ICIMOD

PROCEEDINGS OF THE

Regional knowledge forum on drought: Earth observation and climate services for food security and agricultural decision making in South and Southeast Asia

8–10 October 2018
ICIMOD, Kathmandu, Nepal

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Mountain Environment Regional Information System

About SERVIR

SERVIR connects space to village by helping developing countries use satellite data to address challenges in food security, water resources, weather and climate, land use, and natural disasters. A partnership of National Aeronautics and Space Administration (NASA), United States Agency for International Development (USAID), and leading technical organizations, SERVIR develops innovative solutions to improve livelihoods and foster self-reliance in Asia, Africa, and the Americas.

SERVIR Hindu Kush Himalaya

The International Centre for Integrated Mountain Development (ICIMOD) implements the SERVIR Hindu Kush Himalaya (SERVIR-HKH) Initiative – one of five regional hubs of the SERVIR network – in its regional member countries, prioritizing activities in Afghanistan, Bangladesh, Myanmar, Nepal and Pakistan.

SERVIR-Mekong is a joint initiative of USAID and NASA, implemented by a consortium led by the Asian Disaster Preparedness Center (ADPC) that includes Spatial Informatics Group (SIG), Deltares, and Stockholm Environment Institute (SEI). The SERVIR programme is designed to address this need by using publicly available satellite imagery and technologies to address challenges related to water resources, disasters, climate resilience, agriculture, and ecosystem in the Lower Mekong.

About CSRD

Climate Services for Resilient Development (CSRD) is a global partnership that connects climate and environmental science with data streams to generate decision support tools and training for decision-makers in developing countries. Translating complex climate information into easy-to-understand actionable formats to spread awareness in the form of climate services is integral to CSRD's mission. The CSRD consortium in South Asia is supported by USAID and led by the 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), ICIMOD, International Institute for Climate and Society (IRI), University de Passo Fundo (UPF), and the University of Rhode Island (URI). This consortium provides technical expertise to develop climate products that can expand the knowledge and understanding of farmers and other stakeholders to improve decision making, with the ultimate goal of increasing resilience to climate-related risks.

Contents

Abbreviations and acronyms

ADPC	Asian Disaster Preparedness Center
ASIS	Agriculture Stress Index System
CAS	Chinese Academy of Sciences
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CHT	Chittagong Hill Tracts
CIMMYT	International Maize and Wheat Improvement Center
CKRB	Chitral-Kabul River Basin
CNN	Convolutional neural network
CRAFT	Regional Agriculture Crop Forecasting Toolkit
CSRD	Climate Services for Resilient Development
DMEWS	Disaster Management Early Warning System
DMT	Drought Management Team
EWEA	Early Warning Early Action
FAO	Food and Agriculture Organization
GEE	Google Earth Engine
GEFS	Global Ensemble Forecast System
HKH	Hindu Kush Himalaya
HydroSOS	Hydrological Status and Outlook System
ICIMOD	International Centre for Integrated Mountain Development
IMD	India Meteorological Department
IMERG	Integrated Multi-satellitE Retrievals for GPM
IPCC	Intergovernmental Panel on Climate Change
JPL	Jet Propulsion Laboratory
LDAS	Land Data Assimilation System
MAIL	Ministry of Agriculture, Irrigation & Livestock
MRCS	Mekong River Commission Secretariat
NASS	National Agricultural Statistical Services
NeKSAP	Nepal Food Security Monitoring System
PRISM	Platforms for Real Time Information Systems
RADI	Institute of Remote Sensing and Digital Earth
RDCYIS	Regional Drought and Crop Yield Information System
RHEAS	Regional Hydrological Extreme Assessment System
RLCMS	Regional Land Cover Monitoring System
RWH	Rain Water Harvesting
S2S	Sub-seasonal to Seasonal Forecast System
SAR	Synthetic Aperture Radar
SM	Soil Moisture
SPEI	Standardised Precipitation Evapotranspiration Index
SPI	Standardized Precipitation Index
UC	Union Council
UNESCO	United Nations Educational, Scientific and Cultural Organization
VAWR	Vietnam Academy for Water Resources
VCI	Vegetation Condition Index
WFP	World Food Programme
WMO	World Meteorological Organization

SECTION 1

Introduction

The majority of Asia's rural population depends on rain-fed agriculture for their livelihood. However, due to the effects of climate change, agricultural production faces increasing pressure from frequent and extreme climatic events such as droughts and floods. The 2014 Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) identifies heat-related mortality and malnutrition due to increased drought-related water and food shortages among the top five climate-related risks. The assessment suggests that extreme climate events linked to precipitation and high temperatures will trigger slow-onset events and have adverse impacts on human health, food and water security, and livelihoods, and create new vulnerabilities. South and Southeast Asian countries are among those most prone to natural resource degradation due to intensive human activities and environmental changes. Moreover, producing additional food on limited land and providing economic access to food at the household level to ensure food security will likely continue to be major challenges. There is considerable research being undertaken on agro-climatic monitoring and modelling. Lessons from such work can inform sustainable crop management decisions and provide farmers and decision-makers with alternative farming system options. Similarly, a large amount of information on climate variability is available, although use of such data by decision-makers remains low. User-oriented, easily accessible, timely, and actionable scientific information in the form of advisory services can assist adaptation to environmental change. Such information can also be used to make wise decisions to limit the economic damage and social disruption caused by environmental disasters.

The International Centre for Integrated Mountain Development (ICIMOD) is collaborating with meteorological and agricultural institutions in the Hindu Kush Himalaya through its SERVIR Hindu Kush Himalaya (SERVIR-HKH) and the Climate Services for Resilient Development (CSRD) initiatives to establish agricultural drought monitoring and early warning systems. The aim is to improve the capacity of national agro-meteorology and agricultural agencies to develop data products related to crop monitoring and enhance the knowledge of national scientists about the interpretation of agro-climatic data in their country contexts. Similarly, the SERVIR-Mekong Initiative, hosted by the Asian Disaster Preparedness Center (ADPC), is establishing a regional drought and crop yield information system for the Mekong region in Southeast Asia. The system will assist local governments and the agricultural sector with drought forecasting and implementing short- and long-term mitigation measures during and before droughts.

In this context, ICIMOD and ADPC, under the framework of the SERVIR Initiative, organized a three-day 'Regional knowledge forum on drought: Climate services for food security and agricultural decision making in South and Southeast Asia'. The forum reviewed and assessed 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 region. The regional knowledge forum aimed to deliberate on four key areas related to agriculture and climate services:

- Agricultural and hydrological drought monitoring and early warning systems
- Drought impacts and climate risk financing
- Land use practice and policies
- Crop mapping and yield estimation

The forum reviewed the current status of information services at the regional and national level in the aforementioned areas. The participants at the forum also discussed ways to establish a regional partnership involving national and regional institutions, the private sector, and local and international organizations to improve climate services using Earth observation and to facilitate agricultural decision making for food security in the region.

SECTION 2

Day I

Opening session

The regional knowledge forum on drought was held at ICIMOD from 8 to 10 October 2018. The opening session included speeches by ICIMOD's Director General, David Molden; Secretary of the Ministry of Agriculture and Livestock Development, Government of Nepal, Yubak Dhoj GC; Executive Director of the Asian Disaster Preparedness Centre, Hans Guttman; and Director of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Regional Science Bureau for Asia and the Pacific, Shahbaz Khan.

Speaking at the event, 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. Molden noted that 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.

In the 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.

Molden stressed the importance of a South-South dialogue. He noted that the regional knowledge forum on drought provided cross-learning opportunities between people working with the science and people working with communities in South and Southeast Asia.

Yubak Dhoj GC, Secretary, Ministry of Agriculture and Livestock Development, Government of Nepal said that the Ministry was keen to develop early warning systems and agro-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 had been carried out in Nepal. Weak monsoons in 2014 and 2015 affected Nepal's national gross domestic product negatively and the 2017 floods damaged large swaths of agricultural lands. He said that timely provisioning of climate services and their use for disaster preparedness and management could negate damages from such events.

Hans Guttman, Executive Director, Asian Disaster Preparedness Center (ADPC), emphasised the need to make drought forecasts reliable and trusted to enable actions which save lives and livelihoods. He added that they want to see significant improvement in tools and services to enhance the livelihoods of people.

The Director of the UNESCO Regional Science Bureau for Asia and the Pacific, Shahbaz Khan, highlighted the 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 the need for cross-border cooperation between governments, scientists, and communities to realise early warning systems for droughts and floods.

Drought monitoring and early warning systems

Speakers highlighted that remote sensing-based estimation of key environmental variables such as rainfall, temperature, soil moisture, and evapotranspiration have been increasingly used to develop drought-monitoring tools. However, for better evaluation and bias correction, there is a need to generate more accurate datasets using ground observation. In the South and Southeast Asian regions, several efforts have been made to evaluate satellite-derived rainfall datasets, with encouraging results. For example, the evaluation of the satellite-derived rainfall data i.e., Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) in South Asia presented at the forum showed encouraging results for rainfall estimates in the region. Forum participants suggested building up regional and local cooperative mechanisms that could help in operationalizing Disaster Management Early Warning System (DMEWS) in the region.

