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Climate Services Operational Pathways
Pathways for Transforming Weather, Water and Climate Services in Nepal

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LIST OF ACRONYMS

AAB	Agromet Advisory Bulletin
ADB	Asian Development Bank
AITC	Agriculture Information and Training Center
AKC	Agriculture Knowledge Center
AMIS	Agriculture Management Information System
AWS	Automated Weather Station
BRCH	Building Resilience to Climate-Related Hazards
CAAN	Civil Aviation Authority of Nepal
CCKP	Climate Change Knowledge Portal
CIF	Climate Investment Funds
COVID-19	Coronavirus Disease
CUSI	Composite User Satisfaction Index
DADO	District Agriculture Development Office
DEOC	District Emergency Operations Center
DHM	Department of Hydrology and Meteorology
DLSO	District Livestock Service Office
DRRM	Disaster Risk Reduction and Management
EWS	Early Warning System
FAO	Food and Agriculture Organization
FGD	Focal Group Discussion
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographical Information System
GLOF	Glacial Lake Outburst Floods
GoN	Government of Nepal
GTS	Global Telecommunication System
ICT	Information and Communications Technology
IFC	International Finance Corporation
INGO	International Non-Governmental Organization
JTA	Junior Agriculture Technician
KCC	Kisan Call Centers
KII	Key Informant Interview
LDMC	Local Disaster Management Committee
LEOC	Local Emergency Operations Center
MoALD	Ministry of Agriculture and Livestock Development
MoEWRI	Ministry of Energy Water Resources and Irrigation
MoFE	Ministry of Forests and Environment
MoHA	Ministry of Home Affairs
MoU	Memorandum of Understanding
NAMIS	Nepal Agriculture Management Information System (NAMIS)
NARC	Nepal Agricultural Research Council
NDRRMA	National Disaster Risk Reduction and Management Authority

NEOC	National Emergency Operations Center
NGO	Non-Governmental Organization
NMHS	National Meteorological and Hydrological Services
NTC	Nepal Telecom
NVC	National Vigilance Center
PEOC	Provincial Emergency Operation Center
PMU	Project Management Unit
PPCR	Pilot Program for Climate Resilience
PPP	Public-Private Partnership
RIMES	Regional Integrated Multi-Hazard Early-warning System for Africa and Asia
SPCR	Strategic Program for Climate Resilience
VHLEC	Veterinary Hospital and Livestock Service Expert Center
WFP	World Food Programme
WIS	WMO Information System
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

The Climate Investment Funds (CIF) were established with the mandate to serve as a learning laboratory for scaled-up climate finance through a range of investments to address climate change and accelerate climate action. The CIF Evaluation and Learning (E&L) Initiative is helping to fulfil this mandate by various strategic and demand-driven studies covering some of the most important and pressing challenges facing climate finance funders and practitioners. That also includes ensuring sustainability and enhancing project design and implementation to better respond the needs and capacities of beneficiaries.

Drawing on experience from across the CIF portfolio of investments in clean energy, forests and resilience in 72 developing countries, the E&L Initiative identifies strategic lessons and enables learning that is relevant, timely and used to inform climate programs, strategies, and investments, for both the CIF and the wider climate finance sector.

The study *Pathways for Transforming Weather, Water, and Climate Services* was commissioned by CIF's E&L Initiative to distill lessons from CIF's Pilot Program on Climate Resilience (PPCR) support identifying, designing, and implementing hydrometeorological and climate services investments. It seeks to generate learning and strategic insight into the different operational pathways that can be taken by national hydrological and meteorological agencies to develop, deliver, and strengthen hydrometeorological and climate services.

