategies to anticipate, approximately 70% of extensions said it has been actively providing information on the extent of knowledge. Participants also claimed to have involved farmers in the field observation, practice and evaluate technologies with farmers on improved farming as an adaptation to the impacts of climate change. But there are still extension agents whose states are less active (3%) due to the limited access to information resources. This is supported by the results of the questionnaire stating the low activity of participants seeking information on the climate of the competent institution (eg Meteorological, Climatological and Geophysics Agency).

Through this TOT, it is expected that extensions have a depth knowledge and understanding about climate change (Table 2). Pre-test results showed that the overall average value of the pre-test was 51.49, while the average value of the results of post-test was 66.97. Based on the pre-test and post-test, it appears that the ability of the participants to answer the questions increased significantly, which is shown by the increase in the number of people reaching the criteria of excellent (range 76-88) by 9 people than ever before (one person).

3. TABLE

Table 1. Participant's perceptions on climate change

Understanding climate change	Percentage (%)			
	Very idea	Know	Do not Know	It is not know
It has been climate change	7.7	92.3	0.0	0.0
Climate change affects agriculture significantly	15.4	10.3	66.7	7.7
Climate change requires adjustments to farming	35.9	64.1	0.0	0.0
Climate change can be identified based on natural signs	5.1	43.6	51.3	0.0

Table 2. Results of pre-test and post-test of the participants of TOT in understanding climate change

Range of values	Criteria	The number of people (pre-test)	Number of people (post-test)
0-25	Less	2	0
26-50	Enough	13	2
51-75	Good	23	28
76-100	Excellent	1	9
Total participants		39	39

4. CONCLUSIONS

TOT is a means for extensions to gain knowledge from relevant experts, so that in the preparation of extension materials refer to the informed and accountable. TOT will also be learning between exensions from different regions about strategies for coping with the impact of climate change on farming activities based on site-specific local knowledge. Increased knowledge and understanding of the extension on climate change and adaptation strategies / mitigation will assist farmers in managing the management of farming. Thus it can be said that the extension together with farmers play an important role in anticipating the impact of climate change on farm productivity, which further can be attributed to efforts to maintain the stability of national food security.

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REFERENCES

Amien, I, 2012: Deal with climate change in agricultural development, presentation materials retiree, Research Institute for Agro-climate and Hydrology, Bogor, 5 September 2012, Bogor.

Mardijono, 2008: Perception and Participation Fishermen on the Management Thesis, Coastal Resources Management, Diponegoro University, Semarang.

Pramudia, A, 2011: Module 8.2: Local Wisdom. Module Training of Trainers (TOT) on Climate Change, Jakarta, 19-23 September 2011, the Meteorology, Climatology and Geophysics (BMKG), Indonesia Climate Change Trust Fund (ICCTF) and Ministry of Agriculture (MoA).

Tumiwa, F, 2010: Indonesia's development strategies addressing climate change: Status and Current Policy, Moulds second, Publisher: Friedrich-Naumann-Stiftung fur die Freiheit, Jakarta, 9-73.

Session Ⅳ

SUBTROPICAL PREDICTABILITY ESTABLISHES A PROMISSING WAY FOR ASIAN MONSOON AND TROPICAL STORM PREDICTION
Bin Wang , Baoqiang Xiang, and June-Yi Lee

MULTIDECADAL TRENDS OF TROPICAL CYCLONE AND CHINA SUMMER MONSOON EXTREME RAINFALL
Chih-Pei Chang, Yonghui Lei, Chung-Hsiun Sui, Xiaohong Lin, Fumin Ren

DYNAMICAL SEASONAL FORECASTING FOR AGRICULTURE IN AUSTRALIA
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AGROCLIMATIC ZONING FOR WINTER BARLEY IN KOREA UNDER THE RCP8.5 PROJECTED CLIMATIC CONDITION
Jin I. Yun, Dae-Jun Kim, Jin-Hee Kim, Soo-Ock Kim

MULTI-MODEL ENSEMBLE PREDICTION FOR BOREAL SUMMER INTRASEASONAL OSCILLATION
June-Yi Lee, Bin Wang, Xiouhua Fu, Matthew C. Wheeler

A TIME-SCALE DECOMPOSITION STATISTICAL DOWNSCALING MODEL
Jianping Li, Chengqing Ruan, Yan Guo, and Yun Li

APPLICATIONS OF SEASONAL CLIMATE FORECAST TO CROP YIELD PREDICTION: INTERNATIONAL & DOMESTIC COLLABORATIONS
Hirofumi Sakuma, Keiichi Hayashi, Toshichika Iizumi

PREDICTION OF THE FIRST FROST DATES IN NORTHERN CHINA
Lijuan CHEN, Rongqing HAN, Xiang LI

OUTLOOK ON FREEZE RISK IN MAJOR PEACH GROWING REGIONS IN KOREA UNDER THE RCP8.5 PROJECTED CLIMATIC CONDITION
Soo-Ock Kim, Jin-Hee Kim, Dae-Jun Kim, Jin I. Yun

CLIMATE CHANGE IMPACT ON TYPHOON AFFECTING TAIWAN USING MRI 20-KM MESH AGCM TIME SLICE SIMULATIONS
Cheng-Ta Chen, Teng-Ping Tzeng, Chao-Tzuen Cheng , Akio Kitoh

CLIMATE CHANGE: RISKS FOR RUSSIAN AGRICULTURE
M.A. Sall, E.I. Khlebnikova, I.A. Sall

TITLE:SUBTROPICAL PREDICTABILITY ESTABLISHES A PROMISSING WAY FOR ASIAN MONSOON AND TROPICAL STORM PREDICTION

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Abstract Summary

Monsoon rainfall and tropical storm (TS) impose great impacts on society, yet their seasonal predictions are far from successful. The western Pacific Subtropical High (WPSH) is a prime circulation system affecting East Asian summer monsoon (EASM) and western North Pacific (WNP) TSactivities.Ournumerical experiment results establish that the WPSH variation is primarily controlled by central Pacificcooling/warming and a positive atmosphere-ocean feedback between the WPSH and the Indo-Pacific warm pool oceans. With a physically-based empirical model and the state-of-the-art dynamical models we demonstrate that the WPSHis highly predictable; and this predictability creates a new promising way for prediction of monsoon and TS. The predictions using the WPSH predictability not only yields substantially improved skills in prediction of the EASM rainfall, but also enables skillful prediction of the TS activities that the current dynamical models fail. Our findings highlight the importance of subtropical dynamics in understanding monsoon and TS predictability.

Key words: Subtropical High, monsoon rainfall prediction, tropical storm prediction, predictability

1. INTRODUCTION

Summer monsoon and TSs affect billions of peoples' livelihoods over East Asia including China, Japan, Korea, Indo-China peninsula and Philippines. Prediction of the EASM rainfall and the TS in the WNP is a forefront scientific challenge of great societal importance and economic value. The latest assessment of the world-class climate models' performance clearly demonstrates the models' poor skills in prediction of the monsoon rainfall (1) and their inability to predict WNP TS variations.

The WPSH is a prime circulation system affecting EASM and WNP TSactivities, but the sources of its variability and predictability have not been established. We find that the WPSHvariation faithfully represents fluctuations of EASM strength (r=–0.92)during 1979-2009. Here the WPSH variation is measured bya single objective index defined by summer (June-July-August, JJA) mean 850 hPageopotential height (H850) anomaly averaged over the maximum interannual variability (15°N-25°N, 115°E-150°E). The EASM intensity is objectively measured by the leading principal component of the EASM system (2). An enhanced WPSH also signifies reduced TS days in the subtropical WNP (20-35N, 105-150E) with r= –0.81 and decreased numbers of TS that impact East Asian (Japan, Korea, and East China) coastal areas with r= –0.76. Thus, understanding the sources of WPSH variability and predictability may pavean alternative way for prediction of monsoon and TS activities.

2. DYNAMICS OF THE WPSH

Note that the year-to-year pulse of the WPSH intensity as measured by the WPSH index is not concurrently correlated with El Niño/Southern Oscillation (ENSO) during the boreal summer (r= -0.12 for the period 1979-2009). To unravel the origins of the WPSH fluctuation, we turn to investigate the leading modes of summer mean H850 variation because the first two empirical orthogonal function (EOF) modes of H850 account for 74% of the total variance in the WNP region (10°N-30°N, 100°E-180°E). Surprisingly, the year-to-year fluctuation of the WPSH intensity can be reconstructed extremely well with the principle components (PCs) associated with the two EOFs: (1.226×PC1+1.245×PC2), and the correlation coefficient between the observed and reconstructed WPSH indices is 0.94. Hence, understanding the underlying dynamics of the two EOF modes is of central importance for mining the source of predictability of the WPSH.

The first EOF mode (EOF-1) is characterized by an intense southwest-northeast oriented WPSH, which concurs with suppressed rainfall on its southeast flank and enhanced rainfall in Korea, Japan and the equatorial Pacific. How can this WPSH anomaly sustain itself given the chaotic nature of the atmospheric motion? We argue that a positive feedback between the WPSH and underlying Indo-Pacific warm pool dipolar SST plays a central role. This positive thermodynamic feedback is confirmed by numerical experiments with a coupled model (3), which demonstrates that an initial SST cooling in the WNP can indeed maintain an anomalous WPSH in the ensuing summer. The enhanced WPSH alsowarms the northern IO and conversely, the northern IO warming would help sustain the WPSH. Thus, the interplay between the WPSH and northern IO warming also contributes to the maintenance of the WPSH. In sum, the EOF-1 can be viewed as an atmosphere-ocean interaction mode.

The EOF-2 mode features a strong anomalous WPSH and a weak IO low. The anomalous WPSH ridge and the associated suppressed convection extend from the Philippine Sea southeastward to the equatorial WP. The enhanced WPSH concurs with equatorial central Pacific cooling; and the corresponding principal component is negatively correlated with the Niño3.4 index (SSTA averaged over 5°S-5°N, 170°W-120°W) (r= –0.65). The enhanced WPSH associated with EOF-2 is arguably forced by the central Pacific cooling. This assertion is confirmed by numerical experiments with the ECHAM atmospheric general circulation modelforced by the central Pacific SST cooling, which reproduces realistic precipitation and H850 anomalies.

3. HIGH PREDICTABILITY OF THE WPSH

To estimate the lower bound of the predictability for the WPSH, we built an empirical model to predict the WPSH intensity with three predictors that are tightly linked to the first two EOF modes:

WPSH index=1.704×SSTA(IO-WNP)–0.713×$ENSO_{develop}$–0.283×NAOI (Eq. 1)

where SSTA(IO-WNP) represents the April-May mean dipolar SSTA difference between the IO (10°S-10°N, 50°E-110°E) and the WNP (0°-15°N, 120°E-160°E), which acts as a predictor for EOF1 (r=0.76). The $ENSO_{develop}$denotes the May-minus-March SSTA in the central Pacific (15°S-5°N, 170°W-130°W), which is a predictor for the EOF2 (r=–0.50). Additionally, the North Atlantic Oscillation (NAO)index (NAOI) in April-May is used as a predictor for EOF2 (r=–0.41), because the SSTA associated with anomalous NAO in April-May can lead to the equatorial Pacific SSTA during the following summer, thus providing a predictor for the EOF2. Hence, all three predictors are selected based on the physical processes that govern the two predictable EOF modes.

The physically-based prediction model (Eq. 1) can reproduce the WPSH index realistically with a temporal correlation skill of 0.81 for 1979-2009 at zero-month lead (Fig. 1). To test its predictive capability, the cross-validation methodwith a leaving-three-out approachwas used to re-forecast the WPSH index. The temporal correlation skill for the 31-year cross-validated re-forecast skill is 0.75. As a comparison, we have assessed re-forecast performance of three state-of-the-art coupled climate models in predicting the WPSH index at zero-month lead. The skills of these dynamical models range from 0.72 to 0.76 with a three-model ensemble mean skill of 0.82 for the period of 1981-2009 (Fig. 1). The high predictability of the WPSH may open a new pathway to ameliorate monsoon and TS predictions because of their close relationships with the WPSH.

