CSRD
CLIMATE SERVICES FOR RESILIENT DEVELOPMENT

CIMMYT International Maize and Wheat Improvement Center | ICIMOD | IRI International Research Institute for Climate and Society | UPF Universidade de Passo Fundo | THE UNIVERSITY OF RHODE ISLAND | University of Reading

CLIMATE SERVICES FOR RESILIENT DEVELOPMENT IN SOUTH ASIA

Annual Report
January to December 2018

— Strategic alignment —

CGIAR | RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security | CCAFS

Grant Summary Information

Project name:
Climate Services for Resilient Development (CSRD) in South Asia

Implementing Partner Name:
International Maize and Wheat Improvement Center (CIMMYT)

CGIAR Research Program:
CSRD is mapped to Climate Change, Agriculture and Food Security (CCAFS)

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Report Period:
January 1 to December 31, 2018

Has this project been granted a no-cost extension (NCE)?
A request for a no-cost extension (NCE) has been submitted to Dr. Pete Epanchin on November 13, 2018 that would extend the project to the end of 2019. The request for an NCE is under consideration and we have been advised via email to plan activities in 2019 assuming the extension is granted.

Submitted to:
Dr. Pete Epanchin, Climate Adaptation Specialist
Global Climate Change Office. Bureau for Economic Growth, Education and Environment (E3) USAID | Washington, D.C.

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Cover photos: Md. Zihadul Abedin (top)**,** M. Shahidul Haque Khan (Middle)**,** Elizabeth Gawthrop (bottom)

Project Website: Click here.

Submitted to USAID: December 31, 2018.

[1] Please refer to the section 'Has this project been granted a no-cost extension (NCE)?' for further details.

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Acronyms and Abbreviations

ADB	Asian Development Bank
BACS	Bangladesh Academy for Climate Services
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agriculture Research Institute
BAU	Bihar Agricultural University
BMD	Bangladesh Meteorological Department
BWCSRP	Bangladesh Weather and Climate Services Regional Project
CABI	Centre for Agriculture and Biosciences International
CCAFS	Climate Change Agriculture and Food Security
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal Systems Initiative for South Asia
CPT	Climate Predictability Tool
CSRD	Climate Services for Resilient Development
DAE	Department of Agricultural Extension
DFID	Department for International Development
DST	Decision Support Tool
DSSAT	Decision Support System for Technology Transfer
EWS	Early Warning System
GIS	Geographic Information Systems
HKH	Hindu Kush Himalaya
ICCCAD	International Center for Climate Change and Development
ICIMOD	International Center for Integrated Mountain Development
ICT	Information and Communication Technology
IRI	International Research Institute for Climate and Society
IRRI	International Rice Research Institute
IUB	Independent University of Bangladesh
JTWG	Joint Technical Working Group
LDAS	Land Data Assimilation System
MMM	Multi Model Mean
MOS	Model Output Statistics
MODIS	Moderate Resolution Imaging Spectroradiometer
MoT	*Magnaporthe Oryzae Triticum*
NARC	Nepal Agricultural Research Council
NASA	National Aeronautics and Space Administration
NMME	North American Multi Model Ensemble
PANI	Program for Advanced Numerical Irrigation
PICSA	Participatory Integrated Climate Services for Agriculture
S2S	Seasonal to Sub-Seasonal
SAAO	Sub-Assistant Agricultural Officer
SALDAS	South Asia Land Data Assimilation System

SB	*Stemphylium* blight
SOW	Scope of Work
SSAOs	Sub Assistant Agricultural Officers
SPI	Standardized Precipitation Index
USAID	United States Agency for International Development
UPF	*Universidade de Passo Fundo*
UR	University of Reading
URI	University of Rhode Island
WaterApps	Water Information Services for Peri-urban Agriculture
WRF	Weather Research and Forecasting Model
WUR	Wageningen University and Research

Executive Summary

A global partnership that is aligned with the Global Framework for Climate Services, Climate Services for Resilient Development (CSRD) works to link climate science, data streams, decision support tools, and training with decision-makers in developing countries. CSRD is led by the United States Government and is supported by the UK Government Department for International Development (DFID), UK Meteorological Office, ESRI, Google, the Inter-American Development Bank, the Asian Development Bank, and the American Red Cross. Led by the International Maize and Wheat Improvement Center (CIMMYT), the CSRD initiative in South Asia works with partners to conduct applied research and facilitate the use of climate information to reduce risk for smallholder farmers.

This report details activities of the CSRD project in South Asia during 2018, with emphasis on the second half of 2018 (activities in the first half of 2018 can be found in the semi-annual report). Notable highlights include the following:

- Partnering with the University of Reading (UoR) in 2018, CSRD translated the 'Participatory Integrated Climate Services for Agriculture' (PICSA) training manual into Bangla language and engaged the Bangladesh Meteorological Department (BMD) and the Department of Agricultural Extension (DAE) to pilot PICSA in five Districts across Bangladesh. 40 DAE climate services experts trained by CSRD and UoR have since trained 500 farmers (20% women) in twenty separate PICSA farmer field schools. Farmers involved in these field schools participated in weekly discussion meetings and learning sessions on how to interpret and make use of historical and forecasted climate information to improve farm and livelihood decision making. Now that pre- winter *rabi* season trainings have been completed in five districts, DAE is regularly receiving customized 5-day, location-specific forecasts derived from BMD's Weather Research and Forecasting Model (WRF) for the villages in which PICSA has been piloted. In collaboration with the WaterApps project of Wageningen University and University of Reading, a post-season monitoring and evaluation study will be conducted to assess the effectiveness of PICSA and identify if and how farmers modified crop management decisions or income-generating activity in response to the pre-season trainings and receipt of the 5-day forecasts and management advisories.
- CSRD successfully facilitated two-week science and training exchange during the winter-spring of 2018, which was hosted by IRI at Columbia University, located at the Lamont-Doherty Earth Observatory campus in New York, USA. Four participants each from BMD and DAE participated in the in-depth and intensive trainings on climate services, which emphasized CSRD collaboration and work planning.
- 2018 was an important year for CSRD, which saw the dramatic expansion of partnerships and public engagement in South Asia to promote knowledge and efficient use of climate services. Notable is the co-founding of the Bangladesh Academy for Climate Services (BACS) by the International Center for Climate Change and Development (ICCCAD), the International Research Institute for Climate and Society (IRI) at Columbia University, BMD and the CIMMYT with both in-kind and direct financial support provided by CSRD. BACS convened a number of public events to raise awareness of climate services in Bangladesh, most notably the first of its kind multi-disciplinary and intensive five-day

training on climate services for 23 participants from a diversity of public and private sector organizations, completed in October of 2018.

- Significant progress has been made on climatological research to improve an understanding of the physical drivers of climate in Bangladesh, and to improve the skill of forecasts delivered by the BMD. CSRD is now collaborating hand-in-hand with BMD to revise and improve the current agro-meteorological bulletin for Bangladesh to include an interactive webpage and mobile phone app that allows users to receive sub-district level forecasts combined with easy-to-understand and follow crop-species specific management advisories to avoid risks of drought, excessive rainfall, and thermal stress. The same portal will be linked into DAE's extension and advisory systems for farmers, providing a strong platform upon which climate information services developed through CSRD can be scaled-out to farmers.

- Collaborating with the Bangladesh Agricultural Research Institute, CSRD conducted research station experiments to validate PANI, an irrigation scheduling app, in three districts in southern, central west, and northern Bangladesh. PANI estimates crop water use and amount of plant available soil moisture on a daily basis, while also ingesting and integrating numerical weather forecast outputs. The result is an alert as to whether a specific farmer's field requires irrigation in the next seven days. The field specific alert is sent out on a weekly basis to farmers and irrigation service providers. CSRD also completed business model studies to examine the economic conditions under which the app might be most useful for both farmers and irrigation pump owners. Results from both efforts are being used to implement another season of testing in the 2018-2019 winter season, with the objective of officially releasing the app for use in the second half of 2019.

- CSRD is leading efforts to mitigate the risk of yield-reducing wheat blast infection in South Asia. In collaboration with the University of Passo Fundo (UPF) in Brazil, the CSRD has completed a fully operational beta-version of a weather forecast driven early warning system that estimates the risk of wheat blast outbreak by integrating forecasts of relative humidity, precipitation, and temperature with equations representing the development of wheat blast spores. This early warning system – which will be used by DAE to warn farmers of infection risks so they can take mitigating action – was tested in 2018 with field measurements taken from 800 fields in Bangladesh. Scientists from UPF visited Bangladesh in February-March of 2018 to work with the CSRD team and CSRD partners on data analysis and model development. Further refinement of the model and additional validation will be conducted in early 2019 alongside trainings for DAE on use of the model to provide advisories for farmers. In addition, CSRD has completed a preliminary analysis of historical climate data across South and South East Asia to examine the large-scale geographic risk of disease spread.

- CSRD successfully facilitated an intensive two-week science and training exchange at the International Research Institute for Climate and Society at Columbia University, located at the Lamont-Doherty Earth Observatory campus in New York, in April 2018. Eight senior staff from BMD and DAE attended the training, which provided new opportunities for collaboration and between CSRD partners and exposed participants to new concepts in climate services and climate prediction tools. BMD and DAE continue to build on these experiences in their day to day collaborative work with CSRD in Bangladesh.

- Lentil is an important pulse crop in South Asia, widely eaten as *dhal* with rice. Lentil is highly affected by Stemphylium blight disease which reduces the resilience of smallholder farmers' livelihoods in Bangladesh, India and Nepal. Blight can be partly predicted by cloudy weather, relative humidity, temperature and precipitation. In 2018, CSRD took on an ambitious plan to validate and improve the 'Stempedia' model which makes use of weather data to simulate blight infections and provide advice on the rational use of foliar fungicide application to achieve adequate yields and profits, while limiting environmental impact. To this end, CSRD worked with the Bihar Agricultural University and Nepal Agricultural Research Council through their links to the USAID and Bill and Melinda Gates Funded Cereal Systems Initiative for South Asia to monitor blight in 480 farmers' fields across Bangladesh, India, and Nepal. These data were used to estimate the model's ability to simulate observed infection at a large geographic scale, and provide the basis for modifications in the model's underlying equations to simulate stemphylium blight. Results from this work indicate both over- and under-fit of the model in comparison to observed data in each of the countries studied. The CSRD team is now working to re-calibrate the model to improve fit, while also sampling again from the same number of fields in each country to provide further data to test modifications in calibration. At the same time, CSRD participated in a number of seminars with Universities and national research institute partners on lentil production, most notably in Nepal and India. This has expanded awareness of the model among stakeholders interested in integrated disease management and climate services, providing a basis from which both USAID funded projects will work to foster institutional use of the model as an early warning system for lentil farmers.

- In 2018, CSRD continued its strong collaborations with the Integrated Mountain Development (ICIMOD) to raise awareness of and develop actionable tools to mitigate the negative impact of agricultural drought in South Asia. In addition to facilitating training and exchanges with the Bangladesh Agricultural Research Council (BARC) and Bangladesh Agricultural Research Institutes' (BARI) scientists on this topic, CSRD and ICIMOD's SERVIR Hindu Kush-Himalaya (HKH) initiative facilitated a Regional Knowledge Forum on Drought held at the International Centre for Integrated Mountain Development Centre (ICIMOD) from 8–10 October in Kathmandu. The forum brought together a hundred participants – academics, policy practitioners, researchers, and media persons – affiliated with 50 institutions from in 14 countries across South and South East Asia.
- In addition to these outreach and training efforts, CSRD's partnership with ICIMOD and the SERVIR HKH Initiative has resulted in a beta version of a sub-seasonal to seasonal (S2S) South Asia Land Data Assimilation System (SALDAS) that integrates earth observation data with meteorological conditions, surface and hydrological properties to provide daily estimates of hydrological storage capacity (for example soil moisture, snowpack) and fluxes (rainfall, evapotranspiration, runoff) at a 5 km gridded resolution for the whole of South Asia. Work under CSRD aims to extend this system and test further 1 km^2 downscaled precipitation data as part of the system. To this end, CSRD established three precipitation monitoring grids in Rajshahi, Nilphamari and Dinajpur in Bangladesh (each of which are considered to be potentially drought prone compared to the rest of the country), in which collaborating farmers assisted by collecting daily rainfall measurements. Over the last year, the ICIMOD's integration with the CSRD partnership has partnership has also resulted in significant progress on the development of an online agricultural drought watch portal as a user-friendly interface for these products. The portal disseminates the near real time time-series information on Standardized Precipitation Index (SPI), precipitation, soils moisture and air temperature. The system is being enhanced with the seasonal forecasting options for some of the drought indices in particular locations.

Introduction

Farmers in South Asia provide food to over 1.8 billion people – nearly a quarter of the global population – from small and fragmented farms that in aggregate comprise less than 15% of global agricultural land. In and of itself, this level of productivity is an astonishing outcome. Farmers however face a wide variety of increasingly difficult challenges that undermine their ability to sustainably maintain or increase farm productivity. Among these challenges, climatic variability is a core concern. Rising temperatures and thermal heat stress can lower the productivity of the region's major cropping systems. Delayed and variable monsoon onset and quantity undercut farmers' ability to select appropriate crops and to decide when and how to plant and irrigate them. Extreme weather events including storms and floods present consistent risks to smallholders, while straining regional food production, distribution and supply. New crop pests and diseases pose additional challenges.

Climate Services for Resilient Development (CSRD) is a global partnership that connects climate science, data streams, decision support tools, and training to decision-makers in developing countries. CSRD responds to the challenges faced by smallholder farmers identified above. The partnership is led by the United States Government and is supported by the UK Government Department for International Development (DFID), UK Meteorological Office, ESRI, Google, the Inter-American Development Bank, the Asian Development Bank, and the American Red Cross. In South Asia, CSRD is led by the International Maize and Wheat Improvement Center (CIMMYT), with funding from USAID. The partnership aims to increase resilience to climate change in South Asia by creating and providing timely and useful climate data, information, tools, and services. These activities aligned with the Global Framework for Climate Services and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

CSRD activities in South Asia have three core objectives as follows:

1. Impact-based national-scale decision tool platforms to support the Bangladesh Meteorological Department's (BMD) Sector 3 agro-meteorology track
2. Collaborative development and refinement of South Asian regional-scale agro-climate decision support tools, services, and products
3. Coordination with CSRD partners in-country to ensure progress on the work streams under the CSRD South Asia and Bangladesh working group

This report summarizes and updates readers on CSRD activities during the whole of 2018, with most emphasis placed on work conducted from July through December of 2018 (activities in the first half of 2018 can be found in the semi-annual report). Brief details of work plans for the first half of 2019 are also provided.

Overview of the CSRD consortium in South Asia

In South Asia, CSRD receives guidance from the United States Agency for International Development's (USAID) in addition to the multi-partner CSRD Steering Committee. CIMMYT facilitates research and climate services capacity development and outreach linkages between the CSRD partners in South Asia, with a core focus on Bangladesh and secondary emphasis given to Nepal and India. The CSRD consortium works to improve usefulness and agricultural relevance of meteorological forecasting and climate information through science partnerships, applied research, technical support, and capacity development.

CSRD in Bangladesh

Much of the CSRD consortium's efforts in South Asia emphasize the country of Bangladesh as detailed in the project's Objective 1. The two core project partners include the Bangladesh Meteorological Department (BMD) and Department of Agricultural Extension (DAE), both within the government of Bangladesh (under the Ministry of Defense and Ministry of Agriculture, respectively). BMD works to inform the public with up-to-date on climate information and forecasts. BMD maintains the country's densest network of surface and air observatories, radar and satellite stations, and geomagnetic and seismological observatories. DAE conversely has more than 14,000 grassroots level extension agents know as Sub-Assistant Agricultural Officers (SSAOs). These SAAOs provide regular technical assistance to farmers across Bangladesh. Both organizations are also involved in large-scale World Bank funded climate information services initiatives, including the Bangladesh Weather and Climate Services Regional Project (BWCSRP), and actively make use of CSRD's technical and capacity development products in this and associated initiatives.

CSRD works with both agencies to collaboratively develop decision support tools (DSTs) and climatically informed farmer advisories for improved crop management that reduce production risks. CSRD's technical products are designed to provide relevant advice and weather-forecast based emergency advisories to farmers during cropping seasons when weather and climate information is most crucial. Both direct extension and ICT-based dissemination methods are used to reach farmers. CSRD's overarching goal is to establish strong and collaborative partnerships supporting climate services that will outlast the timeframe of the project. To achieve this goal, CSRD also collaborates with BMD and DAE staff involved in the World Bank funded 'Bangladesh Weather and Climate Services Regional Project' (BWCSRP).

The Bangladesh Agricultural Research Institute (BARI) is another CSRD core partner. BARI works to evaluate the evaluating weather-forecast enabled irrigation scheduling decision support tool developed by CIMMYT known as 'PANI' (Program for Advanced Numerical Irrigation). BARI is also a core collaborator in the development and implementation of a wheat blast (*Magnaporthe oryzae* pathotype *Triticum*) disease risk early warning system for farmers, both nationally (Objective 1) and regionally (Objective 2).

South Asia regional collaborations

The International Center for Integrated Mountain Development (ICIMOD), which manages the USAID funded SERVIR-Hindu Kush Himalaya (HKH) initiative, is a core CSRD partner.

CSRD supports' ICIMOD's ongoing efforts aligned with the SERVIR-HKH develop a remote-sensing enable drought monitoring and forecasting system for South Asia (see Objective 2). This work adds a regional dimension to CSRD' activities in that they encompass drought monitoring efforts in Afghanistan, Pakistan, Nepal, and Bangladesh in support of CSRD's second objective.

CSRD is also collaborating with the Bangladesh Agricultural Research Council (BARC), which is the apex body of the National Agricultural Research System (NARS) in Bangladesh. BARC is sub-contracted by ICIMOD to implement a national center for drought monitoring and forecasting in support of Objective 2. Computer facilities have been provided to BARC through CSRD to build national scientists' capacities to implement a nationally-based drought monitoring and forecasting center using the results of CSRD's work.

Several additional informal yet significant partnerships have developed on an informal and synergistic basis since in 2018. These include Bihar Agriculture University (BAU) in India, and the Nepal Agricultural Research Council (NARC) to develop weather-forecast based models and warning systems for lentil *Stemphylium* disease in Nepal, India, and Bangladesh. An additional informal yet crucial partnership developed since January 2018 is with the International Centre for Climate Change and Development (ICCCAD) at Independent University in Bangladesh. Alongside the International Research Institute for Climate and Society (IRI), as well as CIMMYT through CSRD, ICCCAD is a co-founder organization of the Bangladesh Academy for Climate Services (BACS) that focusses on transformational educational change in climate science, and convening stakeholders for trans-sectoral dialogue of climate services to meet the needs of decision makers across sectors in Bangladesh. BACS activities apply to CSRD's Objective 3.

International collaborations

CSRD has also forged several research and development partnerships with international organizations and advanced research institutes to popularize climate services. CSRD signed an agreement with the University of Reading in 2018 to provide training and technical back-stopping to DAE's implementation PICSA (Participatory Integrated Climate Services for Agriculture) in five districts across Bangladesh. Efforts to implement PICSA under CSRD's Objective 1 in Bangladesh are also supported by a synergistic partnership Wageningen University's Water Information Services for Peri-urban Agriculture (WaterApps) project. In addition to PICSA, the University of Passo Fundo (UPF) in Brazil collaborates with CSRD scientists in Objectives 1 and 2 to model and develop weather-forecast based early warning systems to mitigate the threat of wheat blast disease in South Asia. Both WaterApps and UPF collaborate on an entirely in-kind basis. The University of Rhode Island is another CSRD partner that supported the analysis of climate data and the development of the PANI algorithm in 2018. Further information on team members involved in CSRD activities in South Asia can be found in Annex 1. CSRD's formal subcontractors are found in Annex 2.

CSRD is built on a foundation of strong partnerships, including in-kind synergistic collaborations Wageningen University's WaterApps project, the University of Passo Fundo (UPF), the Nepal Agricultural Research Council (NARC), Independent University of Bangladesh (IUB) and the Bihar Agricultural University (BAU) in India.

CSRD's theory of change and strategic pillars in South Asia

CSRD's theory of change is discussed in detail in the 2016-17 CSRD in South Asia Annual Report. The global CSRD consortium operates with four strategic pillars as shown below. Each of the activities in CSRD's work plan that are reported on in this document are aligned with one or more of these pillars, as described in the 'CSRD's Action and Learning Framework' sections found at the end of each activity summarized in this report.

Pillar I: Create the solution space
Establish a problem-focus, engage key stakeholders, and create a platform for sustained communication and collaboration. Build synergies among relevant programs.

Pillar II: Use quality data, products, and tools
Provide decision-maker access to useful and available information and technology. Develop tailored products and services responsive to specific needs.

Pillar III: Build capacities and platforms
Support the use of targeted products and services. Promote sustainability, scalability, and replicability.

Pillar IV: Build knowledge
Identify and promote good practices among the global climate services community. Support research efforts and innovation that increase the effectiveness of climate services.

Objective 1: Impact-based national-scale decision tool platforms to support the Bangladesh Meteorological Department's (BMD) Sector 3 agro-meteorology track

Sub-Objective 1.1. Agricultural climactic information framework improved

Background

No matter how precise and useful forecasts might be, farmers in South Asia are largely unfamiliar with the use of meteorological and climate information to improve their decision making and farm management capacity. Preliminary field research conducted in 2016-17 when CSRD began to scale-out the use of climate information as a service to farmers – be they in the form of forecasts, early warning systems, or management advisories – will require basic capacity development among farmers to better understand the implications and usefulness of climate information. Sub-Objective 1.1 activities therefore focuses on activities to improve how farmers in South Asia may conceptualize of and plan their livelihoods using climate and weather information. Much of this work involves close coordination and partnership with DAE in Bangladesh, and efforts to assure that front-line agricultural extension agents are able to understand and explain climate information services effectively to farmers, while fostering training and awareness building so that farmers can effectively use climate information to reduce risk in their farming systems.

Activity 1.1.1 Updating agro-meteorological information for major food and income staples in Bangladesh using farmer decision making frameworks

Product 1. Crop-specific farmer decision making frameworks and extension training to improve the quality and usefulness of agro-meteorological forecasts

In 2018, CSRD established a partnership with the University of Reading to work alongside DAE to adapt and pilot the 'Participatory Integrated Climate Services for Agriculture' (PICSA) across five districts in Bangladesh. First developed in sub-Saharan Africa and then in Latin America, the CSRD partnership is now leading Asia's first-ever piloting of the PICSA process. PICSA is a participatory, discovery-learning based approach to educate agricultural extension staff in climate information services. These extension agents subsequently work with groups of farmers well before the start of the agricultural season to analyze historical climate information and use participatory and interactive tools and techniques to identify and choose crop, livestock and livelihood options best suit individual farmers' preferences and circumstances to adapt to climatic conditions. Immediately prior to and during the cropping, season extension staff and farmers meet to discuss and consider the practical implications forecasts on the plans farmers have made. More details on how the PICSA process was planned with the synergistic participation of Wageningen University's WaterApps project, Reading University, DAE and BMD can be found in the 2018 CSRD semi-annual report.

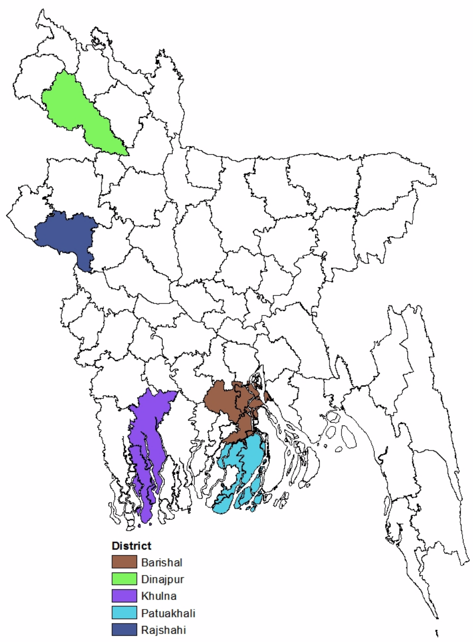
Following intensive planning in April of 2018, and with the support of CSRD, the Department of Agricultural Extension planned and implemented PICSA in five districts of Bangladesh in the second half of the year. Activities commenced in August of 2018 when ten Cadre Officers of DAE who function at Upazila (sub-District) Agriculture Officer and Agriculture Extension Officer levels underwent intensive, week-long training to become PICSA expert trainers.

These Cadre Officer PICSA experts subsequently trained 40 Sub-Assistant Agriculture Officers form ten sub-Districts of Barisal, Dinajpur, Khulna, Patuakhali, and Rajshahi districts in residential trainings.

Left: CSRD translated the 'Participatory Integrated Climate Services for Agriculture' (PICSA) training manual published by the University of Reading into Bangla language so that it can be more easily utilized by extension services in Bangladesh. Right top: Saskia Werners, Uthpal Kumar (Wageningen University's WaterApps project), Fahmida Khan and Ghulam Hussain (CSRD and CIMMYT), Sam Poskitt and Peter Dorward (University of Reading), and S.M. Quamrul Hasan (BMD) meet at Khulna University in Bangladesh to discuss training of DAE extension staff in PICSA methods in April of 2018. Right bottom: Farmers in Khulna District discuss resource allocation maps they drew of their farms to identify climate-sensitive crop and livestock activities as part of the PICSA process. This activity enables farmer data-driven and climate-smart decision making. Photos: T. J. Krupnik.

These 40 extension agents have since trained 500 farmers (20% women) in twenty separate PICSA farmer field schools who participated in weekly discussion meetings and learning sessions during which the tools and techniques utilized in the PICSA process were deployed. Each of these interactive discussions sessions stresses the importance of farmers examining historical climatic records for the locations in which PICSA groups were formed to inform agricultural planning and decision making. To this end, CSRD collaborators in the Bangladesh Meteorological Department were instrumental in the compilation, analysis, and supply of line and bar chart graphs showing historical temperature and precipitation trends that were utilized by DAE and farmers.

Now that pre- winter *rabi* season trainings have been completed in five districts, DAE is regularly receiving customized 5-day, location-specific forecasts derived from BMD's Weather Research and Forecasting Model (WRF) for the villages in which PICSA has been piloted. Forecasts are prepared by BMD's focal points who collaborate with CSRD, and are sent directly to DAE who are subsequently deploying them to lead farmers both in-person and by telephone. Lead farmers then provide forecast information to farmers that are a member of their farmers' organization or group. But before forecasts are transferred to lead farmers, CSRD is assisting DAE by providing farm management advisories based on the forecasted risk of crossing crop-species specific thresholds for thermal stress, dry spells, and heavy rainfall events that could damage crops. This process will continue until May of 2019 when the last crops of the *rabi* season (primarily *boro* rice or maize) are harvested. More details on the thresholds and the scientific basis for this process can be found in Activity 1.3.1.



Districts in Bangladesh in which 'Participatory Integrated Climate Services for Agriculture' (PICSA) are being implemented with DAE's leadership and technical and financial support by CSRD. 500 farmers in 20 different villages in five districts participated in weekly pre-season PICSA learning exchanges and are now receiving customized crop-species specific forecasts for their location as part of PICSA piloting in Bangladesh – the first of its kind in Asia.

Planned activities in Quarters 1 and 2 of 2019:

In collaboration with the WaterApps project and University of Reading, a post-season monitoring and evaluation study will be conducted to assess the effectiveness of PICSA and identify if and how farmers modified crop management decisions or income-generating activity in response to the pre-season trainings and receipt of the 5-day forecasts and management advisories. This information will be utilized to identify ways to improve the PICSA process, which will subsequently be deployed in the following monsoon *aman* rice season with financial support from CSRD and WaterApps, as well as in-kind support from DAE. This second season of activity will continue until roughly November of 2019, after which a last monitoring and evaluation study will be conducted. Prior to the *aman* season, CSRD is investigating ways that BMD can push forecasts using mobile phone and ICT services directly to DAE, lead farmers, and farmers participating in the PICSA groups. Utilizing the results and learning of both seasons of PICSA activities, CSRD is supporting DAE to seek internal funding from Government of Bangladesh bodies to continue and expand PICSA to other locations throughout and implement regular farmer trainings and forecasting as a regular and sustained part of farmer extension programs.

Contribution of Activity 1.1.1 to CSRD's Action and Learning Framework:

Pillar 1, Indicators 1.1 and 1.2, Pillar 2, Indicators 2.1 and 2.2, Pillar 3, Indicators 3.1, and 3.2, and Pillar 4, Indicator 4.1 (see Annex 3).

Sub-Objective 1.2. Climate services capacity development

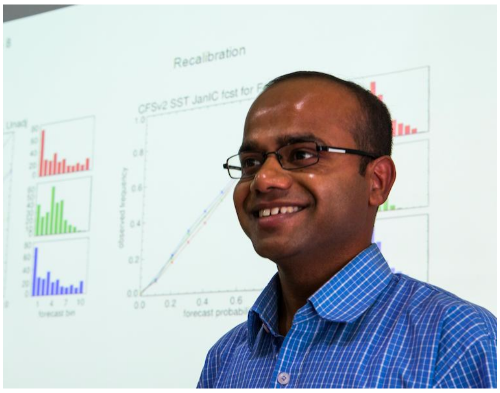
Background

Sub-Objective 1.2 activities also place emphasis on technical improvements in climatological services, data acquisition and analysis, forecasts skill improvements, and climatological research in Bangladesh.

Activity 1.2.1. Climate services capacity development in partnership with the International Research Institute for Climate and Society

Product 1. BMD agricultural climate services assessment

This activity was completed on schedule third quarter of 2017, with the assessment provided in Annex 4 of the 2016-17 CSRD in South Asia Annual Report. The further details of ongoing work resulting from the assessments recommendations are described in the 2018 semi-annual CSRD report. Many of the suggestions provided in the 2017 BMD agricultural climate services assessment were focused on technical skills development and research which are summarized in 'Activity 1.3.1: *Iterative development and refinement of decision support platforms with improved agro-meteorological services visualization and communications tools.*'


IRI's Dr. Nachiketa Acharya provided intensive on-the-job training to CSRD focal point climatologists at BMD in Dhaka during the second half of 2018. Photos: E. Gawthrop.

In addition, a number of other suggestions were made during the assessment for how to improve BMD's existing agro-meteorological bulletin. CSRD has responded by developing a beta-version of an interactive, map based agro-meteorological bulletin and accompanying mobile phone app that integrates numerical weather forecasting model predictions with easy-to-understand crop-species specific management advisories. Further details and visuals of the preliminary version of these products can be found in Activity 1.3.1 below, in the section *Forecast mapping of crop species-specific probabilities of encountering thermal stress.*

Lastly, following on recommendations emerging from the climate services assessments Dr. Nachiketa Acharya from IRI revised Bangladesh in early August of 2018 to conduct on-the-job training for BMD collaborators as well as to advance work on sub-seasonal forecasting. After introducing BMD participants to how they can access North American Multi-Model Ensemble (NMME) and general circulation models available through IRI, training topics included linear regression and ordinary least square regressions to calibrate monthly NMME forecast outputs by fitting ordinary least square regression between models and observed datasets. Methods for preparation of code to generate monthly forecast based on ordinary least squares calibration procedures were also covered, which are currently under iterative testing by IRI and BMD.