The outputs from the study comprise of one synthesis report and three country studies for Jamaica, Mozambique, and Nepal. These three countries have been selected for the study due to their different institutional frameworks, hydrometeorological systems, and socio-economic context. They provide diverse in-depth insights in hydrometeorological and climate service development, delivery, and use. In this respect, the PPCR-supported *Building Resilience to Climate-Related Hazards (BRCH) Project* was selected as a case study project for Nepal to elucidate lessons learned on the process for modernizing hydrometeorological systems and developing climate services to users. It offers insight into challenges and opportunities for climate services development, delivery, and use in the South Asian developing countries.

Qualitative methods, including structured interviews and literature review, were used to identify promising pathways to transform weather, water, and climate services in the three case study countries. In Nepal, the analysis of the data collected revealed five themes regarding critical pathways to continue to transform weather, water, and climate services in the country. These are: improving data resources, improving service design and delivery, improving hydrometeorological services through feedback and evaluation, fostering human resources capacity, and strengthening institutional arrangements. The section below summarizes key findings and recommendations.

1. IMPROVING DATA RESOURCES

- Automated hydrometeorological stations generate real-time and high-quality data. However, the hydrometeorological institution needs to maintain some manual stations constantly as a backup during automated systems failure and others for a few years to verify the correctness of data from the automated stations. Developing a strategy for keeping some and a gradual phasing out of the remaining manual stations is essential. It should go together with the capacity building of local gauge readers.

- Formal data-sharing arrangements (data platform) among different national institutions, sub-national governments, and principal stakeholders strengthen coordination among them for hydrometeorological services and product development. The data platform could be tailored to meet the needs of aviation, infrastructure development (hydropower), climate-resilient development, agriculture, and disaster management sector. The formalization of such structures should continue beyond the duration of the hydrometeorological project.

2. IMPROVING SERVICE DESIGN AND DELIVERY

- Design of climate information and services should target the specific temporal (e.g., seven days - medium-range) and sub-seasonal and seasonal (long-range) forecasts and spatial scale (e.g., location-specific forecasts); and user needs (e.g., impact-based forecasts). It is also crucial to ensure that climate information is contextual and credible and users trust and understand it.

- Decentralizing climate services through collaboration with agencies at the different administrative (e.g., local and provincial) levels is essential to reduce the responsibility burden at the central level while enhancing the delivery of hydromet information services more locally.

3. IMPROVING HYDROMETEOROLOGICAL SERVICES THROUGH FEEDBACK COLLECTION AND EVALUATION

- Interaction with and feedback from different users are crucial in updating, developing, and delivering effective hydrometeorological products and services. Therefore, setting up a formal mechanism (e.g., survey, formal interview, and discussion) is vital to ensure regular feedback collection.

- Informed users can better understand and use available climate information and services, assess gaps, and provide constructive feedback to improve them further. Fostering or promoting an informed user community through public outreach programs (e.g., climate information, education, communication campaigns, awareness-raising activities, and training programs) is critical before collecting end-user feedback and evaluating the hydrometeorological services.

4. FOSTERING HUMAN RESOURCES CAPACITY

- Strengthening the human resources capacity (both in staff numbers and technical skills) is equally essential as improving modern observation networks and forecasting technologies for the sustainability of modernized hydrometeorological services.

- Mapping human resources capacity under different themes such as ICT application, data assimilation, data analysis, research, service, and product development, etc., and consequently developing a long-term strategy for hydrometeorological institution's staffing, updating skills, and responsibilities through initiatives to recruit, retain, train, and support more staff is crucial. It needs to be aligned in the technical refurbishment and service delivery strategy context.

5. STRENGTHENING INSTITUTIONAL ARRANGEMENTS

- Without the financial support mechanisms and plans for sustainable operation of modernized systems, hydrometeorological projects beyond the project timeline may fail. Thus, it is important to explore potential ways to recover costs and ensure financial sustainability. It helps ensure the continuous operation of hydrometeorological infrastructure and delivery of improved weather, climate, and water services. Collaborations among the public and emerging private business sectors such as hydropower, insurance, airlines, and high-value crop agriculture could be one way to ensure financial sustainability.