4. PREDICTION OF EASM AND WNP TS

Using WPSH predictors and predictability, we have attempted to directly predict the EASM intensity, the subtropical WNP TS days and the total number of TS impacting East Asia; and the results show promisingand valuable deterministic and probabilistic prediction skills. The high predictability of the WPSH makes WNP TS prediction possible even though the global models generally cannot directly resolve and predict the tropical cyclones. For example, predictions of the subtropical WNP TS days and the total number of TS impacting East Asian coasts can achieve temporal correlation skills of 0.73 and 0.66, respectively. Furthermore, using the predictability of the two major modes of the WPSH, an empirical model for direct prediction of the EASM rainfall anomalies can be constructed. The direct empirical prediction can provide significantly higher re-forecast skill for summer monsoon rainfall than the dynamical models. The temporal correlation skill for prediction of area-averaged rainfall over East Asia (5°-40°N, 110°-140°E) is 0.50 (empirical) versus 0.21 (dynamical). Thus, the two mechanisms underlying the WPSH variability provide a physical basis for predicting EASM and the WNP TS, and use of the WPSH predictability can significantly improve the monsoon rainfall and TS predictions.

5. DISCUSSION

We used observational analyses and numerical experiments to show the fundamental dynamics governing the WPSH variability. Compared to relative mature midlatitude dynamics (quasi-geostrophic theory) and equatorial dynamics (equatorial wave theory), the subtropical dynamics is an area calling for further major efforts to develop our theoretical understanding. We hope that our work paves a way toward developing subtropical dynamics theories.

Our findings also highlight the importance of translating the models' circulation predictability into rainfall and TS predictability, and motivate additional research in how changes in subtropical circulation may be influencing long-term trends and future changes of monsoon precipitation and TS impacts.

References

1. Wang B, et al. (2009) Advance and prospect of seasonal prediction: Assessment of APCC/CliPAS 14-model ensemble retrospective seasonal prediction (1980-2004). ClimDyn 33:93–117.

2. Wang B, et al. (2008) How to measure the strength of the East Asian summer monsoon. J Clim 21:4449-4461.

3. Xiang B, et al. (2011) Reduction of the thermocline feedback associated with mean SST bias in ENSO simulation. ClimDyn, doi:10.1007/s00382-011-1164-4.

MULTIDECADAL TRENDS OF TROPICAL CYCLONE AND CHINA SUMMER MONSOON EXTREME RAINFALL

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Abstract Summary: Interpretations of extreme rainfall trends in the Asian monsoon regions are complicated by tropical cyclones (TCs) from tropical oceans, whose rainfall trend may be different from the local monsoon (non-TC) rain. In the last half century the trends over the China summer monsoon region have been distorted by western North Pacific typhoons with the TC-related extreme rainfall trend smaller than monsoon-related extreme rainfall. The net impact underestimates the increasing trend in monsoon extreme rainfall over most areas. The largest underestimate occurs in Hainan Island, while an opposite case occurs in Taiwan whose extreme rainfall trend is hugely inflated by local increases in TC rainfall in the last decade. These opposite effects emphasize the importance of considering the different mechanisms of rainfall systems in order to avoid mis-attribution of regional effects on extreme rainfall to thermodynamic consequences of global warming.

Keywords: *Climate, Extreme Rainfall, Monsoon, Tropical Cyclone, Rainfall Trend*

1. INTRODUCTION (headline in CAPITALS, 10pt Bold)

A general theoretical basis for linking global warming with increased rain intensity is that atmospheric water vapor capacity increases with temperature at the rate of approximately 7% per K through the Clausius-Clapeyron equation. With this increase the rain intensity and extreme rainfall events may increase in a warming world (Trenberth et al., 2007) which is a major reason for expecting a positive trend in extreme rainfall observed at land stations. Recently, Min et al. (2011) showed a correspondence between simulated increases in precipitation intensity in models with anthropogenic forcing and observed extreme rainfall trends over the Northern Hemisphere land area. However, the correspondence refers mainly to North America and Europe. Over the Asian monsoon regions, the positive trends are scattered (Min et al., 2011; Ghosh et al., 2012).

In the Asian monsoon region, significant amounts of extreme rainfall can be due to TCs, whose development and characteristics are subject to many dynamic and thermodynamic controls over tropical oceans before they approach the land areas (Knutson et al., 2010). A proper assessment of the monsoon extreme rainfall trend and how it might be related to the increasing vapor capacity needs to consider the effects of TCs.

In this study we use 479 daily rainfall stations in the China mainland and 20 stations in Taiwan during 1958-2010. The rainfall at each station is separated into typhoon (named-TCs)-associated and monsoon (non-typhoon)-associated components using the Objective Synoptic Analysis Technique (Ren et al., 2006). Linear trends are computed for the 90th and 95th percentile extreme rainfall for the total, TC, and monsoon components to study the effects of the TC extreme rainfall on the trend of the monsoon extreme rainfall.

2. TRENDS OF TROPICAL CYCLONE AND MONSOON EXTREME RAINFALL

The 53-year linear trends of typhoon rainfall frequency decreases over the broad domain, while the typhoon rain intensity increases over most of southern China. In general, the decreasing frequency more than offsetting the increasing intensity so the trend of the typhoon rainfall amount tends to decrease except between 25N - 40N where the signal is mixed and insignificant. This causes more stations to have monsoon extreme rainfall trend larger than the total extreme rainfall trend (by a ratio of 11:7). The most notable exception is in Taiwan and a few stations on the southeastern coast of the Chinese mainland, where typhoons moving on the Taiwan path likely approach or make landfall.

In general the TC trend is less positive than the monsoon trend. The smallest impact occurs in Yangzi River Valley where the positive trend of monsoon extreme rainfall is only marginally higher than that of the total extreme rainfall. In central China the monsoon trend is 11% higher, and in southern China the monsoon trend is 29% higher than the total trend because the typhoon trend is near zero. The largest effect occurs in Hainan, where the total extreme rainfall decreases (-15% trend, or -2.8%/decade) but the monsoon extreme rainfall increases (35% trend, or 6.6%/decade). In northeastern China, well inside the northern drought part of the "Southern Flood and Northern Draught" (SFND) pattern, the total extreme rainfall decreases (trend -21%, or -4%/decade) but this includes the typhoon impact that magnifies the -16% trend (-3%/decade) of the monsoon extreme rainfall by almost one third. So the typhoon impacts cause an underestimate of the positive trend, or an overestimate of the negative trend, of the monsoon extreme rainfall in nearly the entire China monsoon region. The results for the 95th percentile rainfall are similar to the 90th percentile with the same signs and magnitudes.

The overall underestimate of the extreme rainfall trend can be physically explained as a result of the decrease, or very small increase, of typhoon rainfall, which is itself due to the fact that the increasing trends of typhoon rain intensity in southern China is not sufficient to offset the overall decreasing trends of typhoon rainfall frequency. In Yangzi River Valley the extreme rainfall trend for typhoon is closest to that for monsoon.

An exception to the negative impact of typhoons on the trend of extreme rainfall occurs in Taiwan, where the observed total extreme rainfall trend is near 20% over the 53 years (3.8%/decade). After removing typhoon rainfall, the monsoon component has a trend of only 11% (2%/decade), so there is an 80% overestimate of the extreme rainfall trend due to typhoons. For the 95th percentile extreme rainfall the observed increasing trend of 46% (8.7%/decade) totally masked the -12% (-2.3%/decade) trend for the non-typhoon rain.

3. CONCLUSIONS

Our results show that since middle-20th century the trend of TC extreme rainfall in most part of the East Asian summer monsoon is less than that of the monsoon extreme rainfall, except in the vicinity of the Meiyu rainbelt where the two trends are similar. This is because any increase in TC rainfall intensity is insufficient to offset the decrease in TC rainfall frequency to produce a trend that matches the monsoon rainfall. Both the intensity and frequency trends are consistent with the global warming model projections. The former may be expected from the theory that precipitation intensity increases with water vapor capacity and the latter from the decrease in relative SST in the western North Pacific in the recent decades. While the present study shows that the trend of monsoon extreme rainfall is more positive than observed, the sign of the trends still varies and remains mostly negative (albeit smaller) in northeastern China after TC influences are removed. This is not surprising because of the development of the dominant multidecadal SFND pattern in the last half century. A more concise picture of the broad scale extreme rainfall trend may emerge if the regional factors that drive the SFND variation can also be isolated.

The opposite drastic effects of typhoons on the trends of extreme rainfall in Hainan and Taiwan further emphasize the importance of considering the different mechanisms of heavy rainfall systems. This is necessary to avoid mingling of the effects due to regional and global drivers in the study of extreme rainfall trends (Ghosh et al., 2012).

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REFERENCES (in 9pt; second line indented for better distinction)

Bougeault, P., P, Binder, A. Buzzi, R. Dirks, R. Houze, J. Kuettner, R. B. Smith, R. Steinacker, and H. Volkert, 2001: the MAP Special Observing Period. *Bull. Amer. Meteorol. Soc.* **82**, 433-462.

Houze, R. A., Jr. 1993: Cloud dynamics, International Geophysics series, Volume **53**, Academic Press, 573 pp.

Schwitalla, T., G. Zangl, H. S. Bauer, and V. Wulfineyer, 2007: Convective initiation in the Black Forest region in high-resolution MM5 simulations. *Proc. 29th Intern. Conf. on Alpine Meterology*, Chambery, France, 261-264

DYNAMICAL SEASONAL FORECASTING FOR AGRICULTURE IN AUSTRALIA

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Abstract Summary: The POAMA is Australia's operational dynamical seasonal prediction system. The latest version, POAMA-2, has been designed to provide forecasts seamlessly across a range of time scales from multi-week to seasonal. One of the main applications of POAMA forecasts is agriculture. A range of operational and experimental products of regional rainfall and temperature are available, including products focusing on extreme events. Studies on the use of POAMA forecasts for managing wheat farm decisions show that the use of POAMA forecasts can lead to significant increase in profit compared to current practices.

Keywords: *POAMA, Climate, Seasonal Prediction, Agriculture*

1. INTRODUCTION

The POAMA (Predictive Ocean Atmosphere Model for Australia) dynamical seasonal prediction system has been developed jointly by the Bureau of Meteorology and CSIRO. Operational climate forecasts from POAMA are issued by the Bureau of Meteorology. The latest version, POAMA-2, contains several enhancements compared to its predecessors, which places it at the leading edge compared with other international systems. These include: a state of the art Ensemble Kalman Filter for ocean data assimilation (Yin et al 2011), a coupled ensemble breeding technique and a pseudo multi-model ensemble based on three model configurations (see, for example, Lim et al 2012).

The skill levels for regional rainfall and temperature over Australia are relatively high for certain regions and seasons, for example, when looking at probabilities of above median rainfall in winter/springing in the south-east. The pseudo multi-model approach and the new breeding ensemble generation method leads to forecasts with significantly improved forecast reliability. Further details of POAMA skill can be found in Cottrill et al (2012), Lim et al (2012), Marshall et al (2012), Shi et al (2012), Spillman et al (2012) and Hudson et al (2011).

2. APPLICATIONS IN AGRICULTURE

A range of operational and experimental products are produced routinely for a range of applications, including agriculture, water management, Great Barrier Reef management and fisheries. The utility of the forecasts for wheat farming in western Australia has been explored. In areas where the model has significant skill, using the forecasts to determine fertiliser application can lead to significant profit gains compared to current practices (Asseng et al 2012).

REFERENCES

Asseng, S., D. Thomas, P. McIntosh, O. Alves, N. Khimashia, 2012: Managing mixed wheat-sheep farms with a seasonal forecast. *Agricultural Systems*, **113,** 50-56.

Cottrill, A., Hendon, H.H., Lim, E-P., Langford, S., Kuleshov, Y., Charles, A. and Jones, D., 2012. Seasonal Climate Prediction in the Pacific using the POAMA coupled model forecast system. *CAWCR Technical Report No. 048*

Hudson, D., Alves O., Hendon H.H., Marshall A.G., 2011. Bridging the Gap between Weather and Seasonal Forecasting: Intraseasonal Forecasting for Australia. *Quarterly Journal of the Royal Meteorological Society.* **137**:673-689. doi:10.1002/qj.769.