Progress has been made in improving hydro-meteorological modelling for drought monitoring. For example, NASA's Hindu Kush Himalaya Sub-seasonal to Seasonal Forecast System (S2S) has been designed for optimal monitoring and probabilistic seasonal forecast of hydrological conditions distributed across the Hindu Kush Himalaya (HKH) and South Asia. The HKH-S2S merges models and satellite observations to get spatially complete monitoring and forecasts in data-limited regions. However, challenges remain, such as uncertainty in

seasonal forecasts of the South Asian monsoon and evaluation of Land Data Assimilation System (LDAS) simulations. Using Earth Observation and merging different ground observations with model outputs through an innovative approach (including data mining/Artificial Intelligence) were recommended to help reduce uncertainties and improve DMEWS.

In addition, there is a strong interest in developing regionally and locally calibrated drought indices as well as integrating/combining several types of data and information on climate and water supply, including satellite-derived products and seasonal forecasts, to provide decision makers with a comprehensive representation of current conditions and outlooks. The participants emphasized that effective and reliable modelling of drought monitoring/prediction tools will need to be directly connected to end users, with stakeholders engaged at all stages of model development and application. The engagement and access to actionable information for DMEWS should also include the most vulnerable, such as women, the elderly, and poor communities. This could help experts and decision makers to better monitor, predict, plan for and cope with the impacts of drought, including food security.

Hideki Kanamaru, Food and Agriculture Organization (FAO), highlighted the importance of early warning and early action. He shared that FAO opted for Early Warning Early Action (EWEA), which translates warnings into anticipatory action by putting plans into action and acting early; it is more effective as it is taken before the disaster happens. Citing examples from the implementation of the EWEA System in Mongolia and Vietnam, he discussed different phases, achievements and learnings from the project. He shared that the project was able to reduce animal mortality by 10% and animal birth mortality by 18%. Kanamaru also showcased the Agriculture Stress Index System (ASIS) and presented a case study from ASIS in Nicaragua. He identified multi-sectoral impact, enhanced evidence, and the need to consider short-term and long-term effects while planning as major learnings from the project.

Ix Hour, Mekong River Commission Secretariat (MRCS), described how a common basin-wide development and procedural framework for managing the Mekong was developed. The regional drought monitoring and forecasting system adopted a Regional Hydrological Extreme Assessment System (RHEAS) to calculate daily drought monitoring and forecasting on meteorological, hydrological, and agricultural indicators for the Lower Mekong Basin (LMB). The system was developed by the MRCS's Drought Management Team (DMT) with technical support from the NASA Jet Propulsion Laboratory (JPL), which was established through SERVIR Mekong. He shared that the system provided monitoring and 90-day forecasts for the region and added that the team was working to build capacity of MRC member countries for drought analysis at the country level. He described how pre-processed drought monitoring and forecasting data from the RHEAS was further processed at the Asian Disaster Preparedness Center (ADPC) and the MRCS for generation and visualization of drought monitoring and forecasting indices before being shared with end users through the websites.

Ashutosh S. Limaye, NASA-SERVIR, shared results from a joint effort of SERVIR and the International Maize and Wheat Improvement Center (CIMMYT) that assessed the accuracy of Climate Hazards Group InfraRed Precipitation Station (CHIRPS) corrected Global Ensemble Forecast System (GEFS)/ (CHIRPS-GEFS) performance in Bangladesh in terms of seasonal precipitation at various lead times, as compared to ground observations and for derived variables such as monsoon onset and dry spells during the rainy season. He shared that both CHIRPS and CHIRPS-GEFS were useful in detecting the onset of monsoon, and added that GEFS has higher false alarm ratio as compared to CHIRPS. Limaye also introduced the ClimateSERV data portal developed under SERVIR, which provides CHIRPS, CHIRPS-GEFS and Integrated Multi-satellitE Retrievals for GPM (IMERG) data to the public.

Ha Hai Duong, Vietnam Academy for Water Resources (VAWR), shared experiences from a pilot application of the Regional Drought and Crop Yield Information System (RDCYIS) for drought monitoring and forecasting in Ninh Thuan province in Vietnam. From 2015–2016, the province experienced the longest recorded drought in over 15 years in Vietnam, leading the local government to declare the drought suffered by some districts a national disaster. He shared that the RDCYIS was built on the locally calibrated RHEAS framework, in cooperation with the ADPC. Duong spoke about the system's ability to capture salient features of drought through a variety of indices. He talked about the detailed model performance including model calibration and validation, and the application of model outputs for drought bulletins, drought management plans and strategies in the province. These would in turn help local authorities prepare and respond to droughts through short and long-term risk mitigation measures. Duong shared that

their future plan is to improve the resolution of the products i.e., from 25*25 km^2 to 5*5 km^2.

Nilesh Wagh, India Meteorological Department (IMD), presented on the use of Standardized Precipitation Index (SPI) to identify all three types of drought – meteorological, agricultural and hydrological – at different temporal scales in various districts of India. Wagh shared IMD's experiences in using SPI to monitor drought in real time and in developing drought outlooks and agricultural advisories. He mentioned different standard tools that could be used to calculate SPI. He concluded that SPI provides magnitude and severity of drought at a given time scale, and is useful in detecting multi-seasonal or multi-year droughts.

Muhammad Abid, COMSATS University, introduced the transboundary Chitral-Kabul River Basin (CKRB) project that aims to develop satellite-enhanced snowmelt flood and drought predictions for the Kabul River Basin (KRB) with surface and groundwater modelling. He shared that there are inherent complexities in water resource management in the Kabul River Basin (KRB), which is shared by Afghanistan and Pakistan. Abid recommended carrying out studies on cropping patterns and resulting demand for agriculture and energy production to determine the magnitude of impact and its time of occurrence in the basin. He also talked about the increasing water demand, the area under cultivation, crop water demand per acre and total water demand of agriculture.

The session chair, Tsegaye Tadesse, University of Nebraska–Lincoln, summarised the discussion, highlighting achievements of the EWEA system, and MRC's drought monitoring and forecasting system, which provides 90-day early warning information using five variable indices. He emphasised the need for higher resolution results and improvement in drought forecasting capabilities. The session chair suggested that the Standardised Precipitation-Evapotranspiration Index (SPEI) has provided better results in dry areas as compared to SPIs.

Drought impacts and climate risk financing

Speakers at this session emphasized that understanding the impacts of drought events and their associated vulnerabilities is critical for efforts towards mitigating drought impacts and developing an understanding on building resilience in the future. Risk financing (e.g., credit and insurance) is an effective tool to minimize losses from hazards such as drought. It can enable early intervention within communities at risk and ultimately help build their capacity to respond and recover faster and more efficiently. Even though there is general progress in climate services in the region, the panel noted that disaster risk management (including drought preparedness and mitigation) suffers from three main weaknesses that have led to preventable damage to lives and livelihoods and greatly increased the cost of responding to disasters: (i) decision-making processes are too slow, (ii) preparedness planning is inadequate and often done too late, and (iii) the current response models are outdated, costly and underfunded.

Discussants suggested that there should be long-term policy interventions, together with capacity building activities for farmers on efficient water use technologies and climate resilient farming. In addition, operationalizing vulnerability assessments by utilizing remote sensing-based analysis in combination with socio-economic, demographic and infrastructural data is critical for identifying the most vulnerable communities. Remote sensing and modelling offer a means to understand changing drought conditions caused by climate variability, their impacts, and approaches to plan effective risk management strategies. Organizations should also work on social protection, so that the most vulnerable can get assistance. Coping strategies work well if they are connected with money generation through micro-financing and building local institutional partnerships.

The participants identified a strong need for improvement on three levels of science-based climate risk financing and how it is used to mitigate drought impacts: (i) local (e.g., resource pooling and parametric insurance), (ii) national (e.g., risk financing policy), and (iii) regional (e.g., country consortium and cross learning). One forum participant noted, "Risk management through risk financing by means of Index-based insurance is very important as finance should be ready before the hazard impacts people."

Sarbeswara Sahoo presented on out-migration of tribal communities from tribal-concentrated areas in Gujarat, India. He said that topography, climate and more specifically drought and its impacts – land scarcity, surplus labour, land division, reduced crop diversity due to water shortage – were the main causes behind such migration. Sahoo shared that

tribals were migrating to urban centres searching for livelihood options, abandoning arable land due to water scarcity. He recommended improvement of agricultural support services and reclamation of common property resources, especially water bodies, and effective implementation of government programmes to check migration.