Product 2. National scientist training, exchange, and CSRD planning with IRI

CSRD successfully facilitated two-week science and training exchange was hosted by IRI at Columbia University, located at the Lamont-Doherty Earth Observatory campus in New York, USA. The Director of BMD, Mr. Shahmsuddin Ahmed, and three lead climatologists from BMD (Abdul Mannan, Bazlur Rashid, and S.M. Quamrul Hassan) participated in an intensive two-week training, while four participants from DAE attended a week-long training.

Dr. M. Shahabuddin and Mrs. Rahana Sultana from DAE collaborating with Mr. Abdul Mannan and Mr. Shahmsuddin Ahmed of BMD in climate services planning for Bangladesh while at IRI in early 2018. Photo: T.J. Krupnik.

These included Dr. M. Shahabuddin (Additional Director Planning & ICT management), Dr. Aziz Mazharul (Additional Deputy Director and Project Director, Agro-Meteorological Information Services), Mr. Md Saiful Islam (Additional Deputy Director, Crop Wing) and Mrs. Rahana Sultana, Upazila Agriculture officer). Further details on this activity can be found in the 2016-17 CSRD in South Asia Annual Report.

Planned activities in Quarters 1 and 1 of 2019:

All activities for this CSRD Product are described in the Product 1 table above. No further international exchanges are planned at this time.

Contribution of Activity 1.2.1 to CSRD's Action and Learning Framework:

Pillar 1, Indicator 1.1and Pillar 4, Indicator 4.1 (see Annex 3).

Sub-Objective 1.3: Development of forecast products, impact assessments, and decision support tools for agriculture, fisheries and/or livestock

Activity 1.3.1: Iterative development and refinement of decision support platforms with improved agro-meteorological services visualization and communications tools

Background

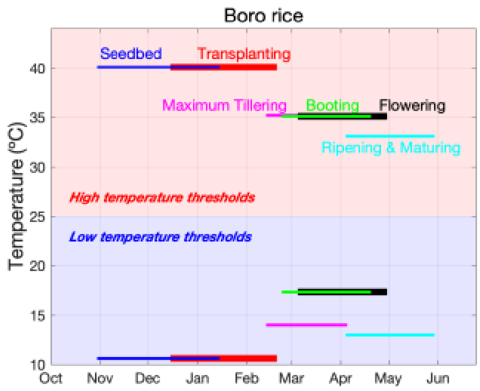
At the request of BMD during pre-CSRD project consultation, three areas for technical support and collaboration were highlighted. These are detailed in this section of the report and are a key component of 'Activity 1.3.1Sector 3 Agro-meteorology track' that responds to BMD's requests for technical assistance. Topics included (1) Provision of GIS maps displaying climatic stresses, (2) forecasts for irrigation management, (3) the development of "impact based agro forecast" systems with emphasis on the development of crop specific pest and disease models.

In response, CSRD's Activity 1.3.1 includes the following research topics and products: (a) Agriculturally short- and extended-range forecasts graphically depicted as climactic stress risk maps for major cereals, (b) an ITC platform for meteorologically integrated irrigation management services, (c) Spatially explicit and meteorologically driven wheat blast (*Magnaporthe oryzae Triticum*, MoT) disease risk assessments for Bangladesh.

Progress on these topics in 2018 are detailed below.

***Product 1. Agriculturally relevant climatological analysis and improved extended-range forecasts and outlooks*[2]**

[2] The initial Scope of Work developed by USAID based on the 12 July of 2016 consultation with BMD suggested focusing on the development of 'Seven-day rainfall forecasts with 15-day accumulative rainfall outlooks' (Task i. ii.). Upon commencement of the project, CSRD staff found that BMD is already generating seven-day rainfall forecasts using WRF model outputs. 15

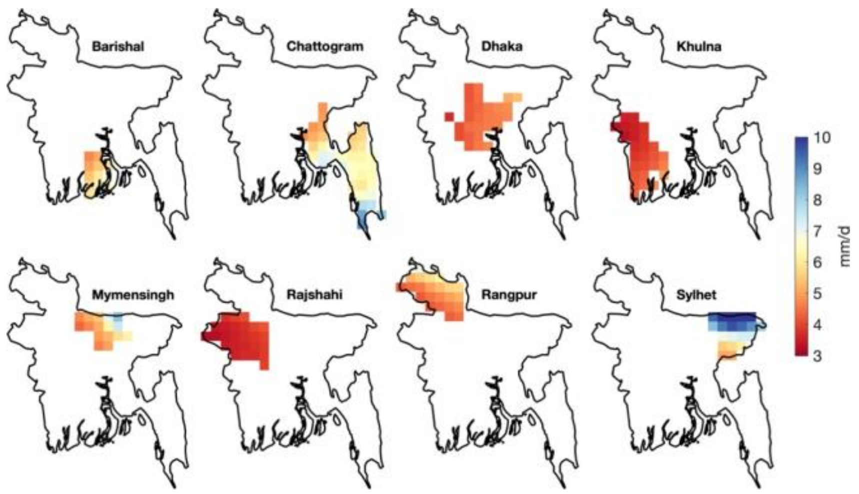


High and low temperature thresholds suggested for Boro rice in Bangladesh and the corresponding date ranges and stages during which they apply. Stage names were omitted for low temperatures.

Utilizing historical climate data to inform the present and future

Deriving actionable climate information for crop planning from historical data

Historical data can be a powerful source of information to provide insights to the design of appropriate climate services and advisories. When analyzed in consideration of crop-species stress thresholds, data collected by BMD and other meteorological agencies can be used to identify opportunities to reduce climate-related production risks, forming the basis of advisories to mitigate against the negative effects of extreme temperatures and precipitation, or dry spells, in addition to other threats. In 2018, CSRD completed the analysis of historical temperature data from BMD weather stations to generate maps of the probability of occurrence of a potential abiotic stress risk associated with high and low temperatures in Bangladesh as per thresholds defined based 350 scientific papers screened from a systematic literature review of >24,000 papers from three databases (Web of Science, Agricola, CABI and Scopus). The resulting database consists in temperature values below/above which the main crops grown in Bangladesh can be subject to a high risk of damage.



Interannual average of daily precipitation for the eight divisions in Bangladesh obtained from APHRODITE precipitation product. Results identify eight distinct precipitation 'zones' in which specific thresholds for rainfall are being set to inform advisories to be deployed by BMD and DAE.

Historical precipitation data obtained from multiple gridded products were also analyzed in terms of their ability to represent precipitation variability in different regions within Bangladesh. This was necessary to establish reference values at the level of Divisions (administrative units in which the results will be aggregated), to be later incorporated into the

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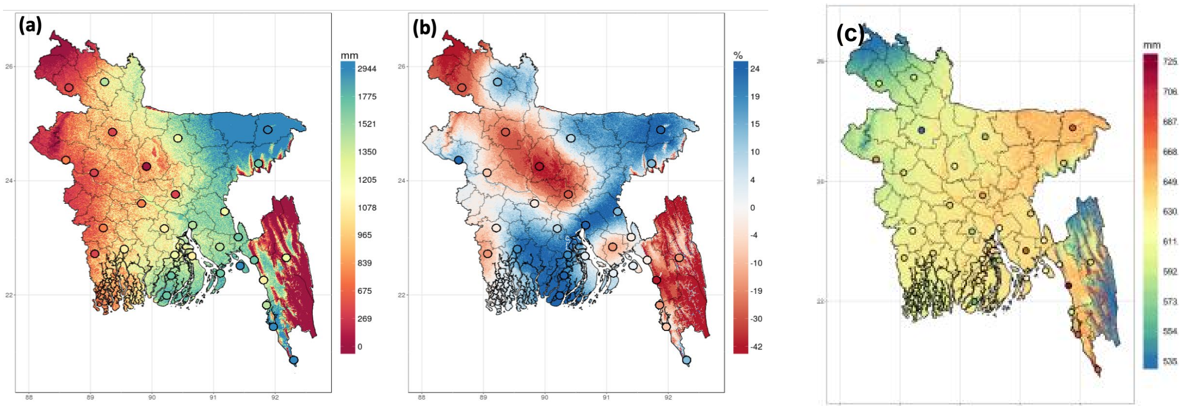
cumulative rainfall outlooks are however relevant in the context of several other forecasting parameters that were identified during the BMD skills assessment. Importantly, these topics are more agriculturally relevant for farmers than generic seven-day or 15-day accumulative rainfall outlooks. With the endorsement of BMD, CSRD has therefore begun focusing on these forecasting needs under this activity product now renamed 'Agriculturally relevant climatological analysis and improved extended-range forecasts and outlooks'.

agrometeorological advisories as well as the previous case of temperatures. The results of this work are depicted above.

Mapping of the seasonal progression of the monsoon and deviation from historical normal

The onset and progression of the monsoon is an important factor influencing cropping systems in South Asia and Bangladesh. At the request of BMD to improve the supply of information on monsoon dynamics, the CSRD team has completed an analysis utilizing physical factors such as landscape elevation and directional aspect as covariates in a geo-spatial regression analysis. The map below shows an example of how accumulated precipitation and anomalies from the historical average will be presented and included in BMD's agro-meteorological bulletin in 2019.

For this specific case study from in July 2017, CSRD's science team observed a spatial distribution that fits well to the climatological pattern of precipitation in Bangladesh, which shows a West-East gradient in the amount of precipitation. On the other hand, for anomalies measured at the same date, it is observed that for some regions this amount is clearly below the average, while for is above. Additional analyses have focused on accumulated reference evapotranspiration and its spatial heterogeneity. This information highlights the need to provide location-specific information, and can be useful for DAE and the Ministry of Agriculture to monitor the rainfall progression for specific crops and in the context of the historical record. The same information can be used to make data-driven decisions based on customized and updated information regarding management of monsoon season transplanted summer *aman* rice, for example, which is Bangladesh's most widely grown crop.

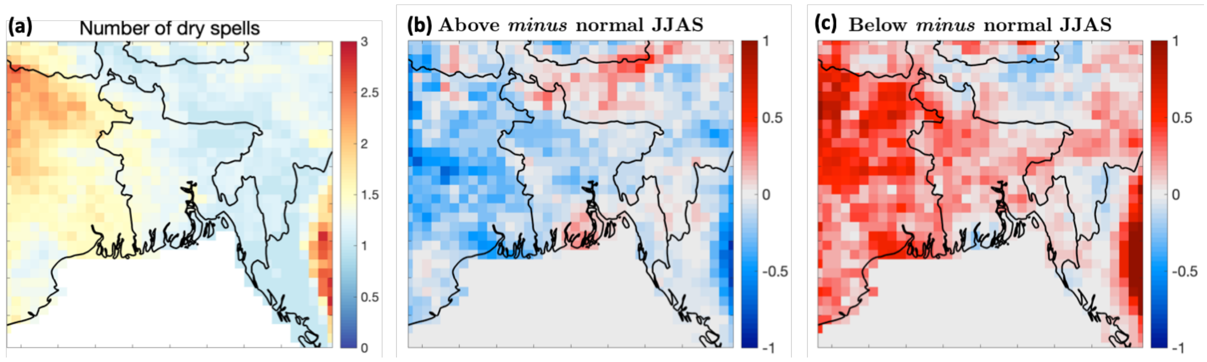


(A) Map of the seasonal progression of precipitation in 2017 until the month of July as shown in the 2018 mid-term annual report. (B) Detailed subsequent analysis of the deviation of accumulated precipitation with respect to the long-term average. (C) Map of accumulated reference evapotranspiration.

Historical mapping of monsoon dry spells (consecutive 5 days with < 1 mm, monsoon seasonal scale)

Despite being Bangladesh a country with a high annual rainfall in average, the strong effect on agricultural systems of wet conditions means that the occurrence of dry spells can have a negative impact on crop productivity, especially when accompanied by high temperature. An enhanced understanding of the spatial and temporal occurrence of dry spells can therefore inform agricultural planners to implement improved risk-mitigating measures in Bangladesh. As detailed in the 2018 mid-term report, after collecting and processing long-term meteorological data from BMD weather stations and public access gridded products, the occurrence of dry spell events over the last four decades for different regions within Bangladesh was quantified and characterized. The CSRD team identified a clear East-West gradient of dry spells using these data.

This analysis was extended in the second half of 2018, through use of long-term gridded precipitation data to better understand the behavior of dry spells in the context of the currently available probabilistic seasonal precipitation forecasts under development by the project. Since these forecasts only provide information about average anticipated conditions for the predicted season relative to past seasons, it is important to understand the behavior of variables of interest at sub-seasonal scales not currently available from these products. It is important to note here that seasonal probabilistic forecasts are usually calibrated using gridded products rather than point data. The maps below show an average interannual climatology of the number of dry spells during the months of June to September (JJAS), and the corresponding composites for dry and wet years classified according to their tercile distribution (in other words, division into three distinct groups).



Average number of dry spells in July to September: (a) interannual average, (b) anomalies during wet years, and (c) anomalies during dry years.

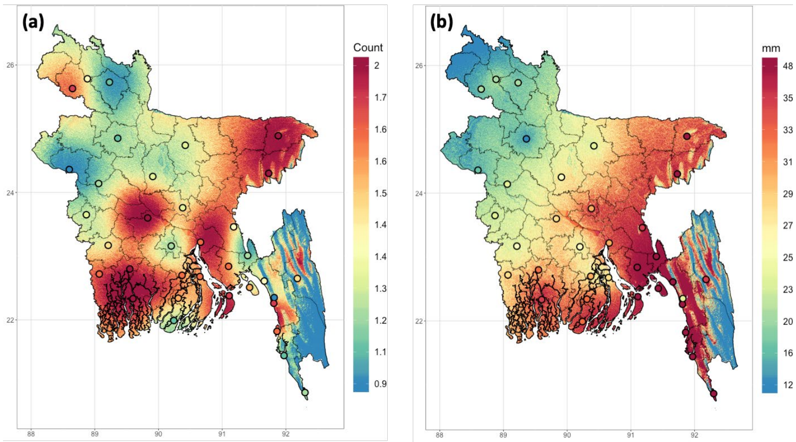
The clear higher and lower number of dry spells for contrasting years corresponds to relevant information when analyzing a seasonal forecast, or also for monitoring of the progress of the rainy season and its long term interannual context, presented previously.

Historical mapping of heavy rain events (moderately heavy and greater in February to March)

Many farmers in Bangladesh experience damage from heavy rainfall and storm events that can reduce yields – sometimes considerably. The locations within Bangladesh that are most at-risk of heavy rainfall events is therefore an important consideration for climate services initiatives aimed at reducing risk to smallholder farmers. Work was undertaken in 2018 to study historical data and measure the occurrence and magnitude defining extreme weather events. These characterized locally and considering statistical incidence in a multi-year time series using data provided by BMD.

Initial analysis focused on identifying extreme rainfall events utilizing daily meteorological data during the pre-monsoon period. Maps of the resulting analysis that were completed in the second half of 2018 show the climatology of precipitation quantity from February to April, indicating where during this period that extreme precipitation events are likely to occur. The 90% percentile of daily precipitation were used to construct maps that will be provided on

BMD's website and in communications products to be developed in 2019 by CSRD to inform the Ministry of Agriculture on how to better prepare for and plan against heavy rainfall induced crop losses. Thresholds determined using these analyses will also be utilized to provide emergency warning systems for particularly weather risk-prone crops, for example for mungbean crops (please see sections below on complementary climate information services initiatives that build on CSRD's work to benefit smallholder farmers in Patuakhali, Bangladesh.



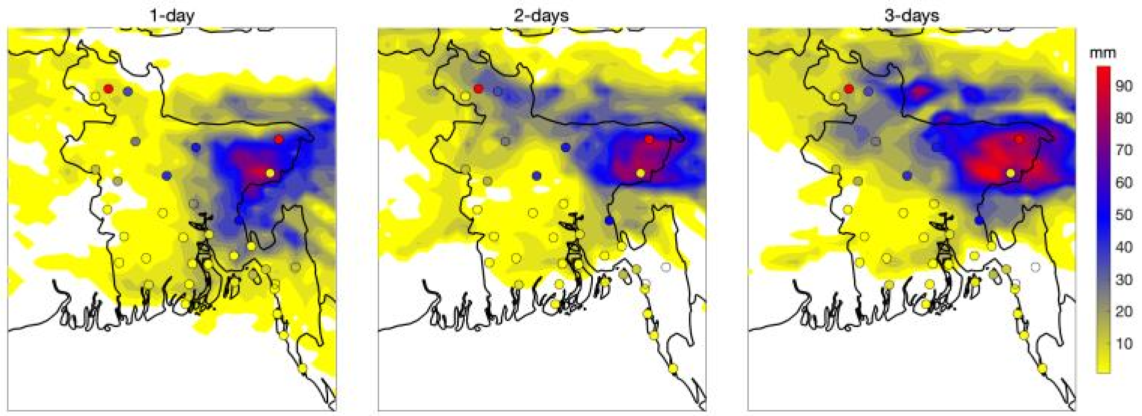
(A) Climatology of number and (B) amount defining a heavy rainfall event of dry spells calculated taking the percentile 90% of precipitation as a threshold.

Forecasting to improve climate information and services in Bangladesh

Quantitative assessment and improvement of BMD forecasting skill

Recent work on the quantitative assessment of the performance BMD's application of the Weather Research and Forecasting (WRF) model over Bangladesh has facilitated the identification of systematic biases – that can now be corrected – in agriculturally-relevant weather variables such as daily precipitation and maximum/minimum temperatures under the model's current configuration. Model outputs are now stored in databased developed by CSRD in 2018. Prior to this initiative, BMD did not maintain WRF outputs, which hampered efforts to do quantitative skills assessments of forecasts. Forecast outputs have been stored from early 2018 until the present, and are still being collected. Utilizing this database, CSRD's researchers worked to assess WRF forecasting skill by comparing model predictions and observations from BMD's network of weather stations. This activity has also been facilitated by IRI which has helped to provide support in the use of statistical tools for forecast assessment and in improvements in best practices for database management. Results generated in 2018 are preliminary and will be updated completed in the coming months as a longer time-series of WRF datasets become available.

As an example of first results, countrywide differences in daily maximum temperatures predicted for the time window of 6 days were identified, corresponding to a systematic negative bias (underestimation) in maximum temperatures. Statistical methods are currently being applied to correct this bias that result from numerous factors, most notably including model parameterizations and the use of global forecasting outputs used as boundary conditions. An example of comparison between WRF numerical forecasting and weather station observations is presented below. This set of maps show precipitation measured by the stations for a rainy event on May-5 of 2017 (colored dots) and the forecasting generated by the model the previous day (1-day), and 2-3 days before. These results highlight the ways in which WRF forecasting performs better for the lower values of rainfall, but for the higher values the discrepancies are greater. Systematic bias such as this is commonly reported in the literature, and as such a variety of solutions to rectify this problem can now be applied.



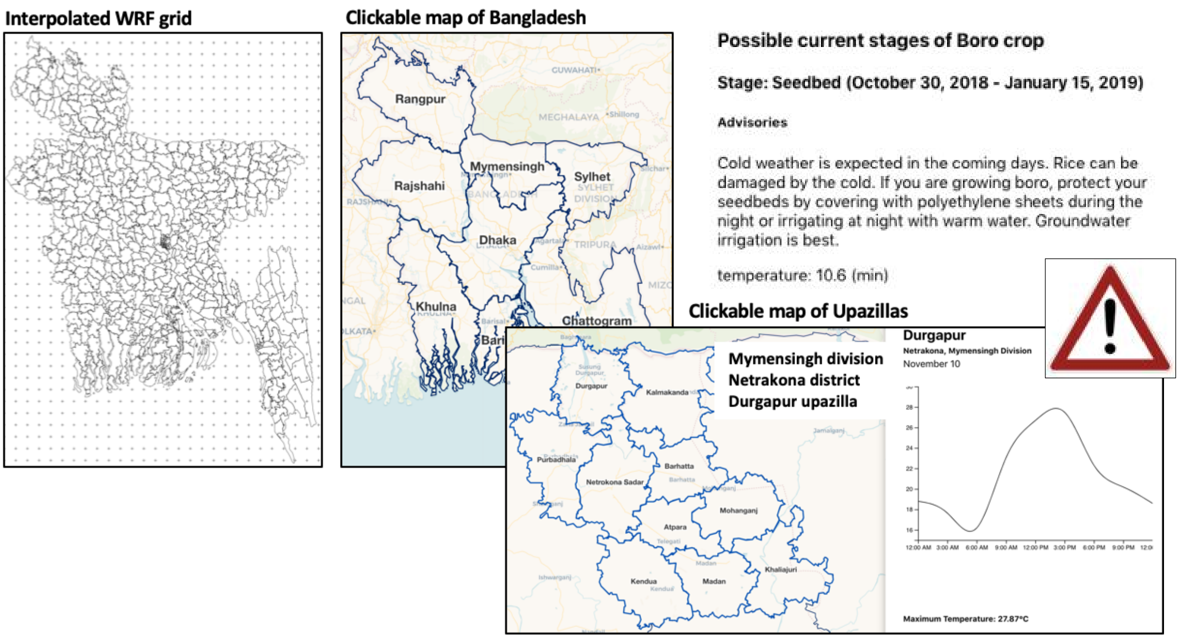
Daily rainfall for a precipitation event registered in May 2017by weather stations (dots) and the corresponding maps generated by the WRF weather forecasting model 1-day to 3-days in advance of the rainfall event.

This illustrates the kind of data processing that is necessary to try to improve the performance of a weather forecasting through model output statistics (MOS). Recognizing that errors in WRF forecasting can be partly generated by limitations in spatial resolution, which can be limited by computing capacities, but also result from the quality or pertinence of input data. A solution to this problem may be to the increase of the spatial resolution of WRF model runs, although an assessment of the quality of the input data is likely to be required. The latter can be done by comparing the performance of the model by using a set of boundary conditions provided by global forecasting such as the NOAA Global Ensemble Forecasting System. Another option can be the use of post-processing MOS to reduce these systematic differences, which has been successfully applied in similar cases. CSRD is currently in discussions with BMD regarding these results to develop plans to implement further research and model improvements to reduce systematic bias.

Forecast mapping of crop species-specific probabilities of encountering thermal stress

Building on the above work streams, improvements in weather forecasting and a reduction in systematic bias are being used to generate a variety of useful agricultural climate services products. Combining regionally specific precipitation thresholds with temperature thresholds, for example, CSRD is engaged with BMD to revise their weekly agro-meteorological bulletin and forecast. The current bulletin provides forecast information in static PDF format with no specific advice on the implications of climate for the management of crops.

The revised bulletin will be housed on the BMD website and will be interactive, providing users the option to point and click on maps at the sub-district level that zoom in and provide crop-specific management advisories based on the ingestion of BMD's Weather Research and Forecasting (WRF) model forecasting outputs.



Example of the preliminary BMD agro-meteorological bulletin web application developed to display the weather forecasting and crop-specific advisories that utilize WRF forecast model outputs and temperature and precipitation thresholds at the sub-district level.

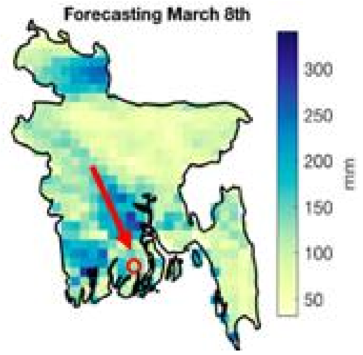
> ***"The proposed newer version of the agrometeorological bulletin developed in collaboration with CSRD will make farming easier by providing the farmers convenient and quickly accessible weather information."***
>
> ***- Mr. Shamsuddin Ahmed, Director, Bangladesh Meteorological Department***

The figure above shows an example of the website currently being developed. Once the outputs from the model are processed using MOS, they are further interpolated to generate a grid that adapts to the size of the targeted administrative units. This forecast is later integrated into an online visualization application enabling users to consult the forecast of variables of interest such as temperatures or precipitation, the occurrence of extreme weather events, and the corresponding advisory to farmers in case there is an agronomic management option for mitigation.

DAE also plans to make use of the same forecast and crop-specific advisory system, which will be later added to the website under development by DAE for the World Bank supported BWCSR project. The preliminary meteorological bulletin (beta version) can be found at this link: http://119.148.6.66:8000/.

Using historical data to determine heavy rainfall event damaging thresholds for mungbean and improving forecasts to provide emergency alerts so farmers can mitigate crop loss risks

Another important outcome of CSRD's work on extreme rainfall events in 2018 has been a complementary mini-project provided by Matt McDonald and the Embassy of the Kingdom of the Netherlands through the 'Blue Gold' project Innovation Fund that is aligned with CSRD. Although one of coastal Bangladesh's most highly profitable crops, mungbean is climate-risk prone in that unexpected heavy rainfall events and storms near harvest time can cause both early and late season waterlogging or destruction of seedpods, both of which significantly reduce yield. Where farmers are able to access weather forecast advisories of heavy rainfall or storms, they can be empowered to more rapidly harvest their crop to avoid significant losses. This two-year project aims to develop farmer-friendly and demand-driven climate- and market-smart mungbean advisory dissemination systems in the Patuakhali region of southern Bangladesh where mungbean is a rapidly expanding but climate-risk prone crop that can be negatively affected by heavy rainfall events that destroy maturing pods and cause waterlogging prior to harvesting. Utilizing the outputs from CSRD's analysis of heavy rainfall events to determine thresholds, this synergistic and complementary project aims to develop apps and ICT based messages providing farmers with five-day advanced forecasts of heavy rainfall events that could negatively affect yield. Further progress on this synergistic initiative will be rman**at**ed in 2019.



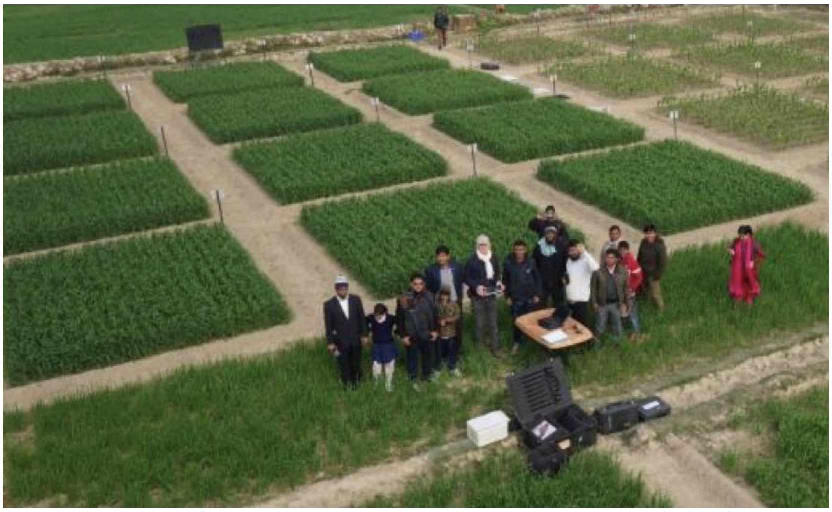
Mungbean crops in Dashmina Patuakhali, Bangladesh severely damaged by storms. Over a quarter-ton per hectare yield decline compared to previous years was recorded across the district in this year – the most significant loss of the last decade. Photo: Daily Star.

Planned activities in Quarters 1and 2 of 2019

Work on the evaluation of the forecasting for different meteorological variables obtained by the BMD WRF model will continue into 2019. This is necessary to verify its performance for different seasons. Research will proceed by applying statistical analysis through MOS techniques. At the same time, the team expects to fully complete the development of the web application for visualization of weather forecasting of variables of interest such as temperatures or daily precipitation, as well as early warning of species thermal risk or other derived events such as dry spells and the corresponding advisories. Trainings of DAE and other relevant partners in the use of these tools will be pursued as part of the third year strategy to assure that research outputs are translated into climate services and development outcomes.

Product 2. Weather forecast based irrigation scheduling with PANI (Program for Advanced Numerical Irrigation)

PANI is an irrigation scheduling app developed by CIMMYT through collaboration with the Bangladesh Agricultural Research Institute (BARI) and BMD that estimates crop water use and amount of plant available soil moisture on a daily basis, while also ingesting and integrating numerical weather forecast outputs. This enables the app to create an alert as to whether a crop field needs to be irrigated in the next seven days. The field specific alert is sent out on a weekly basis to farmers and irrigation service providers. Development of PANI as an irrigation scheduling support tool responds to BMD's request to USAID in 2016 to develop climate services oriented towards forecast-based irrigation planning in Bangladesh.

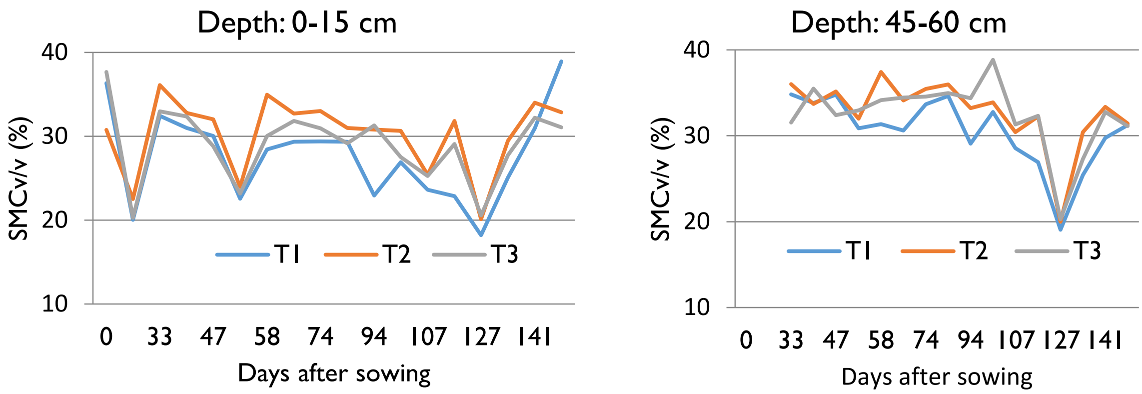


The Program for Advanced Numerical Irrigation (PANI), which integrates soil moisture data, leaf area measurements made with mobile phones, and numerical weather model forecasts to advise when to irrigate wheat and maize, is a collaborative research program between BARI, BMD and CIMMYT under CSRD. This photo shows collaborating in PANI validation experiments planted at the Wheat Research Center (WRC), Dinajpur in 2018.
Photo: Mustafa Kamal

The current version of the PANI app is preliminary and requires field testing before it can be officially endorsed by BARI for use by DAE and other agencies within Bangladesh. CSRD therefore engaged with BARI in the 2017-2018 winter *rabi* crop season to test app performance in three districts, including Barisal, Rajshahi and Dinajpur. These are located in southern, central-western and north-western Bangladesh, respectfully. In each region, the BARI on-station field trials to examine performance of the app.