Lim, E-P., Hendon, H.H., Langford, S. and Alves, O., 2012. Improvements in POAMA2 for the prediction of major climate drivers and south eastern Australian rainfall. CAWCR Technical Report No. 051

Marshall, A.G., D. Hudson, M.C. Wheeler, H.H. Hendon, and O. Alves, 2012. Evaluating key drivers of Australian intra-seasonal climate variability in POAMA-2: a progress report. *CAWCR Research Letters*, 7:10-16.

Shi, L., H. Hendon, O. Alves, J. Luo, M. Balmaseda, and D. Anderson, 2012. How Predictable is the Indian Ocean Dipole? *Mon. Wea. Rev.* DOI: 10.1175/MWR-D-12-00001.1, in press.

Spillman CM, Alves O, Hudson DA, 2012. Predicting thermal stress for coral bleaching in the Great Barrier Reef using a coupled ocean-atmosphere seasonal forecast model. *International Journal of Climatology,* DOI: 10.1002/joc.3486.

Yin, Y., O. Alves, and P. R. Oke, 2011: An ensemble ocean data assimilation system for seasonal prediction. *Mon. Wea. Rev.,* **139**, 786-808.

AGROCLIMATIC ZONING FOR WINTER BARLEY IN KOREA UNDER THE RCP8.5 PROJECTED CLIMATIC CONDITION

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Abstract Summary: Gridded monthly temperature data at 30m cell resolution were prepared for 1971-2100 across each of the 1,695 catchments constituting both North and South Korea. In order to detect the geographical migration of arable lands suitable for winter barley production under the RCP8.5 projected climate condition, maps for daily maximum and minimum temperature in January, each representing a decadal average year for the 9 future periods (2011-2100) as well as the 4 past periods (1971-2010) were used in conjunction with the cold hardiness criterion for 3 major barley cultivar groups. Application of this criterion to the temperature maps at 10-year interval showed a distinct geographical shift of the northern limit for growing barley. The northern limit for malting barley could extend to lower reaches of Yalu and Tumen rivers, while current cultivation zone is confined to the southern coastal plains and Jeju Island. The acreage suitable for growing hulled, unhulled, and malting barley cultivar is expected to increase from 35, 23 and 5% of the whole peninsula in 1980's to 89, 87, and 72% in 2090's, respectively.

Keywords:*Winter barley, Agroclimatic zoning, Cold hardiness, RCP8.5, Climate change*

1. INTRODUCTION

While most grain crops grown in Korea during the summer season are expected to show significant yield loss in the future due to the warming, winter barley is known to show a positive response to the climate change and expected to play an important role in national food security in the future (Shim et al., 2011). The present self sufficiency ratio for cereal grains in South Korea is estimated to be less than 30% and the situation could be worse under the global warming, given the current cropping system based on rice monoculture continues in the future. Furthermore, climate change could exacerbate the chronic food shortage in North Korea. Because winter barley could not survive the cold winter at most of the Korean Peninsula, major cultivation zone was confined to the southern part of the Peninsula, making the acreage and production negligible. However, the northern limit for safely growing winter barley has been shifting toward north due to the recent winter warming (Shim et al., 2002). If we could have a means to detect the geographical migration of arable lands suitable for winter barley production at landscape scales in advance, that should be a great help to policy planners in national food security as well as research agronomists.

2. DATA AND METHODS

2.1 Geospatial Climate Data

Since the spatial resolution for identifying individual farmlands in Korea far exceeds those of the current climate scenario as well as the synoptic observations, many practical methods have been developed to estimate local climates from synoptic data, resulting in a catchment-specific climate mapping scheme (Yun, 2010). Given a single value for a catchment from the nearest weather office or the output grid cell for example, a daily minimum temperature surface at 30m resolution across the catchment can be produced by the cold air drainage and thermal belt effect (Chung et al., 2006), and daily maximum temperature by the solar irradiance effect on sloping surfaces in this scheme. We applied this scheme to each of the 840 official watersheds of South Korea and 855 temporary watersheds of North Korea to produce monthly average maps for daily maximum and minimum temperature, each representing a decadal average year for the 9 future periods (2011-2100) as well as the 4 past periods (1971-2010). The past climate is based on the observations from the 56 synoptic stations operated by Korea Meteorological Administration (KMA), and the future climate is from the recently distributed KMA outlook based on the RCP (Representative Concentration Pathway) 8.5 scenarios. Each of the 1,695 watershed-specific climate maps was joined one by one to make a seamless mosaic representing the high-definition digital temperature surfaces for the Korean Peninsula.

2.2Cold Hardiness Zoning

Cold hardiness criteria for 3 major barley cultivars delineating northern growth limits can be prepared by using January temperature. One of the criteria tells the northern limit coincides with isotherms of -5, -4, and -1℃ in January mean temperature for growing hulled, unhulled, and malting barley cultivars, respectively. Additional criterion of -12, -10, and -5℃ in January minimum temperature is recommended for further refinement of the zonal boundary in the 3 cultivars. We used these criteria to delineate northern limits for winter barley in the future on the high-definition temperature maps.

3. RESULTS AND DISCUSSION

Application of thezoning criterion to the high-definition digital temperature maps at 10-year interval shows a distinct geographical shift of the northern limits. According to the results, most of the North Korean territory except the inland plateau region shall be available for growing winter barley by the year 2050. The northern limit for malting barley, which is least tolerant to freezing temperature, could extend to lower reaches of Yalu and Tumen rivers in 2090s, while current cultivation zone is confined to the southern coastal plains and Jeju Island. The acreage suitable for growing hulled barley cultivar is expected to increase from 35% of the whole Peninsula in 1980's to 89% in 2090's. The suitable acreage will be 87% and 72% in 2090's for unhulled and malting barley cultivars, respectively, compared with 23% and 5% in 1980's.

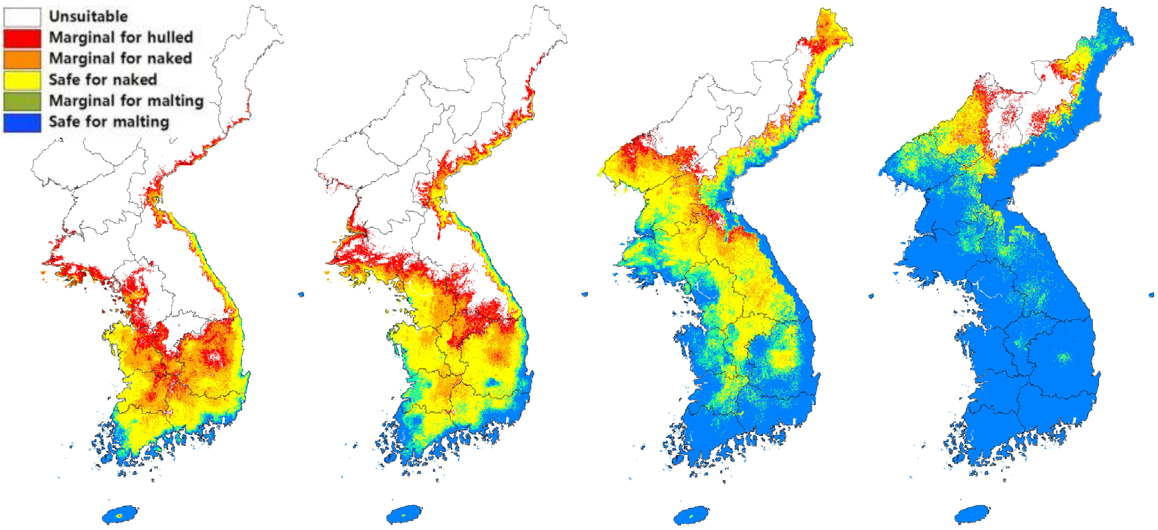

Figure 1. Geographical migration of the northern limits for safe cultivation of the 3 winter barley cultivar groups in Korea. Each panel indicates decadal average pattern for 1981-1990, 2001-2010, 2041-2050, and 2091-2100 from left to right, respectively.

According to a recent modeling studybased on rice monoculture at all the arable lands in South Korea (ca. 2.4 million ha), the potential grain production shall decrease from 15 million tons in 2000s to 12 million tons in 2090s due to the climate change induced environmental deterioration. If winter barley replaces paddy rice at all the acreage, however, theproduction potentialshall increase from 10 million tons in 2000s to 17 million tons in 2090s (Kim et al., 2012). Recent estimates on North Korean acreage might range from 1.4 to 1.6 million ha. If we could plant hulled barley and grow it safely after summer crops at most of the North Korean acreage in 2090s as predicted by this study, we might secure at least 4 million tons of grains which could bring quick relief from famine. Additional studies on cropping systems using modeling techniques are necessary to delineate realistic effects of selecting alternative crops under the climate change scenarios.

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REFERENCES

Chung, U., H. H. Seo, K. H. Hwang, B. S. Hwang, J. Choi, J. T. Lee, and J. I. Yun, 2006: Minimum Temperature Mapping over complex terrain by estimating cold air accumulation potential. *Agricultural and Forest Meteorology* **137**, 15-24.
Kim, D.J., J. H. Kim, J. H. Noh, and J. I. Yun, 2012: Geographical migration of winter barley in Korea under the RCP8.5 climate. *Korean Journal of Agricultural and Forest Meteorology* **14**(3), in press
Shim, K. M., S. H. Yun, Y. S. Jung, J. T. Lee, and K. H. Hwang, 2002: Impact of recent weather variation on yield components and growth stages of winter barley in Korea. *Korean Journal of Agricultural and Forest Meteorology* **4**(1), 38-48 (in Korean with English abstract).
Shim, K. M., S. H. Min, D. B. Lee, G. Y. Kim, H. C. Jeong, S. B. Lee, and K. K. Kang, 2011: Simulation of the effects of the A1B climate change scenario on the potential yield of winter naked barley in Korea. *Korean Journal of Agricultural and Forest Meteorology***13**(4), 192-203 (in Korean with English abstract).
Yun, J. I., 2010: Agroclimatic maps augmented by a GIS technology, *Korean Journal of Agricultural and Forest Meteorology***12**(1), 63-73 (in Korean with English abstract).

MULTI-MODEL ENSEMBLE PREDICTION FOR BOREAL SUMMER INTRASEASONAL OSCILLATION

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Abstract Summary: The wet and dry spells of the Boreal Summer IntraSeasonal Oscillation (BSISO) in the Asian monsoon region strongly influence extreme hydro-meteorological events, major driving forces of natural disaster, and thus the socio-economic activities in the World's most populous monsoon region. Practical useful BSISO indices are proposed for monitoring and prediction purpose based on multivariate empirical orthogonal function (MV-EOF) analysis of daily anomalies of outgoing longwave radiation and zonal wind at 850 hPa in the region 10°S-40°N, 40°-160°E, for the extended boreal summer (May-October) season over the 30-year period 1981-2010. The prediction skill and predictability of the BSISO indices are examined using multi-model ensemble (MME) hindcasts obtained from ten coupled models participated in the IntraSeasonal Variability Hindcast Experiment (ISVHE) project.

Keywords: *Boreal summer intraseasonal oscillation, real-time index, multi-model prediction, predictability*

1. INTRODUCTION

It has been well recognized that the tropical intraseasonal oscillation (ISO) exhibits prominent seasonal variation (e.g., Madden 1986; CLIVAR Madden-Julian Oscillation (MJO) working group 2009; Kikuchi et al. 2012). Compared to boreal winter, during boreal summer the main centers of convective variability associated with the ISO are shifted away from the equator to 10-20°N, and the propagation patterns are considerably more complicated. While the boreal winter ISO (also known as the MJO) shows predominantly eastward propagation, the boreal summer ISO (BSISO) also exhibits northward/northeastward propagation over the Indian summer monsoon (ISM) region (e.g., Annamalai and Sperber 2005), and northward/northwestward propagation over the Western North Pacific-East Asian (WNP-EA) region (Kemball-Cook and Wang 2001), often in conjunction with MJO-like propagation along the equator (Lawrence and Webster 2002). Whereas the MJO has been regarded as applicable in all seasons, albeit with generally weaker variability in boreal summer (Madden and Julian 1972; Wheeler and Hendon 2004), the BSISO has been regarded as a specific mode of the tropical ISO that prevails in boreal summer. Thus, for many applications it is instructive to consider the tropical ISO as described by two modes, the MJO and BSISO. The MJO dominates during boreal winter (December-April) and the BSISO dominates during boreal summer (June-October) with May and November being transitional months during which either mode may prevail (Kikuchi et al. 2012).