Gwyn Rees, Centre for Ecology & Hydrology, introduced the global Hydrological Status and Outlook System (HydroSOS), an initiative by the World Meteorological Organization (WMO) that aims to provide a global operational system for assessing the status of surface- and ground-water systems and predicting how they will change in coming weeks and months. He added that the proposed approach would integrate local ground-based observation, satellite data, weather forecast and hydrological models into the system. He apprised the floor of WMO's plans to establish a pilot HydroSOS in South Asia, which had been initiated in 2016 and extended till 2020. He urged members to support the initiative by contributing expertise, current capabilities, information on their requirements and validation of the System products based on observed data.

Indira Bose, World Food Programme (WFP) – Cambodia, shared that the World Food Programme (WFP), in partnership with the National Committee for Disaster Management (NCDM), and SERVIR Mekong, were working on developing impact-based forecasting for Cambodia to reduce the impacts of disasters. She introduced the Platforms for Real-time Information Systems (PRISM) initiative that leverages technology solutions to strengthen the government's capacity to collect information and improve coordination and response. Bose shared that PRISM serves as the national disaster management information system, and allows different ministries to share data that is useful for NCDM and humanitarian coordination bodies (i.e., national poverty registry), enabling more effective decision-making.

Salar Saeed Dogar, Pakistan Agriculture Research Council (PARC), spoke about a drought risk assessment study carried out in five districts in Pakistan to understand droughts over space and time. He shared that Pakistan had witnessed the worst drought in 2002, with some union councils in drought affected districts categorized as "extreme" and others as "severe" drought intensities. He recommended that getting clear results from the grassroots level is necessary to apply defined indices and tools at union council scale. He recommended adoption of a Drought Mitigation Strategy (DMS), designation of agencies for drought management and training of farmers in the adoption of efficient water use technologies.

Amanda Markert, NASA SERVIR Science Coordination Office (SCO), spoke about risk financing and how it can be leveraged for applications in drought and other extremes to mitigate impact. She shared that parametric (index-based) insurance uses an indicator or proxy of natural hazard (e.g., wind speed, rainfall intensity) to trigger a pay-out, unlike traditional insurance packages that pay for complete replacement of damaged assets. She shared an example of Kenya's Agricultural Insurance System (AIS) that guides payouts made to farmers during incidences of crop failure. She added that SERVIR-Eastern and Southern Africa developed the crop mask and was working towards strengthening the capacity of Kenya's State Department of Agriculture (SDA) to update crop masks on an annual basis to ensure the sustainability of the insurance system. Markert recommended that drought indices derived from Earth observations and models be used to identify potential drought events to guide funding mitigation measurements.

Aneel Salman, COMSATS Institute of Information Technology, presented a case study from the Tharparkar district of Pakistan, which has experienced more frequent consecutive droughts in the current decade. The study analysed linkages between different coping strategies of households and their socio-economic factors during the drought period. Salman recommended opting for climate risk financing models, water management strategies, microfinance programmes, building local institutional partnerships and supporting local self-organization to address drought conditions.

SECTION 3

Day II

The second day of the forum witnessed panel discussions on agricultural land use policies and practices, advances in remote sensing for crop area assessments, in-season crop assessment, and yield forecast. Through group discussions, participants addressed key questions formulated in the session background notes.

Agricultural land use planning and policies

The session comprised presentations on studies on implications of land use practices and policies from Bangladesh, Nepal, and Pakistan. The session highlighted the significance of agricultural land use planning and policies for long-term sustainability of resources and socio-economic progress in the region.

Tariq Ali, Peking University, presented a study focused on virtual trade of land resources in Pakistan. Ali's study used information on Pakistan's trade in fifteen key agricultural commodities over the period 1990–2016, to provide quantitative analysis of policies to ensure sustainable production for trade. He stated that Pakistan's total virtual land trade has been increasing, accompanied by large and increasing net exports of land to other nations. Ali suggested that aligning the agricultural structure towards high land-use value commodities, combined with active promotion of trade in these commodities, could optimize agricultural land use for the country's long-term food security.

Md. Anowar Hussain Bhuiyan, National University, presented on the importance of water resources for agricultural production in the Chittagong Hill Tracts (CHT), Bangladesh. He shared that though 95% of the CHT area is unsuitable for intensive agriculture primarily due to remoteness and inaccessibility, deforestation and land degradation is increasing in the region. Bhuiyan recommended reducing degradation of natural resources, improving access to water, disseminating knowledge for optimum utilization of water, and introducing effective technology to promote sustainable agricultural practices in this region.

Raza Shah, UNESCO-Islamabad, presented on a rain water harvesting (RWH) project in Musazai Sharif Union Council (UC), Dera Ismail Khan District, Pakistan, which set up 16 demonstration sites for RWH along with water filtration units and indigenous technologies like rooftop rainwater systems in local schools. The project revived centuries-old ponds that were in a critical condition and provided trainings to the communities to maintain the ponds for sustained water availability. The project also introduced olive plantations coupled with drip irrigation systems in two model sites, as olives are hardy plants requiring less water with a lifespan of 100 years. Shah shared that policies based on scientific evidence, efficient use of water resources and right crop selection could lead to sustainable land use in drought-stricken areas.

Amina Maharjan, ICIMOD, presented a study on agricultural land use change in Chitwan, Nuwakot and Lamjung districts in the Gandaki River basin, Nepal from 1990 to 2010 vis-à-vis rural outmigration. The study used an innovative interdisciplinary approach integrating macro scale and longitudinal geospatial analysis with quantitative econometric causal analysis and participatory qualitative methods. Maharjan's results show that agriculture land abandonment is higher in mountain areas than in the Tarai. The effect of outmigration on agricultural land abandonment also has an important gender dimension: internal outmigration of women has a significant positive effect on agriculture land abandonment, confirming the increasing feminization of the agriculture sector.

Group work

The session addressed the following key questions:

1. What are the key challenges related to current agricultural land use practices?

   The group discussion summarised some of the key challenges in agricultural land use practices. These include soil erosion, land fragmentation, land conversion, drought, salinity, flood and degree of OM.

2. What is the state of affairs of agricultural land use policies in terms of technical, procedural and social and gender dimensions in South and Southeast Asia?

   The group identified the state of affairs of the existing land use policies. For instance, local regulations overwrite national policies; top-down policies do not fit local needs, poor integrated and sustainable plans for land use planning and slow reaction to regional/global trends.

The per capita land availability and per capita water availability has been decreasing continuously from 1992 to 2016 in Pakistan, as the population is growing.

– Tariq Ali

The main challenge for water resources management in Bangladesh is the lack of knowledge to use water resources efficiently.

– Anowar Hossain Bhuiyan

The main target of current initiatives is water security for all people.

Rainwater harvesting works best when all other options become unviable, and in areas where much water goes wasted.

– Raza Shah

Migration is neither the major nor the only one factor for the changes in land use observed in the HKH region.

– Amina Maharjan

3. How can Earth observation tools and technologies support sustainable agricultural practices?

   The group recommended the use of Earth observation tools to support land use practices for crop monitoring, early forecast, crop yield forecast, land use planning, disaster monitoring and management and provide direct support for farmers and managers using decision support systems (DSS).

4. How to link Earth observation and modelling tools on land use pattern with data on demographic changes?

   The group discussion also came up with recommendations on how to link EO & modelling tools on land use pattern with demographic changes. Some of the recommendations are 1) land use change detection using satellite data for driving forces such as population pressure, job opportunity, economic development, social welfare, and market orientation 2) Land use planning using geospatial data and modelling techniques for the use of existing land use considering socio-economic parameters, soil, topography, weather/climate, market orientation, and national strategies 3) Forecast land use change using models and EO data for prediction of cropland, land use change forecast, competition, type allocation, land degradation prediction, and land use change with socio-economic scenarios.

Advances in remote sensing for crop area assessments

Studies and best practices in South and Southeast Asia presented at the forum showed efforts to assimilate remote-sensing data into crop models to recalibrate model parameters based on remotely sensed crop status on the ground, and to reduce uncertainties in seasonal weather conditions by incorporating ground observations in the models. These presentations discussed in-season crop assessment and yield forecasts using satellite-derived data and field observations to determine key crop production indicators such as crop area, yield, crop condition, cropping intensity and crop-planting proportion. In addition, experts shared their research outputs and experience from other parts of the world.

The forum's panels discussed innovative approaches for regional crop mapping using cloud-based

remote sensing and machine learning in the region. The presentations included lessons learned from new and advanced techniques in remote sensing application for crop area assessments and advanced deep learning algorithm (e.g., convolutional neural network) to predict vegetation levels across large and heterogeneous geographic regions. In addition, open-access cloud-based solutions for crop area mapping for food security planning and policies were discussed.