- Initiation of an inter-institutional initiative, for example, the working group comprising officials from different collaborating agencies, helps work closely on the design and delivery of hydro and agrometeorological products and services. Therefore, fostering inter-institutional coordination and collaboration at a national level should be continued beyond the hydrometeorological project.

- A robust hydrometeorological policy provides the essential legal and regulatory framework for the operation of the National Meteorological and Hydrological Services. It sets the way to issuing licenses and enhancing private sector participation in the area of hydrometeorological services. Furthermore, it also opens opportunities to generate some financial support for the operation of National Meteorological and Hydrological Services. Hence, strengthening the hydrometeorological policy is vital for fostering weather, climate, and water services.

1) CONTEXT

1.1) CLIMATE RISK AND VULNERABILITY IN NEPAL

Nepal is exposed to hydrometeorological hazards such as floods, landslides, droughts, snowstorms, hailstorms, windstorms, avalanches, glacial lake outburst floods, and forest fires (CDKN, 2014). The country's varied geo-climatic system, poor infrastructure, and social vulnerability, including natural resources-dependent livelihoods and widespread poverty levels with 95% of the country's poor people living in rural areas, make the country highly vulnerable to climate-related disasters (The World Bank Group, 2011; IFAD, 2019). Studies indicate that low-income households in Nepal's Himalayan villages and Middle Hills region are more susceptible to climate-related effects than upper-income households. It is observed that only six percent of the extremely poor sought government support in response to floods and landslides compared to almost 90 percent of those with middle incomes (Macchi et al., 2014; Gentle et al., 2014).

Climate variability poses enormous costs to people's life, livelihood, property, and Nepal's economy as a whole (Sapkota, 2016). For example, severe winter droughts in 2006 and 2009, compounded by El Niño, highly impacted Nepal's agriculture sector. It led to food deficits of 400,000 tons, which increased food prices by 117-300 percent in various locations (UNDP, 2013; Wang et al., 2013). In 2017, extreme monsoonal rains caused inundation in 80% of southern Nepal, which resulted in US$ 585 million in damages (National Planning Commission, 2017). In 2019, Nepal also experienced the country's first-ever recorded Tornado in the Southern Bara and Parsa districts, which killed 28 people, injured more than 1,100, and damaged about 2600 buildings (Nature, 2019). Additionally, the burden of climate change, which is related to Sustainable Development Goals-13 (Climate Action), has been estimated to be Nepali rupees 25.6 billion (National Planning Commission, 2018).

Climate change will further increase climate risks and vulnerability in Nepal. Variations in weather patterns and hydrological regimes could intensify floods, droughts, water availability, and thus alter farming systems. Projections suggest that annual temperatures will increase between 1.3-3.8°C by 2060. Changes in precipitation are uncertain as projections vary across different models. Monsoon summers are projected to be wetter and winters are estimated to be drier. Reduced water availability during dry periods could exacerbate agricultural water needs, as an estimated 64% of the country's farmers rely on water from rains of the monsoon season. Furthermore, projected reductions in winter snow, as well as increased temperature, could reduce available snowmelt levels during spring and summer and could result in greater winter runoff in a short term. However, in a long term, increased melting of Himalayan glaciers will reduce Nepal's water supply, rendering many of the country's irrigated lands vulnerable (CCKP, 2021).

1.2) BUILDING RESILIENCE WITH HYDROMETEOROLOGICAL SERVICES

Recognizing the increasing risks posed by climate change and variability, Nepal's Government has established various policies to strengthen climate resilience and disaster preparedness. This includes the country's Second Nationally Determined Contribution, submitted in 2020, which highlights as a key policy priority for adaptation the establishment and strengthening of public weather services, including the Agrometeorological Information System, as well as the establishment of a multi-hazard monitoring and Early Warning System (EWS) covering all provinces by 2030 (GoN, 2020).