Importantly, the BSISO is the dominant source of short-term climate variability in the Asian summer monsoon and global monsoon. It is known to affect summer monsoon onsets (Wang and Xu 1997), the active/break phases of the monsoon (Goswami 2005), and the monsoon seasonal mean (Krishnamurthy and Shukla 2007). It is also a possible source of seasonal climate predictability for precipitation (Lee et al. 2010) and extratropical atmospheric circulation (Lee et al. 2011). Two different periodicities of the BSISO have been identified: periods of 30-60 days and 10-20 days. The wet and dry spells of the BSISO strongly influence extreme hydro-meteorological events, major driving forces of natural disasters, and thus the socio-economic activities in the World's most populous monsoon region.

2. RESULTS

The BSISO indices proposed in this study were designed to better represent fractional variance and the observed northward propagating ISO over the entire ASM region than the RMM index. After considerable sensitivity tests, our chosen method to define the new BSISO indices uses MV-EOF analysis of daily mean OLR and 850-hPa zonal wind (U850) anomalies over the ASM region (10°S-40°N, 40°-160°E) from 1st May to 31st October for the 30 years 1981-2010. The OLR and U850 anomalies were obtained by removing the slow annual cycle (mean and first three harmonics of climatological annual variation) as well as the effect of interannual variability by subtracting the running mean of the last 120 days as in Wheeler and Hendon (2004). We do not apply any other time filtering. After that, the two anomaly fields were each normalized by their area averaged temporal standard deviation over the ASM region. The normalization factor used is 33.04 W m^{-2} for OLR and 4.01 m s^{-1} for U850. After applying the MV-EOF on the normalized OLR and U850 anomalies, we identified the first four MV-EOF modes as important for representing the BSISO over the ASM region. BSISO1 is defined by the first two principal components (PCs) of the MV-EOF analysis, which together represent the canonical northward propagating variability that often occurs in conjunction with the eastward MJO with quasi-oscillating periods of 30-60 days (Fig. 1). BSISO2 is defined by the third and fourth PCs, which together mainly capture the northward/northwestward propagating variability with periods of 10-30 days during primarily the pre-monsoon and monsoon-onset season (Fig. 2). The BSISO1 circulation cells are more Rossby wave like with a northwest to southeast slope, whereas the circulation associated with BSISO2 is more elongated and front-like with a southwest to northeast slope.

The prediction skill and predictability of the BSISO indices are examined using multi-model ensemble (MME) hindcasts obtained from ten coupled models participated in the IntraSeasonal Variability Hindcast Experiment (ISVHE) project. It is noted that the first two MV-EOF modes (BSISO1) are predictable using the coupled models and the bivariate temporal correlation coefficient skill for the two modes reaches 0.5 at 22-day forecast lead for the best model but at 5-day for the worst model. As a phenomenon bridging synoptic weather and seasonal variability, BSISO predictability is strongly affected by both the initial conditions and air-sea coupling. Some existing reanalysis datasets have poor representation of the BSISO. A 'signal-recovery' strategy has been developed to enhance BSISO signal in initial conditions, which results in much improved forecasting skill.

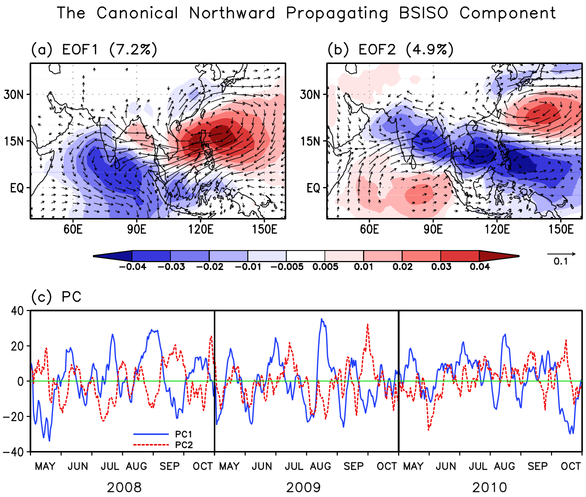

Figure 1. Spatial structure (a, b) and PC time series (c) of the first two leading MV-EOF modes of daily OLR (shading) and U850 anomalies. To display the full horizontal wind vector, the associated V850 was obtained by regressing V850 anomaly against each PC.

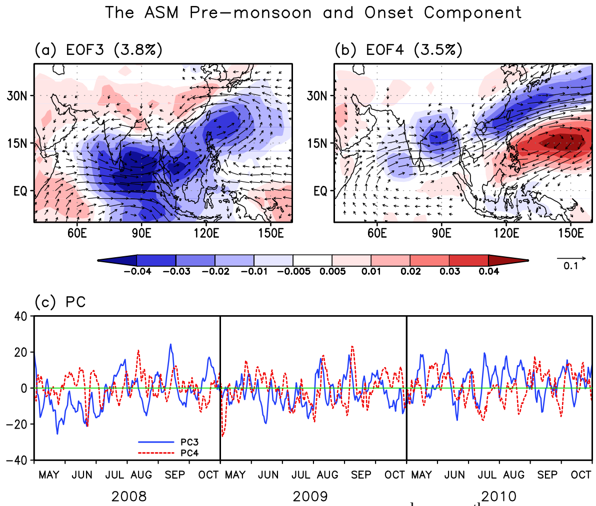

Figure 2. Same as Fig. 2 except for the 3rd and 4th mode

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REFERENCES (in 9pt; second line indented for better distinction)

Annamalai, H., K. R. Sperber, 2005: Regional heat sources and the active and break phases of boreal summer intraseasonal (30-50 day) variability. J Atmos Sci 62:2726-2748.

CLIVAR Madden-Julian Oscillation Working Group, 2009: MJO simulation diagnostics. J Clim 22:3006-3030

Goswami, B. N., 2005: South Asian monsoon In: Lau KM and Waliser DE (eds) Intraseasonal Variability of the Ocean and Atmosphere. 19-61, Springer, Heidelberg, Germany

Kemball-Cook, S., B. Wang, 2001: Equatorial waves and air-sea interaction in the boreal summer intraseasonal oscillation. J Clim 14:2923-2942

Kikuchi, K., B. Wang, Y. Kajikawa, 2012: Bimodal representation of the tropical Intraseasonal oscillation. Clim Dyn. 38:1989-2000

Krishnamurthy, V., J. Shukla, 2007: Intraseasonal and seasonally persisting patterns of Indian monsoon rainfall. J. Clim 20:3-20

Lawrence, D. M., P. J. Webster, 2002: The boreal summer intraseasonal oscillation: Relationship between northward and eastward movement of convection. J Atmos Sci 59:1593-1606.

Lee, J.-Y., B. Wang et al., 2010: How are seasonal prediction skills related to models' performance on mean state and annual cycle? Clim Dyn 35:267-283

Lee, J.-Y., B. Wang et al., 2011: How predictable is the northern hemisphere summer upper-tropospheric circulation? Clim Dyn 37:1189-1203

Madden, R. A., 1986: Seasonal-variations of the 40–50 day oscillation in the tropics. J Atmos Sci 43:3138–3158

Madden, R. A., P. R. Julian, 1972: Description of global-scale circulation cells in tropics with a 40-50day period. J Atmos Sci 29:1109-1123

Wheeler, M. C., H. H. Hendon, 2004: An all-season real-time multivariate MJO index: Development of an index for monitoring and prediction. Mon Wea Rev 132:1917-1932

A TIME-SCALE DECOMPOSITION STATISTICAL DOWNSCALING MODEL

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Abstract Summary: A new statistical downscaling model based on the time-scale decomposition (TSD) approach is proposed. It makes use of distinct downscaling models respectively corresponding to different time-scale variability with distinct different mechanisms. We employ this model to statistically downscale summer (July-August) rainfall over North China as example. The TSD downscaling model makes use of two distinct downscaling models respectively corresponding to the interannual and interdecadal variabilities of summer rainfall over North China. The downscaling model for the interannual summer rainfall variability over North China is linked to June El Niño–Southern Oscillation (ENSO) and June Atlantic Eurasian (AEA) teleconnection, while the one for the interdecadal summer rainfall variability over North China is related to the decadal variability of sea level pressure over the southwest Indian Ocean. The results show that the TSD approach achieved a good skill to predict the observed rainfall with the correlation coefficient of 0.82 in the independent validation period. The model is further applied to obtain downscaled rainfall projections from three climate models under present climate and the A1B emission scenario in future. The resulting downscaled values provide a closer representation of the observation than the raw climate model simulations in the present climate; for the near future, climate models simulated a slight decrease in rainfall, while the downscaled values tend to be slightly higher than the present state. Besides, the TSD model is employed to make seasonal prediction for summer rainfall over North China in 2011 and 2012, and the results show a good performance of the approach, implying the TSD model could be a useful tool for seasonal prediction.

Keywords: *Time-scale decomposition (TSD) downscaling, summer rainfall, seasonal prediction, North China*

1. INTRODUCTION

It is well-known that general circulation models (GCMs) are a very good tool to project the large-scale long-term mean future climate, however, the skillful spatial resolution in most updated climate models is large than or at least 2000–4000 km (Grotch and MacCracken 1991), beyond the demand for regional precipitation prediction, which is sensitive to sub-grid processes. Statistical downscaling is one of methods that can potentially assist in the assessment of climate models and overcoming model uncertainties accompanying future rainfall projections as well. The aim of this work is to propose a new statistical downscaling model based on the time-scale decomposition (TSD) approach and to apply this model to North China (NC) summer rainfall prediction. Given that there are significantly distinct components in rainfall variability at the inter-annual and inter-decadal time-scales, it is desirable to develop a TSD approach to obtain the downscaled rainfall totals by combining two distinct downscaling models for the inter-annual and inter-decadal rainfall variability.

2. TABLE AND FIGURE

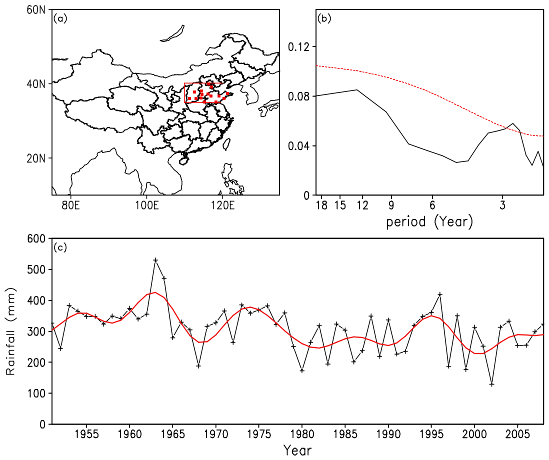

Figure 1 (a) 15 gauge stations used to represent NC (110°–122°E, 35°–40°N) denoted by the red rectangle. (b) Power spectrum for JA rainfall. Peak over the dashed line indicates the confidence level is >80% against a red noise. (c) Total rainfall (mm) during JA (black crossed line) from 1951 to 2008 and its inter-decadal variation with period exceeding 7 yr (red solid line).

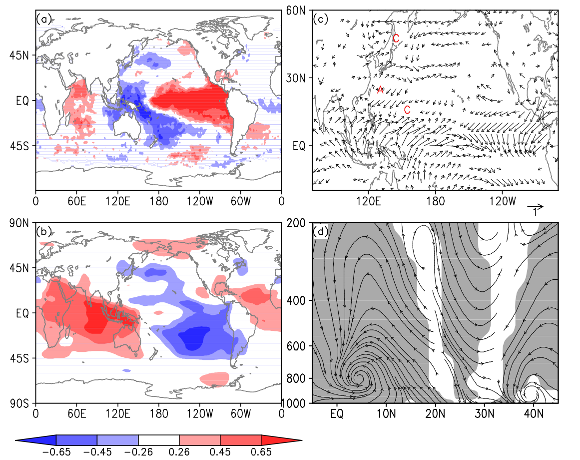

Figure 2 Correlation of detrended time-series between interannual component of the June Nino3 index and inter-annual variability of (a) surface temperature, (b) 850 hPa GHT, (c) surface horizontal winds and (d) meridional circulation along a latitude-pressure cross-section averaged over 100°–140°E in JA during 1951–2008. Shading and vectors indicate significance at the 0.05 level.