Three irrigation treatments for maize and wheat were imposed including 'T1" = Dry: First irrigation 3 weeks after sowing, then stop irrigation until severe stress is detected. Then apply one more irrigation. 'T2' = BARI: Three irrigations at seedling (25-30 DAS) vegetative (40-45DAS), silking (65-70 DAS), and grain filling (95-100 DAS), stage (BARI recommendation), and 'T3' = PANI: First irrigation 25-30 DAS subsequent irrigations according to PANI recommendations. Results from the first season of trials are described below. BARI is also currently in the process of testing the app following modifications made in the app's underlying algorithms based on collected field data. A second season of trials have been planted and will continue in the 2018-2019 winter season in the same locations.

In the 2017-18 season, treatment 3 had to be modified because there were technical challenges including persistent electrical system failures (which are common in Bangladesh in the early months of the year) with the PANI server installed at BMD in Dhaka. The server is a necessary component of the PANI system as it stores numerical weather forecast model outputs that need to be ingested into the PANI algorithm for irrigation scheduling advisories to be made possible. Therefore, the same irrigation schedule as for (T2) was implemented in place of T3. BARI regularly measured all key parameters required to calibrate and validate PANI: depth of water table and soil moisture (gravimetric as well as apparent dielectric permittivity with Theta- and TDR probes). In addition, canopy parameters such as leaf area index (LAI) and percent ground cover were measured on a monthly basis. From late January until late March, weekly canopy temperature measurements were made as well.



Dynamics of gravimetrically determined volumetric soil moisture (SMCv/v) for three irrigation treatments of maize grown at Dinajpur in the winter of 2017/18. The figures are shown for two depths: 0-15 cm and 45-60 cm. All three treatments received an irrigation of 55 mm 3 weeks after sowing. Treatment 1 (T1) did not receive any additional irrigations, whereas T2 received an additional 123 mm and T3 received 119 mm, according to BARI recommendations.

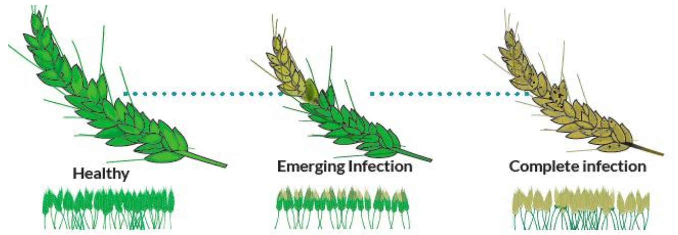
At all three sites, the water tables stayed close to the surface. Soil moisture levels did not differ much between the treatments, indicating that wheat and maize crops benefited from soil moisture supply from capillary rise. The above figure shows the dynamics of gravimetric soil moisture content for maize grown at Dinajpur, the "driest" site, which required the highest amount of irrigation. Due to the capillary up flow, even the plants in the dry treatment did not experience any significant water stress and yield was only slightly reduced as compared to the well-watered treatments. There were significant differences among the sites, however both for wheat and maize. The highest average yield for wheat was recorded for Dinajpur (4.6 t/ha), whereas at Rajshahi, it was only 3.1 t/ha. Dinajpur also had the highest yield for maize (9.5 t/ha). Much lower yields were recorded at Barisal, with 5 t/ha. Despite if the lack of significant treatment effects on yield, the data will nevertheless be useful for the calibration and validation of PANI, as the experiments had been conducted on different soils and in different environments. Efforts have also been made to improve functioning of the server system at BMD, through inclusion of an intermittent power supply to provide consistent server functioning during the cropping season.

Planned activities in Quarters 1 and 2 of 2019:

In the 2018-19 *rabi* winter season, CSRD continues to collaborate with BMD and BARI to run the same sets of experiments. Different sites with lower water tables have been selected for Rajshahi and Dinajpur in the expectation that we will be able to measure water stress, which is necessary for testing PANI under extreme conditions and providing data that BARI can use to consider for endorsement of the app's performance. The new site for Rajshahi will be in the Barind tract, where ground water levels are dwindling and improved experimental results are expected. This area is also likely to be more suitable for PANI from a business model perspective, as many farmers pay for irrigation by time or irrigation number, rather than on a fixed seasonal basis as in other parts of the country. This will enable us to get data for a region where PANI has big potential of being adopted by farmers, as it will presumably help them save water and irrigation investments, and thus reduce the pressure on the water table in the long run.

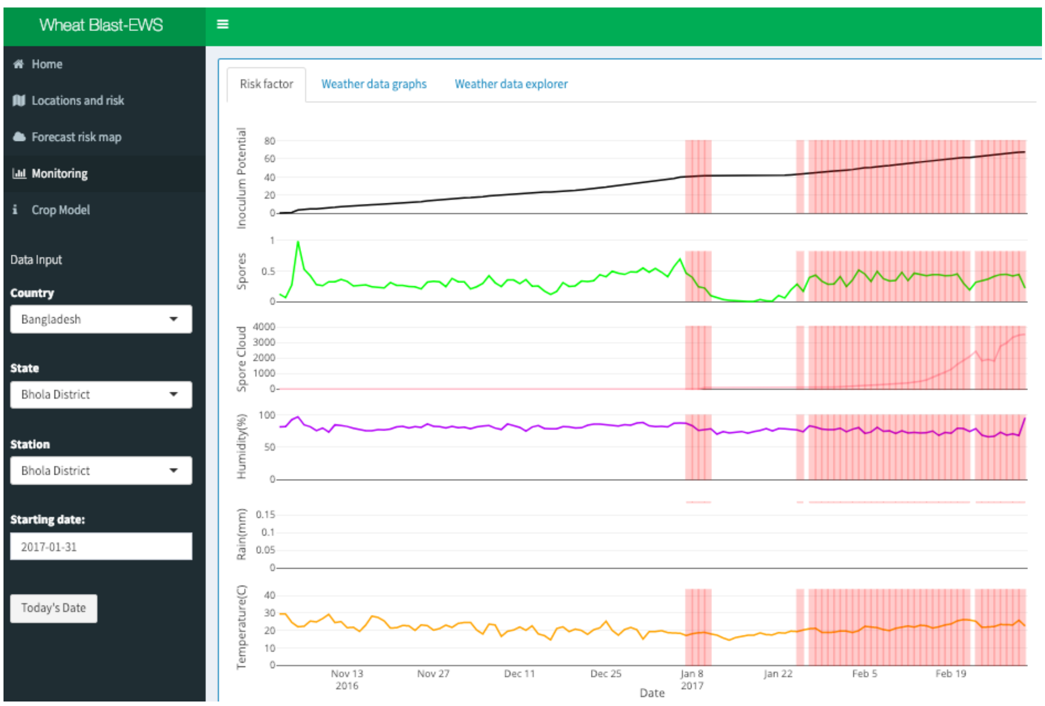
CSRD has also trained 30 Sub Assistant Agricultural Officers (SAAOs) from DAE in the use of the PANI app. They are currently working with farmers in each of the regions in which research station trials are conducted by BARI. Participating farmers working with DAE to evaluate use of the app in on-farm settings will irrigate their fields according to the PANI recommendations, while comparing them to the performance of separate fields in which irrigation will be managed conventionally. All in all, CSRD is targeting 60 fields that will be managed according to PANI, and 60 adjacent fields with conventional irrigation management. Preliminary results from these experiments and on-farm evaluations will be provided in the 2019 semi-annual report (contingent on the granting of the requested no-cost extension for CSRD).

Product 3. Spatially explicit and meteorologically driven wheat blast (Magnaporthe oryzae Triticum, MoT) disease risk assessments for Bangladesh



Wheat blast is a serious disease that undermines the resilience of wheat farmers in Bangladesh. Blast is strongly associated with predictable weather conditions.

Wheat blast, caused by *Magnaporthe oryzae* pathotype *Triticum* (MoT), was first discovered in Brazil in 1985. It subsequently spread across South America. In 2016, MoT unexpectedly appeared in Bangladesh, causing losses on >15,000 ha. It reappeared in 2017 and 2018, with relatively light infections, with reports of some spread to India. South Asian farmers stand to lose considerably with even low levels of infection. Late-season fungicides are only partly reliable, and while progress has been made in releasing resistant varieties in Bangladesh, additional tools are necessary for integrated pest **Cit**agement.



. The integration of temperature, relative humidity, and precipitation that drive the wheat blast spore development model developed through CSRD to simulate the risk of wheat blast infection

Partnering together with scientists from the University of Passo Fundo (UPF) in Brazil who had decades of experience with the disease, CSRD has advanced considerably in the development of a numerical weather model forecast driven model to predict the risk of outbreak in different parts of Bangladesh several days in advance. The model functions by integrating several weather variables including relative humidity, temperature, and also estimates of precipitation to predict the development of inoculum and a spore cloud favoring low-, medium-, or high-outbreak risks. This work is highly relevant and responds to high-priority national concerns. The Bangladesh Ministry of Agriculture for example requested researchers in 2016 to urgently develop a wheat blast early warning system that can be deployed by DAE to assist farmers to reduce the risk of wheat blast infection, and to make rational use of fungicides to control the disease.

Research conducted in 2018 saw initial conceptualization of the wheat blast model and early warning system developed by CSRD and UPF scientists. The system is developed in R programming language with a web interface generated using R Shiny, now available in online preliminary format at: http://dev.sisalert.com.br/shiny/wheatblastmodel/. CSRD also partnered with BARI and the DAE in 2018 to take field measurements of blast incidence and severity from more than 800 farmers' fields across Bangladesh to validate and adapt this model to the climatic conditions found in South Asia. As noted above, disease levels were low, although even this effort generated useful data to help parametrize the model and improve fit.

In addition to the above efforts, CSRD has begun collaboration with the CGIAR Big Data Platform which supplied a mini-grant to CIMMYT in 2018 to deepen collaboration with UPF on the model developed with support from CSRD. This effort focusses improving on the early warning system and modeling framework to coherently manage data requirements for automated time- and spatially-explicit wheat blast outbreak studies in Bangladesh and Brazil,. Because wheat is most susceptible to MoT near flowering, accurate crop phenology development prediction is crucial. Early warning systems can therefore be improved through model estimates for flowering dates, with coupling to weather forecast estimates and dynamic disease models. This work therefore aims to improve flowering predictability to more accurately gauge disease risk by integrating the Decision Support System for Technology Transfer (DSSAT) model to the MoT EWS framework for Bangladesh and Brazil, thereby allowing improved risk assessments.

A pest simulation module in DSSAT is now accessible to the NWheat and CERES-wheat models. To input field observations made in CSRD and validate disease presence and risks more formally, the CSRD team is working with additional resources provided by the CGIAR Big Data Platform to couple dynamic simulation of the MoT life cycle linked to modeled crop phenology to estimate infection and spike damage using the early warning system framework described above. If successful, this will better simulate disease severity and negative yield impacts that can be used for both historical analysis as well as forecasting efforts. Outbreak risk maps should be available in the next semi-annual report using available field trial data to calibrate DSSAT and examine past climactic and crop risks in Bangladesh and Brazil, although the model can be applied to other countries where data are available.

Screenshot of the crop model integration into the wheat blast early warning system model developed through CSRD, made possible with additional collaborative support through the CGIAR Big Data Platform. Integration of a pest simulation module in DSSAT accessible to the NWheat and CERES-wheat models permits users to estimate crop phenological development over time (represented by ascending lines) and risks for wheat blast infection at flowering (red column). Model outputs utilizes wheat data provided by the Bangladesh Agricultural Research Institute for Jashore, Bangladesh.

Planned activities in Quarters 1 and 2 of 2019:

Field sampling to measure the incidence and severity of wheat blast in Bangladesh will proceed using the same protocol developed in 2018. This will provide a robust database that can be used to determine the performance of the model and make additional adjustments to improve performance and fit. Field work also involves the use of spore traps to validate the presence of spores in regions where the model predicts disease presence, but where observed infections might be low. Visiting scientists from UPF will also return to Bangladesh in February – March and work with the CSRD team and BMD to incorporate WRF model forecasts into the early warning system. Both DAE and BMD will be trained on model use and a strategy for delivering early warning messages to farmers. If the model produces acceptable fit with observed data from 2019, the early warning system will be presented to the Ministry of Agriculture for endorsement and institutional use will begin in 2020.

Contribution of Activity 1.3.1 to CSRD's Action and Learning Framework:

Pillar 2, Indicators 2.2 and 2.3, Pillar 3, Indicator 3.1 and Pillar 4, Indicator 4.1 (see Annex 3).

Activity 1.3.2: Agro-meteorological forecast services applications and systems for crops, fisheries and/or livestock developed and refined for medium term decision making co-developed and refined

Background

Activity 1.3.2 provides research and technical inputs for topics identified by USAID as important for climate services development in Bangladesh following their 2016 consultation with BMD and the Ministry of Environment in Bangladesh. Improvements in the analysis of historical climate data, as well as short and sub-seasonal range forecasts are at the heart of these activities, the results of which are being included in BMD's agro-meteorological products and will be of use to DAE activities within complementarity World Bank funded Agro-Meteorological Systems Development project (see Objective 3, Sub-Objective 3.1. Coordination of Bangladesh CSRD partners for further details on the World Bank project collaboration).

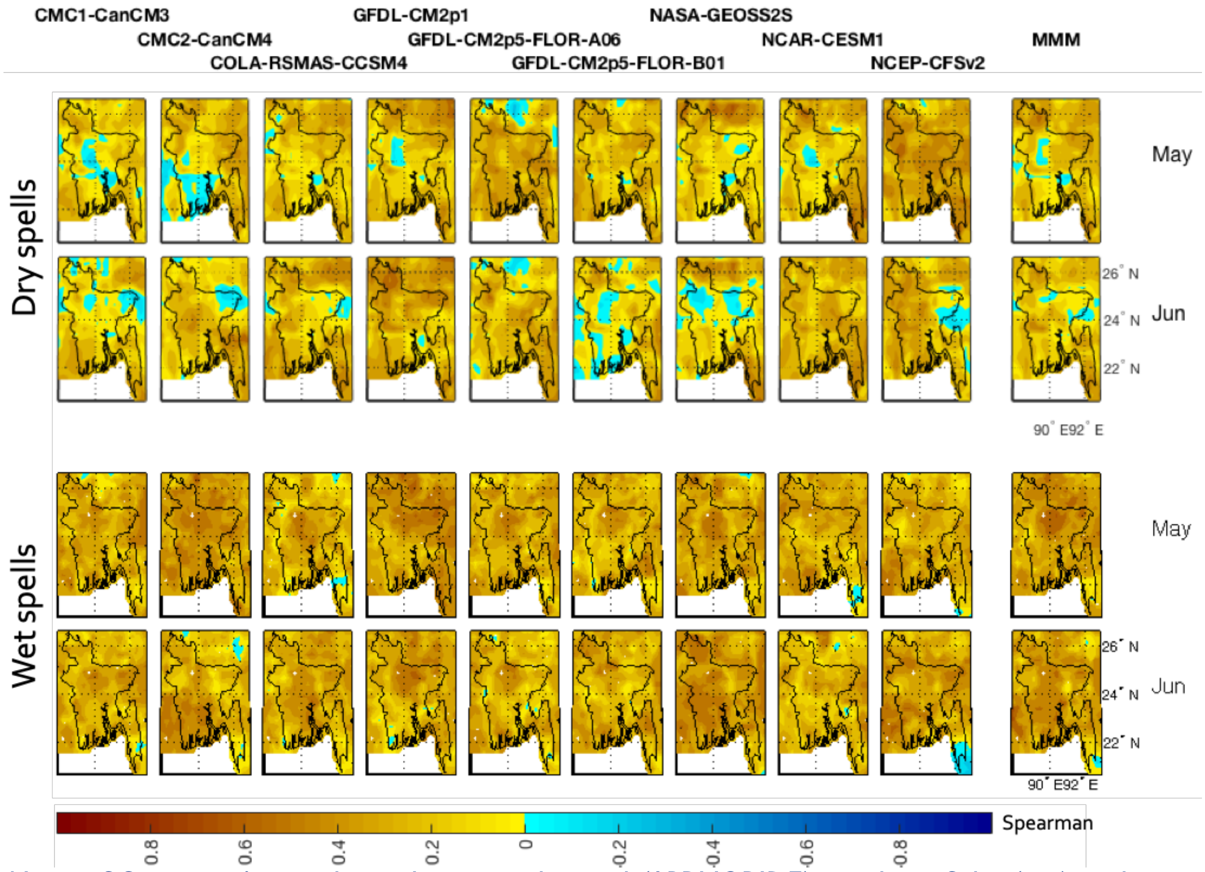
Product 1. Improved seasonal forecasts and climatic stress maps developed and refined

Technical exchanges between CIMMYT, BMD and IRI initiated between 2017 and the deepened during the intensive April 2018 training at IRI in Columbia University sparked work in the development seasonal climatic forecasts in Bangladesh. This activity started with the research and practical work regarding the feasibility of using IRI's Climate Predictability Tool (CPT) to generate a reliable product for seasonal forecasting in Bangladesh. Exhaustive research since then has revealed the existing complexity in generating forecasts at different scales over the region after exploring the use of different global climate drivers as predictors and regions, and multiple global dynamical forecasting models and their performance over Bangladesh. In other words, seasonal forecasting over Bangladesh is not a simple process and presents multiple challenges that need to be overcome. Work completed in forecasting skill analysis has however provided insights into ways in which monthly rainfall and temperature predictions for different seasons might be possible with some (though limited) degree of confidence by using multiple input variables and outputs from general circulation models. Specifically, the seasonal forecasting of average air temperatures performed in general better than for rainfall. In parallel, the forecasts delivered by the North American Multi-Model Ensemble (NMME) dynamical models that can be applied to different areas of Bangladesh have been also evaluated.

One of the options explored in 2018 is the use of NMME models to perform seasonal forecasting in correspondence with the use of sub-seasonal metrics such as the number of dry and wet events during the rainy season. The set of maps presented below shows the results of nine models belonging to the NMME and their ability to represent the number of dry and wet spells predicted during the months of June to September (JJAS) in terms of Spearman's correlation coefficient as a skill metric, for models initiated in May and June.

In this analysis, a dry spell is defined as the number of events with more than five days of precipitation lower than 0.1 mm/day. Wet spells are conversely defined as the number of periods of more than seven days with precipitation higher than 0.8 mm/day. These values were selected according to their corresponding statistical distributions. To evaluate their skill, the APHRODITE precipitation product is used an observational reference. This figure also shows the multi model mean (MMM) values.

Positive correlations were found to be dominant for both the number of dry and wet spells, while negative correlations were more frequent in the case of dry spells. Based on the analysis of the historical climatic information in Bangladesh, presented in Activity 1.3.1, it is already known that the total precipitation for the months of June, July, August and September, and the number of rain events are highly related. Given the number of heavy rainfall events observed, it may be possible to generate information about the probability of occurrence of extreme events at seasonal scales based on forecasts of other metrics such as the number of wet spells, which are highly related to total seasonal precipitation.



Maps of Spearman's correlation between observed (APRHORIDE) number of dry (top) and wet (bottom) spells for nine models belonging to NMME seasonal forecasting in Bangladesh

Planned activities in Quarters 1 and 2 of 2019:

Ongoing activities consider on the evaluation of the seasonal forecasting for different seasonal and sub-seasonal metrics provided by the NMME product over Bangladesh, similar to the above-presented case of dry spells. Another activity corresponds to the evaluation of sub-seasonal (~3 weeks) forecasting provided by products such as the NOAA MME forecasting for Bangladesh. While this research will continue into 2019, the CSRD consortium will also consult with IRI and BMD to determine the next logical steps in analysis, and determine if and how research results can be incorporated in BMD's overall forecast outlooks. In other words, while research will continue, activities in 2019 will pivot towards implementation of research results where possible.

Contribution of Activity 1.3.2 to CSRD's Action and Learning Framework:

Pillar 2, Indicators 2.2 and 2.3, Pillar 3, Indicator 3.1 and Pillar 4, Indicator 4.1 (see Annex 3).

Objective 2: Collaborative development and refinement of South Asian regional-scale agro-climate decision support tools, services, and products

Sub–Objective 2.1: Support to facilitate the development and refinement of regional decision support decision support tools, services, and products

Activity 2.1.1: Coordination support for the International Centre for Integrated Mountain Development (ICIMOD) and partners in drought forecasting

Background

CSRD is an international public-private partnership dedicated to promoting and enabling climate services that increase resilience to the impacts of climate variability and climate change, and that positively change behavior and affect policy in developing countries. CIMMYT leads the CSRD partnership in South Asia in coordination with a wide array of national and international partner organizations. One such partnership is with the International Center for Mountain Research and Development (ICIMOD). This activity adds value to work already conducted by ICIMOD to add three research locations in Bangladesh to ICIMOD's regional efforts in drought monitoring under the SERVIR Hindu Kush Himalayan (KHK) project, and also to support Asian regional capacity development efforts in the use of earth observation data in drought monitoring.

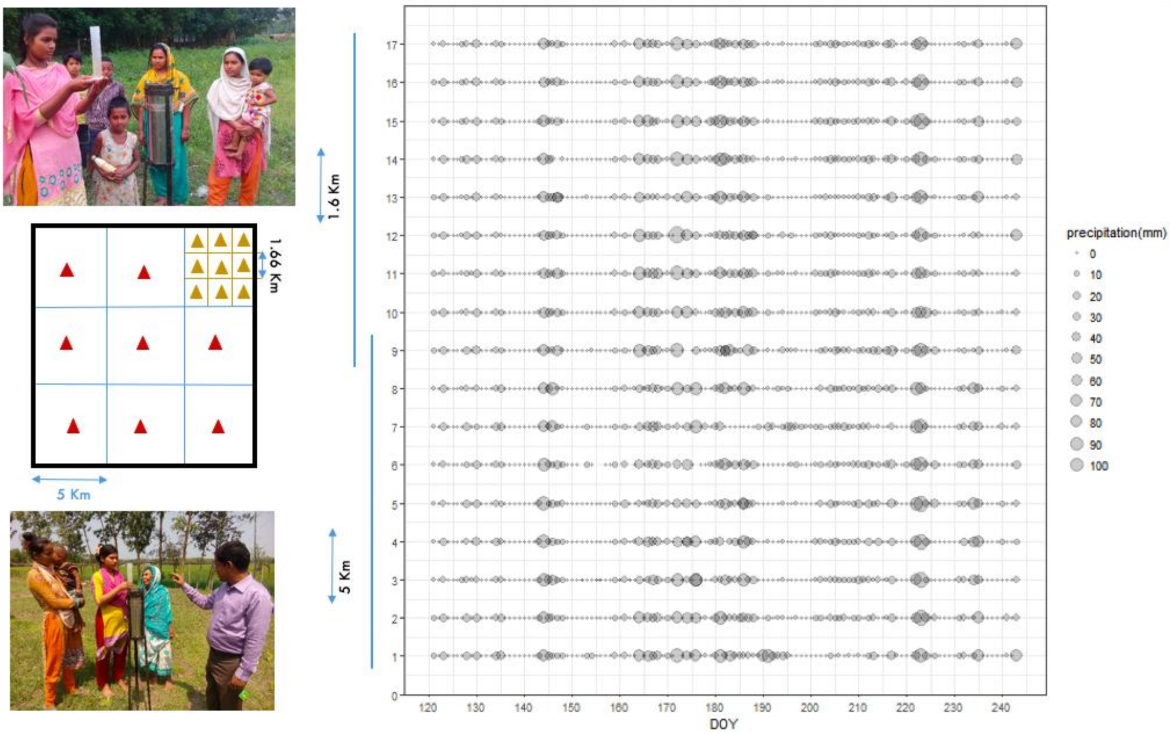
Product 1. Ongoing support for ICIMOD and partners

Ongoing development of the sub-seasonal to seasonal (S2S) South Asia Land Data Assimilation System (SALDAS)

NASA's HKH Sub-seasonal to Seasonal Forecast System (S2S) has been designed for optimal monitoring and probabilistic seasonal forecasts of hydrological conditions distributed across the HKH and South Asian region. The S2S system consists of two primary tools. First, a Land Data Assimilation System (LDAS) is used for real-time monitoring of observation data. The LDAS merges advanced land surface models with satellite-derived estimates of meteorological conditions, surface and hydrological properties to provide daily estimates of hydrological storage capacity (for example soil moisture, snowpack) and fluxes (rainfall, evapotranspiration, runoff) at a 5 km gridded resolution for the whole of South Asia. LDAS is a tool that merges models and observational data in an integrated analysis to yield more reliable and meaningful information. The South Asia LDAS (SALDAS) consist of multiple land surface models and meteorological datasets, and permits flexible parameterization and data assimilation. In the forecasts produced by the system, land surface models are forced with meteorological data extracted and downscaled from global seasonal forecasting systems. This yields an ensemble of seasonal hydrological forecasts that draw their skill both from the meteorological forecasts, but also from the initial hydrological data provided by the LDAS. An initial version of the S2S forecast has been deployed at ICIMOD with support from CSRD and is now being tested.

In the current beta forecasts derived from the SALDAS system, only visualized results from one ensemble member in Nepal are currently available, although work on Bangladesh as another country of relevance to CSRD is ongoing. Additions are being made to really show the ensemble spread and also include the ensemble mean. At that point we will begin disseminating sample forecast products for end user feedback, and the system will be refined and fully operational for 2019.

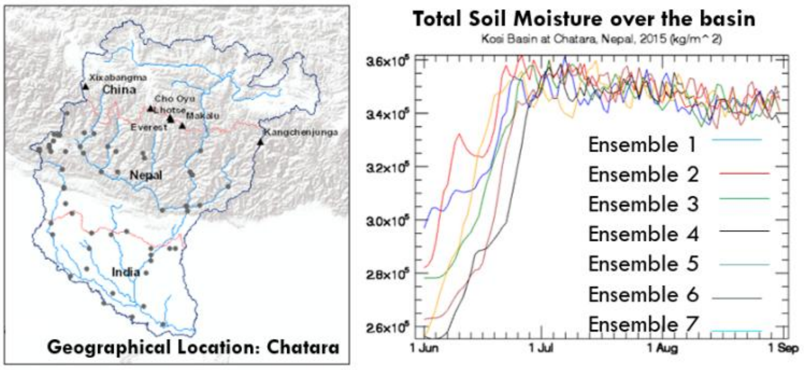
Work under CSRD aims to extend this system and test further 1 km^2 downscaled precipitation data as part of the system. To this end, CSRD established three precipitation monitoring grids in Rajshahi, Nilpharmari and Dinajpur in Bangladesh (each of which are considered to be potentially drought prone compared to the rest of the country), in which collaborating farmers assisted by collecting daily rainfall measurements. This has yielded a high-quality and high-resolution dataset from which downscaling of the system will be attempted in Bangladesh. One monsoon season worth of rainfall data has been collected for this purpose, shown graphically below. The CSRD team is now collecting a second winter and monsoon season dataset to be used for downscaling analysis.



Farmers and youth in Rajshahi, Nilphamari and Dinajpur Districts in Bangladesh assisted in collecting precipitation data from a grid of manual rain gauges (left top and bottom) at 5 km^2 and a 1 km^2 downscaled grid throughout 2018 (left middle). This yielded a high-quality dataset showing differences in precipitation at different resolutions (left graph, with DOY indicating 'date of year in 2018' for which precipitation was observed), which can be used to improve SALDAS downscaling efforts (Photos: Alanuzzaman Kurishi).

Preliminary analysis of precipitation patterns to improve drought forecasting in north western Bangladesh

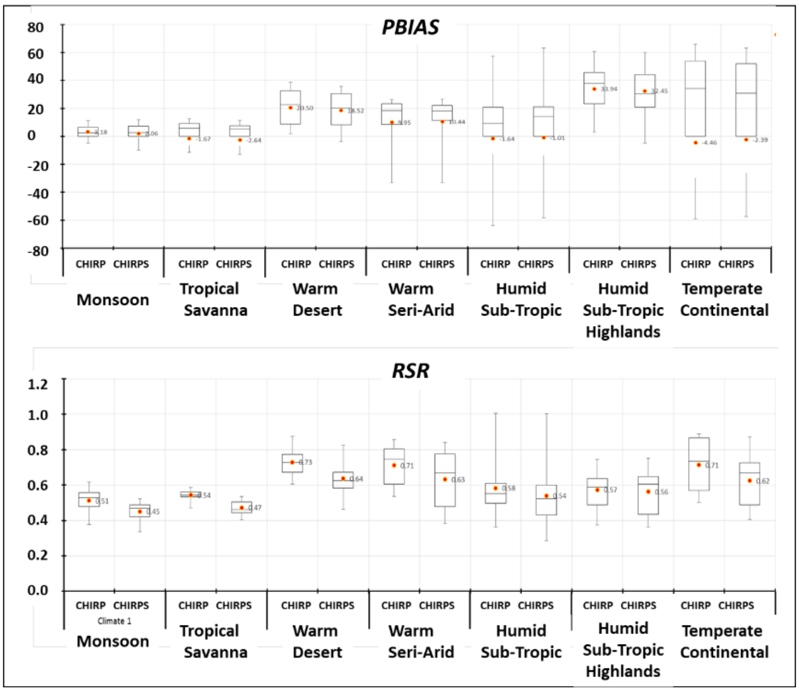
Precipitation is a primary indicator for drought monitoring and early warning systems. South Asia is characterized by considerable spatial and temporal variability in rainfall patterns.



An example of SLDAS derived seasonal outlook on moisture condition in Koshi basin in Nepal providing time-series results for seven ensemble models.

Drought advisories therefore require a dense rain gauge observation network to capture precise precipitation information. However, ground monitoring stations in South Asia are highly inadequate and distributed unevenly. This makes water resources assessment and accurate drought prediction difficult, especially in mountainous regions such as the Himalayan range with limited or no rain gauge network. Earth observation based quantitative assessment of precipitation estimates are becoming an attractive option, especially for data scarce within South Asia.

Among the many products available, the long-term Climate Hazard Group Infra-Red Precipitation Satellite (CHIRP/S) can supply high spatial and temporal resolution data, and can provide an opportunity to develop drought monitoring and early warning applications in data sparse regions using rainfall estimates. However, CHIRP/S data also have some level of uncertainty, and this could affect the accuracy of predictions when they are used in drought outlook scenario.