The panels deliberated on how remote sensing technologies are being integrated with conventional systems for improving efficiency and accuracy of crop models and the challenges of adoption of new technologies. The participants found that the major technical challenges to crop assessments include (i) lack of ground observation (e.g., crop calendar/ types), differentiating inter-cropping patterns, soil profile, quality and resolution of remote sensing data and (ii) lack of understanding of methods and uncertainties of the crop models, tools, and products. The panel suggested that institutional collaboration is needed to integrate satellite, climate, and crop data and models by engaging users and decision makers and tailoring communication to local level as well as defining a process to make information available, thus reducing barriers.

Pete Richards, USAID, introduced a project that tried to identify drought resilience and project impact using synthetic outcomes generated through a convolutional neural network (CNN). He described the workflow for an advanced deep learning algorithm – CNN to predict vegetation levels using historical vegetation patterns, daily weather conditions, and observations of the local relationships between vegetation and weather conditions. The generated synthetic outcomes were used as a counterfactual to identify and estimate drought resilience, and the impact of new agricultural policies and programmes on agricultural productivity. Richards showcased several examples including ones from Nepal. He concluded that CNN models, combined with remote sensing and estimations, can offer a low cost, generalizable method for identifying and assessing causal change.

Muhammad Fahad, University of Agriculture, Pakistan presented on the methodology using multi-temporal Landsat time-series imageries for wheat area estimation in Faisalabad district, Pakistan. Fahad explained the importance of the Normalized Difference Vegetation Index (NDVI) variable for the classification of wheat from other cultivated and non-cultivated areas. Accuracy assessment results showed the overall accuracy, commission error and omission error as 77% with ±5% as standard error, 23% and 28% respectively. He also highlighted mixed pixels originating from linear tree plantations, and small land holdings used for agriculture as some of the bottlenecks in such an approach. He recommended that the accuracy of similar exercises could be improved by minimising mixed pixels located at field borders and using Sentinel imagery that have a higher ground resolution.

Sawaid Abbas, Hong Kong Polytechnic University, shared his experiences of using the Google Earth Engine (GEE) platform and Sentinel imagery for crop area mapping in Punjab Province, Pakistan. Abbas processed multi-temporal data from Sentinel-2 and Sentinel-1 satellites in the GEE platform to characterize phenology of major crops, viz., wheat and potato in Rabi (winter) crops and sugarcane, cotton and rice for Kharif (summer) crops. A comparison between results from the study and results from semi-automated supervised classification showed consistent results for wheat and sugarcane while over-estimating statistics for rice and cotton. Abbas stated that by incorporating recent data on crop development stage, the framework could generate near-real-time scenarios for crop area. He further added that cloud-based solution is transparent, repeatable and replicable in areas with similar cropping systems, and presented a strong potential to replace existing enterprise-based solutions.

Varun Tiwari, ICIMOD, shared his experiences of using Sentinel 1 Synthetic Aperture Radar (SAR) data and Sentinel 2 (10m spatial resolution) optical data in a GEE platform for mapping wheat sown area in Afghanistan. He spoke about the importance of crop area estimation; crop yield estimation for crop yield forecasting; pricing; distribution-export and import; formulation of policy. Tiwari suggested that integrating optical and SAR data helped improve the accuracy of crop classification, while GEE enabled the processing of high volume of data. He apprised the floor of ICIMOD's interest to continue the wheat crop classification using the same approach, improved field data collection in coordination with the Ministry of Agriculture Irrigation and Livestock (MAIL), Afghanistan, and capacity building of MAIL staff for the sustainability of the project and regular update in crop maps.

Farrukh Chishtie, ADPC, provided a brief overview of the Regional Land Cover Monitoring System (RLCMS) that had twenty collaborating agencies.

The RLCMS uses an innovative cloud based remote sensing and machine learning approach utilizing the GEE platform. Chishtie presented ADPC's approach for the Mekong regional crop mapping products, where they combined a regional database of reference training data on crop type, crop seasons and irrigation conditions with remote sensing data and used machine learning algorithms to create probability maps. Chishtie also showcased how harmonic trends of crop seasons were derived to calculate seasonality, and a time-series of annual crop and rice maps from 1990 to date. Finally, he concluded that using open tools increased involvement and partnership of multiple stakeholders in the development process.

Group work

The session came up with recommendations on how remote sensing technologies can be integrated with the conventional system for improving efficiency and accuracy of crop area statistics and the challenges in adoption of new technologies.

The session addressed the following key questions:

1. What are the opportunities and bottlenecks in the adoption of geospatial technologies for crop area estimation in South and Southeast Asia?

   Freely available data, improved spatial and temporal resolutions, and availability of free and open source software and cloud-based platforms such as the Google Earth Engine, improved storage capacity and data processing to store and manage large geospatial datasets, access to advanced algorithms such as machine learning present a whole gamut of opportunities.

   However there are bottlenecks. Weather conditions (cloud/aerosol contamination), differences in field vs pixel scale, and diversity of agricultural practices and different inter-cropping patterns are some of the hurdles. A general lack of ground observation data, financial resources, technical capacity (trained staff) and lack of consideration for local context often affect the adoption of geospatial technologies for crop area estimation in South and Southeast Asia.

2. How to optimize field data collection mechanisms from ICT technologies and field-based institutional setups?

   The key recommendation for optimizing field data collection mechanisms was to use crowdsourcing technologies (e.g., Collect Earth Online) and mobile applications. Other recommendations included standardization of data collection and data sharing at different levels (policy concerns), developing and maintaining open channels of communications (inter-ministry and inter-agency), involving students in data collection, and defining and teaching/training best practices and using new techniques (drones and the internet).

3. What are the next steps for integrating remote sensing methods in the institutional crop area estimation process?

   Active learning approaches for improved field data collection, methodologies to assimilate remote sensing and ground data collection, data mining, exploring the use of high-resolution base maps for high frequency and promoting the use of remote sensing/GIS within the institutional structure for proper operations.

In-season crop assessment and yield forecast

Agriculture and food security issues continue to be major challenges in South and Southeast Asia. Drought is a major challenge that can result in severe food shortages and depleted pastures, threatening the livelihoods and lives of millions of people. These impacts are especially pronounced as many people depend on rain-fed agriculture in a highly variable climate. Early information like in-season yield assessments and forecasts about potential end-of-season production could help national ministries and NGOs better plan and respond to possible food security crises. Additionally, crop assessments and modelling techniques can provide insight and guidance on optimal planning strategies and agricultural practices that can help to mitigate future drought impacts, providing valuable information to policymakers, agriculture extensions and farmers alike. The session explored novel techniques for cropland assessments and yield estimations, such as remote sensing and modelling techniques, and discussed knowledge gaps and solutions needed to integrate these methods into decisions support systems.

Wu Bingfang, Institute of Remote Sensing and Digital Earth (RADI), Chinese Academy of Sciences (CAS), made the keynote presentation for the session. He emphasized that an integrated approach, sustainable and resilient agriculture practices are needed to attain Goal 2: Zero Hunger, one of the Sustainable Development Goals. He singled out information gap

in food security as the biggest challenge, and added that cloud computing can be an effective technique for utilising free satellite data for in-season crop monitoring and yield forecasts. He introduced CropWatch – China's leading crop monitoring system, part of RADI, CAS. Wu shared that the system aims to improve food information availability, quality and transparency globally. He shared CropWatch's hierarchical approach for crop production monitoring which uses specific environmental and agricultural indicators on different scales to assess global, regional, and national (as well as sub-national) crop conditions, production, and agricultural trends. Wu also provided an overview of the different components within the CropWatch Cloud system – CropWatch-Pro (a web service for people to produce crop monitoring products), CropWatch-Explore (a web service for users to explore and visualize data), CropWatch-Analysis (an open tool available to the public for analyses of data), and CropWatch-Bulletin (a web space for people to read/download the CropWatch Bulletin). Wu shared that CropWatch planned to reach different countries by customizing the system according to local context, and integrating it with local technical systems. As an example, he explained how CropWatch was customized for Mozambique, which led to information being incorporated into Mozambique National Agro-Meteorological Bulletin in June 2018.

Wei Xiong, CIMMYT-China, presented an assessment of the potential impacts of past drought anomaly (1961–2010) on summer maize yield, using a process based crop model, CERES-Maize, in China. The CERES-Maize used gridded geographical data, with yield difference between irrigated and rain fed conditions defined as the potential yield loss caused by drought. Wei's team used the anomaly percentage of potential yield loss to reflect the inter-annual and inter-decadal variation of estimated impact of drought on maize in China. Wei shared that there was a decreased drought risk for summer maize production in China, and also indicated that the drought had moved to northeastern China during the past fifty years. Linkages between national maize yield loss and atmospheric circulation index realized through the assessment were used to establish a simple conceptual forecasting model.