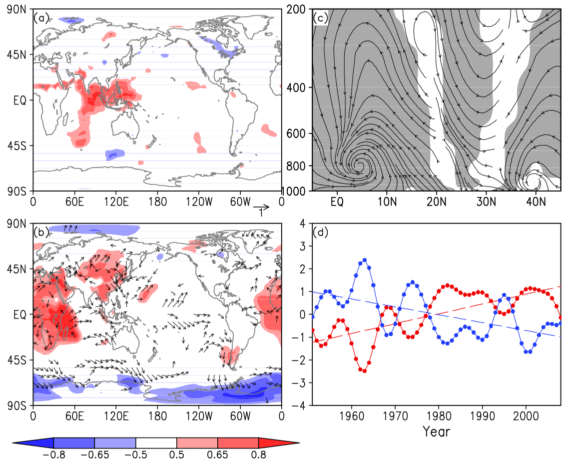

Figure 3 Correlation of detrended time-series between the interdecadal component of June SLP over southwestern Indian Ocean (X_{1D}) and inter-decadal variability of (a) SAT, (b) SLP (shading) and surface winds (vectors) in June and (c) meridional circulation over 100°–140°E in JA during 1951–2008. Shading and vectors drawn indicate significance at the 0.05 level. (d) Normalized time-series (dotted line) and the associated linear trend (dash line) of X_{1D} (red) and NC JA rainfall (blue) during 1951–2008.

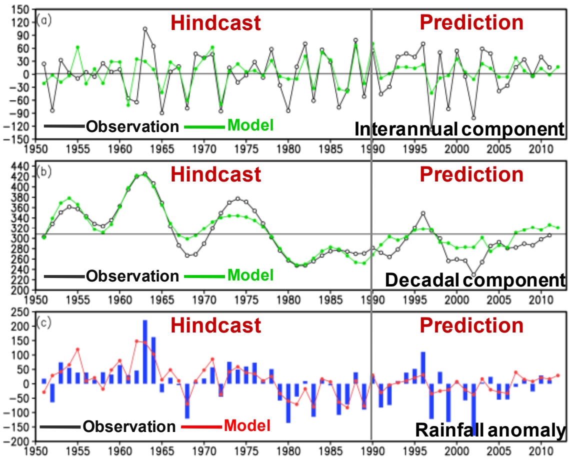

Figure 4 (a) Inter-annual component, (b) inter-decadal component and (c) anomaly of the observed and downscaled July–August NC rainfall (mm) during 1951–2012.

3. CONCLUSIONS

We proposed a TSD approach to downscale NC summer rainfall through modeling the inter-annual and inter-decadal rainfall variability by the IAM and IDM, respectively. The inter-annual components of June Niño3 index and June Atlantic Eurasian (AEA) teleconnection are linked to the inter-annual rainfall variability by the IAM, while the inter-decadal component of SLP over the southwestern IO was linked to the inter-decadal rainfall variability by the IDM. Both the IAM and IDM show good skills to downscale the inter-annual and inter-decadal rainfall variability in NC summer rainfall. The downscaled total rainfall can be obtained by summing up the two downscaled components from the IAM and IDM. The results indicated that the TSD approach has a relatively high predictive capability for NC summer rainfall.

We have also applied the downscaling model to GCM-generated predictors and estimated the long-term rainfall conditions for both the present day (1951–1999) and the near future (2010–2024 and 2035–2049) under A1B emission scenario. For the present climate, in all cases, the downscaled values showed smaller percentage errors than did the raw GCMs' simulations. This superiority indicated that the downscaled predictions are more reliable for representing the present day climate, thus implying a better representation of the future climate. For future projection, a majority of downscaled values from predictors simulated by GCMs indicated a slightly increase in rainfall, which is different from the raw GCMs' projection. This result indicates that there is less chance to happen large changes, such as severe long-term droughts or floods (relative to the present day state) for the next 40 yr under A1B emission scenario.

The TSD model is also employed to make seasonal prediction for summer rainfall over North China in 2011 and 2012, and the results show a good performance of the approach, implying the TSD model could be a useful tool for seasonal prediction.

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REFERENCES

Grotch, S. L., and M. C. MacCracken, 1991: The Use of General Circulation Models to Predict Regional Climatic Change. *J. Climate*, **4**, 286-303.

Guo, Y., J. Li, and Y. Li, 2012: A time-scale decomposition approach to statistically downscale summer rainfall over North China. *J. Climate,* **25**, 572-591.

Li, Y., and I. Smith, 2009: A Statistical Downscaling Model for Southern Australia Winter Rainfall. *J. Climate*., **22**, 1142-1158.

Li, J., and Q. Zeng, 2002: A unified monsoon index. *Geophys. Res. Lett.*, **29**, 1274, doi: 10.1029/2001GL013874.

APPLICATIONS OF SEASONAL CLIMATE FORECAST TO CROP YIELD PREDICTION: INTERNATIONAL & DOMESTIC COLLABORATIONS

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Abstract Summary: The short-term climate variability prediction provides valuable information for varieties of adaptation issues including agricultural managements under the influence of the ongoing climate change, and hence it is an important theme not only for climate study in itself but also for its applications to socio-economic activities. A well-known stumbling block for the applications of short-term climate variability prediction is (C)GCM's output bias of which magnitude generally far exceeds the tolerable limits end-users presuppose and, such being the case, some sort of bias corrections become essential requirements for application studies. By casting light on the salient difference between the short-term climate variability prediction and the long-term climate projection, here we propose a new high-performance bias correction method valid exclusively for the former. The new method utilizes the Maximum Entropy Method (MEM) for time series analysis that can be successfully applied to data with relatively short length and we demonstrate that the new method is superior to the prevailing method of quantile(Q)-matching.

Keywords: *Short-term climate prediction, Bias correction, Agricultural applications*

1. INTRODUCTION

Based on our successful a decade-long achievements on the tropical climate variability prediction by SINTEX-F1 coupled model (Luo et al. 2008), newly established Application Laboratory (APL) in JAMSTEC initiated a couple of international and domestic collaborations with agricultural research institutes: (I) *Climate Change Adaptation Rainfed Area Management* (CCARA) project of IRRI/JIRCAS in which seasonal climate forecast is to be used for a newly developing integrated rice cultivation managements system, and (II) joint project with NIAES which aims at the development of the world's first large-scale global crop model that runs with seasonal climate prediction data. A major goal of both projects is to evaluate the utility value of short-term (or seasonal) climate prediction information for crop yield estimate, and the former focuses on the enhancement of unstable rainfed rice production efficiency under the influence of the modulation of natural short-term climate variability in the Southeast Asian region caused by the global warming, while the latter undertakes growing severe food insecurity problems on the global scene involving food-import as well as food-export countries.

One of the significant consequences of the ongoing global warming is the fact that the climate mean states as well as the deviations from it we call anomalies are also changing so that any statistical method based on the past a few decades becomes less reliable and the role played by coupled general circulation models (CGCM) in evaluating near future states (in the sense of seasonal climate prediction) is now becoming quite important than ever. In spite of the recent intensive progresses on (high-resolution) CGCM's developments and performance validation studies, we can regretfully say that, in almost all application studies, the accuracy of the raw prediction output data from (C)GCM is far from that end-users demand. One of the major bottleneck removals in such applications is bias correction of model outputs. The problem of bias correction is not new and innumerable studies have been done so far. Especially, in relating to recent global warming impact studies, it has being discussed in a broader context of downscalings (Wilby et al. 2002). In order to cope with this problem, it is worthwhile to point out a salient difference between the short-term climate prediction we are focusing on here and the long-term climate projection in climate change problem. In the latter, climate as a pure statistical state is the main concern, while the former is more akin to daily weather forecasts in the sense that predictable slowly changing sea surface temperature (SST) plays a key role in it. A typical or prevailing method of bias correction employs an idea of Q-matching (Panofsky & Brier 1958) in which *one to one correspondence* between cumulative distribution function (CDF) of model output and that of observational data is used for the correction of given model bias. Since this *one to one correspondence* is of statistical nature, it happens that this method may (actually do) obscure the unique aspect of time evolution of the particular event we are going to predict, which motivated us to look into the time dependent characteristics of model bias and into a method which deals with that.

2. NEW MEHOD EMPLOYED FOR THE SHORT-TERM CLIMATE PREDICTION

The above-mentioned observation leads us to a problem formulation in which a time series of model bias defined as the difference between observational value and corresponding model output is studied. For simplicity, we assume that those two data are resolution consistent, since we think that resolution inconsistency issue is more relevant to an interpolation problem rather than model bias problem. The crux of short-term climate prediction is to capture deterministic behaviors of such climate modes as ENSO, IOD and seasonal variations etc. against chaotic background (Shukla 1998). Our experiences tell that temporal behaviors of dominant model bias are not chaotic in nature. If this is the case, then, based on Wold decomposition theorem for time series data, the dominant deterministic parts of model bias in a certain learning period can be expressed in terms of generalized trigonometric functions and this expression can be extended into adjacent future time domain to cancel out fully the model bias in prediction. Actual realization of this procedure to be applied for given data with relatively short length is not easy and definitely needs high-accuracy algorithms. To this end, we employ a numerically improved code (Saito et al. 1994) for the Maximum Entropy Method (MEM) (Burg 1975) which enables us to perform high-resolution power spectrum analysis. For monthly precipitation at Perth in Australia, the performance validations of the new and Q-matching methods are given in the following Fig. 1. Actually, what we are interested in is the prediction of several months ahead and it is shown that the normalized prediction errors in the one year prediction period of 2000-2001 are respectively 0.4 (MEM) and 0.63 (Q-matching).

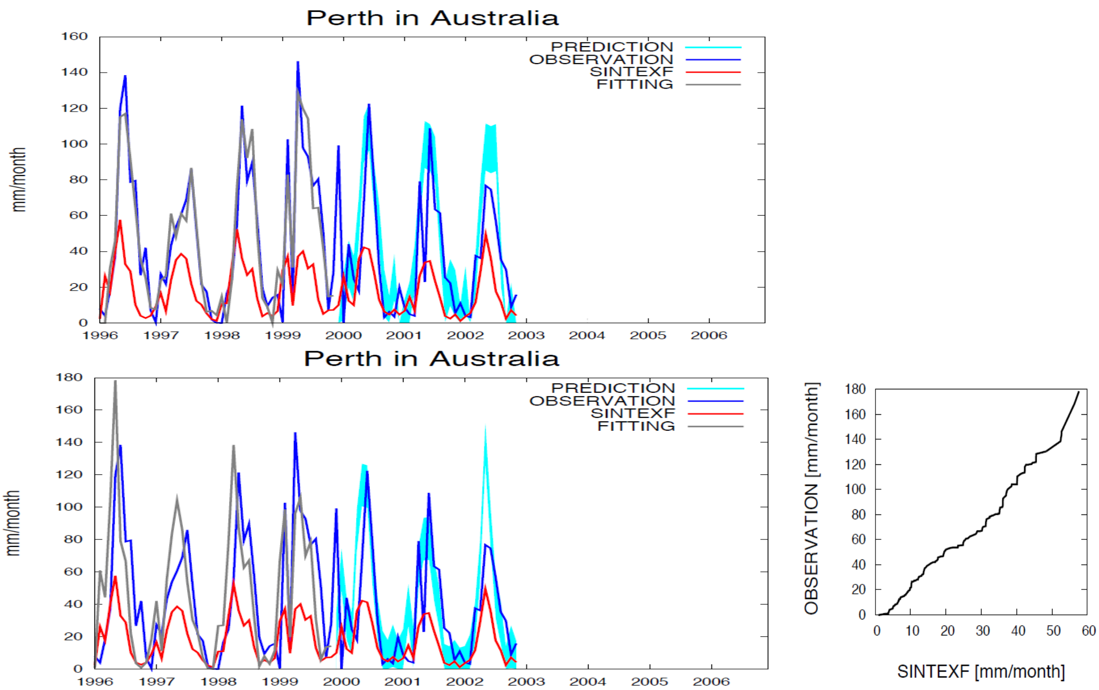

Figure 1. (Upper) Corrected precipitation prediction around Perth beginning from the year 2000: Dark blue and red curves are GPCP's precipitation and SINTEX-F's output respectively. A grey curve in a learning period (not shown the entire domain) is the least square fitting curve and light blue is the bias corrected prediction curve with a standard deviation of the fitting error imposed on it. (Lower left) Similar correction based on Q-matching. (Lower right) the one to one correspondence between CDFs.