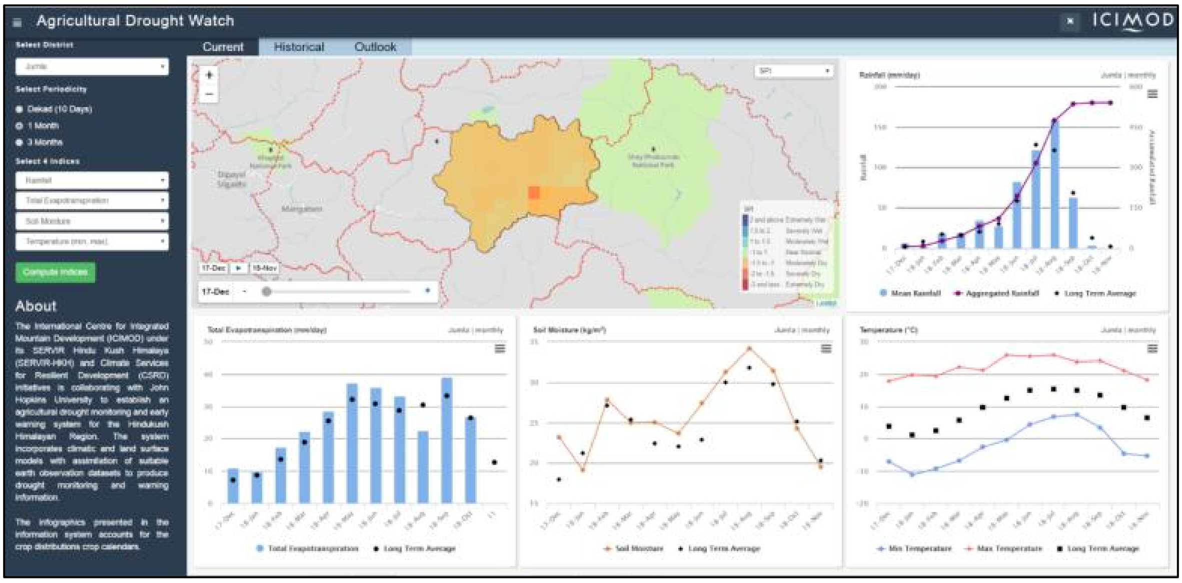


Comparison of compared monthly precipitation estimates from CHIRP, CHRIPS and APHRODITE with 130 existing rain gauges representing eight climate divisions of Bangladesh, Nepal and Pakistan. Above: Percent measured bias in estimations. Below: Root Mean Square Error.

The objective of this work is to make improvements by evaluating the existing spatiotemporal pattern of the long-term CHIRP/S across the eight major climate divisions of South Asia, including locations in CSRD working countries. In this study, we compared monthly precipitation estimates from CHIRP, CHRIPS and APHRODITE with 130 existing rain gauges (representing 8 key climate divisions of Bangladesh, Nepal and Pakistan) and gridded observation using several statistical metrics in the long-term period of 1981–2012. Overall, the data indicate that CHIRP/S performs better in wet regions than in arid and semi-arid areas and achieves greater accuracy during summer than in winter season.

Drought data analysis and visualization made easy: Development of an online data exploration system

Through the collaborative work, an integrated agriculture drought monitoring and early warning system has been developed in beta form for Bangladesh, Nepal and Pakistan. The data products currently focus on Nepal although Bangladesh and Pakistan are in the process of being brought online. Products will mainly include estimated baseline on crop type maps, multiple drought indices for meteorological drought, agriculture drought and hydrological drought monitoring information and seasonal weather outlooks to facilitate short- to medium-term advisories. CSRD is also in discussion with partners on ways to test and improve the skill of outlooks as data from outlooks are stored in the systems servers. The system primarily depends on operational gridded climate data products from remote sensing, e.g., CHIRP/CHIRPS precipitation from Climate Hazard Group, NMME Forecasts, Moderate Resolution Imaging Spectroradiometer (MODIS) satellite vegetation, MODIS snow covered area, meteorological forcing datasets from global models, and ground water assessment from GRACE (satellite derived groundwater assessment), etc. Drought indices for precipitation, soil moisture, vegetation conditions and evaporative stress are produced by fusing these products linking them with district level agriculture practices and crop calendars.



User interface of Agricultural Drought Watch Tethys open source platform.

Since the writing of the 2018 semi-annual CSRD report, significant progress on the development of the online agricultural drought watch portal has been made. The system makes use of the Tethys platform, an open-source system. Tethys platform is a suit developed with python, geo-server and various other open source applications. The portal provides various drought indices that have been generated using customized LDAS outputs. The portal disseminated the near real time time-series data such as Standardized Precipitation Index (SPI), precipitation, soils moisture and air temperature. The system is enhanced with the seasonal forecasting options for some of the drought indices in particular locations. The system can also be adapted if partner organizations request customization.

Planned activities in Quarters 1 and 2 of 2019

In the next progress period one of the key activity includes piloting the application of high resolution (1km) drought forecast in at least two of the three Districts in Bangladesh where observational data are collected. This research will be conducted in close cooperation John Hopkin University working on LDAS. Preparation of journal manuscripts one based on regional data analysis and other of work related to north western pilot districts will be accomplished. Another training and dissemination workshop will also be is anticipated in the first quarter of 2019.

Contribution of Activity 2.1.1 to CSRD's Action and Learning Framework:

Pillar 1, Indicator 1.1, Pillar 2, Indicator 2.2, and Pillar 4, Indicator 4.1 (see Annex 3).

Activity 2.1.2. Regional learning platform for climactically refined decision support tools to support integrated disease management in lentil in smallholder farming systems

Background

The productivity of lentil (*Lens culinaris*) in South Asia is severely affected by diseases, which are in turn highly affected by prevailing weather conditions. Stemphylium blight (SB), caused by *Stemphylium botryosum*, is a key threat to the resilience lentil production and the of livelihoods of millions of smallholder farmers of Bangladesh, India and Nepal. Lentil is a popular legume that is cooked as *dhal* that is typically eaten with rice, and is an important component of nutrition-sensitive farming systems in the region.

Weather conditions including cloudiness, temperature, precipitation and relative humidity directly have a direct influence on the incidence and severity of SB in lentil. The coincidence of cloudy weather with precipitation, relative humidity and appropriate temperature ranges for SB may vary considerably between locations within a growing season and also between seasons within a location. This makes the development of climate services for to support integrated disease management for lentil a challenge. While application of foliar fungicides can control the disease, uncertainty in forecasts pose additional challenge to planning their rational use. If farmers apply too much fungicide when it is not needed, their profits will decrease while the negative environmental consequences of their crop production practices. In response to these issues 'Stempedia' model is under large-scale field testing and calibration with support from CSRD to assess the regional and seasonal risks of the disease within South Asia. Our ultimate goal is to utilize weather forecasts to drive a model that can be used for emergency warning systems informing farmers when and where the use of foliar fungicides may be rational to limit disease inflicted yield losses, while also minimizing environmental externalities.

Product 1. STEMPEDIA: Lentil Stemphylium blight disease forecasting systems in Bangladesh, Nepal, and India[3]

To achieve the above objectives, field data were collected across Bangladesh, India, and Nepal during the growing season of 2017-18. Field work in in India was made possible through CSRD's synergistic and in-kind collaboration with the USAID and Bill and Melinda Gates Funded Cereal Systems Initiative for South Asia, or CSISA. Additional in-kind support was provided by pathologists from Bihar Agricultural University who provided laboratory analysis examining *S. botryosum* presence. Field sampling in Nepal was conversely supported directly by the CSRD as well as through CSISA collaborations, in partnership with the Nepal Agricultural Research Council's (NARC) National Grain Legume Research Program. NARC enthusiastically supported field work and provided extremely helpful technical guidance and laboratory analysis. In Bangladesh, CSRD funded all field work that was implemented with help from the DAE.


Left: Severely impacted lentil suffering from Stemphylium blight in the fields in Meherpur District in Bangladesh. Photo: Timothy Krupnik. Right: Root diseases of lentil, which can be seen as symptoms of leaf discoloration, at early growth stage in Bardiya, Nepal. Photo: Moin Salam

In the 2018 semi-annual CSRD report, preliminary results on SB disease status in Bangladesh were presented together with initial field validation of the '*Stempedia'* model. This report presents additional analysis of measured diseases in all the three countries, consultation of stakeholders on the results, and testing the performance of the model in relation to available weather information. Data on diseases were collected from 480 farmers' fields, 160 each in Bangladesh, India and Nepal. Fields were located in five sites (Jashore, Magura, Meherpur, Faridpur and Rajbari) in Bangladesh, five sites (Barh, Mokama, Barhaiya, Masaurhi and Paliganj) in the State of Bihar, India, and in four sites (Kanchanpur, Kailali, Bardiya and Banke) in Nepal.

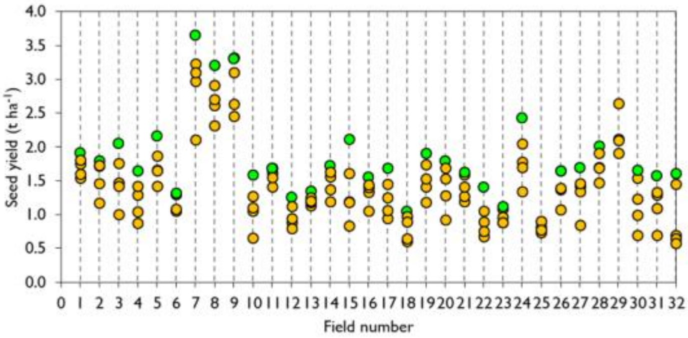
Lentil disease variability within and across countries

Fields were chosen to represent a gradient precipitation, temperature, and relative humidity across countries as shown in the 2016-2017 Annual Report. This provides a more robust evaluation of the model's performance in differing environments, while generating a high-quality dataset for model calibration. With assistance from the partner organizations listed

[3] Note that this work stream replaces 'Precision Nutrient Management' as described in the original CSRD SOW for South Asia. The change to the current work stream was agreed with USAID in Q3 of 2017, and was chosen because of the potential for rapid model validation and impact in the context of integrated disease management across Nepal, India, and Bangladesh.

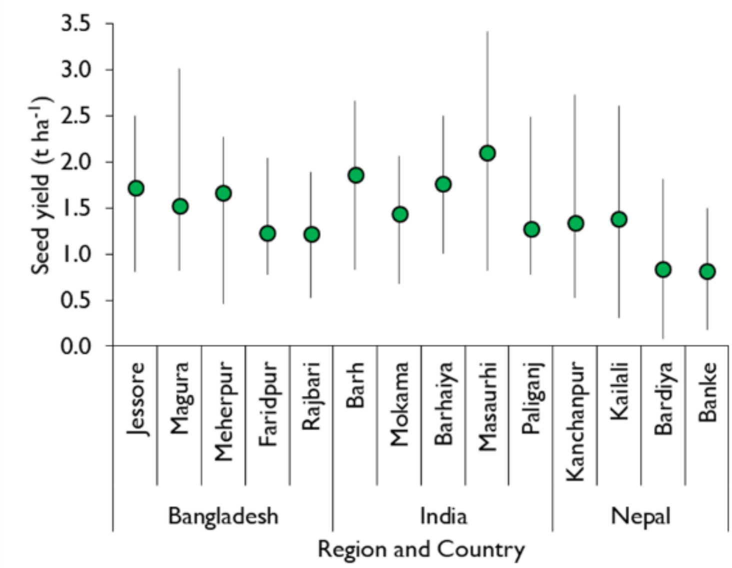
above, the CSRD team measured the status of SB and other diseases three times before harvest. In addition to Stemphylium, fields were also attacked additional root diseases. The incidence of the diseases was however low in Indian sites (maximum of ~13% fields in Mokama) compared to Bangladesh and Nepal, which had much higher incidence of disease.

All fields observed in Kanchanpur and Kailali were infected, while 87-89% were infected in Bardiya and Banke of Nepal. Disease incidence raged from 40 to 87% in Bangladesh, with Meherpur district locations worst affected. SB was the dominant disease, but the presence of other diseases was noticeable (12-26% of the total incidence in Bangladesh and Nepal). As indicated above, the other diseases were predominantly root diseases.



Spatial distribution of lentil yield in each of the 32 fields in Magura site of Bangladesh. These data are for 2017-18 growing season.

Field-to-field variation within a location in the occurrence of Stemphylium blight disease was also observed. For example, variability ranged from 7 to 90% in Faridpur, 29 to 98% in Meherpur, both in Bangladesh. Variability was conversely 70 to 100% in Kailali of Nepal. The incidence of blight was however low in observed fields in India. Visual pathogenicity tests performed in two laboratories in Nepal clearly confirmed typical fungal conidia in the isolates prepared from diseased samples collected from monitoring sites.

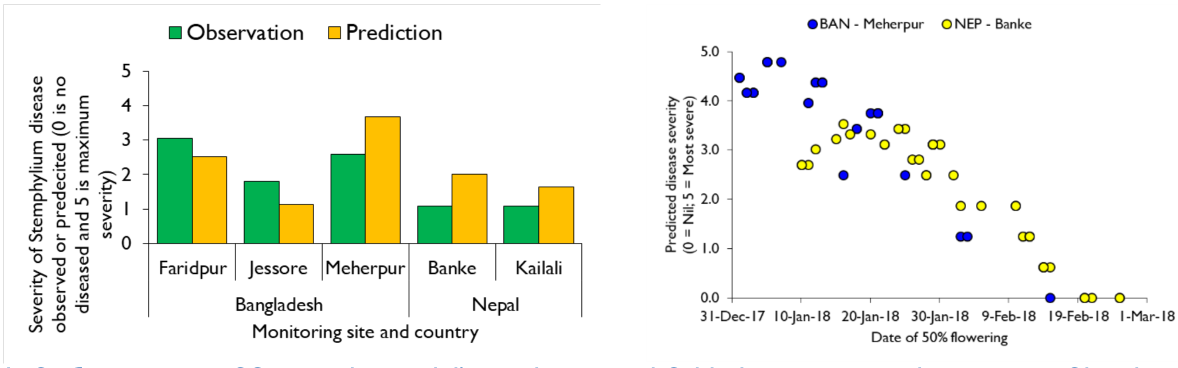


Average (filled circles) and range (vertical bars) of seed yield of lentil in sampling sites of Bangladesh, the State of Bihar of India, and Nepali terrai during 2017-18 growing season

In addition to disease scoring, yield data were collected from all sampled fields five locations within fields where the diseases were monitored. Altogether, there 800 yield measurements were made in each country. Variation in yield within and between sites was significant. In general, fields in India were higher yielding, while the Nepalese sites had poorer yields. The average highest yield of 2.1 t ha^{-1} was recorded in Masaurhi of India, and the lowest of 0.8 t ha^{-1} in Bardiya and Banke of Nepal. It is interesting to note that spatial variability in the yields within the fields in each site was also high. Taking Magura site of Bangladesh as an example, the yield in different sampling areas ranged from a high of 3.7 t ha^{-1} to a low of 2.1 t ha^{-1} in field number seven. Similar variability was also found in other fields in other sites across the three countries.

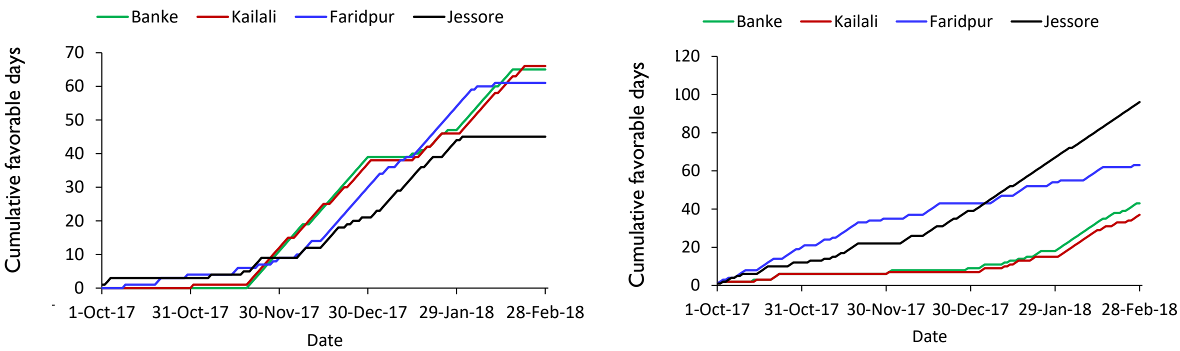
Weather-based stemphylium model validation and performance

Essential weather variables from five weather stations, representing five disease-monitoring sites (three in Bangladesh and two in Nepal), were collected from each of the meteorological agencies in Bangladesh, Nepal and India for *Stempedia* model testing. Data have been analyzed for Nepal and Bangladesh and show that in each of the tested sites there was some underestimation or overestimation between observation and model's prediction. Such variation is however small when considering the severity scale of the SB. Nevertheless, there is clear cope of improving model's performance, which CSRD is currently focusing on by modifying the underlying equations in the model to improve fit to observed data.



Left: Comparison of Stempedia model's prediction and field observation on the severity of lentil Stemphylium disease in three sites of Bangladesh and two sites of Nepal. Right: Comparison of Stempedia model's prediction and field observation on the severity of lentil Stemphylium disease in three sites of in Meherpur, Bangladesh Banke in Nepal

The model was run to test its behavior in predicting the disease pattern against wide range of flowering periods. In Meherpur within Bangladesh, early flowering resulted in less sever disease pressure, although disease increased with delays in sowing that in turn delayed flowering, which pushed the crop into weather conditions more suitable for SB infection. Further analysis was undertaken to observe the differences in disease-favoring 2017-18 weather variables in Bangladesh and Nepal. Preliminary results indicate that cloudy weather and temperature ranges appropriate for the disease start earlier in Bangladesh than the Nepali sites.



Left: Temperature-induced cumulative favorable-days for spore release of Stemphylium botryosum, the causal fungus of Stemphylium blight disease of lentil, in Faridpur and Jashore Bangladesh, and Banke and Kailai in Nepal. Right: Cloudy weather induced cumulative favorable-days for spore release of Stemphylium botryosu, in Faridpur and Jashore weather of Bangladesh, and Banke and Kailai weather of Nepal.

CSRD regional collaborations to support weather-based disease modeling systems in South Asia

Members of the CSRD science team leading Stemphylium model testing presented this year's activities in seminars at the Bihar Agricultural University in Bhagalpur, NARC in Nepal, and at CIMMYT field offices with participation from national extension partners in Jashore and Faridpur in Bangladesh.


Left: Dr. Moin Salam of CSRD delivering a presentation of lentil Stemphylium blight modeling work at the Bihar Agricultural University, India, on 18 September 2018. Audience included the Vice Chancellor Dr. Ajoy Kumar Singh (left front row) and University Deans. Photo: Abhijeet Ghatak. Right: Moin Salam and Dr. Rajendra Darai, Senior Scientist and Coordinator of the Nepal Agricultural Research Council's Grain Legumes Research Program, Nepal in his office on 20 November 2018. Photos: Sagar Kafle

Activities for 2018-19 field measurements, which began in October of this year, started with revision of the sampling protocol based on learnings from the previous year. Trainings in the revised protocol were conducted in October and November in all three countries. These included laboratory work to identify SB spores. Surprisingly, during a training session in Nepal, early symptoms of SB were identified from sampled fields. These samples, which were taken from a very young crop and at a stage of growth during which infection is thought to be very rare, was confirmed in the laboratory test. This observation has opened a new window of thinking of the epidemiology of SB, helping to improve modeling efforts.

Planned activities in Quarters 1 and 2 of 2019:

The following activities will be completed in 2019. An equal number of field observations of disease severity and incidence will be collected in Bangladesh, Nepal and India to help calibrate and improve model fit. A comparison of NASA-sourced weather data with measured data from each country will be conducted to help verify and fill gaps in existing station records in Bangladesh, Nepal, and India. This includes the development and testing of algorithms for conversion of solar radiation into cloudiness to be used for model runs. In consultation with national partner, CSRD will design and implement forecasting sites in three countries based on weather pattern scenario analysis. Finally, model validation activities will include improvements in the model's predictability through calibration and parameter estimation, the preliminary development of a forecasting system in three countries that will likely undergo continued testing in CSISA after the completion of the CSRD project. In addition, CSRD will work on disease scenario analysis based on historical and future climate model runs.

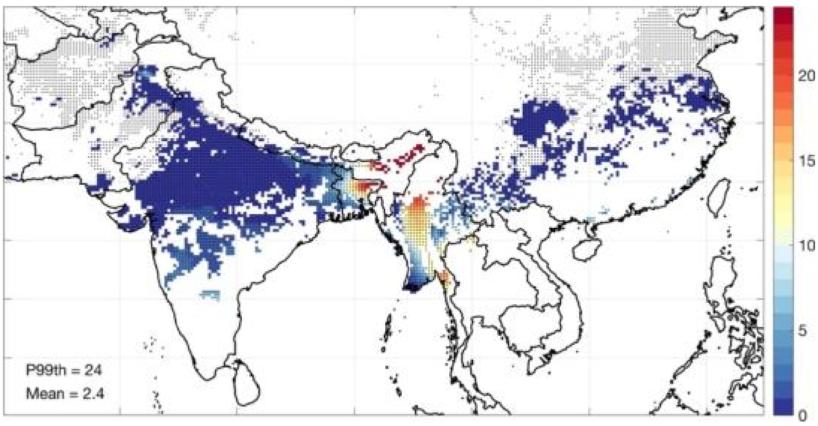
Contribution of Activity 2.1.2 to CSRD's Action and Learning Framework:
These efforts contribute to Pillar 2, Indicator 2.1, and Pillar 4, Indicator 4.1(see Annex 3).

Activity 2.1.3. Application of historical, near-term, and future climate data applied to develop spatially explicit wheat blast (*Magnaporthe oryzae* Triticum) disease risk assessments for South Asia

Product 1: Climatically driven regional disease risk assessment for wheat blast (Magnaporthe oryzae Triticum)

Wheat blast has been officially reported in Bangladesh since February of 2016, the year during which 15,000 hectares of wheat were affected with sometimes severe yield losses. A fungal disease, the development of wheat blast and its spread are controlled in part by temperature, humidity, precipitation and wind patterns. Given the short time elapsed since this date, as well as the limitations in available field observation and meteorological data, the temporal and spatial patterns related to the incidence and severity of the disease are not yet clear. They require further systematic study to develop effective weather-based forecasting systems – especially for countries neighboring Bangladesh. The risks of wheat blast spreading beyond Bangladesh, which is the only country where it has been officially reported in South Asia, is currently being addressed by CSRD through the use of multiple datasets. The goal of this work is the provision of information and modeling of historical climate with biological models to identify areas beyond Bangladesh where the development of wheat blast disease may develop.

Ongoing work in 2018 permitted the estimation of the potential incidence of wheat blast based on climate suitability represented by a generic infection model for fungal plant pathogens. This builds on the work described in Objective 1, while adding more nuisance to the model and examining the whole of Asia. Results presented in the following maps show the inter-annual average number of potential wheat blast infections during the winter season, when wheat is grown, across the whole of South and South-East Asia, including China.



Spatial pattern of the interannual average number of potential infections in Asia per season. Black dot symbols represent grid cells with presence of wheat. P99th is the 99% percentile of model run results.

This climate based analysis was first performed by using hourly gridded data for the period 1951-2010 over the study region. A generic model was applied that has been widely cited in the epidemiology literature to be appropriate for use in forecasting pathogens that have a biology and ecology which are not widely understood. The model makes use of estimates of cardinal temperatures and wheat leaf wetness duration assumptions for single-event outbreaks of the disease triggered by weather conditions. By integrating this data, the model provides information on the climatic suitability for potential wheat blast infection events, the large-scale factors acting as drivers and their variability, and spatiotemporal patterns. Readers are referred to a more extensive analysis of climate suitability for what blast is provided in Annex 4.

Planned activities in Quarters 1 and 2 of 2019:

Further parameterization of this model will be conducted in 2019 to provide exploratory information to agricultural policy matters in countries and regions identified to be most at risk of infection based on spatial maps of wheat production areas. The CSRD team will however focus more on the pragmatic aspects of forecasting and early warnings, and assuring use of the model system described in Objective 1, as this work is complementary.

Contribution of Activity 2.1.3 to CSRD's Action and Learning Framework:

Pillar 2, Indicator 2.2, Pillar 4, Indicator 4.1 (see Annex 3).

Objective 3: Coordination with CSRD partners in-country to ensure progress on the work streams under the CSRD South Asia and Bangladesh working group

Sub-Objective 3.1. Coordination of Bangladesh CSRD partners

Background

CSRD works to support a range of national of partners in Nepal, Bangladesh, and India through coordination, training opportunities, and networking across countries. The section below provides some highlights for CSRD's work with partners in 2018, with emphasis on the second half of the year. Other highlights from early 2018, including CSRD staff participation in the annual Gobeshona Climate Change conference in Dhaka, seminars on wheat blast modeling from visiting Brazilian scientists at BMD, and formation of the Bangladesh Academy for Climate Services (BACS) can be found in the 2018 semi-annual CSRD report.

The Bangladesh Academy for Climate Services (BACS)

Jointly founded by the International Center for Climate Change and Development (ICCCAD), the International Research Institute for Climate and Society (IRI) at Columbia University, Bangladesh Meteorological Department (BMD) and the International Maize and Wheat Improvement Center (CIMMYT) through CSRD, the Bangladesh Academy for Climate Services (BACS) was inaugurated in August this year at BMD. BACS has received in-kind and direct financial support through CSRD, and also the Adapting Agriculture to Climate Today, for Tomorrow (ACToday) project, part of Columbia World Projects, the academy aims to embed climate thinking in decision-making processes and close the gap between climate information providers and end users.

BACS offers three functions supporting climate services in Bangladesh:

- A Convening role to open trans-sectorial and multi-stakeholder dialogue on climate services (defined as the production, translation, dissemination and use of climate and weather data to improve decision making), in order to identify existing initiatives, challenges and opportunities.
- Develop tailored certification short courses for students and early to mid-level professionals to help address identified needs.

- Create graduate level curricula to train a new generation of weather, climate and sector experts with the skills needed to face the uncertainties of the coming decades.

In addition to multiple prior events reported on in the 2018 semi-annual CSRD report, BACS offered first of its kind 5-day training in Bangladesh in October of 2018 comprised of educational discussion sessions, informative presentations, question and answer sessions, and a field visit to Manikganj, a district next to Dhaka. During the training, participants learned the basics of climate science, climate services and available products, as well as strategies that would enhance the use of climate services.

"We would like to be able to use forecasts to anticipate future disasters and act early to mitigate losses. Therefore, understanding how to translate and apply the forecasts is of importance to me" said one of the participants, Lamiya Mahpara Ahmed, Analyst at Start Fund Bangladesh. "Similarly, learning the feasibility and limitations of climatology will help us design our forecasting needs." The course focused mainly on a deeper understanding of climate services as well as the challenges and expectations involved.

BACS training participants work in smaller groups during one of the training sessions to determine the kind of climate information needed to make decisions in their job positions. Photo: D. Dinh (IRI).

Twenty three participants from private sector, educational institutes, government departments, and international NGOs attended the training held at BMD's headquarters. The field visit component enabled the participants to put the decision-making flowchart (DMF) for climate services studied during the training to practice in a real-life setting with farmers.

"As a development practitioner, without much technical background in climate services, this course has been significantly important for me in building competency on relevant issues like weather forecasting, the uses of climate data, the cope and limitations of climate services, as well as the challenges involved", explained Hossain Ishrath Adib, Head of Programme Implementation, Practical Action.

At the end of the training, participants also identified climate-sensitive decisions within their respective fields and developed an understanding of existing decision-making processes. Equipped with this knowledge, participants can better understand their demands for climate information as well critically assess the current use of climate information within their field.

Through the training, the participants became better connected with the trainers and organizing partners — particularly BMD — for inquiries, ideas, and questions regarding the course materials as well as climate services and climate forecasts in Bangladesh. The participants also joined a BACS Facebook group to stay in touch with one another and with the next training cohorts. In a few months, the participants will meet again to discuss how they have applied the information from the course and to learn from each other's experience.

CSRD and synergies with the World Bank funded Bangladesh Weather and Climate Services Regional Project (BWCSRP)

Carlo Montes and Timothy J. Krupnik and of CSRD jointly presenting the objectives, national and international partnerships and updates on CSRD activities at the second meeting of Joint Technical Working Group of the World Bank funded Bangladesh Weather and Climate Services Regional Project (BWCSRP). Ms. Arati Belle, Disaster Risk Management and Climate Specialist, South Asia DRM and Climate Change Unit, World Bank and Task Team Leader of BWCSRP, Mr. Shamsuddin Ahmed, Director, BMD and other members of the working group were present at the meeting. Photo: M. Shahidul Haque Khan.

CSRD has continued to foster strong collaboration, including deepening links with the World Bank funded Bangladesh Weather and Climate Services Regional Project (BWCSRP). This 'sister' project aims to strengthen Bangladesh's capacity to deliver reliable weather, water, and climate information services and improve access to such services by priority sectors, and provides strong opportunity to scale-out and scale–up the results of CSRD's work.

The second meeting of Joint Technical Working Group (JTWG) of BWCSRP was held on November 04, 2018 in the Conference Hall of BMD. Timothy J. Krupnik and Dr. Carlo Montes of CSRD jointly made a presentation describing the objectives, national and international partnerships and updates on CSRD activities and shown how these have supported DAE and BMD's objectives synergistically with the World Bank Bangladesh Climate Services project. CIMMYT continues to work closely with both partners to accelerate the supply of appropriate climate information to farmers and achieve out-scaling of the project's technical and capacity development products through the BWCSRP.

Planned activities in Quarters 1 and 2 of 2019:

CSRD will support a symposium at the January 2019 Gobeshona conference on climate change research in Bangladesh, during which graduates from the first BACS training will present their ongoing work on climate services. Further coordination on implementation of wheat blast data collection, model calibration, and development of a full early warning system for wheat blast disease will be undertaken in February-March, with training provided to BMD and DAE by visiting scientists from the University of Passo Fundo in Brazil. Trainings in drought monitoring for BMD, DAE, and BARC staff are also anticipated in the second quarter of 2019 led by ICIMOD in coordination with CSRD.

Contribution of Sub-Objective 3.1 to CSRD's Action and Learning Framework: Pillar 2, Indicator 2.2 (see Annex 3).

Sub-Objective 3.2. Policy maker, agro-metrological services, extension, and farmer awareness of agro-meteorological forecasts and decision support tool platforms for agriculture increased

Background

Key activities that were conducted in 2018 to supports CSRD's Objective 3, which aims for general capacity development of national and regional partners in agricultural climate services, are detailed below.

On-the job training on application of GIS and Remote Sensing for agriculture and drought monitoring as part of CSRD's collaboration with ICIMOD

In March of 2018, a two-week on-the-job training took place in Kathmandu for BARC and BARI staff on the application of remote sensing technologies and tools in drought monitoring and crop mapping. The training strengthened the remote sensing capabilities Dr. Suraya Parvin, Senior Scientific Officer from BARC and Mr. Kowshik Kumar Sah, Scientific Officer FMP Engineering Division of BARI. Both participatins also introduced to a suite of remote sensing and GIS tools including SPIRITS, QGIS, ArcMap, GeoCLIM, as well as Google Earth Engine.

In April of 2018, ICIMOD collaborated with CSRD to organize a 5-day workshop held in Dhaka at BMD headquarters on the use earth observation data and products for drought Monitoring. Twenty four Government of Bangladesh staff representing different government organizations and universities in Bangladesh were trained in the use of satellite data products for drought monitoring and early warning. 20 (16 male and 4 female) participants from BARC, BMD, BARI, BRRI, DAE, CIMMYT, ICIMOD, selected NGOs and private sector partners attended the workshop, which was facilitated by resource persons from BARC, BMD, CIMMYT, ICIMOD, NASA-SERVIR, and John Hopkins University. Further details can be found in the 2018 semi-annual CSRD report.