Walter Lee Ellenburg, NASA SERVIR SCO, shared results from a study that assimilated satellite-derived microwave and thermal-infrared coupled soil moisture (SM) profiles into a crop model for yield estimates. The study was conducted over parts of the southeastern United States from 2006–2010. He shared that while agricultural simulation models played a key component in testing new technologies, seeds and cultivars, inaccurate input information and model related errors added to model uncertainties. He recommended assimilating satellite observations of soil moisture (SM), vegetation index, etc. into crop models to reduce input and model related uncertainties. Irrigated regions observed highest improvements. The rain-fed model simulation failed to register additional water supply but remotely sensed profiles were able to detect such supplements. Ellenberg stated that by assimilating remotely sensed SM profiles into crop model the errors were reduced nearly by a factor of five compared to open-loop yield errors against National Agricultural Statistical Services (NASS) reported yields.

Ved Prakash Singh, India Meteorological Department, shared his experiences from a modeling exercise for estimating rice and wheat yields for Madhya Pradesh and Maharashtra in central India, incorporating weather variables and Vegetation Condition Index (VCI) derived from remote sensing methods. Singh suggested that yield forecasts generated by the proposed model were validated against actual production data. Positively coupled comparison results implied that it can be applied for both crops (rice and wheat) to generate more accurate and region-based real-time yield forecast in developing countries. He recommended the incorporation of other remote sensing parameters, along with VCI, in weather-based crop yield forecasting models to improve model performance and accuracy.

Saurav Suman, United Nations World Food Programme (WFP), shared his experiences in using the CCAFS Regional Agriculture Crop Forecasting Toolkit (CRAFT) for yield estimation of rice and wheat in Nepal. CRAFT includes a crop simulation module, a weather and seasonal forecast simulation module, and a geographic information system module, and is primarily used for in-season forecasting of crop production. Suman shared that there is limited data on crop management and variety, and that the model performed well for wheat but had more room for improvement on rice estimates. More research required for satellite-derived datasets. He stated that the model was producing regular updates for the nation, which were disseminated through the Nepal Food Security Monitoring System (NeKSAP) website. He added there was more demand for subnational predictions as well. Suman proposed using CHIRPS data for short-term and long-term yield estimates and blending DHM data with CHIRPS.

The session chair, Ashutosh S. Limaye, summarised the session, noting that a combination of weather and remote sensing derived indices – Vegetation Condition Index (VCI) – can improve results in yield estimation. He suggested that in-season crop yield estimates require strong collaboration within ministries.

Group work

The session addressed the following key questions:

1. What are the major technical challenges to crop assessments and yield prediction in South and Southeast Asia?

   The group divided major technical challenges to crop assessments and yield prediction in two categories – data and methods used for crop assessment, and yield estimation.

   The challenges with respect to data are integration of weather information – current and forecasted, lack of data on crop type and soil profiles, disaggregated data with differing formats, problems with resolution (spatial, temporal) of remote sensing data, constraints based on scale and temporal need for information, lack of interdisciplinary collaboration. Most importantly, validation and accuracy assessment of models.

   Statistical/empirical and simulation are two types of models used for crop assessment and yield estimation. Lack of knowledge on how to use (set-up, process, parameterise and run) these models is a major challenge.

2. What kinds of innovative solutions are needed to address the dearth of data on cropping practices and production?

   The group suggested the following solutions:

   - Use of remote sensing and image analysis as it provides information for data sparse regions. The use of drones or Unmanned Air Vehicles (UAV) as it provides detailed information for targeted regions.
   - Location and crop-specific models: some of the regions can have many climatic and agricultural zones. Integration of weather forecasts – emphasis on long-term and seasonal forecasts
   - Improve capacity building to build knowledge and expertise.
   - Consolidate information and ensure knowledge continuity by transfer and documentation of information.
   - Inclusion of information on other drought effects such as disease and pests.

3. What are the next steps for integrating these methods in decision making and allowing end users to use them?

   - Understand and contribute to the decision-making process. It would help to build trust in science, data and models. It will also bridge the gaps between different disciplines.
   - Have a review process in place to assess success and failure and a proper monitoring and evaluation process – what worked, what did not, and how can it be improved?
   - Understand methods to communicate and disseminate information and advisories. Tailoring communication to the local level and defining a process for making information available would help reduce barriers.

SECTION 4

Day III

Panel discussion: Emerging Earth observation technologies and their adoption in South and Southeast Asia

Eklabya Sharma, ICIMOD, moderated a panel discussion with a panel comprised of Ashutosh S. Limeye, Amit Wadhwa, D.R. Pattanaik, Archana Shrestha and Tsegaye Tadesse. The panel discussed the challenges and/or opportunities in the adoption of emerging technologies in drought monitoring in South and Southeast Asia, primarily with regard to three aspects i) maturity of models, methods and/or technology used, ii) data access and availability, and iii) institutional capacity. Ashutosh S. Limeye shared that scientists need to reassess and change their focus to the end user so that the science is usable. He recommended that new products be designed based on mutual learning and understanding with end users, and data portals increase data accessibility for end users. Limaye emphasised institutional capacity building as an important aspect, and suggested looking for examples that worked, and replicating them for local audiences. Limeye recommended that institutions should include people who understand the models and outputs and also build awareness of how to use the data to fit the different contexts.

Tsegaye Tadesse, National Drought Mitigation Center-NASA, shared that models used for monitoring and forecasting drought should be based on ground observations, and be accurate as far as possible for better forecasting, mitigation and planning. He added that several models and predictions at the regional, global, national and local level were available, but more needs to be done to ensure data availability, and capacity building must be carried out to increase the efficiency of the models. He stressed that validation of models is equally important.

D.R. Pattanaik, India Meteorological Department, said that technological advances have led to improved model accuracy in the last twenty years. He added the development process should be further improved so that users are able to utilize model outputs. He shared that the evolution of models and technology helped in reducing gaps.

Focus has to be on getting out the best products as per user need and wider collaboration with partners and with the government for mitigation of drought impacts.
– Pete Richards

There is no other alternative for regional collaboration than sharing knowledge, data, and examples, along with capacity building through exchange of human resources, tools, and technologies.
– Abid Hussain

Women in Nepal and other parts of Asia are by default primary users of natural resources, but they are not considered primary stakeholders during planning and policy making.

Who is synthesising information matters a lot in policy formulation.
– Dibya Gurung

Archana Shrestha, Department of Hydrology and Meteorology, Nepal, highlighted lack of data as one of the main challenges in monitoring climate induced hazards in Nepal. She mentioned that Nepal's Department of Hydrology and Meteorology (DHM) is working to establish more automated weather stations and make data available on SPI and SPEI. Once the department has enough stations, the data could be used for validation of models. Nepal has yet to start forecasts on drought. Shrestha suggested that operationalizing services and continuing them would be important once they have been identified as fit for a certain group of users. She stressed that reviewing existing products and improving them is equally important for institutional capacity building

Amit Wadhwa, World Food Programme, Nepal, advocated the benefits of involving the private sector in data management. He stated that there were challenges in bringing in the private sector and in providing them access to data. Wadhwa recommended opting for private-public partnership models, examining how organizations utilize available information and developing helpful and practical interventions for end users as important aspects for consideration.

Panel discussion: Policy actions for operationalizing climate and agriculture services

David Molden moderated a panel discussion focused on three questions:

- The status of drought in countries and their preparedness strategy
- Bottlenecks in drought monitoring, evaluation, assessment and mitigation of droughts
- Financial resource planning for droughts

Pete Richards highlighted climate resilience as an important issue, and identified preparation at the household level, provisioning of index-based insurance and keeping markets fluid as ways for the best products. Efficient products have to be considered, and partnerships have to be open to innovative ideas. American companies pay climate service startups. Data scientists need to search for innovation and move out of their comfort zones to get more funds

Abid Hussain reflected on the current status of drought in Bangladesh and other challenges such as population increase, shrinking land, conversion of arable land for off-farm business. However, preparedness for drought is a top priority in Bangladesh, and some of the measures include adoption of heat tolerant crop varieties, crop tuning, and planting of shallow-rooted crops in drought-affected areas. He stressed the importance of promoting regional collaboration by sharing knowledge and experiences, sharing data in terms of application development, institutional capacity building, sharing of resources and utilisation, and exchange of tools and technologies. Many initiatives have failed due to a lack of policy support and a flawed development process. There has to be policy support, institutional support and belongingness at the regional level. Building the awareness of beneficiaries regarding services is important, and it should create impact. The process should involve the users in field validation and demonstration, and as well as in piloting. Products should be customized according to the local context (e.g., use the local language) and delivered free of cost (or at a low cost) in a timely manner. He said execution of projects is difficult due to non-availability of data such as a desired resolution map, lack of reliable data, lack of skilled workforce, and information gap.

Gender expert and event panellist Dibya Gurung emphasized the need to make policy more gender responsive. She asked how much space and financial investment drought and resilience is receiving at the national and international level. She asked how we can make women primary stakeholders and translate the findings of initiatives such as GIS modelling into policies that benefit primary stakeholders. Scientists and practitioners need to take local bodies into consideration, and the findings have to make sense to at least the representative authority at the local level.