3. CONCLUSION

The superiority of the new method is demonstrated for the short-term climate prediction and we can expect further a potential application of it to seamless prediction bridging the gap between seasonal and sub-seasonal time scales, which is quite important for agricultural applications.

REFERENCES

Burg, J. P., 1975: Maximum entropy spectral analysis, *Ph.D. dissertation, Dept. of Geophysics, Stanford Univ.*

Luo, J. J., S. Behera, Y, Masumoto, H. Sakuma, and T. Yamagata, 2008: Successful prediction of the consecutive IOD in 2006 and 2007, *Geophys. Res. Lett.*, **35**, L14S02. (AGU Journal Highlight)

Panofsky, H. A. and G. W. Brier, 1958: *Some Applications of Statistics to Meteorology*, Penn. State Univ. Press, University Park.

Saito, K., A. Koyama, Y. Sawada, and N. Ohotomo, 1994: A Recent Advance in Time Series Analysis by Maximum Entropy Method, *Hokkaido Univ. Press.*

Shukla, J., 1998: Predictability in the midst of chaos: A scientific basis for climate forecasting, *Science* **282**, 728-731.

Wilby, R., C. Dawson and E. Barrow, 2002: SDSM – A decision support tool for the assessment of regional climate change impacts, *Environ. Model Software*, **17**, 147-159.

PREDICTION OF THE FIRST FROST DATES IN NORTHERN CHINA

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Abstract : China is a large agricultural country. Some crops are planted widely from Southern China to Northern China, and meteorological disasters occurred there may reduce the yields of the crops. Among the meteorological disasters, frost is one of the heavily affected meteorological disasters for autumn crops. It is necessary to study the climatic features of frost and predict the first frost date in advance so as to give necessary information to the farmers to reduce the related losses. Beijing Climate Center has developed an operational sub-system which can provide the climatic features and outlook of the first frost date based on more than 200 representative stations in Northern China. A statistical prediction method was developed by using selected predictors from ocean and atmospheric fields. The predictors were used to obtain a stepwise regression equation to provide the prediction of the first frost date. Results show that the method can give a high skill prediction, and the sub-system can also provide frost monitoring information for the related governments and farmers. Further analyses show that the first frost dates have clear climatic features including inter-annual and decadal scales.

Keywords: *first frost date; climatic features; prediction; Northern China*

1. INTRODUCTION

China is a large agricultural country. Meteorological disasters occur frequently and may reduce the yields of the crops in China. Among the disasters, frost is one of the heavily affected meteorological disasters for autumn crops. It is necessary to study the climatic features of frost and predict the first frost date in advance so as to give necessary information to the farmers to reduce the related losses. Analyses of the ground surface temperature and air temperature near the ground from observation stations show that the ground surface temperature has a close relationship with the first observed frost dates, so a unified definition of the first frost date is defined by using the data of the station ground surface temperature (Han et al, 2010). Data analyses show that the first frost dates have clear climatic features including inter-annual and decadal scales (Li et al.,2008; Ye et al., 2008). The first frost date has delayed more days than normal since 1990s. This may be associated with global warming (Ma, 2003). A statistical prediction method for the first frost dates in autumn was developed by using selected predictors from ocean and atmospheric fields in summer. The predictors were selected by REOF analysis and calculations of correlation coefficients. A stepwise linear regression model was developed by using the selected predictors and evaluated by using the hindcast and independent sample test.

2. DATA ANALYSIS AND FORECASTING APPROACHES

We have selected the ground surface temperature from 233 stations and defined the first frost date as the day when the daily lowest temperature is less than or equal to 0^{o}C. The defined first frost date has a close relationship with the observed frost date and can be used as a good substitute data. The climate distribution (figure1) shows that the frost dates begin from late August to late November in Northern China. The dates depend on latitude and altitude and show earlier in northern Xinjiang, eastern Inner Mongolia and northwestern Heilongjiang province, then march from northwest part to southeast part in Northern China. The distributions of mean square deviation of the first frost dates show that the earlier of the first frost dates, the smaller of the mean square deviation. That means the inter-annual scale is large in southern part of Northern China (figure1). The first frost dates delayed more days than normal since 1990s (figure2). This may be associated with the increased temperature tendency in the world.

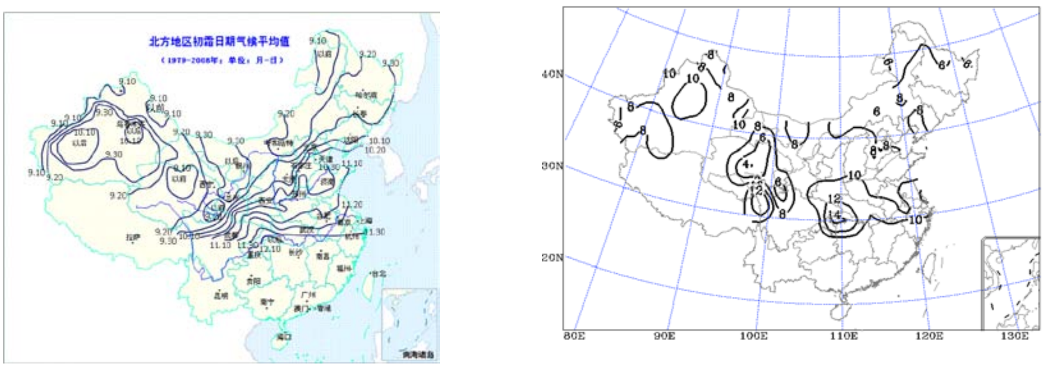

Figure 1. Climate distribution (left) and inter-annual changes (right, mean square deviation) of the first frost dates in northern China (average: 1979-2008; units: day)

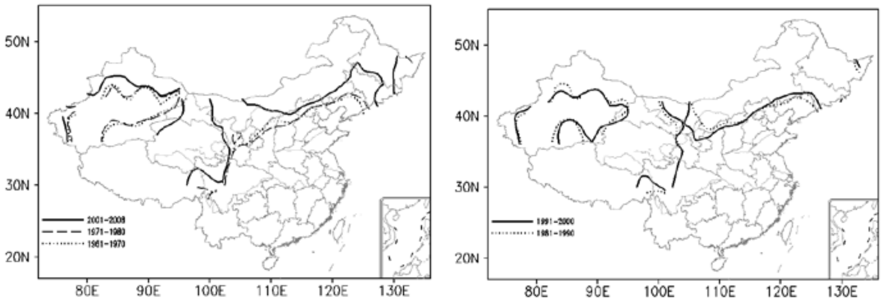

Figure2. Spatial distribution of the first frost dates on September 30 for 5 decades

In operation, the prediction of the first frost date is issued to users in late August. The statistical prediction method for the first frost date in autumn can be developed by using selected predictors from ocean and atmospheric fields in summer, especially in July. The predictors were chosen by REOF analysis and calculation of the correlation coefficient (R) between REOF eigenvectors and atmospheric/oceanic fields. A stepwise linear regression model was developed by using the selected 11 predictors (figure 3). The hindcast and independent sample test show that the skill is higher in most of regions except mountainous areas.

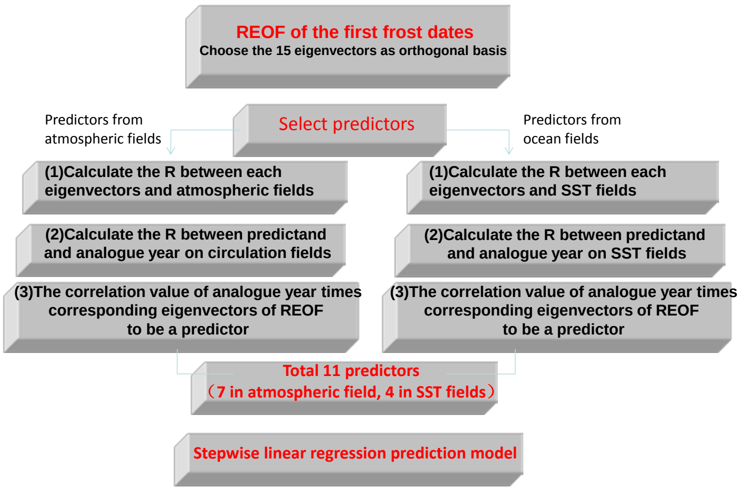

Figure3. The flowchart of statistical prediction model for the first frost dates (R: correlation coefficient)

3. CONCLUSIONS

Based on monitoring and prediction of the first frost date, we have developed an operational sub-system which can provide the climatic features and outlook of the first frost date for more than 200 representative stations in Northern China in real-time. Evaluation of the model performance shows that the skill is higher in most of Northern China. We will further develop the model and provide the modified monthly predictions to satisfy the users' demand.

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REFERENCES

HAN Rongqing, LI Weijing, AI Wanxiu, SONG Yanling, YE Dianxiu, HOU Wei, 2010: The Climatic Variability and Influence of First Frost Dates in Northern China. ACTA GEOGRAPHICA SINICA. 65(5), 525-532. (Chinese paper with English abstract)

Li Xiang, Chen Lijuan, Zhang Peiqun, 2008: Characteristics of interdecadal variations in first-frost date in northern China during 1954-2005. Advances in Climate Change Research, 4(1), 21-25. (Chinese paper with English abstract)

Ma Zhuguo, 2003: Variation of frost days and its relationship to regional warming in northern China. Acta Geographica Sinica, 58(Suppl.), 31-37. (Chinese paper with English abstract)

Ye Dianxiu, Zhang Yong, 2008: Characteristics of frost changes from 1961 to 2007 over China. Journal of Applied Meteorological Science, 19(6), 661-665. (Chinese paper with English abstract)

OUTLOOK ON FREEZE RISK IN MAJOR PEACH GROWING REGIONS IN KOREA UNDER THE RCP8.5 PROJECTED CLIMATIC CONDITION

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Abstract Summary: Freeze risk of dormant buds of peach (*Prunus persica* cultivar 'Changhowon Hwangdo') was evaluated at 3 major peach growing areas in Korea under the climatic condition projected by RCP8.5 scenario. Thirty sets of daily temperature data for every 10 years from 1981 to 2100 were generated randomly by a stochastic weather generator from the monthly data. A thermal time - based dormancy depth index, closely related to the cold tolerance of peach buds, was calculated for each decade from the daily data. Combined with daily minimum temperature, dormancy depth was converted to potential risk of freezing damage. According to the calculation, frequency of freezing damage would be reduced in all 3 regions and the reduction rate could be as high as 55 to 75% by 2080's. However, the severe class risk (over 80% damage) will not disappear in the future and most occurrences will be limited to December to early January. The site-specific evaluation process suggested by this study could serve as a cornerstone for adaptation measures to climate change in agricultural sector.

Keywords: *Peach, Freeze risk, Cold hardiness, Climate change, RCP8.5,*

1. INTRODUCTION

Peach (*Prunus persica)* is a temperate zone fruit tree adapted to winter cold through dormancy, but shows a relatively weak cold tolerance compared with other fruits like apples, pears and grapes. The risk of freezing damage for dormant peach buds is affected by the dormancy depth as well as the ambient temperature (Chung et al., 2009). Warm winters projected by the climate change scenarios might act adversely to the freezing risk in peach trees through weakening of cold tolerance contrary to expectations.

Recently, the climate change scenarios based on RCP (Representative Concentration Pathway) 8.5 was released by Korea Meteorological Administration (KMA) and widely adopted as a national standard for the climate outlook by year 2100. Since the spatial resolution for detecting individual orchards far exceeds the KMA products (~12.5km resolution), we need deeply downscaled climate data to assess climate change impact at landscape scales.

This study was carried out to detect a possible change in freeze risk at landscape scales in 3 major peach growing areas under the future climate projected by RCP8.5 scenario. We used a catchment-specific climate mapping scheme based on recently developed techniques in geospatial climatology to reproduce the local climates at 30m by 30m grid cells (Yun, 2010).