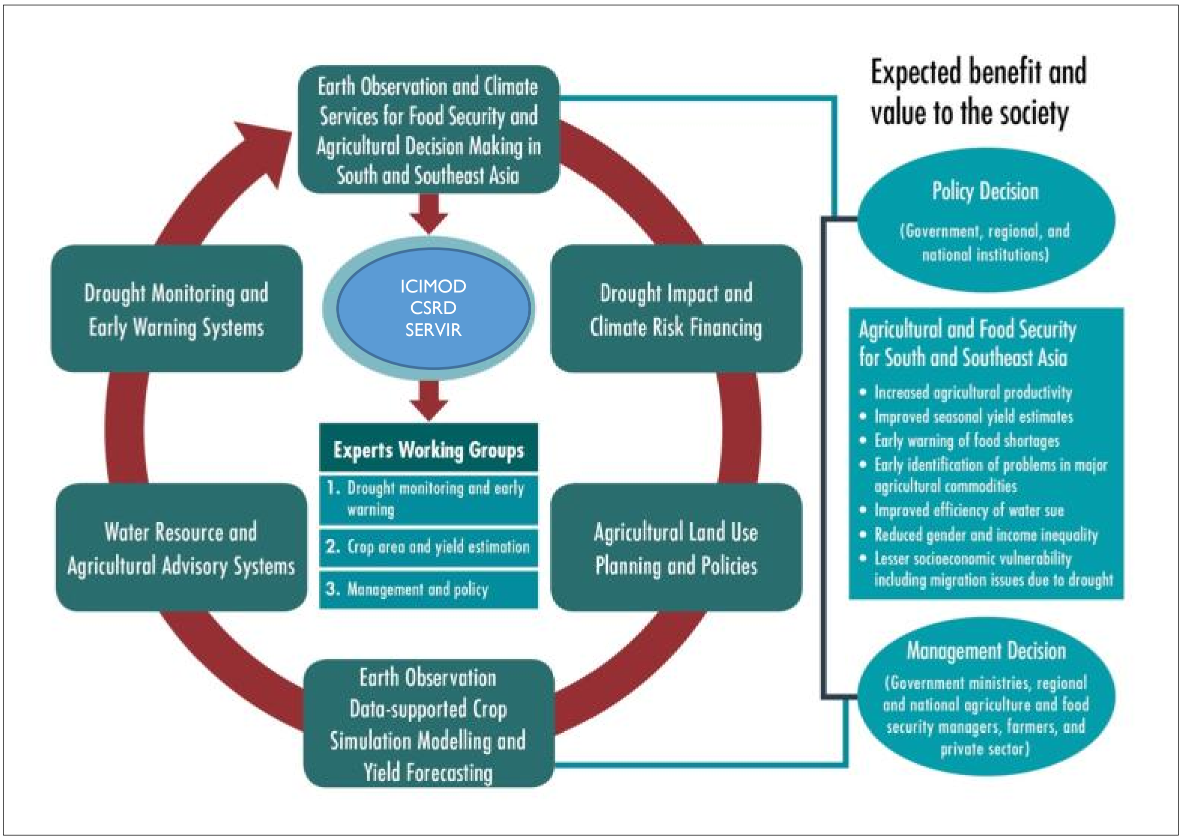
The SERVIR-HKH and CSRD supported Regional Drought Forum: Cooperation in Sharing Information on Natural Hazards

The Regional Knowledge Forum on Drought was held at the International Centre for Integrated Mountain Development Centre (ICIMOD) from 8–10 October with support and sponsorship from CSRD. The key objectives of this forum were to (i) review current status and needs for sustained information services at regional and national levels for drought monitoring, crop monitoring, and climate services; and (ii) establish a regular forum and related expert groups to foster regional cooperation on agriculture and food security related services. To meet these objectives, the forum engaged participants from countries in the Hindu Kush-Himalaya (HKH) and the lower Mekong regions via panel discussions and breakout groups that focused on three main topics.

On behalf of USAID, CSRD contributed financially to the forum, which brought together a hundred participants – academics, policy practitioners, researchers, and media persons – affiliated to 50 institutions based in 14 countries – in Asia and beyond – participated in the event. The forum received good participation from regional and local institutions engaged in providing and using agricultural and meteorological services, and scientific professionals and researchers. In the three days deliberations including 37 talks the experts reviewed existing national practices and policies related to drought monitoring and forecasting, crop monitoring and agriculture advisory services, and cross learning relevant to countries in the HKH and the lower Mekong regions. Discussing examples from South and Southeast Asia, panelists at the forum showcased the value that Earth observation technologies and climate services bring to establishing national and regional drought monitoring and early warning systems and agro-advisory services.

The regional drought forum was a diverse and interactive event for scientists, policy makers, and other partners from across South and South East Asia. Photos: Jitendra Bajracharya

As part of the objective of the Forum, the participants at the forum discussed ways to establish a regional partnership (innovation platforms) through participation of national and regional institutions, private sectors, local and international organizations to improve climate services using Earth Observation and facilitate agricultural decision making to help with food security in the region. Thus, three working groups (WGs) were proposed at the forum: (i) Drought monitoring and early warning, (ii) Crop area and yield estimation, and (iii) Management and policy. The value and benefit of Earth Observation for drought risk management and food security, which were discussed at the forum, are also highlighted in the figure below. These WGs will have regional coordinators (e.g., experts from ICIMOD, CSRD, and SERVIR) and representatives from each country's key institutes in the region. The WGs are expected to help in knowledge sharing and exchange of data resources as well as building institutional capacity needed to address drought monitoring and food security issues. Volunteering members of these WGs will meet periodically to share their experiences and lessons learned. In addition to fostering collaboration at the regional scale, the forum participants strongly recommended including training local experts in capacity building.



The framework of the main thematic areas and expected benefits of the proposed experts' working groups at the Regional Knowledge Forum on Drought.

Contribution of Sub-Objective 3.2 to CSRD's Action and Learning Framework: Pillar 3, Indicator 3.1(see Annex 3).

Implementation challenges

No significant implementation challenges were experienced during in 2018. As indicated in the 2018 semi-annual CSRD report, good progress is being made in pursuit of CSRD's technical, capacity development, and partner networking objectives. In comparison to the challenges faced in 2017 and the consequent delays in project implementation and delivery can be found in the 2016-17 CSRD in South Asia Annual Report, the project is performing well._Also of relevance, CSRD has submitted a request for a no-cost extension (NCE) to USAID on November 13, 2018 that we anticipate will be approved, and which will extend the project to the end of 2019. The request for an NCE is under consideration and we have been advised via email to plan activities in 2019 assuming the extension is granted. This will permit more complete delivery of a number of the CSRD products and work streams, especially as the project will be able to capture two additional cropping seasons to collect field data, calibrate models, test and refine climate services products and weather-based early warning systems for diseases. Extension will also facilitate improved networking and capacity development among partners, and fuller transfer of collaboratively developed products to national systems for sustained implementation and scaling through synergistic projects and ongoing but separate programs.

Annexes

Annex 1. Key Staff and Core Partner Designations

Name	Role	Institution	Address	Phone	Email	Comments
CIMMYT – BANGLADESH						
Dr. Timothy J. Krupnik	Systems Agronomist and CSRD Project Leader	CIMMYT	Dhaka, Bangladesh	+880-175-556-8938	t.krupnik@cgiar.org	55% FTE
Dr. Urs Christoph Schulthess	Senior Scientist Remote Sensing	CIMMYT	Dhaka, Bangladesh	+880-178-766- 9073	U.Schulthess@cgiar.org	15% FTE In-Kind contribution
Dr. Carlo Montes	Agricultural Climatologist	CIMMYT	Dhaka, Bangladesh		c.motes@cgiar.org	100% FTE
Dr. Ghulam Hussain	Senior Consultant: Project coordination and partner liaison	CIMMYT	Dhaka, Bangladesh	+880- 171-5885608	sghussain.bd@gmail.com	100% FTE
Dr. Moin Salam	Senior Consultant: Lentil *Stemphylium* modeling and forecasting	CIMMYT	Dhaka, Bangladesh	+880-185-5871938	moinsalam1@gmail.com	50% FTE on consultancy basis
Mr. Ansar A Siddiquee Iqbal	Project Manager	CIMMYT	Dhaka, Bangladesh	+880-171-3044764	a.siddiquee@cgiar.org	25% FTE
Dr. Shafiq Islam	Jashore Hub Coordinator	CIMMYT	Jashore, Bangladesh	+880-171-145 1064	Shafiqul.Islam@cgiar.org	In-kind contributions to lentil disease model validation in Bangladesh through CSISA
Dr. Dinabandhu Pandit	Senior Technical Coordinator (CSISA)	CIMMYT	Faridpur, Bangladesh	+880-171-213 0599	d.pandit@cgiar.org	In-kind contributions to lentil disease model validation in Bangladesh through CSISA
Mr. Khaled Hossain	Research Associate	CIMMYT	Dhaka, Bangladesh	+880-171-7765505	m.k.hossain@cgiar.org	100% FTE
Mr. Mustafa Kamal	Research Associate	CIMMYT	Dhaka, Bangladesh	+880-171-7425006	m.kamal@cgiar.org	100% FTE
Mr. Md. Motasim Billah	Data Specialist	CIMMYT	Dhaka, Bangladesh	+880-182-4367257	--	100% FTE
Mr. Shahidul Haque Khan	Communication Specialist	CIMMYT	Dhaka, Bangladesh	+880-171-3330981	msh.khan@cgiar.org	25% FTE

Name	Role	Institution	Address	Phone	Email	Comments
Ms. Fahmida Khanam	Program Assistant	CIMMYT	Dhaka, Bangladesh	+880-171-3409446	Fahmida309@gmail.com	100% FTE
Mr. ASM Alanuzzaman Kurishi	Research Associate	CIMMYT	Dinajpur, Bangladesh	+880-171-5803856	a.kurishi@cgiar.org	75% FTE
Mr. Mani Krishna Adhikary	Agricultural Development Officer	CIMMYT	Dinajpur, Bangladesh	+880-171-2544706	m.adhikary@cgiar.org	100% FTE
Mr. Anarul Haque	Extension Agronomist	CIMMYT	Rajshahi, Bangladesh	+880-171-9546672	an.haque@cgiar.org	100% FTE
Mr. Md. Ashraful Alam	Technical Officer	CIMMYT	Dhaka, Bangladesh	+880-172-7022007	a.alam@cgiar.org	30% FTE
Mr. Golam Morshed Rokon	Agricultural Development Officer	CIMMYT	Barisal, Bangladesh	+880-171-9408321	g.rokon@cgiar.org	In-Kind contribution in 2017 through the Dutch Funded "Groundcover' app project; 100% FTE from January 2018
Ms. Sumona Shahrin	Consultant research associate	CIMMYT	Dhaka, Bangladesh	+880-187-5315084	sumonashahrin@yahoo.co m	30% FTE
Md. Washiq Faisal	Consultant research associate	CIMMYT	Dhaka, Bangladesh	+880-174-0603385	faisal.washiq@gmail.com	30% FTE
CIMMYT - NEPAL						
Dr. Andrew McDonald	Systems Agronomist	CIMMYT	Kathmandu, Nepal	+977 9808757832	a.mcdonald@cgiar.org	In-kind strategy guidance and contributions
CIMMYT - India						
Dr. R.K. Malik	System Agronomist and CSISA India Country Coordinator	CIMMYT	Patna, India	+977 9745060768	m.devkota@cgiar.org	In-kind contributions to lentil disease model validation in India through CSISA
Dr. Poonia SP	CSISA India Research Platform Coordinator		Patna, India	+91 8292525557	S.Poonia@cgiar.org	In-kind contributions to lentil disease model validation in India through CSISA
Dr. Tek Sapkota	Agricultural Systems and Climate Change	CIMMYT	New Delhi, India	--	T.Sapkota@cgiar.org	15% FTE, 10% in-kind CCAFS contribution

Name	Role	Institution	Address	Phone	Email	Comments
CIMMYT - GLOBAL						
Dr. Bruno Gérard	Sustainable Intensification Program Director	CIMMYT	El Batan, Mexico	+52 (55) 5804 2004 ext. 2123	b.gerard@cgiar.org	3% FTE strategy and guidance
REGIONAL AND INTERNATIONAL PARTNERS						
International Center for Integrated Mountain Development (ICIMOD)						
Dr. Mir Abdul Matin	Theme Leader, Geospatial Solutions, Science and Data Lead (SERVIR-Hindukush Himalaya)	ICIMOD	Kathmandu, Nepal	+977-984-377-5633	mir.matin@icimod.org	ICIMOD focal point for CSRD in South Asia.
Mr. Faisal Mueen Qamar	Remote Sensing Specialist Geospatial Solutions	ICIMOD	Kathmandu, Nepal	---	faisal.qamer@icimod.org	Lead analyst for CSRD in South Asia activities.
International Research Institute for Climate and Society (IRI, Columbia University)						
Dr. Simon J. Mason	Chief climate scientist	IRI	Palisades, NY, USA	+1-845-680-4514	simon@iri.columbia.edu	IRI focal point for CSRD in South Asia. 10.5% FTE
Dr. James Hansen	Senior Research Scientist CCAFS Theme Leader	IRI	Palisades, NY, USA	+1 (845) 680-4410	jhansen@iri.columbia.edu	5% FTE
Mr. John Furlow	Deputy Director for Humanitarian and International Development	IRI	Palisades, NY, USA	+1 (845) 680-4466	jfurlow@iri.columbia.ed u	In-kind contribution through the Columbia World program and ACToday
Dr. Eunjin Han	Associate Research Scientist: Crop modeling	IRI	Palisades, NY, USA	--	eunjin@iri.columbia.edu	8% FTE
Dr. Nachiketa Acharya	Post Doctorial Research Scientist: Sub-seasonal forecasts	IRI	Palisades, NY, USA	--	nachiketa@iri/columbia.ed u	15% FTE
Dr. Colin Kelly	Associate Research Scientist: Temperature forecasting	IRI	Palisades, NY, USA	+1 (845) 680-4463	ckelly@iri.columbia.edu	8% FTE

Name	Role	Institution	Address	Phone	Email	Comments
Ms. Mélody Braun	Staff Associate	IRI	Palisades, NY, USA	--	m.braun@iri.columbia.edu	13% FTE
Mrs. Ashley Curtis	Senior Staff Associate	IRI	Palisades, NY, USA	--	acurtis@iri.columbia.edu	13% FTE
Mrs. Elizabeth Gawthrop	Science Communication Specialist	IRI	Palisades, NY, USA	--	gawthrop@iri.columbia.edu	4% FTE
Bangladesh Meteorological Department (BMD)						
Mr. Shamsuddin Ahmed	Director	BMD	Agargaon, Dhaka, Bangladesh	+ 880-2 891 4576	info@bmd.gov.bd	20% FTE
Mr. Md. Abdul Mannan	Meteorologist, Storm Warning Center	BMD	Agargaon, Dhaka, Bangladesh	+880-29135742	mannan_u2003@yahoo.co.in	20% FTE
Mr. S.M Quamrul Hassan	Meteorologist, Storm Warning Center	BMD	Agargaon, Dhaka, Bangladesh	+880-19162255449 +880-2 9135742	smquamrul77@yahoo.com, quamrul.hassan@bmd.gov.bd	20% FTE
Mr. Md. Bazlur Rashid	Meteorologist, Storm Warning Center	BMD	Agargaon, Dhaka, Bangladesh	+880-2 9135742	bazlur_rashid76@yahoo.com	20% FTE
Mr. Md. Tariful Newaz Kabir	Meteorologist, Agromet Division	BMD	Agargaon, Dhaka, Bangladesh	+88 01938595320	kabir5797@gmail.com	
Department of Agricultural Extension (DAE)						
Dr. Aziz Mazharul	Additional Deputy Director and Project Director, Agro-Meteorological Information Services (DAE part)	DAE	Farmgate, Dhaka, Bangladesh	+880-2 9130928	azizdae@gmail.com	In-kind contribution through the World Bank funded Agro-Meteorological Information Services project
Dr. M. Shahabuddin	Additional Director Planning & ICT management	DAE	Khamarbari, Farmgate, Dhaka, Bangladesh	+880-1742601461	shahabipm@gmail.com	20% FTE
Mrs. Rahana Sultana	Upazila Agriculture officer	DAE	Khamarbari, Farmgate, Dhaka, Bangladesh	+880-1715551091	rahanaplp@yahoo.com	20% FTE
Mr. Md Saiful Islam	Additional Deputy Director, Crop Wing	DAE	Khamarbari, Farmgate, Dhaka, Bangladesh	+880-171-5332319	anntara2008@yahoo.com	20% FTE

Name	Role	Institution	Address	Phone	Email	Comments
Md. Fazlul Hoque	District Training Officer	DAE	Khamarbari, Barisal, Bangladesh	+880-172-8251836	f.hoq1542@gmail.com	In-kind contribution to administering district based training work
Md. Monzurul Haque	District Training Officer	DAE	Khamarbari, Rajshahi, Bangladesh	+880-171-1224280	monzurul.aeo@gmail.com	In-kind contribution to administering district based training work
Nikhil Chandra Biswas	District Training Officer	DAE	Khamarbari, Dinajpur, Bangladesh	+880-193-8826855	ncbiswasdae@gmail.com	In-kind contribution to administering district based training work
Bangladesh Agricultural Research Institute (BARI)						
Md. Shariful Bin Akram	Scientific Officer	BARI	Wheat Research Centre, Dinajpur, Bangladesh	+880-1717-545797	sariful.santo@gmail.com	Time in-kind; sub-grant costs for experiments only
Md. Jakir Hossain	Scientific Officer	BARI	Regional Wheat Research Station, Shampur, Rajshahi, Bangladesh	+880-1710-375943	zakzubari@gmail.com	Time in-kind; sub-grant costs for experiments only
Shiek Shamsul Alam Kamar	Scientific Officer	BARI	Regional Agricultural Research Station, Rahmatpur, Barisal, Bangladesh	+88 01724-461414	alamkamar91@gmail.com	Time in-kind; sub-grant costs for experiments only
***Universidade de Passo Fundo* (UPF)**						
Dr. José Maurício Cunha Fernandes	Senior Scientist – Plant Epidemiology	UPF	Passo Fundo, RS, Brazil	--	mauricio.fernandes@embrapa.br	Time in-kind for scientific coordination
Mr. Felipe de Vargas	Computer scientist	UPF	Passo Fundo, RS, Brazil	--	119685@upf.br	100% FTE (wheat blast computer model coding)
University of Reading (UR)						
Dr. Peter Dorward	Professor, School of Agriculture, Policy and Development	UR	Reading, UK.	+44 (0) 118 378 8492	p.t.dorward@reading.ac.uk	Currently being determined
Dr. Samuel Poskitt	Post-Doctoral Scholar	UR	Reading, UK	--	samuel.poskitt@reading.ac.uk	Currently being determined

Name	Role	Institution	Address	Phone	Email	Comments
Dr Graham Clarkson	Senior Research Fellow, School of Agriculture, Policy and Development	UR	Reading, UK	+44 (0) 118 378 5036	g.clarkson@reading.ac.uk	Currently being determined
Bihar Agricultural University (BAU)						
Dr. Abhijeet Ghatak	Assistant Professor of Plant Pathology	BAU	Sabour, Bihar, India	--	ghatak11@gmail.com	In-kind contribution to lentil disease monitoring activities
Bangladesh Agricultural University (BAU)						
Dr. M.A. Farukh	Professor, Department of Environmental Science	BAU	Mymensingh-2202, Bangladesh	+880-1712-106603/	BAU	Mymensingh-2202, Bangladesh
Wageningen University: WaterApps project						
Dr. Saskia Werners	Assistant Professor of Adaptive Water Management	WUR	Wageningen University & Research Teams WSG - CALM (Water Systems and Global Change) PO Box 47, 6700 AA Wageningen, the Netherlands	+31 317 486442	saskia.werners@wur.nl	In-kind contribution to PICSA work
Mr. Uthpal Kumar	PhD Student	WUR	Wageningen University & Research Teams WSG - CALM (Water Systems and Global Change) PO Box 47, 6700 AA Wageningen, the Netherlands	--	uthpal.kumar@wur.nl	In-kind contribution to PICSA work
Nepal Agricultural Research Council (NARC)						
Dr. Rajendra Darai	Senior Scientist and Coordinator, Grain Legumes Research Program	BAU	Khajura, Banke, Nepal	--	Nglrp_khajura@narc.cov.np	In-kind contribution to lentil disease monitoring activities

Name	Role	Institution	Address	Phone	Email	Comments
International Centre for Climate Change and Development (ICCCAD)						
Dr. Saleemul Huq	Director	ICCCAD	House-27,Road 1, Block-A, Bashundhara R/A, Dhaka 1229	+880-177-9754662	saleemul.huq@iied.org	In-kind contribution to Bangladesh Academy for Climate Services (BACS)
Dr. Feisal Rahman	Research Coordinator	ICCCAD	House-27,Road 1, Block-A, Bashundhara R/A, Dhaka 1229	+880-170-6849030	feisal1702@gmail.com	In-kind contribution to Bangladesh Academy for Climate Services (BACS)
Ms. Tasfia Tasnim	Research Officer	ICCCAD	House-27,Road 1, Block-A, Bashundhara R/A, Dhaka 1229	+880-193-0511433	tasfia.tasnim@icccad.net, tasfia2507@gmail.com	In-kind contribution to Bangladesh Academy for Climate Services (BACS)
Ms. Anne Laurie Pilat	Visiting Researcher	ICCCAD	House-27,Road 1, Block-A, Bashundhara R/A, Dhaka 1229	-	annelaure.pilat@gmail.com	In-kind contribution to Bangladesh Academy for Climate Services (BACS)

Annex 2. Project subcontractors and key partners' designations

Partner	Partnership Objective	Strategic Alignment	Leveraging Opportunity	Anticipated or committed funding (USD)	Objective and activity contributions (Core activity contributions)	Status of Partnership
Bangladesh Meteorological Department (BMD)	Integrative CSRD partner to produce and control the quality of climate information and forecasts. Iterative development of climate services frameworks and decision support tools.	Pillars 1, 2, 3, and 4	BMD is Bangladesh's lead agency for meteorological forecasting in Bangladesh and is interested to improve the quality of their ag-meteorological forecasts. Improvement of short-term and seasonal forecasts and integration of the resulting information as crop specific climate service advisories will be deployed through CSRD partners.	$68,459. Note that in agreement with BMD on November 13, 2018, the sub-grant amount was reduced to reflect BMD's largely in-kind and intellectual contribution to CSRD.	Sub-Objective 1.1., Activity 1.11., Sub-Objective 1.2, Activity 1.2.1., Sub-Objective 1.3: Activity 1.3.1 (all three sub-activities), Activity 1.3.2, Sub–Objective 2.1, Activity 2.1.1, Objective 3, Sub-Objective 3.1.	The sub-grant agreement between CIMMYT and BMD was signed on 29 August 2017 (Dated June 15, 2017) with full approval of the Ministry of Defense. Sub-grant copies are available for review upon request. The sub-grant amendment modifying the full amount that was completed on 13 November is also available on request.
Department of Agricultural Extension (DAE)	Iterative development of climate services frameworks and communication strategies. Extension and dissemination of agriculturally relevant	Pillars 1, 2, 3, and 4	DAE has over 14,000 field extension agents operating throughout Bangladesh. DAE also has capabilities in ICT tools for extension purposes.	$100,000	Sub-Objective 1.1., Activity 1.11., Sub-Objective 1.2, Activity 1.2.1., Sub-Objective 1.3: Activity 1.3.1 (all three sub-activities), Activity 1.3.2, Sub–Objective 2.1, Activity 2.1.1,	The Sub-grant agreement between CIMMYT and DAE has been signed on 16 October 2017. CIMMYT maintains a formal partnership MoU with the DAE, collaboration in CSRD has been initiated and is ongoing, although a formal
Bangladesh Agricultural Research Institute (BARI)	Validation and improvement of irrigation scheduling decision support tools (PANI). Collaborative	Pillars 1, 2, 3, and 4	BARI is Bangladesh's lead institute for research in non-rice crops, with significant technical capacity in irrigation and wheat related research.	$30,000	Sub-Objective 1.3: Activity 1.3.1 (PANI and wheat blast activities)	The sub-grant agreement between CIMMYT and BMD has been signed on 8 August 2017 and is now under way. Sub-grant copies are available for

Partner	Partnership Objective	Strategic Alignment	Leveraging Opportunity	Anticipated or committed funding (USD)	Objective and activity contributions (Core activity contributions)	Status of Partnership
	research to develop and improve wheat blast forecasts and decision support systems.					review upon request. Please see report sections on PANI for more details. Sub-grant copies are available for review upon request.
International Research Institute for Climate and Society (IRI)	Skills assessments and advanced forecasting and agriculturally relevant climate services training for BMD and DAE, consistent technical backstopping and support.	Pillars 1, 2, 3, 4	Scientists at IRI have been collaborating with BMD for over four years. CSRD is leveraging this partnership provide consistent technical support and backstopping to BMD, and to develop improved climate services communications and extension strategies with DAE through IRI's contributions to *CCAFS's Research Theme on Adaptation through Managing Climate Risk*.	$300,000	Sub-Objective 1.1., Activity 1.11., Sub-Objective 1.2, Activity 1.2.1., Sub-Objective 1.3: Activity 1.3.1 (all three sub-activities), Activity 1.3.2, Objective 3, Sub-Objective 3.1.	The sub-grant agreement has been signed between IRI and CIMMYT on 31 August 2017. Sub-grant in near final stages of development, signatures and formalization expected by approximately the third week of May, 2017. Sub-grant copies are available for review upon request.
International Centre for Integrated Mountain Development (ICIMOD): Sub-grant 1	Collaborative development and refinement of South Asian regional-scale decision support tools, services, and products with emphasis on seasonal to sub-seasonal drought forecasts and integration with BARC[1].	Pillars 1 and 4	Drought modeling downscaling at different resolutions and development of seasonal to sub-seasonal forecast of drought aligned with ongoing work in the SERVIR-Hindu Kush Himalaya (HKH) program	$195,000	Sub-Objective 1.1., Activity 1.11., Sub-Objective 1.2, Activity 1.2.1., Sub-Objective 1.3: Activity 1.3.1 (all three sub-activities), Activity 1.3.2, Objective 3, Sub-Objective 3.1.	The sub-contract agreement between CIMMYT and ICIMOD has been signed and completed on 1 May 2017. Sub-grant copies are available for review upon request.

Partner	Partnership Objective	Strategic Alignment	Leveraging Opportunity	Anticipated or committed funding (USD)	Objective and activity contributions (Core activity contributions)	Status of Partnership
International Centre for Integrated Mountain Development (ICIMOD): Sub-grant 2	Collaborative implementation of the October 8-10 2018 Regional Knowledge Forum on Drought held in Kathmandu.	Pillar 3	Awareness raising of climate services and earth observation data and tools to popularize drought monitoring and forecasting in collaboration with the SERVIR-Hindu Kush Himalaya (HKH) program	$25,000	Sub-Objective 3.2	The sub-contract agreement between CIMMYT and ICIMOD has been signed and completed on 14 September 2018. Sub-grant copies are available for review upon request.
Universidade de Passo Fundo (UPF)	Collaborative development and refinement of disease forecasting model and decision support system for wheat blast early warnings, supporting BARI	Pillars 2, 4	• Establish a web-based application and decision support tool (DST) for in-season 5 and 10-day lead time forecasts to present the probabilistic risk of wheat blast infection • Adapt a surveillance smartphone application to Bangladesh. • Engage with CIMMYT's partners in Bangladesh to incorporate input and feedback on performance of the application DST detailed in Objective 1, and to assist in training and advising partners on use of the application DST	$15,000	Objective 1, Sub-Objective 1.3, Activity 1.3.1: (MoT forecasting) Objective 2, Sub–Objective 2., Activity 2.1.3.	A consultancy has been awarded to Mr. Felipe de Vargas of UPF for 11 months (total value of the consultancy is $15,000). Total duration of the consultancy was June 2017-May 2018, with potential for renewal based on performance. de Vargas is supervised by Dr. José Maurício Cunha Fernandes, Senior Scientist – Plant Epidemiology at UPF, and developer of the preliminary wheat blast forecasting model. The terms of reference for de Vargas are available upon request
University of Reading	Embed PICSA into DAE programming	Pillars 2, 3	• Identify the key opportunities for a locally adapted form of PICSA to enable farmers to make	Under negotiation (likely $47,419)	Objective 1, Sub-Objective 1.3, Activity 1.3.2,	The sub-contract agreement between CIMMYT and University of Reading has been

Partner	Partnership Objective	Strategic Alignment	Leveraging Opportunity	Anticipated or committed funding (USD)	Objective and activity contributions (Core activity contributions)	Status of Partnership
			effective plans and decisions in the context of (a) existing farming and livelihood systems and (b) climate and related challenges • Provide technical support and training for the piloting of PICSA with DAE and other stakeholders • Develop recommendations for the wider roll out of PICSA in Bangladesh by DAE		Objective 3, Sub-Objective 3.2	drafted. Now it's being scrutinized for legal matters. It is likely to be signed soon. However, the scoping visit for PICSA implementation was conducted during 5-13 May 2018.

Annex 3. Monitoring, Evaluation and Learning Plan

Cumulative action and Learning Framework Report for 2018

Climate Services for Resilient Development (CSRD)

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
Pillar 1: Create the solution space	**1.1.** Number of collaborative climate services development processes (e.g., working groups) established with identified problem focus and participation of key stakeholders.	• Collaboration among the CIMMYT-CSRD partners in an integrated way, including Bangladesh Meteorological Department (BMD), International Centre for Integrated Mountain Development (ICIMOD), Department of Agricultural Extension (DAE), International Research Institute for Climate and Society (IRI), the Bangladesh Agricultural Research Institute (BARI), Universidade de Passo Fundo (UPF), University of Rhode Island (URI), and University of Reading (UoR)	• Number of formal climate services working groups that have a clearly defined problem focus and participation of approved and designated stakeholders	**Achieved:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • A webinar took place on 11 October at 8:30 AM in the CIMMYT office. Dr. Jose Mauricio Fernandes from UPF made a presentation on wheat blast model that they have developed. The meeting was attended by focal points from DAE and BMD, the Director, WRC and other relevant scientists • Dr. Jose Mauricio Fernandes from UPF visited Bangladesh in early 2018. • UoR was invited to the CSRD Technical Exchange in September of 2017 to present on PICSA. This led to considerable interest by DAE in PICSA. Ongoing discussions between CSRD and UoR have focused on their inclusion in the CSRD project to achieve the aims detailed in Annex 2. • The 4th Gobeshona Annual Conference for Research on Climate Change in Bangladesh was held during January 8-11, 2018 organized by ICCCAD at the Independent University Bangladesh, Dhaka. On January 10, 2018 a parallel session of the Conference CSRD-CIMMYT organized a Symposium on Climate Services in Bangladesh which was attended by 51 participants. • On January 11, 2018 a coordination meeting with IRI, BMD and CIMMYT was held at the CSRD office at BMD. Besides participants from BMD and CIMMYT, Drs. John Furlow, Melody Braun and Nachiketa Acharya from IRI attended the meeting. Discussions were held on the planning for next steps to build a platform for Bangladesh Climate services Academy, review the assignments of BMD scientists

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
				given by Dr. Simon (IRI) and Planning for IRI visit in March 2018 and agenda for the workshop at IRI. • Five CSRD coordination meetings were held at the CSRD office, BMD and DAE. • On July 01, 2018 a preparatory meeting was held at DAE to discuss and plan for arranging training on Participatory Integrated Climate Services for Agriculture (PICSA) of ten Cadre Officers of DAE as Experts (ToT) and 40 SAAOs' ToT for PICSA. • On August 13, 2018 CSRD Partners' coordination meeting was held in the CSRD office at BMD. Dr. Moin us Salam made a presentation on Stempedia and discussed on the activities carried out in Nepal and India. BMD presented on the progress of their work and next steps related to CSRD. DAE reported on the progress made on the implementation of PISCA approach and their future plan for the rabi season. BARC reported on the progress made so far on the drought monitoring. Mr. Mutasim Billah of CIMMYT presented the work in-progress on his web-enabled point-click and visualization toolkit for weather forecast and agmet advisories. Total Participants: 14 (12 male and 2 female).
		• Sub-grants awarded to CSRD partners awarded	• Signed documentation of sub-grant agreements or consultancies with eight CSRD partners (BMD, DAE, ICIMOD, IRI and BARI, UPF, URI).	**Achieved:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • All sub-grants with partners have been signed and are detailed in Annex 2 of this report.
		• National scientist training, exchange, between CSRD partners and IRI	• Completion of at least 10 days of exchange training with DAE and BMD focal points at IRI at Columbia University.	**Achieved** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • During March 26 - April 06, 2018 the Climate Services for Resilient Development Workshop cum Retreat was held at the International Research Institute, Columbia University, New York. Dr. Timothy J.