The Disaster Risk Reduction National Strategic Plan of Action (2018-2030) prioritizes the expansion and modernization of real-time hydrometeorological observation systems, the development and operation of mathematical forecasting models for major hazards, and the upgrade of existing operational EWS (GoN, 2018). The National Climate Change Policy passed in 2019 emphasizes the need to develop a system for collecting, analysing, and transmitting real-time data by expanding weather stations' network to identify the impacts and tendencies of climate change (GoN, 2019).

Before the establishment of the above policies and action plans to address climate hazards, Nepal's Strategic Program for Climate Resilience (SPCR), under the Climate Investment Funds' (CIF) Pilot Program for Climate Resilience (PPCR), contributed to strengthening climate resilience and disaster preparedness since 2013. It aimed to enhance the government's capacity to manage climate-related hazards and further strengthen the country's climate-resilient and disaster risk management framework. The SPCR focused on four key areas of intervention: watershed management in mountain eco-regions, mainstreaming climate change risk management in development, private sector participation, and climate-related hazards. The last area comprised the "Building Resilience to Climate-Related Hazards (BRCH) Project", a $31 million seven-year project launched in 2013 and completed in 2020.

The BRCH Project had as an objective to enhance the government's capacity to mitigate climate-related hazards by improving the accuracy and timeliness of Hydrometeorological forecasts and warnings for vulnerable communities countrywide. It focused on the development of an agriculture management information system services to help farmers address climate-related production risks. The BRCH project aimed to contribute to sustained growth and poverty alleviation by making Nepal's communities and economy more resilient to climate change.

The project had as beneficiaries the Department of Hydrology and Meteorology (DHM), responsible for monitoring and forecasting hydrology and meteorology, and the Ministry of Agriculture and Livestock Development (MoALD), responsible for providing agrometeorological services for the agriculture and livestock sector. Furthermore, the project beneficiaries included populations at risk from hydrometeorological hazards and those whose agricultural productivity could increase from high-quality hydrometeorological and agrometeorological information.

The project was designed with respect to four strategic objectives:

- **Institutional strengthening and capacity building:** Strengthening institutional frameworks, building technical capacity, and improving data transmission to World Meteorological Organization's (WMO's) Global Telecommunication System (GTS) and WMO Information-System (WIS).

- **Modernization of observation infrastructure and forecasting:** Improving the status of surface hydrometeorological observation networks and enhancing infrastructure for hydrometeorological data management, weather, and flood forecasting.

- **Enhancement of the service delivery system**: Enhancing the provision of real-time or near real-time data to users, developing and operating an authoritative public weather service, delivering warnings on extreme and high impact events, and establishing the National Framework for Climate Services.

- **Creation of an Agriculture Management Information System (AMIS):** Developing the AMIS infrastructure, improving access to AMIS data and linkage between AMIS and WMO AMIS, increasing adoption of AMIS tools by farmers, increasing extension services and community training, improving efficiency to disseminate and obtain feedback of agrometeorological information, capacity building of farmers and technical staff, and increasing satisfaction of users with AMIS services.