2. DATA AND METHODS

Given a single value for a catchment from the nearest weather office, a daily minimum temperature surface at a 30m resolution across the catchment can be produced by considering the cold air drainage potential (Chung et al., 2006). Daily maximum temperature can be estimated at the same resolution by applying the solar irradiance effect on sloping surfaces (Chung et al., 2009).

We applied these schemes to each of the 840 official watersheds of South Korea to produce monthly average maps for daily maximum and minimum temperature in a reference period (1971-2000). Decadal temperature anomalies projected by RCP8.5 scenario were then added to the reference temperature to produce future temperature surfaces at 30m resolution, each representing a decadal average year for the 9 future periods (2011-2100). Among them, monthly temperature data for the present decade (2000s) and the future 3 decades (2020s, 2050s, 2080s) were extracted and spatially averaged for the pixels corresponding to peach orchards in Icheon (A), Chungju (B), and Yeongcheon-Gyeongsan region (C), which comprise the major peach production regions in Korea (Fig. 1).

Thirty sets of daily temperature data for each decade were generated randomly by a stochastic weather generator. The daily data were used to calculate a thermal time - based dormancy depth index which is closely related to the cold tolerance of peach buds. Combined with daily minimum temperature, dormancy depth can be used to estimate the potential risk of freezing damage on peach buds (Kim et al., 2009). We calculated the freezing risk for each day from November 1 to March 15 in 2000s, 2020s, 2050s, and 2080s, respectively, and counted the number of days with non-zero risk.

3. RESULTS AND DISCUSSION

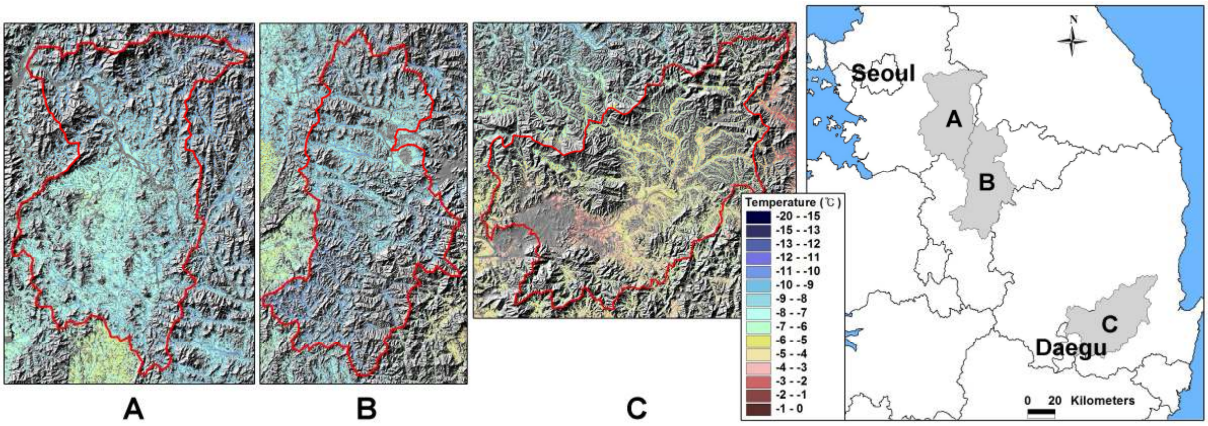

Figure 1. Temperature surfaces across Icheon (A), Chungju (B), and Yeongcheon-Gyeongsan region (C) produced at 30m resolution and their geographical locations.

When the freeze risk was calculated daily for the winter period (from 1 November to 15 March) in the present decade (2000s), regions A and B showed high frequency of freezing damage (30 and 31%), but region C showed low values (16%) across the whole period. In the future decades, the frequency would be reduced in all 3 regions and the reduction rate could be as high as 55 to 75% by 2080's. Figure 2 shows the temporal shift of the simulated freezing risk in the future. In the near future (2020s), there is a significant increase in the frequency of days with severe risk (over 80%) after mid February in regions A and B. But the freezing risk in February decreases steadily to less than the present level and the severe risk days are confined to the early December to early January period in 2080s. Regardless of the warmer winters in the future, the severe class risk at peach orchards will not disappear at all. However, most occurrences with severe damage will be limited to December to early January according to the calculation. This phenomenon might be explained by shortened cold hardiness period caused by winter warming as well as sudden cold waves resulting from the higher inter-annual climate variability projected by the RCP8.5 scenario.

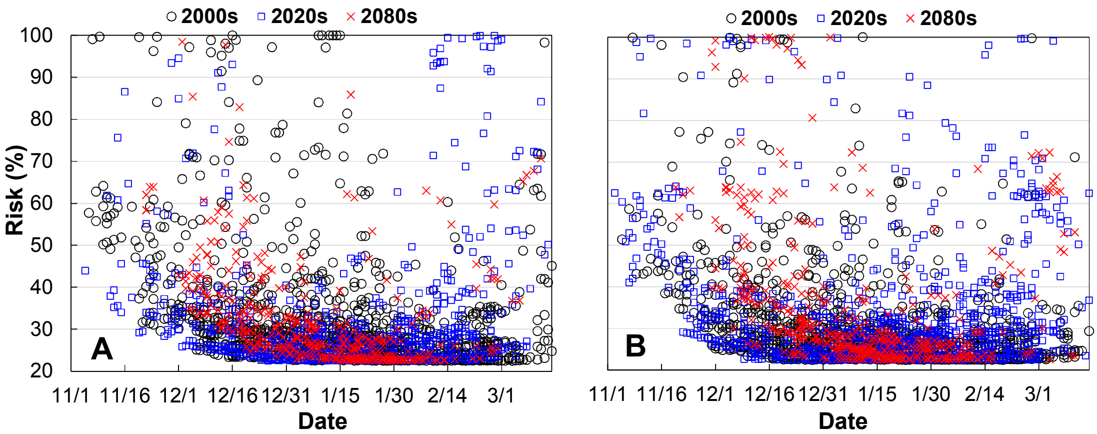

Figure 2. Temporal change in freeze risk of 'Changhowon Hwangdo' peach buds predicted by stochastically generated daily temperature data for the future climate under the RCP8.5 scenario in 2 peach production basins (Left: Icheon, Right: Chungju)

Acknowledgements:

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REFERENCES

Chung, U., H. H. Seo, K. H. Hwang, B. S. Hwang, J. Choi, J. T. Lee, and J. I. Yun, 2006: Minimum Temperature Mapping over complex terrain by estimating cold air accumulation potential. *Agric. For. Meteorol.* **137**, 15-24.

Chung, U., H. C. Seo, J. I. Yun, S. J. Jeon, K. H. Moon, H. H. Seo, and Y. S. Kwon, 2009: Extrapolation of daily maximum temperature in a mountainous terrain. *Asia-Pac. J. Atmos. Sci.* **45**(4), 473-482.

Kim, J. H., S. O. Kim, U. Chung, J. I. Yun, K. H. Hwang, J. B. Kim, and I. K. Yoon, 2009: Geospatial assessment of frost and freeze risk in 'Changhowon Hwangdo' peach (*Prunus persica*) trees as affected by the projected winter warming in South Korea Ⅱ. Freezing risk index based on dormancy depth as a proxy for physiological tolerance to freezing temperature. *Kor. J. Agric. For. Meteorol.* **11**, 213-220.

Yun, J. I., 2010: Agroclimatic maps augmented by a GIS technology. *Kor. J. Agric. For. Meteorol.* **12**, 63-73.

CLIMATE CHANGE IMPACT ON TYPHOON AFFECTING TAIWAN USING MRI 20-KM MESH AGCM TIME SLICE SIMULATIONS

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Abstract: In this study, the future projected change of typhoon affecting Taiwan was investigated using a 20-km mesh Meteorological Research Institute (MRI) atmospheric general circulation model. Realistic rainfall distributions associated with typhoon were found for simulated tracks that resemble observed tracks. The maximum wind speed and minimum surface pressure relationship along the simulated typhoon tracks is similar to the observation. The seasonal cycle and climatological spatial distribution of typhoon track density distribution are reasonably captured. The future (2075–99) projection for typhoons affecting Taiwan by MRI 20-km mesh climate model indicates a significant reduction (by about 20%) in typhoon frequency of occurrence except for super typhoon (wind speed high than 130 knots). Although the typhoon frequency changes at individual grids are typically insignificant for statistical test, the data aggregation to a larger region that typhoons affecting Taiwan can show a significant reduction using monte-carlo test. For the rainfall associated with Taiwan landfall typhoons, projected future change is about 20-30% within the 200km radius from storm center. Nevertheless, frequency of occurrence of gridded rainfall events exceed 50 mm/hr can be more than tripled, suggesting substantial risk increase for floods in the future.

Keywords: *Climate Change, Tropical Cyclone, Typhoon.*

1. INTRODUCTION

Hurricane and Typhoon are the major contributors to the annual damage and economic lost due to natural disaster around the world (EM-DAT, 2009). How the characteristics of these high-impact weather extremes will change in a warming climate has attracted considerable interests from research community. Currently the assessment on the future projected change in tropical cyclone from modeling study concluded that the global frequency of tropical cyclones will likely either decrease or remain essentially unchanged in the future (Knutson et al., 2010). The projected changes in individual basins, on the other hand, are less certain. Despite the number reduction of tropical cyclones, the mean intensity and associated rainfall near cyclone center are likely to increase with anthropogenic greenhouse warming (Knutson et al., 2010). For climate change impact study, the previous global or basin-wise projected changes in tropical cyclone frequency and intensity have only limited usefulness. It would require regional and local information on the detailed changes in the tropical cyclone activities for impact analysis and adaptation planning, and national assessment on storm-related socioeconomic loss. Nevertheless, the reliability of simulated tropical cyclone tracks and intensity distribution for a specific region is much less than the whole basin and uncertainty much higher. Here we present a preliminary study for regional analysis on future projected change in typhoons affecting Taiwan.

2. MODEL VALIDATION

The MRI-AGCM 3.2 model is used to simulate both the present-day climate (1979-2003) and projected climate at the end of 21st century (2075-2099) under the Intergovenmental Panel on Climate Change (IPCC) A1B Scenario. The brief description of the model features and the characteristics of global tropical cyclone activity and their projected changes are discussed in Murakami et al. (2012). The model well simulated the global distribution of tropical cyclones and could reproduce extreme intense tropical cyclones (Categories 4 and 5) that were often lack in global climate model simulation. Since the tropical cyclone detection and tracking scheme is less reliable for relatively weak tropical cyclone, here we will only discuss the those tropical cyclone reach category 1 (maximum wind exceed 33 m/s) or typhoon according western Pacific RSMC. Figure 1 is climatological mean distribution of typhoon passage frequency near Taiwan sampled with 1°x1° box from observation (IBTrACS data archive) and MRI model simulation. On average, for a box near Taiwan, there are about 8.3 typhoons passed through (typhoon center location available at 6 hours intervals) during the 25 year period. There is a slightly underestimate for typhoon occurrence in the MRI model (7.2 per 25 years). But the distribution is reasonably well with more occurrences over the south and east sides of the Taiwan and less on the northwest side. It is noteworthy that the stochastic nature of tropical cyclone genesis and movement might present the detailed tracks comparison from one model realization. Nevertheless, the result here is encouraging. The model does not have problem to capture the proper seasonal cycle with most of typhoon occurred from June to October. The relationship between the typhoon center sea level pressure and surface maximum wind speed long the tracks near Taiwan are also well reproduced even though the model resolution is only 20-km (Fig. 2). For the rainfall associated with typhoon with additional topographic effect from Taiwan, the model simulation resemble to the observed spatial distribution and accumulated amount if similar typhoon track and intensity from observation are used.

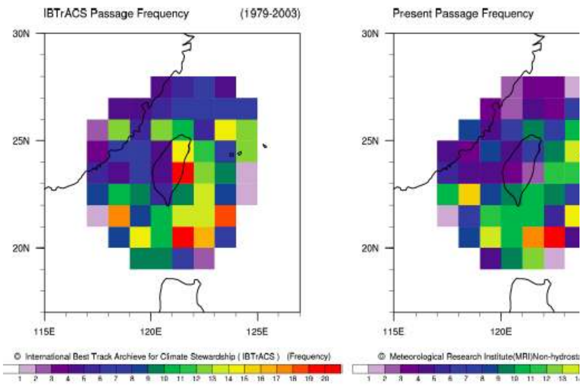

Figure 1. The frequency distribution of typhoon occurrence near Taiwan from observation (IBTrACS, left) and model simulation (right) during 1979-2003 period.