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
				Krupnik and Dr. Carlo Montes from CIMMYT, Mr. Md. Abdul Mannan, Mr. SM Quamrul Hasan Mr. Md. Bazlur Rashid from BMD participated in the workshop from March 26 to April 06, 2018. In the second week (from April 02-06, 2018) Dr. M Shahab Uddin, Dr. Mazharul Aziz, Mrs. Rahana Sultana and Mr. Md Saiful Islam of DAE; Mr. Shamsuddin Ahmed Director (BMD) and Dr. Sk. Ghulam Hussain from CIMMYT joined the workshop. Further details are presented in Objective 1, Sub-Objective 1.2, and Activity 1.2..
		• BMD and DAE knowledge and technical skill gaps identified	• Completion of BMD forecast and communication skill, and DAE communication skills completed	**Achieved** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • During March 26 - April 06, 2018 the Climate Services for Resilient Development Workshop cum Retreat was held at the International Research Institute, Columbia University, New York. Dr. Timothy J. Krupnik and Dr. Carlo Montes from CIMMYT, Mr. Md. Abdul Mannan, Mr. SM Quamrul Hasan Mr. Md. Bazlur Rashid from BMD participated in the workshop from March 26 to April 06, 2018. In the second week (from April 02-06, 2018) Dr. M Shahab Uddin, Dr. Mazharul Aziz, Mrs. Rahana Sultana and Mr. Md Saiful Islam of DAE; Mr. Shamsuddin Ahmed Director (BMD) and Dr. Sk. Ghulam Hussain from CIMMYT joined the workshop. • During August 01-05 and 07 Dr. Nachiketa Acharya of IRI came to Bangladesh to train BMD focal persons for CSRD project on R software, and show how the IRI Maproom works, how to connect BMD 's information with IRI maproom etc. The training was attended by three focal persons of BMD. Dr. Acharya also had meeting with CIMMYT.
		• BMD, DAE, BARC, BARI, ICIMOD, IRI and other secondary partners' involvement in CSRD (supply of in-kind human resources, facilities, logistics)	• Letters of support from CSRD collaborating organizations clarifying in-kind partnerships and support	**Achieved** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • CSRD has achieved in-kind staff time contributions to support agricultural climate services work from several organizations (See Annex 5 for further details) • BMD has approved office-space to CSRD staff in their headquarters in Dhaka, Bangladesh. The office has been furnished and officially opened in

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
				January of 2018 as a facility to support CSRD researchers and the above-mentioned Climate Services Academy. A signage has been installed at the entrance of the room. BMD is also providing venue and logistics for holding workshops and training. A Training workshop on Use of Satellite Data Products for Drought Monitoring was held during April 15 -19, 2018 at the brand new training facility of BMD. The training was organized by ICIMOD. A total of 20 (16 male and 4 female) participants from BARC, BMD, BARI, BRRI, DAE, CIMMYT,ICIMOD, Selected NGO and private sector partners attended the workshop and was facilitated by resource persons from BARC, BMD, CIMMYT, ICIMOD, NASA-SERVIR SCO, and John Hopkins University.
Pillar 2: Utilize quality data, products, and tools	**2.1.** Number of and type of information and technology resources identified and offered, or brokered, by CSRD to meet problem needs and support targeted climate services.	• Crop specific forecasting maps + management advisories refined and made publically available with ongoing refinement following user feedback	• Support to CSRD partners in developing regional drought monitoring and forecasting products and interfaces • Report on planning sessions to develop crop specific forecasting maps + management advisories • Prototype crop specific forecasting maps + management advisories • Public launch of crop specific forecasting maps + management advisories • Refinements made in crop specific forecasting maps +	**Achieved** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • Refinements in the crop specific forecasting maps + management advisories continued throughout 2018. • An application has been developed for providing BMD's Meteorological Forecast based Agricultural Advisories by CIMMYT. The beta version of the app will be housed in the CSRD server at BMD which can be reached through the BMD website. • On November 19, 2018, a meeting was held at the CSRD office at BMD with the Agro-meteorology Division, CSRD focal persons and the Director of BMD to share the prototype of agromet advisory related app developed by CIMMYT. As per suggestion of BMD Director Mr. Billah and Dr. Hussain met the Communication Engineer, Mr. M.A. Matin of BMD to find out a means for housing the application in BMD website.

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
			management advisories	
	2.2. Number of tailored products developed to support specific decisions	• Establishment of Program for Advanced Numerical Irrigation (PANI) prototype, subsequent field calibration experiments incorporating precipitation forecasts implemented with BARI	• Availability of PANI prototype application • Protocols for field experiments, and upload of resulting datasets to publically available databases • Revised PANI prototype following CSRD partner and farmer evaluation.	**Achieved**: Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • Training on PANI Apps was conducted in two locations (Barisal Sadar and Babuganj Upazila) of Barisal District, in two locations (Dinajpur Sadar and Biral Upazila) of Dinajpur District and in two locations (Tanore and Charghat Upazila) of Rajshahi District on December 10, 13 and 27 of 2018, respectively. Five SAAOs from each Upazila (total 30 SAAOs) were trained to use the PANI Apps. • A user manual in for PANI Bangla has been prepared and shared with the trainees. **In Progress:** • Discussions continue with BARI, BMD, and DAE regarding the feasibility of different public platform (portal and/or application DSTs) for the longer-term housing of PANI. • Refinement of PANI will take place in 2019.
		• Agriculturally relevant climatology, extended-range and outlooks articulated as climactic stress risk maps generated	• Prototype availability of agriculturally relevant climatology, extended-range forecasts and outlooks articulated as climactic stress risk maps • Refinement of agriculturally relevant climatology, extended-range forecasts and outlooks articulated as climactic stress	**Modifications:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • Initial USAID consultation with BMD in 2016 revealed an interest in developing seven-day precipitation forecasts with 15-day accumulative rainfall outlooks. Subsequent consultations with CSRD during the skills assessment and IRI trainings however resulted in new priorities being set that better reflect and respond to management decisions made by farmers and agricultural decision makers in the DAE and other relevant organizations. As such, the Product from these activities has been renamed 'agriculturally relevant climatology, extended-range forecasts and outlooks'. These changes are detailed below and are under research and therefore in progress, with completion anticipated before Q2 of 2018.

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
			risk maps based on CSRD partner and farmer feedback • Formal establishment of agriculturally relevant climatology, extended-range forecasts and outlooks articulated as climactic stress risk maps on BMD website, with links from other CSRD partner websites	• Key sub-products resulting from this work will include the following, which have been agreed on by CSRD partners: **Historical Monitoring** • Crop-specific thermal stress risk mapping • Monsoon progression: Seasonal accumulation • Monsoon progression: Deviation from the norm • Pseudo-monsoon onset • Monsoon dry spells (consecutive 5 d < 1 mm, monsoon seasonal scale) • Heavy rain events (moderately heavy and above, February-March) • Improved language, text, format for agricultural meteorological bulletin produced by BMD (note that this work is being used synergistically in the complementary CSMSM project in Patuakhali, Bangladesh. **Forecasts** • Crop-specific thermal stress risk mapping (extended range, < 14 day periods) • Heavy rain events (moderately heavy and above, 0-15 day forecasts in Feb-March) • Further details on progress are provided in Objective 1, Sub-Objective 1.3, Activity 1.3., Product 1.
		• Spatially explicit and meteorologically driven *Stemphylium* disease risk assessments model for South Asia (Replacement for previous Precision Nutrient Management work stream as agreed on with USAID)	• Preliminary model availability • Field protocols for model calibration in India, Bangladesh, and Nepal • Model converted to R code for integration into a formal DST	**Achieved** Achievements listed below are for the 2018 calendar year. Readers are referred to the [2016-2017 Annual Report] for details of accomplishments from November 2016 to December 2017. • Field data collection from India, Bangladesh and Nepal was completed in 2018 as detailed in Product 1 from Objective 2. Analyses and model refinement are underway. • Model converted to R code for integration into a formal DST has been completed **In Progress:**

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
			• Refinement and improvement of model to improve suitability in India, Bangladesh, and Nepal	• Further data are being collected from over 800 farmers' fields in Bangladesh, India and Nepal to validate the model in the 2018-19 season. • Combined with weather data from each country, the model will be refined and improved to increase suitability in India, Bangladesh, and Nepal • Where adequate model fit is achieved, CSRD will explore opportunities for developing a Lentil *Stemphylium* blight disease forecasting and early warning system in South Asia
		Spatially explicit and meteorologically driven wheat blast (MoT) disease risk assessments model for Bangladesh and South Asia	• Coding for preliminary back-casting and forecasting models for MoT disease risk competed • Prototype of MoT forecasting DST completed Refinement and public availability of MoT forecasting DST	**Achieved** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • MoT forecasting in Bangladesh DST is reliant upon regular access to BMD WRF model outputs. In 2018, CSRD achieved installation of a server to access BMD WRF model outputs as inputs to the MoT forecasting model (for details on the server, please see Objective 1, Sub-Objective 1.3, Activity 1.3., Product 1) • Two Skype meetings (September 3 and October 23, 2018) with Professor Jose Mauricio Fernandez and Felipe Vargas, were held on the overall progress and with modeling work and wheat blast fungus spore trap protocol has been developed and a prototype of the fungus spore trapping gadget has been designed. Weather, soils, and DSSAT-based genetic coefficients of wheat varieties have been provided by CIMMYT for running the wheat blast model with Bangladesh data for calibration and validation. • A beta version of this wheat blast model and decision support tool is available online, and is a direct result of CSRD's efforts. Please see http://dev.sisalert.com.br/shiny/wheatblastmodel/. **In Progress:** • Based on models developed by Cruz et al. (2016), preliminary code and maps have been generated using ECMWF climatologies for the South and South-East Asian region to determine land area that may be at risk of wheat blast infection. This work is in progress and can potentially be incorporated into a forecasting model, although further effort is needed to refine the current climatological model. For further details, Annex 4 of this report.

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
				• Efforts to implement regional forecasting efforts in South Asia remain heavily dependent on the Government of India and Nepal's directives in mitigating risks of wheat blast. Through CIMMYT, CSRD is well positioned to interact with the relevant Indian and Nepali research and meteorological agencies. Next step decisions will be taken depending on how each Government chooses to respond to the risk of wheat blast.
		• Contributions to climate services products developed by other CSRD partners to support specific decisions	• Number of climate services products developed by other CSRD partners that the CSRD South Asia and Bangladesh group contributed to	**Achieved:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • CSRD supported ESRI by facilitating several skype meetings with partners to present a preliminary portal and repository of shapefiles and datasets that can be publically accessed to support climate services decision making. • CSRD in South Asia's Project Leader continues to liaise with the World Bank delegation responsible for administering the large-scale Agro-Meteorological Information Services project in Bangladesh in which BMD, DAE, and the BWDB collaborate. DAE has agreed to incorporate the tools and products developed through CSRD into the Agro-Meteorological Information Services project, as stipulated in the CSRD sub-grant for CSRD. • The Bangladesh Academy for Climate Services (BACS) co-founded by the International Center for Climate Change and Development (ICCCAD), the International Research Institute for Climate and Society (IRI) at Columbia University, the International Maize and Wheat Improvement Center (CIMMYT), and the Bangladesh Meteorological Department (BMD) has been formally launched on August 5, 2018 at Bangladesh Meteorological Department (BMD) Auditorium, Dhaka. The objective of the launch event was to raise awareness and present the objectives of the Bangladesh Academy for Climate Services. The vision of the academy is to create awareness around the need for better use and understanding of climate and weather information in Bangladesh, which BACS aims to respond to. The launch will serve as a networking opportunity for various stakeholders involved in BACS as well as in the creation, translation, dissemination and use of weather and climate information. The Bangladesh Academy for Climate Services (BACS) is to set up a trans-sectoral and

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
				multi-stakeholder dialogue on climate services, developing tailored certification short courses and creating graduate level curricula to train a new generation of weather, climate and sector experts. The first week-long course is on Introduction to Climate Services, going to be started on 21 October, 2018. Early-to mid-career professionals and students working in fields related to agriculture and food systems, disaster preparedness and response, public health, or aligned fields who would like to be actively engaged in defining needs and developing climate services for their sectors in Bangladesh can get enrolled to this course. Sixty participants (50 Male and 10 Female) from BMD, ICCCAD, IRI, DAE, CIMMYT, Dhaka university, World fish, UN-WFP, IWM, iDE, IOM, CCDB, UNDP, LGED, Bangladesh university of professionals, BIID, BRAC university, University of Arizona, and Syngenta Foundation-Bangladesh. attend the event • BACS organized a Learning Hub event (LHE) with a view to formally introduce the Bangladesh Academy for Climate Services (BACS) across government agencies. The program was hosted by the Programming Division of Planning Commission, Government of Bangladesh at the NEC-1 Committee Room of the Planning Commission, Sher-e-Bangla Nagar, Dhaka on August 06, 2018. The event was attended by 45 (32 Male and 13 Female) participants from Physical Planning Commission, Programming Division Planning Commission, MoDMR, IWFM/BUET, BBS,BMD, GED Planning Commission, Agricultural Division Planning Commission, MOFL, Water Resources and Rural Institution Division Planning Commission, DoE and ADB and IRI, ICCCAD and CIMMYT. • The participants discussed on the best possible way to utilize BACS to support the achievements of country objectives and explore how BACS can help address climate challenges faced by different government agencies. Participants provided a range of general comments some of them are discussed here. This event is very important for planning commission and Programming Division because they need to include climate information as 7th five year plan. There is a knowledge gap for screening or apply climate change in appraisal process of development project/ program. Need more decision with the day-long workshop. Short course on climate change with climate services (3 days long) can be arranged to stimulate the young learners, officials etc. Partnership in capacity development among government and non-government

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
				organization is very important. Being a climate vulnerable country and to combating climate change challenges Climate Finance is one of the useful tools that we need to be more knowledgeable about it. Government, NGO and people from rich background can help on how to make operational climate services and in a participatory way, what would be the business model for climate service by holding workshops and making sessions with people from grassroots level, for example: direct victims of climate change, farmers etc. Awareness programs at rural areas, may be useful for resilience. The event was sponsored by ICCCAD, IRI and CIMMYT. • During October 21-25, 2018, BACS's 1st short training course: Introduction on Climate Service took place at BMD with the objective equip 20 participants from different organizations and disciplines with a basic understanding of climate, climate services, and available products and to learn strategies for beginning/improving use of climate services in existing decision systems using decision-making flowcharts (DMF). Also to identify climate-sensitive decisions within their respective fields and develop an understanding of existing stakeholder/organizational decision-making processes. With this knowledge, participants will be able to articulate better their demand for climate information as well critically assess the current use of climate information within their field/institution. The training was facilitated by CIMMYT, ICCCAD, IRI and BMD. **Progress:** • CSRD and CIMMYT remain available to support ADB on CSRD related efforts in South Asia. ADB however has not been overly pro-active in reaching out for support. CSRD is in contact with the ADB office in Bangladesh and regionally in the Philippines, and remains at ADB's disposal for assistance. • The *Bangladesh Climate Services Academy* will be presented and discussed in a Symposium on Climate Services in Bangladesh at the Gobeshona 5 conference in January 2017.
	2.3. Number of people benefitting from CSRD activities.	• Quantification of people and agricultural land area benefitting from CSRD activities	• Number of people (disaggregated by gender)	**Achieved:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017.

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
			participating in research activities and/or applying technologies or management practices resulting from CSRD research products • Number of people (disaggregated by gender) trained resulting from the CSRD partnership • Number of hectares upon which farmers participating in research activities and/or applied technologies or management practices because of CSRD's research products	• *Number of hectares upon which farmers participating in research activities and/or applied technologies or management practices because of CSRD's research products: Farmers on 66 hectares (400 male farmers/100 female farmers) are participating in Participatory Integrated Climate Services for Agriculture (PICSA) activities, Farmers on 0.32 hectare (160 male farmers) in Bangladesh, Farmers on 5.11 hectare (160 male famers) in India and Farmers on 0.33 hectare (149 male farmers/11 female) in Nepal are participating in Lentil Stemphylium blight disease forecasting systems and Farmers on 8 hectares (60 male farmers) in Bangladesh are participating in PANI.* • *Number of people (disaggregated by gender) participating in research activities and/or applying technologies or management practices resulting from CSRD research products: (400 male farmers/100 female farmers)* are participating in Participatory Integrated Climate Services for Agriculture (PICSA) activities. Another 158 people, 86 male and 72 Female. Division by organization and gender (male/female) is as follows: organizing of PICSA in Bangladesh (54/60) and DAE staff involved in organizing PICSA exploratory focus groups in Bangladesh (32/12). • Number of people (disaggregated by gender) trained resulting from the CSRD partnership: 209 people, 180 male and 29 female, excluding farmers involved in PICSA. Division by training event and gender (male/female) is as follows: Master training of trainers in PICSA activities in Khulna, (11/3), training of trainers on Sub-Assistant Agriculture Extension officers (SAAOs) in PICSA activities from Barishal, Dinajpur, Khulna, Rajshahi and Patuakhali, (37/3), training of trainers on Sub-Assistant Agriculture Extension officers (SAAOs) in PANI Application from Barishal, Dinajpur and Rajshahi (28/2), BACS (Bangladesh Academy for Climate Services) first short training in Introduction to Climate Services at Bangladesh Meteorological Department (BMD) (16/4) and ICIMOD Drought Monitoring Training (16/4) and Training in Lentil Stemphylium blight disease on Additional Directors, Deputy Directors, District Training Officers , Upazila Agriculture Officers, and Sub-Assistant Agriculture Officers of DAE and BARI officers in Bangladesh (65/11)

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
				In Progress: • Activities continue as planned.
Pillar 3: Build capacities and platforms	**3.1.** Number of new capabilities to operate, deliver, or utilize climate services that are demonstrated.	• At least 150 DAE agents trained as trainers to extend use of PICSA and CSRD DSTs to DAE sub assistant agricultural officers (SAAOs).	• Training inventories and pre- and post-training test scores	**Achieved:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • Ten Cadre Officers of DAE (Additional Deputy Director (Crops) (1) Upazila Agriculture Office (2) Agriculture Extension Office (7)) were drawn from ten selected Upazilas of five Districts. International participants two from Columbia University, USA, one CCAFS-PhD Student from Nigeria, PhD Student of Wageningen University & Research, Netherlands, who works for the Water Apps, two students from Independent University, Bangladesh-IUB and six participants from CIMMYT-Bangladesh participated in the training. The training was held at the CSS Ava Center, Khulna during 9 to 13 July 2018. The main facilitators were Prof. Peter Dorward, and Dr. Sam Poskitt, of University of Reading, UK; Dr. Shahab Uddin, Additional Director, DAE and Mr. Qamrul Hassan, Meteorologist, BMD. Logistics and was provided by DAE and CIMMYT. • Training of Trainers (SAAOs) on Participatory Integrated Climate Services for Agriculture (PICSA) was held at BRAC Learning Center, Dinajpur during July 29 to August 02, 2018. Twenty SAAOs attended the training from Dinajpur Sadar and Birol Upazilas of Dinajpur District, Durgapur Upazila of Rajshahi and Patuakhali Sadar and Dumki Upazilas of Patuakhali . Major facilitation was done by five previously trained AEOs of the mentioned Upazilas. Dr. Sam Poskitt, of University of Reading, UK; Dr. Shahab Uddin, Additional Director, DAE and Mr. Qamrul Hassan, Meteorologist, BMD also attended to overview the proceedings of the training course. Total SAAOs: 20 (19 Male and 1 Female) • Training of Trainers (SAAOs) on Participatory Integrated Climate Services for Agriculture (PICSA) was held at BRAC Learning Center, Barisal during September 9 – 13, 2018. Twenty SAAOs

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
				attended the training from Babuganj and Barisal Sadar Upazila of Barisal District, Paba Upazila of Rajshahi and Batiaghata and Rupsh of Khulna. Major facilitation was done by five previously trained AEOs of the mentioned Upazilas. Dr. Sam Poskitt, of University of Reading, UK; Dr. Shahab Uddin, Additional Director, DAE and Mr. Md. Tariful Newaz Kabir, Meteorologist, BMD also attended to overview the proceedings of the training course. Total SAAOs: 20 (19 Male and 1 Female). • During October 27–Nov 01, 2018, Dr. Samuel Poskit of University of Reading, UK visited Bangladesh receive feedback from agricultural extension field staff on their experiences with the ongoing PICSA roll out activities and also to identify both what has gone well and what has been challenging. Emphasis was given in resolving the technical and logistical problems that field staff have been faced. Plans for further work with farmers in the lead up to the rabi season and for the communication of seasonal and short-term forecasts during the season, as well as how these may be used by farmers. These activities were done with 24 SAAOs and 6 UAOs from Khulna, Barishal and Patuakhali districts and 16 SAAOs and 4 UAOs from Rajshahi and Dinajpur districts. **In Progress:** • Activities are under way as planned.
		• At least 350 SAAOs subsequently trained in interpreting and communicating meteorological information effectively to farmers.	• Training inventories and pre- and post-training test scores	**In Progress:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • The trained DAE SAAOs are now conducting PICSA field schools with 20 farmers communities each composed of 25 (15-20 male and 5-10 female) farmers in 10 Upazilas of 5 pilot Districts. There will be six meetings with each community that started in September 2018 before the rabi season and end in April-May 2019.

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
	3.2. Number of efforts aimed at better understanding existing activities, new opportunities, and any limitations of climate services to achieve scale, replication or sustainability.	• Farmer decision making surveys	• Decision tree and/or choice experiment surveys deployed with farmers in CSRD field sites • Decision tree and/or choice experiment surveys data made publically available on DATAVERSE	**In Progress:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • Surveys were delayed and not completed in 2018. The reason for this set-back was the delay in achieving formal agreements with the BMD and hence DAE to participate in CSRD activities. Until agreements were reached BMD and DAE staff were prevented by organizational rules from commenting on and assistance with administering surveys. • Surveys are now under development and will be deployed and completed before the next reporting period if an NCE is granted (before Q3 of 2019).
		• PANI business model study	• Geographically explicit business model study (quantitative and qualitative) articulating the conditions under which irrigation scheduling services are most feasible deployed in CSRD field sites	**Achieved:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • An literature review was completed to determine components for business model studies that were deployed and reported on in the 2018 semi-annual report. **In Progress:** • This activity is completed.
		• Number of people (disaggregated by gender) in CSRD partner organizations contributing towards, operating, or using climate services to improve agricultural decision making	• Participant observation, listing, and validation of collaborators at BMD, DAE, ICIMOD, IRI and UPF, and BARI contributing towards,	Achieved: Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • Number of people (disaggregated by gender) in CSRD partner organizations contributing towards, operating, or using climate services to improve agricultural decision making 157, 123 male and 34 female. Disaggregation by organization and gender (M/F): CSRD staff and partners (56/9), IRI training exchange on BMD and DAE focal members at Columbia University in New York, (7/1), Design workshop for the Bangladesh Academy for Climate Services (BACS) (28/11), Learning Hub:

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
			operating, or using climate services to improve agricultural decision making	BACS: Climate Services across government agencies (31/12), and Interns from IUB (Independent University, Bangladesh) (1/1) In Progress: • Further progress will be made in 2018 and reported on in the 2018 Annual Report.
Pillar 4: Build knowledge	**4.1.** Number of captured and shared lessons learned (e.g., case studies) pertaining to the policy, practice, and research of climate services development, adoption, and maintenance.	1. **Report:** Initial report on crop specific climate thresholds and farmer decision making framework for key food and income staples identifying ways to incorporate meteorological information.	• Availability of short report/case study/success story	**Achieved:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. This details progress on a narrative report on crop-specific weather constraints and farmers' decision making processes with respect to crop management and weather in in Bangladesh has been made (See Objective 1, Sub-Objective 1.3, Activity 1.3.1, Product 1). **In progress:** • Crop specific climate thresholds continue to be refined for farmer decision making are being refined following CSRD partner feedback. A systematic literature review has been completed as described in the 2018 semi-annual report. Rather than develop a short report, information on how the thresholds are being used will be developed in the first half of 2019 as part of the methodological description of the improved BMD bulletin described in Objective 1, Sub-Objective 1.3: Activity 1.3.1 of this report.
		2. **Report:** Farmer decision making survey analysis. Information used to further refine packaging of climactic information presented by BMD and DAE.	• Availability of short report/case study/success story	**In progress:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • As detailed in this report, this activity has been delayed due to prioritization of other work streams and the opportunity seized by CSRD to pilot PICSA in Bangladesh that was not initially proposed in CSRD's scope of work, but which was included in the project opportunistically. This has caused some delays in implementation • Surveys are now being written and will be deployed in the first half of 2019.

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
		3. **Report:** Potential for incorporation of maps and decision tools into existing decision support platforms (CARFT, LCAT, CPT, etc.).	• Availability of short report/case study/success story	**In progress:** • Report to be developed as part of IRI sub-grant completed in Q1 of 2019. Report results will be incorporated into scientific papers (see below).
		4. **Report:** Business model appropriateness and results of PANI calibration experiments.	• Availability of short report/case study/success story	**In progress:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • A short business model report is available upon request, and was detailed in the 2018 mid-year report. • An additional agronomic report to be developed based on field experiments conducted in in CSRD will be made available at Q3 of 2018 if an NCE is granted.
		5. **Graphical report (Maps):** Use of historical gridded climatic data to evaluate the past frequency of occurrence of the climactic conditions conducive to wheat blast outbreak	• Availability of short report/case study/success story	**Achieved:** Achievements listed below are for the 2018 calendar year. Readers are referred to the 2016-2017 Annual Report for details of accomplishments from November 2016 to December 2017. • This report is completed and available in Annex 4 of this document.
		6. **Report:** STEMPEDIA: Lentil *Stemphylium* blight disease forecasting systems in Bangladesh, Nepal, and India	• Availability of short report/case study/success story	**In progress:** • This item is on schedule. An initial report on 2017/18 lentil disease monitoring and model validation activities will be completed after by Q2 of 2019. • An initial report on model performance in Nepal, Bangladesh, India will be supplied after the CSRD project.
		7. **Report:** BMD and DAE forecast and	• Availability of short report/case study/success story	**Achieved:** • This report has been delivered. Please see the 2016-2017 Annual Report for the report, with implications discussed in the 2018 mid-year report.

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
		climate services assessment report		
		8. **Success story or Case study:** At least 10 CSRD case studies and success stories completed	• Availability of short report/case study/success story	**Achieved:** • Two success stories were included in the semi-annual report completed in April of 2017. • Three more success stories were included in the 2016-2017 Annual Report • Another three success stories were included in the 2018 mid-year report. • Five more success stories are included in this report, alongside a news story on ICIMOD-CSRD collaboration and the Regional Drought Monitoring conference. • Twelve success stories are now completed (2 more than required by CSRD's SoW. **In progress:** • Despite completion of the required number of success stories, more will be made available in the 2019 mid-year and 2019 end-year report if the requested NCE is granted.
		9. **Scientific paper:** Farmer decision making structures: What role is there for climate information in Bangladesh?	• Paper drafted and submitted to open-access, per review journal	**In progress:** • As indicated above, surveys to build the data needed for this activity have been delayed to re-prioritization of work streams and PICSA activities. Surveys are now under way to catch up for lost time. • A scientific paper will be submitted to a peer-reviewed journal before the completion of the CSRD project in 2019 if an NCE is granted..
		10. **Scientific paper:** Opportunities and constraints for agricultural climate services in Bangladesh	• Paper drafted and submitted to open-access, per review journal	**In progress:** • This activity has been delayed to coordination issues with priority work topics with CSRD's collaboration with IRI, which is leading initial drafting of this paper. Anticipated submission is now shifted to mid 2019.
		11. **Scientific paper:** Incorporating forecast information into irrigation scheduling services in Bangladesh	• Paper drafted and submitted to open-access, per review journal	**In progress:** • Anticipated submission before the completion of the CSRD project in 2019 if an NCE is granted.

Pillar	Indicator(s)	Milestones	Measurement method	Progress report (2018)
		12. Scientific paper: Towards early warning systems for MoT in South Asia	• Paper drafted and submitted to open-access, per review journal (BARI, BMD, DAE, UPF)	**In progress:** • Anticipated submission before the completion of the CSRD project in 2019 if an NCE is granted.
		13. Scientific paper: Feasibility assessment of drought forecasting for agricultural climate services: A comparison of resolution scales (led by ICIMOD with BARC)	• Paper drafted and submitted to open-access, per review journal	**In progress:** • Anticipated submission this paper, which is led by ICIMOD in collaboration with CSRD, will be in mid-2019. Slight delays have been experienced due to the workload associated with ICIMOD's hosting of the Regional Drought Monitoring Forum.

Annex 4. Modeling the climate suitability for wheat blast infection and its variability in South and Southeast Asia: A preliminary analysis

1. Introduction

The occurrence of crop diseases caused by fungal pathogens are among the main abiotic stresses that farmers must face. Although the advances in resistant varieties and chemical control are widely applied, losses associated with fungal diseases incidence are still considerable (Fisher et al., 2012). These risks are amplified given increasing international trade. Where biosafety standards are poor and shipments of food products can cause the spread of pests and diseases. This is likely to have been the case with the recent appearance in Bangladesh, and unofficially in India, of wheat blast disease caused by the fungus *Magnaporthe oryzae* pathotype *Triticum* (MoT) in 2016 (Malaker et al., 2016). Prior to appearance in Bangladesh, wheat blast disease was only found in in South America, where they have caused considerable losses in wheat producing states in Brazil (Cruz et al., 2016), Bolivia and Argentina (Duveiller et al., 2016).