Basanta Shrestha stressed the importance of a regional data policy and harmonization, and the need to invest in human resources and policies to encourage the private sector to invest in the sustainable running of projects. There are dedicated institutions of government, there are multiple stakeholders, and all sectors have a role, so the open data services have much importance in this region. The key challenge to the scientific community is – can we make business sense out of it and can we serve the needs of local authorities who are hungry for ideas to implement on the ground?

Supply vs demand theory also applies to drought management policies as technology offers a solution and provides methods and technologies that locals (end users) need. There is a gap in supply and demand in the HKH.

Young people serve as a "tech force" and contribute to knowledge generation and communication of the gathered information.
– Basanta Shrestha

Do we have policies? Yes. And are these policies solving problems? No.

Policies should be synced across different levels because a single institution cannot solve the problem.

Policy syncing at the regional and national scale is important because one stakeholder alone cannot solve the problem. Second generation multi-stakeholder partnership has to be used for knowledge sharing.

Like data analysis using Artificial Intelligence, we need policy analysis to see the trend and correlation.
– Aneel Salman

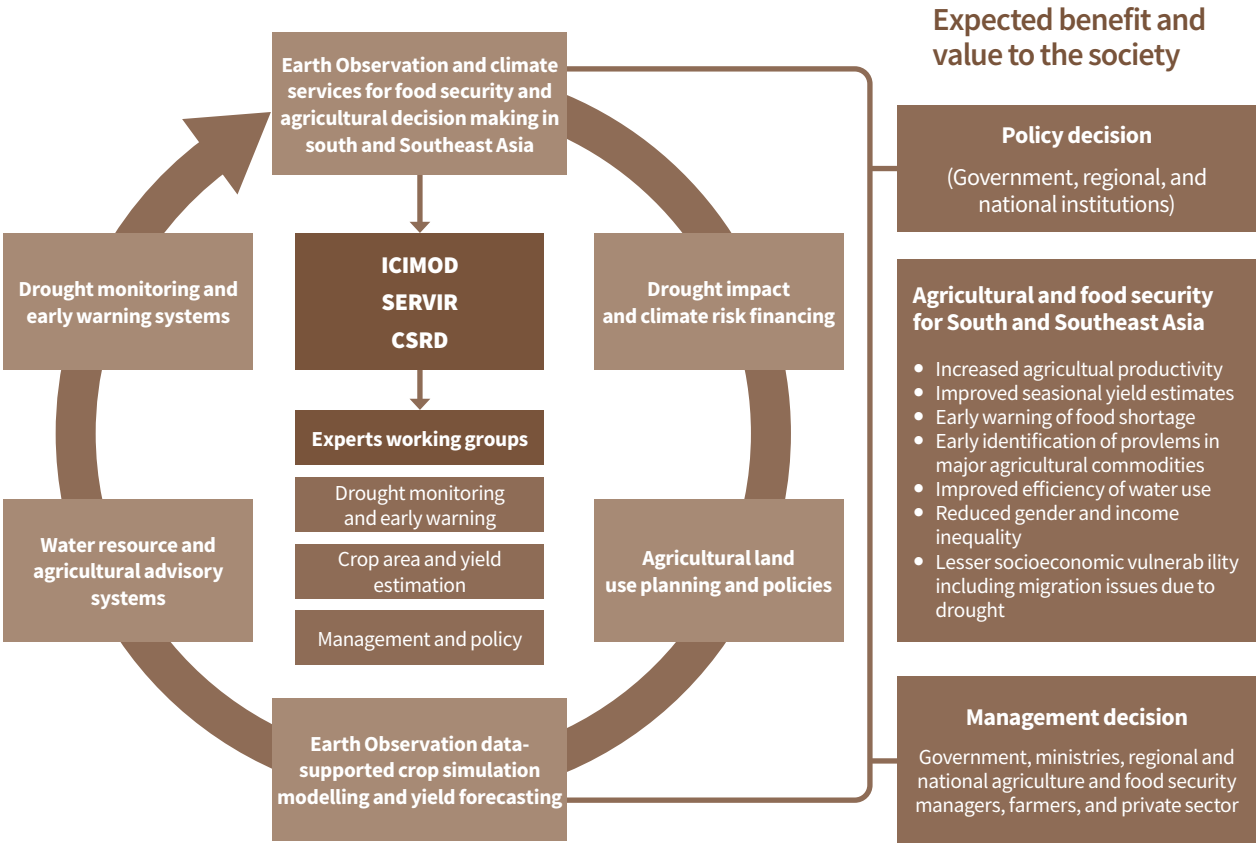
Aneel Salman emphasised the need for policies to ensure food security. There is a lack of harmony in policy formulation as each sector works in isolation. He also talked about policy paralysis during the implementation phase and tried to draw lessons from mechanisms from developed countries such as minimum support price (MSP). He said the entire policy cycle should be assessed before going for implementation to see whether and how it works.

Establishment of expert working groups to foster regional cooperation

Given the multi-faceted nature of drought and its links to food security and socio-economic issues related to race, class and gender, a strategic partnership is necessary for building engaged and drought-resilient communities. In breakout groups, the participants at the forum discussed ways to establish a regional partnership – an innovation platform – with the participation of national and regional institutions, the private sector, and local and international organizations to improve climate services using Earth observation and facilitate agricultural decision making to help with food security in the region. Three working groups (WGs) were proposed at the forum:

- Drought monitoring and early warning
- Crop area and yield estimation
- 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 Figure 1. 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 in building institutional capacity to address drought monitoring and food security issues. Volunteer 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 training local experts in capacity building.


Earth Observation and climate services for food security and agricultural decision making in south and Southeast Asia
ICIMOD
SERVIR
CSRD
Experts working groups
Drought monitoring and early warning
Crop area and yield estimation
Management and policy
Drought monitoring and early warning systems
Drought impact and climate risk financing
Water resource and agricultural advisory systems
Agricultural land use planning and policies
Earth Observation data-supported crop simulation modelling and yield forecasting
Expected benefit and value to the society
Policy decision
(Government, regional, and national institutions)
Agricultural and food security for South and Southeast Asia
Increased agricultual productivity
Improved seasional yield estimates
Early warning of food shortage
Early identification of provlems in major agricultural commodities
Improved efficiency of water use
Reduced gender and income inequality
Lesser socioeconomic vulnerab ility including migration issues due to drought
Management decision
Government, ministries, regional and national agriculture and food security managers, farmers, and private sector

Annexes

Annex I: List of participants

SN	Country	Full Name	Institution
1	Afghanistan	Sayed Burhan Atal	ICIMOD Country Office
2	Afghanistan	Waheedullah Yousafi	ICIMOD Country Office
3	Afghanistan	Asadullah Rahmatzai	Kabul University
4	Afghanistan	Fawad Auobi	Kabul University
5	Afghanistan	Md. Kazem Yosufi	Kabul University
6	Afghanistan	Nasrin Faqiri	Kabul University
7	Afghanistan	Sediqullah Reshteen	Kabul University
8	Bangladesh	Hasan Md. Hamidur Rahman	Bangladesh Agricultural Research Council
9	Bangladesh	Kabir Uddin Ahmed	Bangladesh Agricultural Research Council
10	Bangladesh	Md. Abeed Hossain Chowdhury	Bangladesh Agricultural Research Council
11	Bangladesh	Mostafa Ali	Center for Environmental and Geographic Information Services
12	Bangladesh	Iftekhar Mahmud	N/A
13	Bangladesh	Pravez Babul	N/A
14	Bangladesh	Anowar Hossain Buiyan	National University
15	Cambodia	Hideki Kanamaru	Food and Agriculture Organisation
16	Cambodia	Ix Hour	Mekong River Commission
17	Cambodia	Le Thi Huong Lien	Mekong River Commission
18	Cambodia	Prak Thaveak Amida	Ministry of Agriculture, Forestry and Fisheries of Cambodia
19	Cambodia	Chanvibol Choeur	World Food Programme, Cambodia
20	Cambodia	Indira Bose	World Food Programme, Cambodia
21	China	Wu Bingfang	Chinese Academy of Sciences
22	China	Urs Christoph Schulthess	CIMMYT
23	China	Wei Xiong	CIMMYT
24	China	Tariq Ali	Peking University
25	Hong Kong	Sawaid Abbas	The Hong Kong Polytechnic University
26	India	Sarbeswara Sahoo	Global Informal Labour Institute
27	India	D.R. Pattanaik	India Meteorological Department
28	India	Nilesh Wagh	India Meteorological Department
29	India	Shirish Khedikar	India Meteorological Department
30	India	Ved Prakash Singh	India Meteorological Department
31	India	Padma TV	PRESS
32	Indonesia	Shahbaz Khan	United Nations Educational, Scientific and Cultural Organization
33	Nepal	Arjun Kumar Shrestha	Agriculture and Forestry University ,Chitwan
34	Nepal	Kishor K.C.	Central Bureau of Statistics
35	Nepal	Bashudev Neupane	Central Department of Environmental Sciences, Tribhuvan University
36	Nepal	Binod Parajuli	Central Department of Environmental Sciences, Tribhuvan University
37	Nepal	Kribina Pathak	Central Department of Environmental Sciences, Tribhuvan University
38	Nepal	Kripa Shrestha	Central Department of Environmental Sciences, Tribhuvan University
39	Nepal	Sijal Pokhrel	Central Department of Environmental Sciences, Tribhuvan University
40	Nepal	Arun Kafle	Department of Agriculture
41	Nepal	Priyambada Joshi	Department of Agriculture
42	Nepal	Kishwor Aryal	Department of Forest and Soil Conservation
43	Nepal	Prakash Singh Thapa	Department of Forest and Soil Conservation
44	Nepal	Archana Shrestha	Department of Hydrology and Meteorology,MoPE
45	Nepal	Prakash Acharya	District Agriculture Development Office
46	Nepal	Faisal Mueen Qamar	ICIMOD
47	Nepal	Angeli Shrestha	ICIMOD
48	Nepal	Bhoj Raj Ghimire	ICIMOD
49	Nepal	Bikram Shakya	ICIMOD
50	Nepal	Birendra Bajracharya	ICIMOD
51	Nepal	Deepak Kumar Shah	ICIMOD