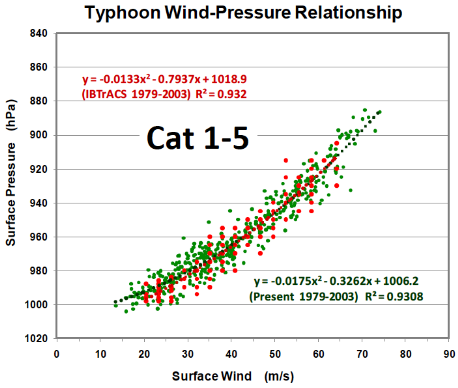

Figure 2. The minima sea level pressure and maximum surface wind speed along the typhoon tracks near Taiwan.

3. PROJECTED CHANGE

The projected frequency of typhoon occurrence near Taiwan are mostly reduced in the 1°x1° sample box. The averaged 7.2 typhoon occurrence per 25 year period lower down to 5.7 in the future (2075-2099). Using the monte-carlo method, this 20% decrease is significant at 90% level. For northern part of region, even though total typhoon number did not change significantly, there is a significant reduction for categories 1-3 typhoons and significant increase for categories 4-5 typhoons, indicating a shift in typhoon intensity in the future. Finally, for the extreme rainfall events associated with typhoon that have enormous societal impacts, the sampled grid rainfall over Taiwan when typhoon passed, despite the general reduction of occurrences in the future, the number of heavy rainfall events exceed 50 mm/hr become more than triple in the future climate (Fig. 3).

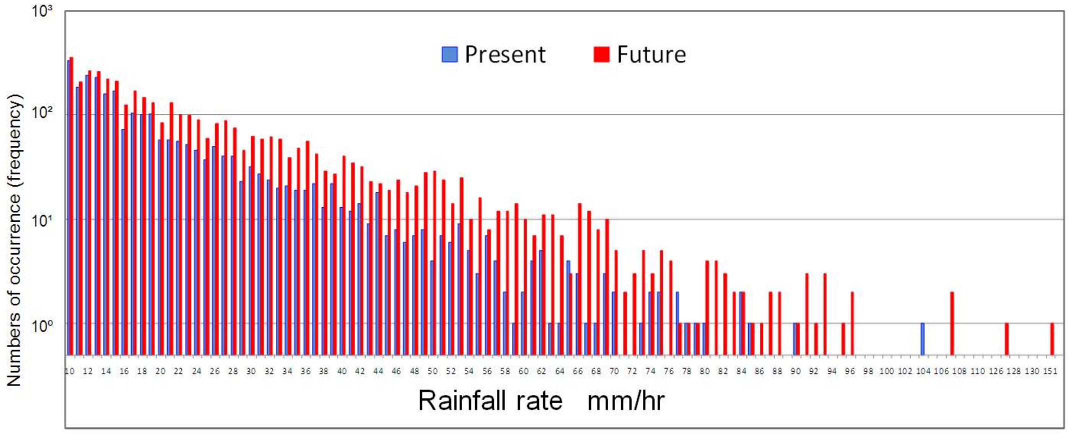

Figure 3. Simulated present-day (blue) and projected future (red) change in hourly grid-point rainfall when typhoon affecting Taiwan. The model grid rainfalls were sampled when typhoon center is within 300km from coast.

Acknowledgements:

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REFERENCES

EM-DAT, 2009: The OFDA/CRED Unternational Disaster Database, www.emdat.be, Universite Catholique de Louvain, Brussels, Belgium.

Knutson, T. R., J. L. McBride, J. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J. P. Kossin, A. K. Srivastava and M. Sugi, 2010: Tropical cyclones and climate change. *Nature Geoscience*, **3**, 157-163.

Murakami, H., and Coauthors, 2012: Future Changes in tropical cyclone activity projected by the new high-resolution MRI-AGCM. *J. Climate*, **25**, 3237-3260.

CLIMATE CHANGE: RISKS FOR RUSSIAN AGRICULTURE

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Abstract Summary: On the basis of climatic models developed in the Voeikov Main Geophysical Observatory we discuss the change of some climate characteristics that are essential for the adaptation of agriculture to climate change. Figures with changes of date sustainable spring transition at 0ºC, sums of active temperatures and of the length of the growing season are presented. Also we discuss problems with maize in Krasnodar region from the climate point of view. This example demonstrates that nowadays risks for agriculture inspired by global warming have to be into account.

Keywords: *Climate, Agriculture*

1. INTRODUCTION

The territory of Russia is a region of the Earth where the temperature increases more quickly. Calculations on the basis of climatic models developed in the Voeikov Main Geophysical Observatory show that the mid-Century temperature will raise at 2-5ºC (1-3ºC in summer) almost in all the territory of the country. It leads to climate impacts on natural systems, population, economy, and in particular, on agriculture.

2. DISCUSSION: AGRO CLIMATIC SITUATION

For the most part of the Russian territory climate change leads to positive results. Length of growing season and sum of active temperatures (>10ºC) arises. (See Figures 1, 2). Territory where highly productive agriculture is possible increases in some times.

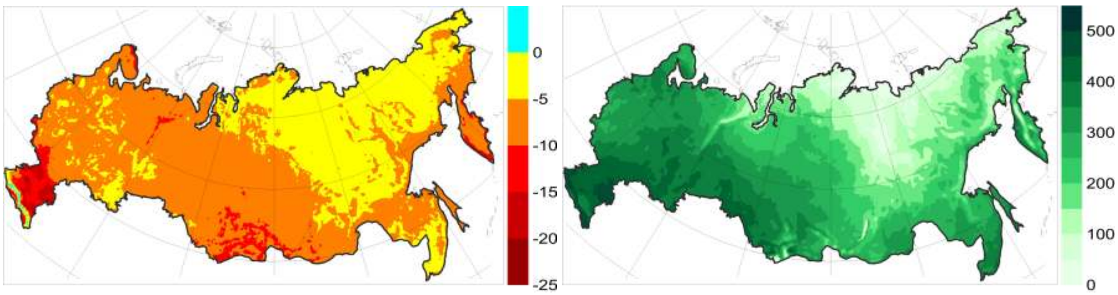


Figure 1. Change of agro climatic indices in warm season. Left: Date of sustainable spring transition at 0ºC (in days); Right: sum of active temperatures above +10ºC

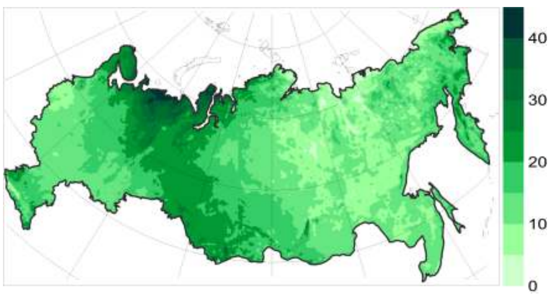


Figure 2. Change of the length of the growing season (in days)

According to calculations, there is a tendency to increased moisture deficit during the growing season in the most parts of Russia. This feature is well expressed in the June-July to mid-XXI. Moisture deficit comes a month earlier (in May) in the southern and central regions of European part of Russia in comparison with other regions.

So if we speak about climate *tendency* we should say that the main problem is the problem of adaptatation. Solving of this problem is possible on the base of changing of structure of sown areas, usage of another crop variety, irrigation and so on. Real risks arise in some regions. Unfortunately these regions are the most productive agricultural regions of Russia. These risks are connected as with the mentioned tendency as with a growing of interannual variability of climate parameters. Here we shortly discuss only one example.

3. EXAMPLE: MAIZE IN KRASNODAR REGION

Maize is not a very popular in Russia because it is very sensitive to the temperature regime. Russia has to import maize, in the same time we export wheat. Ratio of the maximum annual productivity of land to minimum annual productivity of land is 2.7 (for the period of 1990-2010). See Figure 3. This is an interesting situation, because Russian agriculture is very geographically diversified. A small harvest in one region is compensated by the harvest in another one. But this figure demonstrates that the Russia at all is the country of risk farming.

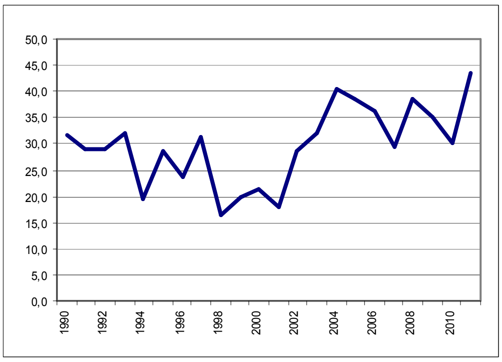


Figure 3. Russian average maize productivity of land (hwt per ha)

Krasnodar region is situated in southern Russia and due to its natural and climatic resourses it is the most productive agricultural region of the country. Maize hybrids that are used in this region have length of growing from 90 up to 150 days. Existing climate change affects the most productive maize hybrids with a long length of growing. In Figure 4 you can see that sum of active temperatures increase up to dangerous values and the same situation with such an extremely dangerous for maize characteristic as the number of days with daily mean temperature >30ºC

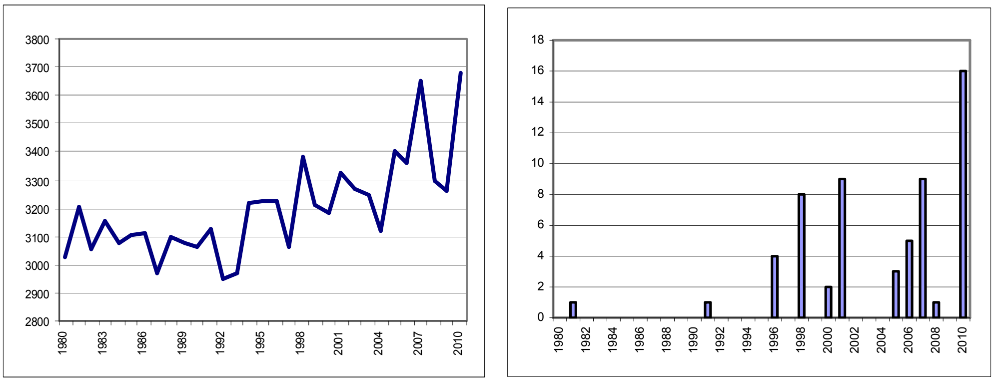
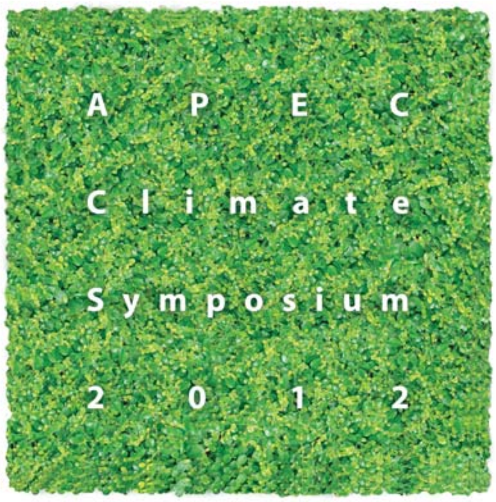


Figure 4. Climatic characteristics of Krasnodar region. Left: Sum of active temperatures (>10ºC, may-september); Right: Number of days with daily mean temperature >30ºC

As to our opinion all it means that farmers will have to stop production of maize in Krasnodar region. At the same time similar warming process in the regions which are situated to the north of this region makes them more attractive for maize production.

3. CONCLUSION

Multiple influences of climate change and the diversity of their effects on agriculture on the vast territory of Russia necessitate the development and implementation of adaptation programs with a thorough regional perspectives. The ongoing changes in some of the most important characteristics of the regional climate, give reason to believe that Russia is growing shortage of adaptation. Delays in the adoption and implementation of government decisions, in particular in the field of agriculture, climate change, first of all - aggravation or increased frequency of dangerous weather and climate events means in the near future, a significant increase in the costs of adaptation..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