The incidence and impact of fungal diseases and their spread in different regions depends, among other factors, on the cultural practices associated with agronomic management, the susceptibility of the varieties, and prevailing environmental conditions (Anderson et al., 2004). Multiple tools have been developed for the monitoring and forecasting of fungal diseases outbreaks based on field observations or empirical and deterministic numerical models that combine relevant weather variables to generate an early warning of potential risk of disease outbreaks (e.g. Launay et al., 2014). Given increasing availability of secondary environmental data and computing capacities, the use of simulation models for the diagnosis and forecasting of favorable conditions for the development of crop diseases is increasingly important (e.g. Donatelli et al., 2017).

Applications vary from regional or national assessments of climate suitability for particular diseases (Bebber et al., 2017), sensitivity analysis to environmental drivers and parameterizations (Bregaglio et al., 2012) or future projections in risks of crop diseases associated with climate change (Bregaglio et al., 2013). Given that the conditions for the establishment of fungal diseases are relatively well described and there is agreement that factors such as atmospheric humidity and temperature are important drivers that can trigger their development, it is possible to use mathematical models to assess the potential incidence of specific diseases in under-studied regions where primary data may be lacking. Integrating these approaches, the spatial and temporal patterns associated with climatic factors can be discerned. The later becomes relevant in the case of wheat blast in Bangladesh and the potential for expansion to new wheat producing areas in Asia, and the associated impact that the disease may have on food security in a highly populated area.

In this context, the aim of this work is to provide a preliminary and general overview of the spatial and time variability in climate suitability that may influence the development of wheat blast in South and Southeast Asia, based on the analysis of the results obtained from a climate-driven infection model. This initial analysis considers potential climate suitability only given map products of estimated wheat cropped area; further effort to test model parameters examine resulting variability under different assumptions of biological envelopes for weather variables are needed. The information generated by this work however represents an initial estimate of the potential pressure of wheat blast disease associated with climate variables, and that can used to help inform regional planning regarding early warning systems and local extension activities.

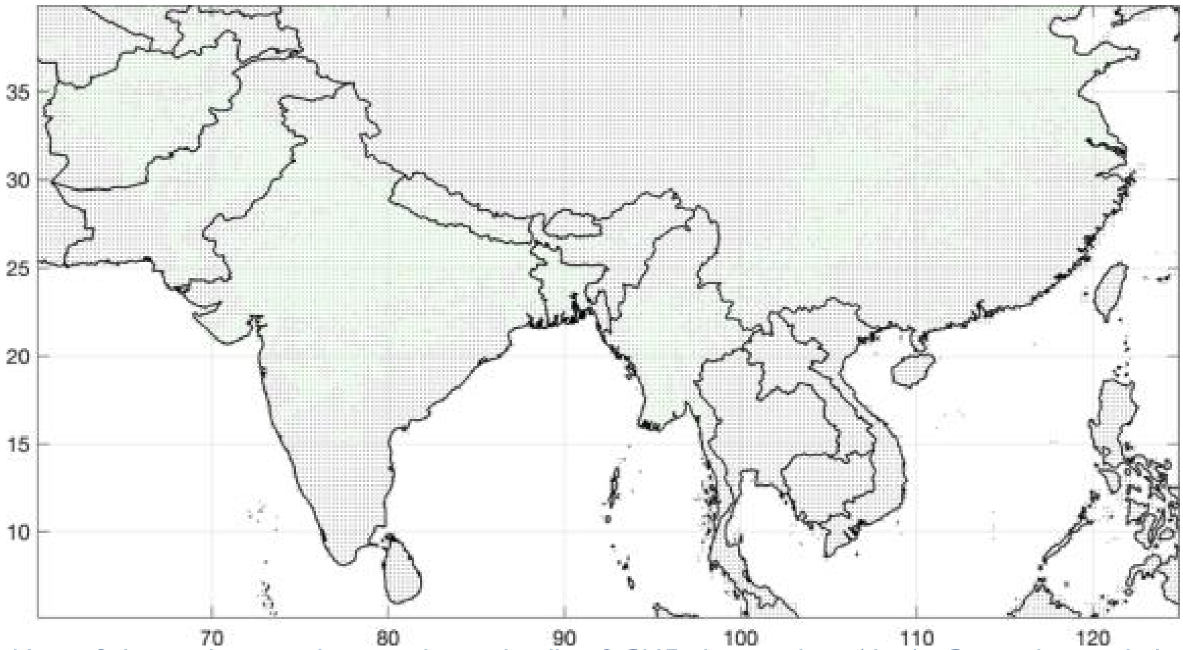
2. Study area and datasets

2.1 Study area and datasets

A large number of global climate products are now available that can be used in modeling and diagnostic of crop diseases. However, climate information must be provided at appropriate time and space scales that are appropriate given knowledge of the development and infection behavior of crop pathogens. For example, a short (within day) precipitation can trigger the development of a disease when the amount of rainfall is adequate and is accompanied by temperatures within the biological thresholds of a pathogen if they occur during a phenological stage of a crop that is associated with high disease susceptibility. Among the meteorological variables most used for crop diseases, air temperature, precipitation, and relative humidity are important. If available, measurements of leaf wetness duration are similarly important in estimating infection (Donatelli et al., 2017). Complex transport-based models also integrate wind speed and direction to predict movement of spores from source to sink locations.

Most global gridded products are provided at daily time-steps. This temporal resolution which may limiting for the study of crop diseases that can be triggered by weather events that occur within a 24 hour period. Although there are methods to statistically disaggregate daily time series to hourly values via empirical models or weather generators (e.g. Bregaglio et al., 2010), their accuracy can be limited by the available historical data. In this study, the global 3-hourly Princeton University Global Meteorological Forcing (GMF) dataset (Sheffield et al., 2006) version 3.0 to produce historical meteorological observations. This product corresponds to a 0.25° x 0.25° resolution dataset generated by merging global observation-based products with the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis (Kalnay et al., 1996). The observational products include the Global Precipitation Climatology Project (GPCP; Adler et al., 2003), ground truth precipitation data from stations, the Climatic Research Unit (CRU) precipitation and temperature (Harris et al., 2013), the NASA Langley surface radiation budget (Stackhouse et al., 2004), in addition to the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA; Huffman et al., 2007). The later allows disaggregation from daily to 3-hourly values. Other meteorological variables such as incoming radiation, specific humidity, surface pressure and wind speed are corrected and downscaled using elevation data as a covariate. The preliminary output datasets are further corrected for systematic biases, with random errors removed using in situ measurements (Chaney et al., 2014).

To generate the final dataset to be used in this study, the domain and GMF grid presented in the figure below were considered. Hourly time series data for air temperature, air specific humidity, and surface atmospheric pressure were generated from the original 3-hourly values by applying a spline interpolation method to obtain a 60-years hourly time-series dataset for the period 1951-2010. As explained below, the infection model used requires relative humidity as an input, which was calculated by widely used thermodynamic relationships combining specific humidity, atmospheric pressure and temperature (Wallace and Hobbs, 2006). In addition to the above-presented datasets, the Spatial Production Allocation Model (MapSPAM) of You et al. (2017) global crop production data product was used as a wheat mask (Figure 1).



Map of the study area showing the grid cells of GMF climate date (dots). Green dot symbols correspond to wheat MapSPAM grids.

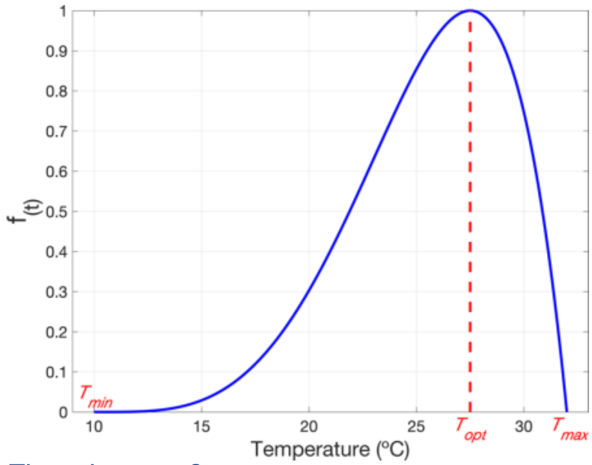
2.2 Infection model

Considering its use in previous studies at the regional scale using grilled data (Bregaglio et al., 2013), and its biological meaningful parameterizations, the generic potential infection model developed by Magarey et al. (2005) was selected to be applied with the above-described data. As mentioned by Bregaglio et al. 2012, this model has been shown to respond acceptably to input data variability. The model considers both hourly air temperature and leaf wetness (or relative humidity) duration to simulate the response of a generic fungal pathogen by means of two functions describing its sensitivity to both variables.

The model uses the air temperature response function proposed by Yann and Hunt (1999), which combines a set of pathogen's cardinal temperatures to estimate the shape of the response as:

$$f(t) = \left(\frac{T_{max} - T}{T_{max} - T_{opt}}\right)\left(\frac{T - T_{min}}{T_{opt} - T_{min}}\right)^{(T_{opt}-T_{min})/(T_{max}-T_{opt})} \quad (1)$$

where $f(t)$ (dimensionless, values from 0 to 1) is the temperature response function. T (°C) is the hourly air temperature, and T_{min}, T_{max} and T_{opt} are the minimum, maximum and optimum temperatures for infection, respectively. These cardinal temperatures were taken from Cruz et al. (2016), who suggested the following values for wheat blast: T_{min} = 10°C, T_{max} = 32°C, and T_{opt} = 27.5°C. As an example, the next shows the resulting shape of $f(t)$, where an exponential increasing response to temperature is observed between T_{min} and around 20°C, which turns from almost lineal to a decreasing increment until T_{opt}, to then drop drastically until $f(t)$ = 0 at T_{max}.



The shape of temperature response curve obtained by Equation (1) using parameters for wheat blast (explained the text).

The air temperature response *f*(*t*) is later scaled to the assumed pathogen wetness duration requirement according to the following relationship:

$$W(t) = \begin{cases} \frac{WD_{min}}{f(t)}, & \text{if } \frac{WD_{min}}{f(t)} \leq WD_{max} \\ 0 & elsewhere \end{cases} \quad (2)$$

where $W(t)$ (dimensionless, values from 0 to 1) corresponds to the wetness response function, and WD_{min} and WD_{max} (hours) are the minimum and maximum leaf wetness duration requirement for infection, respectively.

As explained by Magarey et al. (2005), when infection models use hourly forcing data, it is necessary to know the number of hours that may interrupt a wet period without terminating the infection process. For this, the model considers the impact of critical dry periods through the parameter *D*50 that is calculated as:

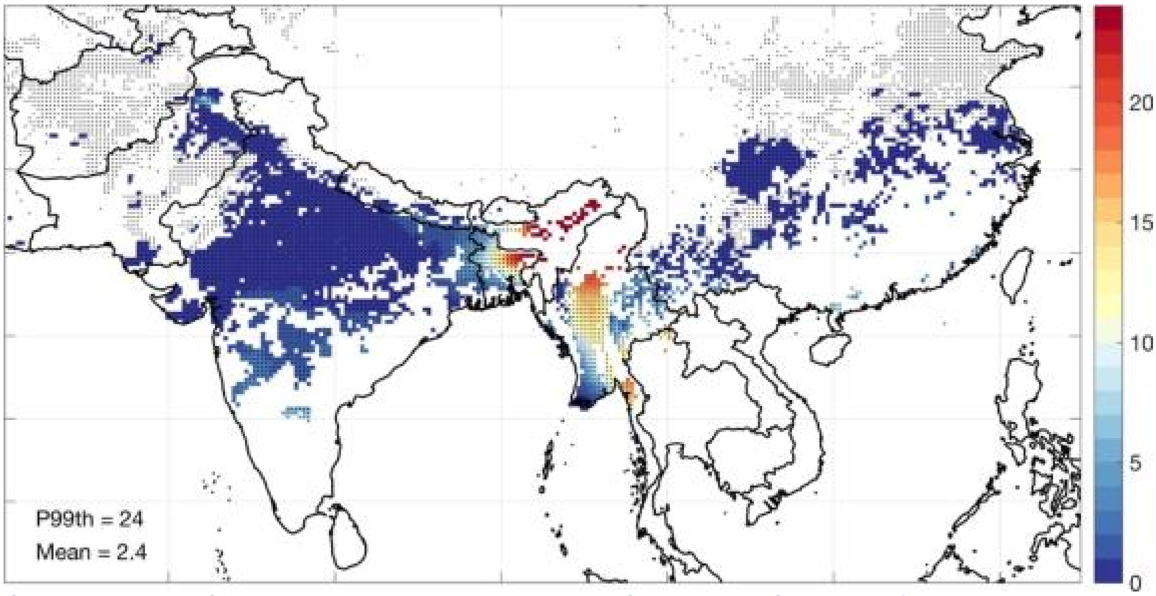
$$W_{sum} = \begin{cases} W_1 + W_2, & \text{if } \ D < D50 \\ W_1, W_2 & elsewhere \end{cases} \quad (3)$$

where W_{sum} is the sum of the surface wetting periods and W_1 and W_2 indicate two wet periods separated by a dry period (*D*, in hours). As in Magarey et al. (2005), *D*50 is defined as the duration of a dry period at relative humidity < 95% that will result in a 50% reduction in disease compared with a continuous wetness period. Like this, if $D > D50$, the model considers the two wet periods as separated wetting events and potential infection. When the leaf is wet and $f(t) > 0$, the model generates and included and additional cohort of spores and considers that an infection event occurs if the value of W_{sum} ranges between WD_{min} and WD_{max} (Bregaglio et al., 2012).

The above equations were solved for an assumed period between November 1st and March 31st, representing a range of potential winter season wheat production in South and South East Asia. Although a realistic and spatially explicit time window representative of wheat phenology should be used, we selected this period as a first guess for the estimation of what blast potential infection along the continent during the cold season.

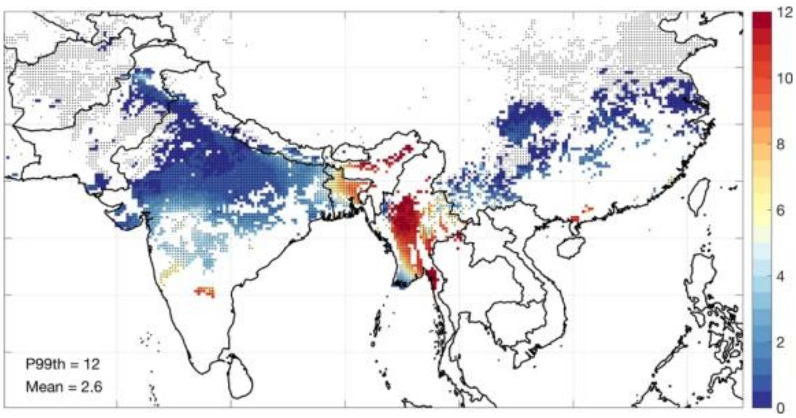
3. Initial results

In this section, model results are presented as maps of average conditions and variability between 1951-2010, also as the relationship between the number of potential infections and global climate indices, and summarized for the main wheat producing countries in Asia. The figure below the modeled interannual average number of potential infections for Asia. The spatial pattern of wheat blast risk shows wheat-producing areas whose range of air temperature and humidity during the cold season are unlikely to represent conditions conducive to the development and outbreaks of the disease based on the biological thresholds described above. This is the case of most areas in Afghanistan, Pakistan and Northern China. On the other hand, Bangladesh, Myanmar and the small area where wheat is cultivated in North East India show the higher number of potential infections driven by weather conditions, where, in average, approximately 20 outbreaks are estimated were estimated. Then mean seasonal number of potential infections is 2.4 and the maximum 80, interquartile range from 0.1 to 1.7.



Spatial pattern of the interannual average number of potential infections in Asia. Black dot symbols represent grid cells where the MapSPAM model indicates the potential presence of wheat. P99th is the 99% percentile.

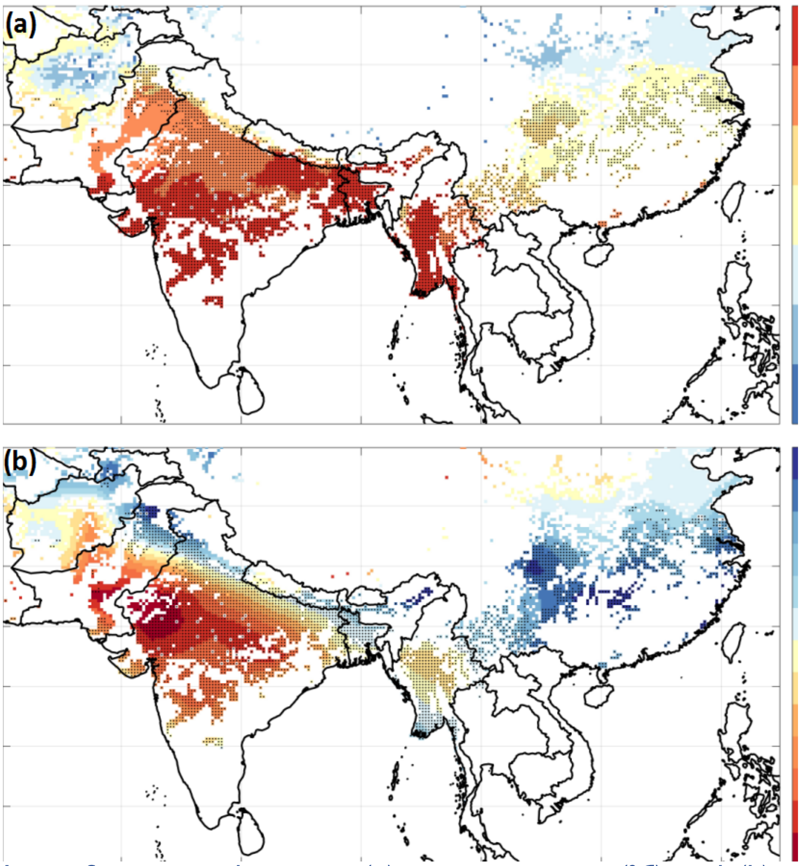
The figure below shows the interannual standard deviation of potential infections in Asia, where it is possible to observe a strong interannual variability in the areas of higher incidence (Bangladesh, Myanmar), but also southward increase in India, which suggests that the occurrence of years of higher risk than others may be important. Note however that the MapSPAM product appears to predict wheat presence in a number of locations in Bangladesh and Myanmar where the crop is currently not cultivated, or where hydrological conditions and low-lying elevation in deltaic areas prevent the cultivation of wheat.



Interannual standard deviation of the spatial pattern potential infections in Asia. Black dot symbols represent grid cells where the MapSPAM model indicates the potential presence of wheat. P99th is the 99% percentile.

In order to summarize the above results by country, interannual and spatial statistics were aggregated. The figure shows the distribution of the spatial differences of potential infections in the five main wheat producing countries in Asia. It is clear from this figure that Myanmar and Bangladesh are the countries with the highest potential incidence of wheat blast, followed by India, China and Pakistan, although as indicated above, the MapSPAM product should be validated with other crop mask datasets given its questionable fit with known wheat producing areas in both countries. Countries with lower incidence show a higher number of points considered outliers, which indicates that the risk of infection concentrates in a smaller area. The figure shows a similar information for the distribution in the interannual country-averaged number of potential infections. In this case, it is possible to see that in spite of the low average incidence in India, China and Pakistan, the observed inter-annual variability observed can be important. Further work is required to weight the number of potential infections by wheat producing area in each country.

In order to further understand these results, maps of interannual averages of air temperature and relative humidity are displayed in the maps below. Although consisting of global averages values, the regions whose winter climate does not represent a risk for the development of wheat blast, as in the case of Afghanistan or the northeast of China, appear to have average temperatures that are too low, out of the range for development of the disease according to the model (Magarey et al., 2005; Cruz et al., 2016) and the period for which we modeled wheat as being cultivated. Further work is however required to re-calibrate model outputs with improved estimates of the date-ranges in which wheat may be grown, especially because wheat in Afghanistan and parts of the study area in China can be grown both during the winter and also the spring, the latter harvested in September. In the case of central India, where the number of potential infections is lower for the same latitude of Bangladesh or Myanmar but where wheat is grown in the winter, it is observed that despite presenting favorable temperature conditions, atmospheric humidity appears to be is too low in relation to the ideal range, thereby reducing potential infection number.

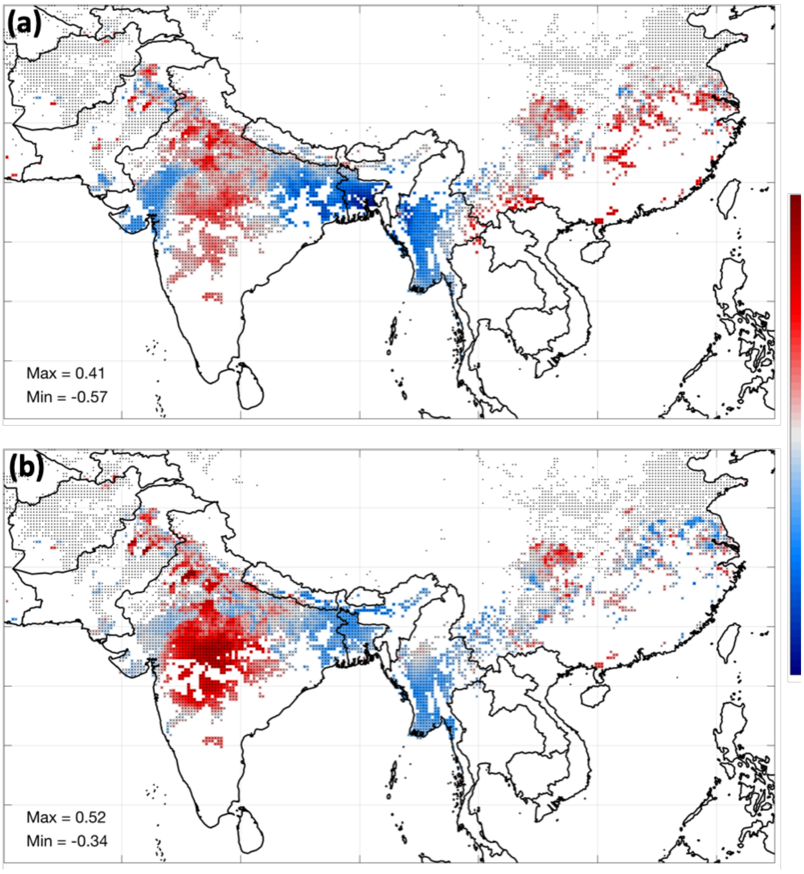


Maps of interannual average (a) air temperature (°C) and (b) relative humidity (%) during the cold season. Black dot symbols represent the points of Figure (3) where wheat blast is present.

The availability of long-term climate time series makes it possible to provide an initial analysis of the relationship between the potential weather-based incidence of wheat blast and large-scale drivers that control the interannual climate variability in Asia, such as El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD), considered two of the main factors controlling interannual climate variability over the region. For this, the local correlation between the number of potential infections and the

Oceanic Niño Index[4] (ONI) and the Dipole Mode Index[5] (DMI) were calculated. Both for ONI and DMI, the average values between October and December were considered for the analysis, though as noted above, further work considering spring wheat areas must also be considered in future research.

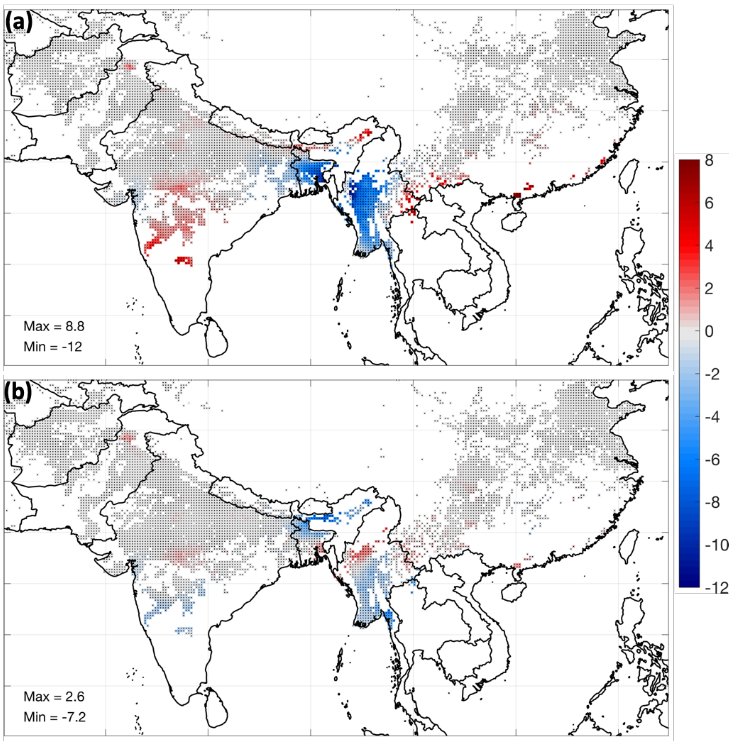
The figure to the right shows the correlation between the number of potential infections and ONI/DMI. A similar spatial pattern of positive and negative correlations is observed, with variation in the magnitude of the correlations. However, this behavior is reversed in areas of eastern China, where correlations with ONI (DMI) are positive (negative). This area is also a location where spring wheat is grown, indicating that further analysis is needed to unpack the effect of climate on potential infection of wheat in this area. The highest magnitudes of positive correlations for both ONI and DMI were found in India, with values that can be close to 0.5. The highest magnitudes in negative correlations are observed in Bangladesh and Myanmar for both ONI and DMI, in the Indian area west of Bangladesh, in addition to western India in the case of ONI.



(a) Local correlation between the number of potential infections and ONI. (b) As in (a) but for number of potential infections and DMI.

In order to explore how the potential incidence of wheat blast in Asia might behaves with respect to the different phases of ENSO and IOD, the average incidence index provided by the model was calculated for the El Niño phases (ONI > 0.5) and La Niña (ONI < -0.5). Similarly, the average incidence of the disease was calculated for the positive and negative phase of DMI. Results are presented as the difference between both phases (positive *minus* negative) as shown below. In general, this preliminary analysis indicates that unlike the interannual correlation (Figure 7), the spatial pattern is less clear for the different phases of ENSO and IOD. However, in areas with highest incidence in Bangladesh and Myanmar, in addition to the southern part of India, the correlation seems to be clearer. For the case of ENSO, the positive phase (El Niño) is observed to induce negative anomalies in the number of potential infections in relation to the negative phase (La Niña) in Bangladesh and Myanmar, relationship that is reversed in India.

[4] https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php
[5] https://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/DMI/



Composites of the difference between number potential infections for the positive and negative face of ONI (a) and DMI (b).

On the other hand, the anomalies induced by the positive phase of DMI in relation to the negative are associated with lower incidence of wheat blast in the north of Bangladesh, and some parts of India and Myanmar, but these anomalies are positive in the south of Bangladesh.

4. Concluding remarks

The results obtained in the present work allow us to conclude the following. First, the results from the infection model show that there is an important spatial variability in the climatic suitability for the establishment of wheat blast in Asia. For the MapSPAM model masks of wheat producing regions, the higher potential dissemination is observed in Bangladesh, Myanmar and some regions in India, although these areas need to be refined with additional maps that may produce more accurate representations of wheat growing areas. Given the MapSPAM masks, these regions also show at the same time the higher interannual variability, so wheat blast incidence could present a considerable threat during years of with particularly high favorable conditions.

On the other hand, wheat producing regions with too low temperature and humidity in China or India are unlikely to present an important potential for wheat blast establishment, since the infection model applied in this work considers temperature and humidity thresholds to estimate the potential risk. This however needs to be validated using additional biological thresholds and cardinal temperature assumptions for wheat blast development, as other models (e.g., Fernandes et al. 2016) utilize different values. However, the high interannual variability presented by these areas imply that in some years the conditions could be suitable for wheat blast. The latter results may be relevant when planning disease prevention actions through new varieties or early warning systems such as those underdevelopment in CSRD.

According to the observed relationship between interannual variability in the number of potential infections and the associated large-scale climatic drivers (ENSO, IOD), there appears to be a clear relationship with ONI and DMI indices, associated with their impact on air temperature and humidity. In turn, the different phases of ENSO and IOD show a greater contrast in Bangladesh and Myanmar in terms of the incidence of wheat blast, especially in the case of ONI. This should be explored further using different indices and lead-time periods in order to establish statistical relationships that can be used in forecasting systems.

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Annex 5. In-kind letters of support from partners

Government of the People's Republic of Bangladesh
Bangladesh Meteorological Department
Meteorological Complex, Agargaon,
Dhaka-1207, Bangladesh.

Phone: + 88 02 9123838
Fax: + 88 02 8118230, 9103908
E-mail: info@bmd.gov.bd
Web: www.bmd.gov.bd

Date: 04 December 2018

To

Timothy J. Krupnik
Systems Agronomist
Climate Services for Resilient Development in South Asia (CSRD) - Project Leader
Cereal Systems Initiative for South Asia (CSISA) - Bangladesh Country Coordinator
International Maize and Wheat Improvement Center (CIMMYT) | Sustainable Intensification Program
House 10/B. Road 53, Gulshan-2, Dhaka- 1213, Bangladesh

Subject: Involvement with in-kind support in the development initiative along with Climate Services for Resilient Development in South Asia (CSRD)

Dear Dr. Krupnik,

With this letter, I would like to confirm that Bangladesh Meteorological Department (BMD) has been involved with Climate Services for Resilient Development in South Asia (CSRD) Project since the beginning of 2017. Our three staff are involved with CSRD activities. We have participated and facilitated in the formation of Bangladesh Academy of Climate Services (BACS) and its inauguration. BMD has also paticipated actively in the organization of 5-day long training course entitled 'Introduction to Climate Services', which was held during 21-25 October 2018 at BMD and jointly organized by International Centre for Climate Change and Development (ICCCAD), Bangladesh Meteorological Department (BMD), International Research Institute for Climate and Society (IRI) at Columbia University, and the International Maize and Wheat Improvement Center (CIMMYT).

Considering the involvement of our staff and the institutional policy and payment guideline the in-kind contribution to CRSD has been estimated at about BDT 3,000,000 [Three million Taka] or USD 35,295 [Thirty Five thousand two hundred ninety five].

We look forward to continue our cooperation with and support for the important CSRD work.

Thank you,

4.12.18
(Shamsuddin Ahmed)
Director
Bangladesh Meteorological Department

গণপ্রজাতন্ত্রী বাংলাদেশ সরকার
কৃষি সম্প্রসারণ অধিদপ্তর
খামারবাড়ি, কৃষি খামার সড়ক, ঢাকা-১২১৫

Government of the People's Republic of Bangladesh
Department of Agricultural Extension
Khamarbari, Krishi Khamar Sarak, Dhaka-1215

ডি,ও,নং- 983.