52	Nepal	Ganesh Bhattarai	ICIMOD
53	Nepal	Gauri Shankar Dangol	ICIMOD
54	Nepal	Ishaan Kochar	ICIMOD
55	Nepal	Kabir Uddin	ICIMOD
56	Nepal	Kushal K.C	ICIMOD
57	Nepal	Maxim Shrestha	ICIMOD
58	Nepal	Mir Abdul Matin	ICIMOD
59	Nepal	Nishanta Khanal	ICIMOD
60	Nepal	Prashanti Sharma	ICIMOD
61	Nepal	Rajesh Shrestha	ICIMOD
62	Nepal	Rajesh Bahadur Thapa	ICIMOD
63	Nepal	Ramesh Silwal	ICIMOD
64	Nepal	Shova Bhandari	ICIMOD
65	Nepal	Sudip Pradhan	ICIMOD
66	Nepal	Trilochana Basnett	ICIMOD
67	Nepal	Utsav Maden	ICIMOD
68	Nepal	Smohit Shrestha	International Rice Research Institute
69	Nepal	Vishnu Prasad Pandey	International Water Management Institute
70	Nepal	Bhoj Raj Sapkota	Ministry of Agricultural, Land Management and Cooperatives
71	Nepal	Shib Nandan Prasad Shah	Ministry of Agriculture and Livestock Department
72	Nepal	Sudip Devkota	Ministry of Agriculture and Livestock Department
73	Nepal	Yubak Dhoj G.C	Ministry of Agriculture and Livestock Department
74	Nepal	Madhusudhan Guragain	Nagarik News
75	Nepal	Ram Chandra Adhikari	National Agriculture Research Center
76	Nepal	Ghanashyam Malla	Nepal Agricultural Research Council
77	Nepal	Robert Banick	World Bank
78	Nepal	Man Bahadur Kshetri	World Food Programme
79	Nepal	Moctar Aboubacar	World Food Programme
80	Nepal	Nicola Bidento	World Food Programme
81	Nepal	Pushpa Shrestha	World Food Programme
82	Nepal	Saurav Suman	World Food Programme
83	Nepal	Sridhar Thapa	World Food Programme
84	Nepal	Amit Wadhwa	World Food Programme, Asia
85	Pakistan	Aneel Salman	COMSATS Institute of Information Technology
86	Pakistan	Muhammad Abid	COMSATS Institute of Information Technology
87	Pakistan	Salar Saeed Doggar	Pakistan Agricultural Research Council
88	Pakistan	Muhammad Raza Shah	United Nations Educational, Scientific and Cultural Organization
89	Pakistan	Muhammad Fahad	University of Agriculture
90	Sri Lanka	Laksiri Nanayakkara	World Food Programme
91	Thailand	Hans Guttman	ADPC
92	Thailand	Farrukh Chishtie	Asian Disaster Preparedness Center/SERVIR-Mekong
93	Thailand	Peeranan Towashiraporn	Asian Disaster Preparedness Center/SERVIR-Mekong
94	Thailand	Senaka Basnayake	Asian Disaster Preparedness Center/SERVIR-Mekong
95	Thailand	Susantha Jaysingha	Asian Disaster Preparedness Center/SERVIR-Mekong
96	Thailand	Wadee Deeprawat	Asian Disaster Preparedness Center/SERVIR-Mekong
97	Thailand	Panu Nunagjumnong	Geo-Informatics and Space Technology Development
98	United Kingdom	Gwyn Rees	Center for Ecology and Hydrology
99	United States	Benjamin Zaitchik	John Hopkins University
100	United States	Ashutosh S. Limaye	NASA-MSFC
101	United States	Amanda M. Weigel	National Aeronautics and Space Administration-SCO
102	United States	Kel Markert	National Aeronautics and Space Administration-SCO
103	United States	Walter Lee Ellenburg	National Aeronautics and Space Administration-SCO
104	United States	Tsegaye Tadesse	National Drought Mitigation Center-NASA
105	United States	Pete Richardson	United States Agency for International Development
106	Vietnam	Nguyen Ngoc Thanh	Department of Water Resources
107	Vietnam	Nguyen Thuy Linh	Department of Water Resources
108	Vietnam	Ha Thanh Lan	Institute of Water Resources and Planning
109	Vietnam	Tri Deri Setiyono	International Rice Research Institute
110	Vietnam	Do Minh Phuong	National Institute of Agricultural Planning and Projection
111	Vietnam	Nguyen Minh Tien	Vietnam academy for Water Resources

Annex II: Agenda

Day 1 (8 October 2018)		
09:00–11:00	**Session 1: Opening session** • Forum background and objectives: *Birendra Bajracharya, ICIMOD* • Welcome from host and co-host: *David Molden, ICIMOD and Hans Guttman, ADPC* • Keynote speech: *Shahbaz Khan, UNESCO* • Remarks by chief guest: *Yubak Dhoj G.C., Ministry of Agriculture and Livestock Development, Nepal* • Vote of thanks: *Faisal M. Qamer, ICIMOD*	
11:00–11:30	*Tea break and group photo*	
11:30–13:15	**Session 2: Drought monitoring and Early Warning Systems** Chair: *Hans Guttman, ADPC*	
13:15–14:00	*Lunch break*	
14:00–15:45	**Session 3: Parallel Session**	
	(3a) Drought monitoring and early warning systems Chair: *Tsegaye Tadesse, University of Nebraska–Lincoln*	**(3b) Drought impacts and climate risk financing** Chair: *Pete Richards, USAID*
15:45–16:00	*Tea break*	
16:00–17:15	**Session 4: Climate Services and Climate Risk Financing Challenges and Opportunities (Group work)** • Moderator will elaborate on broader issues on the topic. Followed by the break-out group work. • Breakout structure: The group work will be structured around the Key Questions formulated in the Session background notes. • Moderators: *Benjamin Zaitchik, John Hopkins University, and Farrukh Chishtie, ADPC*	
18:30–20:00	*Forum dinner*	

Day 2 (9 October 2018)

09:00–10:00	Recap day – 1
10:00–11:15	**Session 4: Agricultural Land Use Practices and Policies** Chair: *Prak Thaveak Amida, Ministry of Agriculture, Forestry and Fisheries of Cambodia*
11:15–11:35	*Tea break*
11:35–13:15	**Session 5: Advances in Remote Sensing for Crop Area Assessments** Keynote speech by *Pete Richards, USAID* Chair: *Peeranan Towashiraporn, ADPC*
13:15–14:00	*Lunch break*
14:00–15:45	**Session 6: In-season Crop Assessment and Yield Forecast** Keynote speech by *Wu Bingfang, RADI* Chair: *Ashutosh S. Limaye, NASA-SERVIR MFC*
15:45–16:00	*Tea break*
16:00–17:15	**Session 7: Earth Observation for Agricultural Land Use Planning and Food Security Policies (Group work)** • Moderator will elaborate on broader issues on the topic. Followed by the break-out group work. • Breakout structure: The group work will be structured around the key questions formulated in the session background notes Moderators: *Mir Matin, ICIMOD,* and *Walter Lee Ellenburg, NASA-SERVIR SCO*

Day 3 (10 October 2018)