তারিখ ঃ 02/12/2018

To

Timothy J. Krupnik
Systems Agronomist
Climate Services for Resilient Development in South Asia (CSRD) - Project Leader
Cereal Systems Initiative for South Asia (CSISA) - Bangladesh Country Coordinator
International Maize and Wheat Improvement Centre (CIMMYT) | Sustainable Intensification Program, House 10/B. Road 53. Gulshan-2. Dhaka, 1213, Bangladesh

Subject: Involvement with in-kind support in the development initiative along with Climate Services for Resilient Development in South Asia (CSRD).

Dear Dr. Krupnik,

With this letter, we would like to confirm that our organization Department of Agricultural Extension (DAE) has been involved with Climate Services for Resilient Development in South Asia (CSRD) Project since the July/2017. Our 05 Officers and 02 Secondary technical staffs are directly involved from DAE head quarter and field level officers & SAAOs are also involved with CSRD activities in the Project area as ten Upazilas of five districts of Bangladesh. We are spending 20% of our time in this project.

We have participated and facilitated Implementation of field level all activities of CSRD project in respective Districts & Upazilas. Considering the involvement of our Department and the institutional policy and payment guideline the in-kind contribution to CSRD has been estimated at 22078US$ in word Twenty Two Thousand Seventy Eight US$.

We look forward to continue our cooperation with and support for the important CSRD work.

Thank you,

02/12/18

(Dr. M Shahab Uddin)
Additional Director (Project Planning)
PPI & ICT Wing and
CSRD Lead (DAE Part), DAE, Khamarbari, Dhaka.
Phone:- 02-55028201
E-mail:- shahabipm@gmail.com.

Phone: Office: 9140850, 9140857, Fax No. 9111502 ফোনঃ ৯১৪০৮৫০, ৯১৪০৮৫৭, ফ্যাক্সঃ ৯১১১৫০২

International Centre for Climate Change and Development (ICCCAD)

Date: 03 December 2018

To

Timothy J. Krupnik
Systems Agronomist
Climate Services for Resilient Development in South Asia (CSRD) - Project Leader
Cereal Systems Initiative for South Asia (CSISA) - Bangladesh Country Coordinator
International Maize and Wheat Improvement Center (CIMMYT) | Sustainable Intensification Program
House 10/B. Road 53. Gulshan-2. Dhaka, 1213, Bangladesh

Subject: Involvement with in-kind support in the development initiative along with Climate Services for Resilient Development in South Asia (CSRD)

Dear Dr. Krupnik,

With this letter, I would like to confirm that my organization International Centre for Climate Change and Development (ICCCAD) at Independent University, Bangladesh (IUB) has been involved with Climate Services for Resilient Development in South Asia (CSRD) Project since the January, 2018. Our 2 researchers along with our Research Coordinator (part-time involvement in BACS) are involved with the Bangladesh Academy for Climate Services (BACS) as part of the CSRD activities.

We have participated actively in organizing the 'BACS Design Workshop', 'BACS Launching Event', 'Learning Hub Event (LHE) on Climate Services across Government Agencies' and '1st BACS Training Dialogue: Introduction to Climate Services', staring from the planning to the report writing. Also, the team from ICCCAD has contributed in submission of Department of State grant proposal of BACS. Considering the involvement of our researchers and the institutional policy and payment guideline, the in-kind contribution to CRSD has been estimated at USD 7,000 which is seven thousand dollars.

We look forward to continuing our cooperation with and support for the important CSRD work.

Thank you,

Saleemul Huq

Dr. Saleemul Huq
Director
International Centre for Climate Change and Development (ICCCAD)
at Independent University, Bangladesh (IUB)
House: 27, Road: 01, Block: A, Bashundhara R/A, Dhaka-1212
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Secretariat : Plot – 16, Block-B, Aftabuddin Ahmed Road, Bashundhara R/A, Dhaka- 1212, Bangladesh
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The International Research Institute for Climate and Society

December 4, 2018

Timothy J. Krupnik
Systems Agronomist
Climate Services for Resilient Development in South Asia (CSRD) - Project Leader
Cereal Systems Initiative for South Asia (CSISA) - Bangladesh Country Coordinator
International Maize and Wheat Improvement Center (CIMMYT) | Sustainable Intensification Program
House 10/B. Road 53. Gulshan-2. Dhaka, 1213, Bangladesh

Subject: Involvement with in-kind support in the development initiative along with Climate Services for Resilient Development in South Asia (CSRD)

Dear Dr. Krupnik,

With this letter, we would like to confirm that the International Research Institute for Climate and Society (IR), Columbia University has been involved with Climate Services for Resilient Development in South Asia (CSRD) Project since June 2017. Nine of our staff, including researchers, are involved with CSRD activities.

IRI's activity under CSRD includes technical backstopping, training and research for climate service development in Bangladesh. Considering the involvement of our staff and researchers and the institutional policy and payment guideline, the in-kind contribution to CRSD, specifically work done under other projects complementing and enhancing CSRD activities and outputs, has been estimated at $87,000 USD, or eighty-seven thousand dollars United States Dollars.

Thank you,

Ashley Curtis
Research Staff Associate
The Earth Institute, Columbia University, Lamont Campus
61 Route 9W, Monell Building
Palisades, NY 10964-8000 USA

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UNIVERSIDADE DE PASSO FUNDO

PROGRAMA DE PÓS-GRADUAÇÃO EM COMPUTAÇÃO APLICADA

Campus I - Km 292 - BR 285, Bairro São José, CEP 99052-900
Passo Fundo/RS – Fone (54) 3316-8354
ppgca@upf.br

Date: November 29, 2018

From: José Maurício C. Fernandes
Professor/Senior Researcher
Universidade de Passo Fundo
BR 285, São José | Passo Fundo/RS | CEP: 99052-900
Brazil

To: Timothy J. Krupnik
Systems Agronomist
Climate Services for Resilient Development in South Asia (CSRD) - Project Leader
Cereal Systems Initiative for South Asia (CSISA) - Bangladesh Country Coordinator
International Maize and Wheat Improvement Center (CIMMYT) | Sustainable Intensification Program
House 10/B. Road 53. Gulshan-2. Dhaka, 1213, Bangladesh

Subject: Involvement with in-kind support with the development initiative along with Climate Services for Resilient Development in South Asia (CSRD)

Dear Dr. Krupnik,

This letter is here to confirm that our organization the Universidade de Passo Fundo has been involved with CSRD project since the beginning 2017. Currently, three faculty members are engaged in the CSRD project. Considering the involvement of our faculty members the total yearly cost per institutional policy and payment guideline has been calculated as USD$ 10,000 (ten thousand US dollars).

Thank you,

José Maurício Fernandes
Professor/UPF/PPGCA

WAGENINGEN
UNIVERSITY & RESEARCH

To
Timothy J. Krupnik
Climate Services for Resilient Development in South Asia (CSRD) - Project Leader
Cereal Systems Initiative for South Asia (CSISA) - Bangladesh Country Coordinator
International Maize and Wheat Improvement Center (CIMMYT)
Sustainable Intensification Program
House 10/B. Road 53. Gulshan-2. Dhaka, 1213, Bangladesh

Chair Water Systems and Global Change

DATE
5 December 2018

SUBJECT
In-kind support CSRD

YOUR REFERENCE
SW18-010Rec
SW18-010Rec

HANDLED BY
S.E. Werners

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saskia.werners@wur.nl

Subject: Involvement with in-kind support with the development initiative along with Climate Services for Resilient Development in South Asia (CSRD)

Dear Dr. Krupnik,

With this letter, I would like to confirm that my organisation Wageningen University & Research has been involved with CSRD project since 2017. We have participated in meetings and started to cooperate in the CSRD work to make hydro-climatic information easier to understand for farmers and other decision makers in the agricultural sector. The work focusses on developing appropriate training and technical materials on climate services for extension services and farmers. Together with the University of Reading and CSRD, we introduce the Participatory Integrated Climate Services for Agriculture (PICSA) approach. A cooperation we support from our work in the WaterApps project and the DeltaCAP project.

So far, four members of our staff and students have been involved in CSRD in Dhaka and Khulna in particular. We have facilitated field visits with 70 farmers in peri-urban Khulna. Next to Wageningen University, Staff and students of Khulna University have provided support to CSRD. Since August, we support a research assistant to monitor the implementation of PICSA in the Khulna region. She regularly updates CSRD on the progress. We will support the further implementation of PICSA in Aman season.

Considering the involvement of our staff and students, the in-kind contribution to CRSD is estimated as 15.000 euro (in words fifteen thousand euro).

We look forward to continue our cooperation with and support for the important CSRD work.

With kind regards,

Dr. Saskia E. Werners
Assistant Professor Adaptive Water Management

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Annex 6. CSRD success stories and communications pieces

No more doubts about droughts

A regional drought forum delves into the current state of climate information availability and calls for sharing information regarding natural hazards.

Droughts have affected agriculture, food security, and the livelihoods of millions of people in South and Southeast Asia with increasing frequency and severity. As the climate continues to change, agricultural productivity across nations will likely suffer as changes in rainfall patterns and intensity affect agricultural production. This scenario demands a dramatic increase in the availability of timely and accurate information on climate and crop conditions.

Agricultural and hydrological drought monitoring and early warning systems; drought impacts and climate risk financing; land use practices and policies; and crop mapping and yield estimation are key areas related to agriculture and climate services. These issues and the emerging potential of Earth observation information and climate modelling for reducing climate-related vulnerabilities in the agriculture sector in South and Southeast Asia were discussed at a forum held in Kathmandu. The Regional Knowledge Forum on Drought was held at the International Centre for Integrated Mountain Development (ICIMOD) from 8–10 October, 2018.

The knowledge forum established an expert working group comprised of representatives from different institutions working on drought early warning systems and agriculture advisory services to foster regional cooperation on agriculture and drought monitoring and management. Discussing examples from South and Southeast Asia, panellists at the forum showcased the contributions Earth observation technologies and climate services make to establishing national and regional drought monitoring and early warning systems and agro-advisory services. Their contribution is especially important in cases where ground level data are minimal or non-existent. The forum also reiterated the need for regional collaboration in developing and sharing information on climate-induced hazards.

Delegates at the Regional Knowledge Forum on Drought, ICIMOD, Kathmandu. Picture: Jitendra Bajracharya/ ICIMOD

Climate Services for Resilient Development (CSRD) is a global partnership whose core mission is to translate actionable climate information into easy to understand formats to spread awareness and use of climate services. The CSRD consortium in South Asia is led by the International Maize and Wheat Improvement Center (CIMMYT) in partnership with the Bangladesh Meteorological Department (BMD), Bangladesh Department of Agricultural Extension (DAE), Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), International Center for Integrated Mountain Development (ICIMOD), International Institute for Climate and Society (IRI), University de Passo Fundo (UPF), University of Rhode Island (URI) and the University of Reading (UoR).

The event was organized by ICIMOD and ADPC under the framework of the SERVIR initiative, a joint initiative between the United States Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA). The Climate Services for Resilient Development (CSRD), the International Maize and Wheat Improvement Center (CIMMYT), and the World Food Program (WFP) partnered in organizing the knowledge forum.

Strategic alignment

Published by: International Maize and Wheat Improvement Center (CIMMYT); House 10/B, road 53, Gulshan 2, Dhaka 1212, Bangladesh
For more information pls. contact: t.krupnik@cgiar.org

End of despair over disparity

The Bangladesh Academy for Climate Services helps bridge information gaps and provides a platform for stakeholders to communicate their findings and needs.

In Bangladesh and many other countries, there is a disconnect between climate science and its use. Hence, decision makers ranging from policy makers to farmers could benefit from increased access to relevant climate information. This creates the need for a platform to connect the users and producers of climate information. Therefore, to ensure that actionable climate service information is delivered to decision makers, the Bangladesh Academy for Climate Services (BACS) was launched on 5 August, 2018 in the Bangladesh Meteorological Department (BMD). The academy was jointly founded by the International Center for Climate Change and Development (ICCCAD), the International Research Institute for Climate and Society (IRI) at Columbia University and the International Maize and Wheat Improvement Center (CIMMYT).

BACS was created to open trans-sectorial and multi-stakeholder dialogue on climate services to identify existing initiatives, challenges and opportunities. The academy also aims to design tailored certification courses for students and early- to mid-level professionals to help address identified needs, and plans to create graduate-level curricula to train a new generation of weather, climate and sector experts with the skills needed to face the uncertainty of the coming decades.

Speaking at the event, Dr. Timothy J. Krupnik, senior scientist and systems agronomist at CIMMYT, said, "This academy is vital for bringing climate information to the public and is open for partners who are working in this area. Our job is to help the improvement of the use of climate services in Bangladesh."

The courses offered by BACS are intended for early- to mid-level professionals and students who are working in fields related to agriculture and food systems, disaster preparedness and response, and public health, among others, and who want to actively engage in developing climate services for their sectors in Bangladesh.

Dr. Saleemul Haque, Director of International Centre for Climate Change and Development (ICCCAD) explained why it was necessary to introduce an academy like BACS.
Photo: M. Shahidul Haque Khan

Climate Services for Resilient Development (CSRD) is a global partnership whose core mission is to translate actionable climate information into easy to understand formats to spread awareness and use of climate services. The CSRD consortium in South Asia is led by the International Maize and Wheat Improvement Center (CIMMYT) in partnership with the Bangladesh Meteorological Department (BMD), Bangladesh Department of Agricultural Extension (DAE), Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), International Center for Integrated Mountain Development (ICIMOD), International Institute for Climate and Society (IRI), University de Passo Fundo (UPF), University of Rhode Island (URI) and the University of Reading (UoR).

Strategic alignment

Published by: International Maize and Wheat Improvement Center (CIMMYT); House 10/B, road 53, Gulshan 2, Dhaka 1212, Bangladesh
For more information pls. contact: t.krupnik@cgiar.org

Filling the gaps in climate forecasting

The first graduates of the BACS training program learned to make better decisions regarding climate services.

The first training course of the Bangladesh Academy for Climate Services (BACS) concluded on 25 October in the conference room of the Bangladesh Meteorological Department (BMD). BACS was jointly founded by the International Center for Climate Change and Development (ICCCAD), the International Research Institute for Climate and Society (IRI) at Columbia University and the International Maize and Wheat Improvement Center (CIMMYT), under the Climate Services for Resilient Development (CSRD) partnership in South Asia. The academy has taken the first steps to ensure important climate information and other services are delivered to the relevant parties by conducting a training program that began on 21 October 2018.

The BACS training program focused mainly on a deeper understanding of climate services and also on the challenges and expectations involved. Photo: Shahidul/CIMMYT

Participants from the private sector, educational institutes, government departments, and international NGOs attended the training program. The 5-day program included educational discussion sessions, informative presentations, question-and-answer sessions, and a field visit to Manikganj, a district adjacent to the capital of Bangladesh. The visit was organized to teach participants about the decision-making flowchart (DMF) in detail, which will help them make better decisions regarding climate services.

"It is crucial to decipher forecasts correctly to anticipate future disasters and for taking necessary precautions. Also, learning about the feasibility and limitations of climatology will help us design our forecasting needs," said participant Lamiya Mahpara Ahmed, an analyst at Start Fund Bangladesh. At end of the training program, participants identified climate-sensitive decisions within their respective fields and developed an understanding of existing decision-making processes. The program also aimed to provide participants with a basic understanding of climate data, climate services, and available products, as well as teach them about strategies that will enhance their use of climate services.

Climate Services for Resilient Development (CSRD) is a global partnership whose core mission is to translate actionable climate information into easy to understand formats to spread awareness and use of climate services. The CSRD consortium in South Asia is led by the International Maize and Wheat Improvement Center (CIMMYT) in partnership with the Bangladesh Meteorological Department (BMD), Bangladesh Department of Agricultural Extension (DAE), Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), International Center for Integrated Mountain Development (ICIMOD), International Institute for Climate and Society (IRI), University de Passo Fundo (UPF), University of Rhode Island (URI) and the University of Reading (UoR).

"As someone with limited technical knowledge, issues like weather forecasting, using climate data, and acknowledging limitations and challenges have become easier for me to understand and work with, thanks to this course," said Hossain Ishrath Adib, Head of Programme Implementation in Practical Action

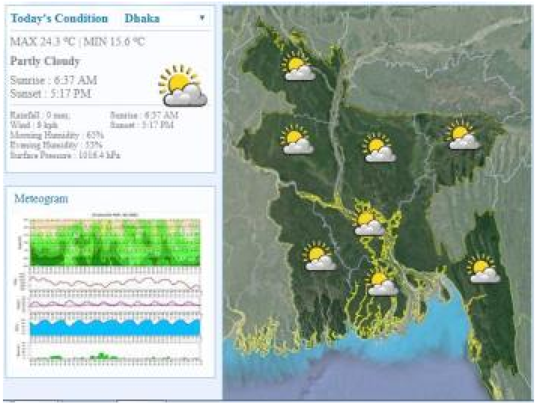
Strategic alignment

Published by: International Maize and Wheat Improvement Center (CIMMYT); House 10/B, road 53, Gulshan 2, Dhaka 1212, Bangladesh
For more information pls. contact: t.krupnik@cgiar.org

Forecasts made feasible for farmers

In partnership with CSRD, BMD to start working on a newer, updated version of weekly agrometeorological bulletin for the benefit of farmers and decision-makers.

The generation of relevant and high-quality agrometeorological information must be communicated effectively to end users. One of the ways in which the Bangladesh Meteorological Department (BMD) communicates such information to farmers and decision makers is through a weekly agrometeorological bulletin. The bulletin includes information on the weekly relevant weather variables, weather forecasts for coming two weeks and a general interpretation regarding the implications for local crops. BMD is keen on updating the information provided through its bulletin towards a better-developed and relevant product by including a better design, high-quality graphics, text and more relevant variables regarding weather forecasts and monitoring. For this, CSRD is working with BMD and the International Research Institute of Climate and Society (IRI) of Columbia University in the identification of relevant information to be provided in the context of local crops and different seasons in Bangladesh in terms of general variables and extreme weather events.



CSRD is working closely with BMD to launch a newer, updated version of agrometeorological bulletin for the farmers and decision-makers.

New climatic and geographic databases have been generated in order to work in a new up-to-date product that can be useful for extension agents and agricultural planners regarding agro climate conditions experienced during previous days and their implications for crops and management decisions, and also in the context of long-term observations to contrast against previous seasons. This information is complemented by the weather forecasting of the following 5 days, which provides information about basic variables as well as computed ones, which will be accompanied by a series of advisories to provide management options and possibilities for different crops and seasons.

Climate Services for Resilient Development (CSRD) is a global partnership whose core mission is to translate actionable climate information into easy to understand formats to spread awareness and use of climate services. The CSRD consortium in South Asia is led by the International Maize and Wheat Improvement Center (CIMMYT) in partnership with the Bangladesh Meteorological Department (BMD), Bangladesh Department of Agricultural Extension (DAE), Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), International Center for Integrated Mountain Development (ICIMOD), International Institute for Climate and Society (IRI), Universidad de Passo Fundo (UPF), University of Rhode Island (URI) and the University of Reading (UoR).

A simple and practical way to provide this information will be through a web application in which users can quickly access updated and tailored information, useful for decision making based on customized and updated information, as well as through a weekly generated document which will include more detailed analysis. Speaking of the bulletin, Mr. Shamsuddin Ahmed, Director, BMD says, "The proposed newer version of the agrometeorological bulletin will make farming easier by providing the farmers convenient and quickly accessible weather information."

Strategic alignment

Published by: International Maize and Wheat Improvement Center (CIMMYT); House 10/B, road 53, Gulshan 2, Dhaka 1212, Bangladesh
For more information pls. contact: t.krupnik@cgiar.org

The fight against blight

CSRD scientists help farmers use the right amount of fungicide with the help of the weather-based *Stempedia* model.

Lentils are an integral part of many nutrition-sensitive farming systems in Bangladesh, India, and Nepal. However, lentil fields in South Asia are being plagued by diseases, the most prominent being Stemphylium blight (SB). The prevalence and intensity of this disease fluctuate under varying weather conditions and can be controlled by the application of foliar fungicides. However, farmers often find it difficult to determine the frequency and amount of fungicide they should use. This requires special consideration because fungicides affect yield as well as the environment. To address this issue, the 'Stempedia' model was developed by scientists working with Climate Services for Resilient Development (CSRD) to assess the regional and seasonal risks of SB within South Asia and ultimately help farmers decide how much fungicide to use.

Identified early symptom of lentil Stemphylium blight (leaf, shown on arrow heads) in farmer's field in Bardiya site of Nepal on 20 November 2018, and laboratory testing of the sample for pathogenic confirmation (right). Photo: Moin Salam

Climate Services for Resilient Development (CSRD) is a global partnership whose core mission is to translate actionable climate information into easy to understand formats to spread awareness and use of climate services. The CSRD consortium in South Asia is led by the International Maize and Wheat Improvement Center (CIMMYT) in partnership with the Bangladesh Meteorological Department (BMD), Bangladesh Department of Agricultural Extension (DAE), Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), International Center for Integrated Mountain Development (ICIMOD), International Institute for Climate and Society (IRI), Universidad de Passo Fundo (UPF), University of Rhode Island (URI) and the University of Reading (UoR).

Data on SB were collected during the 2017-2018 growing season from 480 farmers' fields in Bangladesh with support from India's Department of Agricultural Extension (DAE), and the help of the Cereal Systems Initiative for South Asia (CSISA) funded by USAID, the Bill & Melinda Gates Foundation, and Bihar Agricultural University (BAU). In Nepal SB data were collected with the assistance of the CSRD project in partnership with the Nepal Agricultural Research Council's National Grain Legume Research Program (NGLRP).

The CSRD team assessed the status of SB before harvest and found that it was more prevalent in Bangladeshi and Nepalese sites than in Indian sites. After 800 yield datasets were compiled from all the sampled fields in each country, it was found that Indian sites produced better yields, while Nepalese sites generated poorer yields. Relevant weather data were used to run the Stempedia model and results showed that in each of the tested sites, there was either a slight underestimation or overestimation between the observed data and the model's prediction. The model is currently being calibrated to achieve better prediction accuracy, and more data from a similar number of fields in the three countries are being collected for comprehensive model testing.

Speaking about the Stempedia model, Dr. Anurag Kumar of CSISA, Bihar, India, said, "Farmers in Bihar had no clue how to control the disease and had been blindly using chemicals for controlling SB. This model will guide farmers on when to use fungicides or whether to use them at all."

Strategic alignment

Published by: International Maize and Wheat Improvement Center (CIMMYT); House 10/B, road 53, Gulshan 2, Dhaka 1212, Bangladesh
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Annex 7. *The SERVIR-HKH and CSRD supported Regional Drought Forum Calls for Cooperation in Sharing Information on Natural Hazards*

Delegates at the Regional Knowledge Forum on Drought, ICIMOD, Kathmandu. Photos: Jitendra Bajracharya

Increasing frequency and severity of droughts have affected agriculture, food security, and the livelihoods of millions of marginal and vulnerable people in South and South East Asia. Addressing food insecurity resulting from changes in agricultural productivity and an upsurge in demand is a major concern. As the climate continues to change, agricultural productivity across nations will likely suffer, with changes in rainfall patterns and intensity affecting agricultural production, especially in marginal rain-fed areas. This scenario demands a dramatic increase in timely and accurate information on climate and crop conditions. Earth observation technologies and climate services are effective means to generate and share such information.

Agricultural and hydrological drought monitoring and early warning systems; drought impacts and climate risk financing; land use practice and policies; and crop mapping and yield estimation are key areas related to agriculture and climate services. These and the emerging potential of Earth observation information and climate modelling in reducing climate related vulnerabilities in the agriculture sector in South and Southeast Asia were discussed at a forum held in Kathmandu recently. The Regional Knowledge Forum on Drought was held at the International Centre for Integrated Mountain Development Centre (ICIMOD) from 8–10 October with support from CSRD.

Yubak Dhoj GC, Secretary, Ministry of Agriculture and Livestock Development, Government of Nepal addresses the gathering. Photos: Jitendra Bajracharya

Speaking at the event, the Director General of ICIMOD, David Molden said that drought preparedness measures, coupled with climate-resilient adaptation practices, could play a vital role in improving food security across the HKH. "Drought monitoring and early warning systems, can underpin national- and local-level planning and agro-advisories to help local populations and governments prepare for drought and cope with its impacts on agriculture," he said.

In the Hindu Kush Himalaya (HKH), food insecurity is more severe in the mountains than in the plains. Despite the region's wealth of natural resources, a significant percentage of the population experiences food insecurity and malnutrition – 31% of the population is food insecure, while 50% faces malnutrition.

Discussing examples from South and Southeast Asia, panellists at the forum showcased the value that Earth observation technologies and climate services bring to establishing national and regional drought monitoring and early warning systems and agro-advisory services. Their contribution is especially important in cases where ground level data is minimal or non-existent.

Secretary at the Ministry of Agriculture and Livestock Development, Nepal, Yubak Dhoj GC, said, "The Ministry is keen on developing early warning systems and agri-advisories on drought to provide timely information to line institutions, local bodies, and farmers on climate-induced vulnerabilities." He noted that limited research and studies on drought have been carried out in Nepal. He added that weak monsoons in 2014 and 2015 affected Nepal's national gross domestic product negatively and that the floods in 2017 damaged large swathes of agricultural lands. He said that the timely provisioning of climate services and their use for disaster preparedness and management could negate damages from such events.

Executive Director of Asian Disaster Preparedness Center (ADPC), Hans Guttman, said, "We need to make drought forecasts reliable and trusted to enable actions which save lives and livelihoods. We want to see significant improvement in tools and services for the betterment of the livelihoods of people."

Hans Guttman, Executive Director, ADPC addresses the gathering. Photos: Jitendra Bajracharya

The forum also reiterated the need for regional collaboration in developing and sharing information on climate-induced hazards. Director of the UNESCO Regional Science Bureau for Asia and the Pacific, Shahbaz Khan, said, "We need to extend beyond borders, not just physical borders but also disciplinary borders." Citing examples of national and regional endeavours in climate risk management in Latin America and Africa, he stressed on the need for cross-border cooperation between governments, scientists and communities to realize early warning systems for droughts and floods.

Annex 8. Links to other cangrtion:ommunications and news and pieces about CSRD

Agrilinks website

1. **Building the Resilience of South Asia's Smallholder Farmers Through Effective Climate Services** *By M. Shahidul Haque Khan*

   Climate Services for Resilient Development (CSRD) is a global partnership that is committed to promoting and providing climate services information to build resilience among small hold farmers to the impacts of climactic variability and weather shocks.
   https://www.agrilinks.org/post/building-resilience-south-asias-smallholder-farmers-through-effective-climate-services

2. **Accelerating Smallholder Farmers' Access to Climate Services in Bangladesh** *By M. Shahidul Haque Khan*

   The International Maize and Wheat Improvement Center (CIMMYT), which leads CSRD in South Asia, is partnering with the Bangladesh Meteorological Department (BMD), the Department of Agricultural Extension (DAE) and the University of Reading in the United Kingdom, to adapt and pilot the 'Participatory Integrated Climate Services for Agriculture' (PICSA) approach across 20+ villages in Bangladesh in 2018.
   https://www.agrilinks.org/post/accelerating-smallholder-farmers-access-climate-services-bangladesh

CCAFS website

3. **Expanding horizons: The Bangladesh Academy for Climate Services** *By M. Shahidul Haque Khan*

   A first of its kind in Bangladesh, an academy was launched with the aim to embed climate thinking in decision-making processes and close the gap between climate information providers and end users.
   https://ccafs.cgiar.org/news/expanding-horizons-bangladesh-academy-climate-services#.XCCENVwzaUn

4. **Newly founded Bangladesh Academy for Climate Services held its first training course** *By M. Shahidul Haque Khan, Sultana Jahan, Dannie Dinh*

   Sector leaders in Bangladesh gathered at the Bangladesh Academy for Climate Services training to learn about climate services and using climate information in decision-making.
   https://ccafs.cgiar.org/news/newly-founded-bangladesh-academy-climate-services-held-its-first-training-course#.XCCT8VwzaUI

CIMMYT website

5. **In pictures: Six agricultural innovations combating climate change** *By Correspondent*

The photo story from the International Maize and Wheat Improvement Center (CIMMYT) shows the advantages of joint action by farmers, researchers, governments, not-for-profits and businesses.
https://www.cimmyt.org/in-pictures-six-agricultural-innovations-combating-climate-change/

6. **On-the job training boosts drought monitoring skills in Bangladesh** *By M. Shahidul Haque Khan, Sarah Sayeed Gazi*

   A two-week on the job training was organized with the support of the International Maize and Wheat Improvement Center (CIMMYT)-led Climate Services for Resilient Development (CSRD) initiative in South Asia, alongside the International Centre for Integrated Mountain Development (ICIMOD).
   https://www.cimmyt.org/on-the-job-training-boosts-drought-monitoring-skills-in-bangladesh/

Dhaka Tribune website

7. **Bangladesh Academy for Climate Services launched** *By SM Abrar Aowsaf*

   Bangladesh Academy for Climate Services (BACS) was launched at the Bangladesh Meteorological Department (BMD) in Dhaka, Bangladesh. BACS has been created to open trans-sectoral and multi-stakeholder dialogue on climate services to identify existing initiatives, challenges and opportunities.
   https://www.dhakatribune.com/bangladesh/dhaka/2018/08/06/bangladesh-academy-for-climate-services-launched

ICIMOD website

8. **Bangladesh Agricultural Research Council and Partners to Collaborate on Strengthening Climate Services for Drought Monitoring** *By ICIMOD Correspondent*

   The International Centre for Integrated Mountain Development (ICIMOD), the Bangladesh Agricultural Research Council (BARC), and the International Maize and Wheat Improvement Centre (CIMMYT) organized a day-long consultation and user engagement workshop on collaborative development of agricultural drought monitoring services in Bangladesh.
   http://www.icimod.org/?q=28739

IRI website

9. **"We need climate information." – Bangladesh's agriculture community drives creation of new climate services** *By Elisabeth Gawthrop*

   A series of training workshops were conducted to improve the forecasting capabilities of the Bangladesh Meteorological Department (BMD), while also strengthening the relationship between BMD and Bangladesh's Department of Agriculture Extension (DAE). The activities focused on new climate information products developed especially for DAE's needs, which would ultimately to help the farmers it serves.

https://iri.columbia.edu/news/we-need-climate-information-bangladeshs-agriculture-community-drives-creation-of-new-climate-services/

10. **Creating Climate Services in Bangladesh** *By Elisabeth Gawthrop*

4th annual Gobeshona Conference for Research on Climate Change was held in Bangladesh. The conference focused on research-based solutions to local vulnerabilities in Bangladesh and brought together researchers, policymakers, government and non-government representatives, donor agencies and international organizations.
https://iri.columbia.edu/news/creating-climate-services-in-bangladesh/

11. **Climate mapping tools support resilient development in East** *Tesfamariam Tekeste*

IRI helped to organize the Climate Services for Resilient Development (CSRD) Technical Exchange workshop in Zanzibar on August 2017, which was held immediately after the 47th Greater Horn of Africa Climate Outlook Forum (GHACOF47) in order to capitalize on the presence of many climate and sector experts from across the region.
https://iri.columbia.edu/news/mapping-tools-to-support-climate-services-in-east-africa/