09:00–10:00	Recap day – 2
10:00–12:30	Policy-level Deliberation
10:00–10:30	Key Messages and Lessons from Day 1 and Day 2 *Faisal M. Qamer, ICIMOD,* and *Senaka Basnayake, ADPC*
10:30–11:30	**Panel Discussion** Emerging Earth Observation Technologies and its adoption in the South and East Asia Region Moderated by *Eklabya Sharma, ICIMOD*
11:30–12:30	**Panel Discussion** • Policy Actions for Operationalizing Climate and Agriculture Services Moderated by *David Molden, ICIMOD* • Short Briefing on Establishing Thematic Working Group or Expert Groups *Faisal M. Qamer, ICIMOD*
12:30–13:30	*Lunch break*
13:30–15:00	**Session on Formalizing Knowledge Forum and Expert Groups** Moderators: *Mir Matin, ICIMOD,* and *Farrukh Chishtie, ADPC*
15:00–15:30	**Closing Session**

Annex III: List of talks at the drought forum

Drought Monitoring and Early Warning Systems
Session Chair: *Hans Guttman*
Session hosts: *Senaka Basnayake, Sudip Pradhan*
Rapporteurs: *Binod Parajuli, Kripa Shrestha*

1. Drought Monitoring and Forecast with the NASA Hindu Kush Himalaya Sub-Seasonal to Seasonal Forecast System (HKH-S2S) – Benjamin F. Zaitchik
2. Application of Regional Drought and Crop Yield Information System to Enhance Drought Monitoring and Forecasting in Lower Mekong Region – Susantha Jayasinghe, Farrukh Chishtie, Kostas Andreadis, Narendra Das, Kel Markert
3. Regional Cooperative Mechanism on Drought Monitoring and Early Warning for Mongolia: Experiences and Lessons – Wu Bingfang
4. Evaluation of Gridded Rainfall Data Products for Drought Monitoring in South Asia – Faisal M. Qamer, Walter Lee Ellenburg, Mir Matin, Ashutosh S. Limaye, Carlo Montes, HM. Hamidur Rahman, Timothy J. Krupink, Kushal K.C.
5. Retrospective Drought Study and Developing Satellite-Derived Combined Drought Index for Crop Assessment: A Case Study from Balochistan, Pakistan – Tsegaye Tadesse, Faisal M. Qamer, Walter Lee Ellenburg, Sarva T. Pulla, Vikalp Mishra.
6. Operationalizing Agriculture Drought Monitoring and Early Warning System in South Asia – Mir Matin, Faisal M. Qamer, Kiran Shakya, Nishanta Khanal, Birendra Bajracharya, Benjamin F Zaitchik, Bhoj Raj Ghimire.
7. Water Scarcity, Drought and Gendered Vulnerabilities in Hindu Kush Himalaya (HKH) – Pranita Bhushan Udas, Chanda G Goodrich

Drought Monitoring and Early Warning Systems
Chair: *Tsegaye Tadesse*
Session hosts: *Susantha Jayasinghe* and *Bhoj Raj Ghimire*
Rapporteurs: *Kribina Pathak, Ishaan Kochhar*

8. Agriculture Stress Index System and Early Warning Early Action in Asia – Hideki Kanamaru
9. Drought Monitoring and Forecasting System of the Lower Mekong Basin – Ix Hour, Andres Felipe Marin Munoz, Anthony Kiem
10. Assessing CHIRPS-GEFS Medium-Range Precipitation Forecasts in Bangladesh – Ashutosh Limaye, Walter Lee Ellenburg, Carlo Montes, Begum Rushi, Vikalp Mishra, Emily Adams, Eric Anderson, Emil Cherrington, Africa Flores, Kel Markert, Dan IrwinDownscaled Drought Assessment in the Northern Part of Bangladesh – Md Sahadat Hossain, Ibnul Quader Jargis
11. Drought Monitoring and Prediction Over India from Weekly to Monthly Scale Using Standardized Precipitation Index – Pulak Guhathakurta, Nilesh Wagh, A K Sahai
12. Flood and Drought Predictions for the Kabul River Basin (KRB) – Muhammad Abid, Jay Sagin, Zaineb Abid

Drought Impacts and Climate Risk Financing
Chair: *Pete Richards*
Session hosts: *Abid Hussain* and *Amanda M. Weigel*
Rapporteurs: *Bashudev Neupane, Sijal Pokhrel*

13. Drought and Migration of Tribal Communities from Central Gujarat – Sarbeswara Sahoo
14. HydroSOS: A New Hydroclimate Service to Support Food, Energy and Water Sectors in South Asia – Gwyn Rees, Guna N Paudyal, Alan Jenkins, Harry Dixon, Katie Smith
15. Innovations for Risk Informed Emergency Preparedness and Response – Indira Bose, Chanvibol Choeur
16. Drought Hazard Vulnerability and Risk Assessment at the Union Council Scale in Punjab, Pakistan – Bashir Ahmad, Bilal Iqbal, Naveed Mustafa, Salar S. Doggar
17. "Risky Business": Risk Financing for Drought Resilience Applications – Amanda Markert, Eric Anderson
18. Climate Resilience and Risk Financing – Evidence from Tharparkar, Sindh – Aneel Salman

Agricultural Land Use Planning and Policies
Chair: *Prak Thaveak Amida*
Session hosts: *Rajesh Thapa* and *Urs Schulthess*
Rapporteurs: *Bashudev Neupane and Kribina Pathak*

19. Sustainable land use for international agricultural trade: The case of Pakistan – Tariq Ali, Wei Xie

20. The Importance of Water Resource for Agriculture Production in Chittagong Hill Tracts (CHT), Bangladesh – Md. Anowar Hossain Bhuiyan, Md. Abud Darda

21. Rainwater Harvesting to Combat Water Scarcity – A Case Study from Dera Ismail Khan District, Pakistan – Raza Shah

22. Understanding Rural Outmigration and Agricultural Land Use Change in the Gandaki Basin, Nepal: 1990 to 2010 – Amina Maharjan, Ishaan Kochhar, Vishwas Chitale, Giovanna Gioli, Abid Hussain

Advances in Remote Sensing for Crop Area Assessments
Chair: *Peeranan Towashiraporn*
Session hosts: *Kabir Uddin* and *Kel Markert*
Rapporteurs: *Binod Parajuli and Kripa Shrestha*

23. Identifying Drought Resilience and Project Impact through Convolutional Neural Network-Generated Synthetic Outcomes – Louis Reymondin, Pete Richards, Andres Cubides

24. Wheat Area Estimation Using Landsat-Based Time Series Imagery – Muhammad Fahad, Matthew C. Hansen, Ahmad Khan, Peter Potapov, Ashfaq Ahmad

25. Open-Access Cloud-Based Solution of Crop Area Mapping for Food Security Planning and Policies: A Case Study from Punjab Province, Pakistan – Sawaid Abbas, Muhammad Kamran Lodhi

26. Synergistic Use of High Resolution Optical and Synthetic Aperture RADAR for Wheat Sown Area Mapping in Afghanistan – Varun Tiwari, Mir A Matin, Faisal M Qamer, Walter Lee Ellenburg, Birendra Bajracharya, Krishna Vadrevu, Rushi Begum, Waheedullah Yusafi

27. An Innovative approach for regional crop mapping using cloud based remote sensing and machine learning – Ate Poortinga, Nguyen Hanh Quyen, Farrukh Chishtie

In-season Crop Assessment and Yield Forecast
Chair: *Ashutosh S. Limaye*
Session hosts: *Walter Lee Ellenburg* and *Kiran Shakya*
Rapporteurs: *Sijal Pokhrel and Ishaan Kochhar*

28. Global Crop Watch – Wu Bingfang

29. Simulation of Summer Maize Yield Influenced by Drought in China During 1961–2010 – Wei Xiong, Cao Yang, Wu Yongfeng, Feng Liangzhi, Yang Jie

30. Crop Modelling Using Remotely Sensed Soil Moisture – Vikalp Mishra, Lee W. Ellenburg, James F. Cruise, John R. Mecikalski

31. Yield Estimate of Rice and Wheat Crops Considering Weather and Remote Sensing Together for Central India – Ved Prakash Singh, Shirish Khedikar

32. Application of Regional Drought and Crop Yield Information System to Enhance Drought Monitoring and Forecasting in Ninh Thuan Province in Vietnam – Ha Hai Duong, Farrukh Chishtie, Susantha Jayasinghe

33. CRAFT based in-season yield assessment in Nepal – Saurav Suman, Dhiraj Gyawali, Moctar Aboubacar, Kurt Burja, Pushpa Shrestha, Paresh B. Shirsath, Arun K.C., Pramod K. Aggarwal

Annex IV: Media coverage of the event

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Annex IV: Photographs

Photos from the event are available for download from ICIMOD's account on Flickr from the following URL https://www.flickr.com/photos/icimodgallery/albums/72157702092287304

Annex IV: Presentations from the session

PDF copies of the presentations made at the Regional Knowledge Forum on Drought are available for download at http://bit.ly/2LBJ2cj

Annex V: Book of abstracts

The book of abstracts comprising summaries of papers presented at the forum is available at http://servir.icimod.org/regional-knowledge-forum-drought

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