2) STUDY: PATHWAYS FOR TRANSFORMING WEATHER, WATER, AND CLIMATE SERVICES

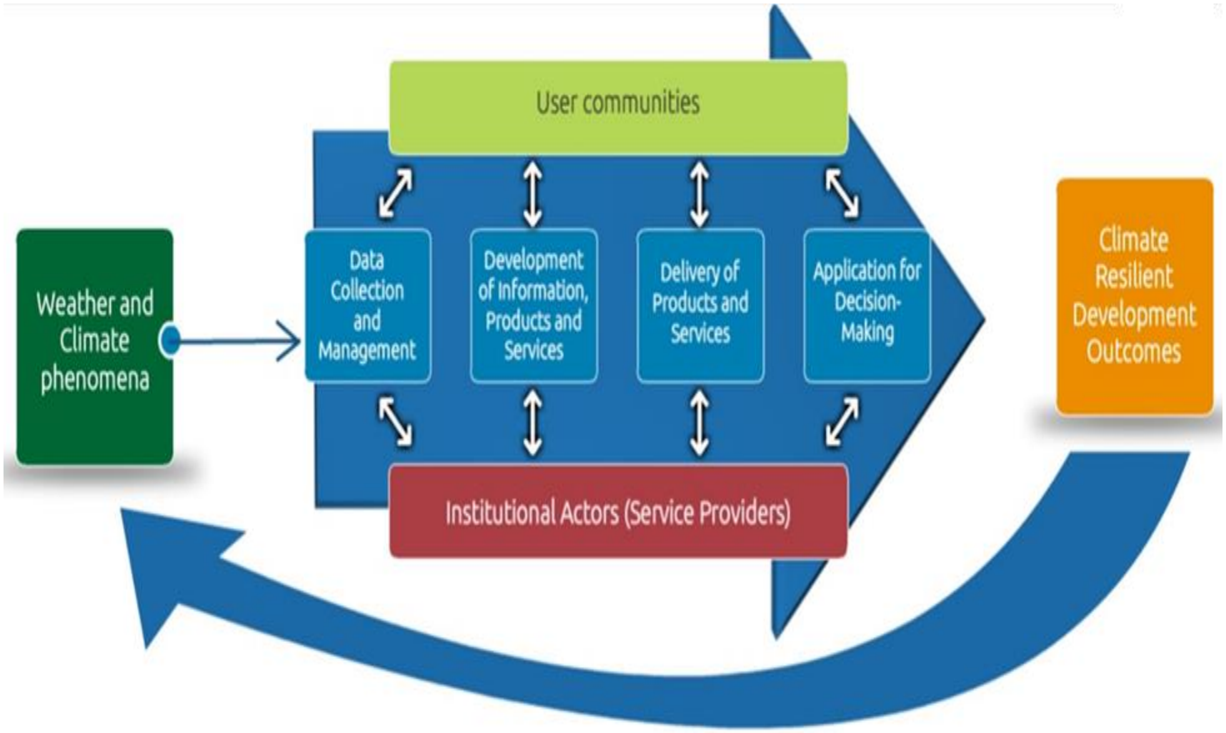
The study *Pathways for Transforming Weather, Water, and Climate Services* was commissioned by CIF's E&L Initiative to distill lessons from CIF's Pilot Program on Climate Resilience (PPCR) support in identifying, designing, and implementing hydrometeorological and climate services investments. It seeks to generate learning and strategic insight into the different operational pathways that can be taken by national hydrological and meteorological agencies to develop, deliver, and strengthen hydrometeorological and climate services.

Furthermore, the study aims to comprehend the aspects that allowed or limited the development, delivery, and use of hydrometeorological and climate services by gathering lessons learned on: the mechanisms that can improve coordination between hydrometeorological and climate service providers and sector institutions to improve the development, delivery, and use of hydrometeorological and climate information; the elements within the climate services value chain that promote or obstruct the delivery and use of hydrometeorological and climate services; and, the extent to which intermediary users and end-users utilize and are aware of hydrometeorological and climate services.

The outputs from the study comprises of one synthesis report and three country studies for Jamaica, Mozambique, and Nepal. These three countries have been selected for the study due to their different institutional frameworks, hydrometeorological systems, and socio-economic context. They provide diverse in-depth insights on hydrometeorological and climate services development, delivery, and use. In this aspect, the PPCR-supported *Building Resilience to Climate-Related Hazards (BRCH) Project* was selected as a case study project for Nepal to elucidate lessons learned on the process for modernizing hydrometeorological systems and delivering climate information and services to users. Furthermore, it offers insight into challenges and opportunities for climate services development, delivery, and use in the South Asian developing countries.

The themes explored for generating knowledge and distilling lessons in the three country studies were based on the components of the hydrometeorological and climate services value chain conceptual and analytical framework outlined in Figure 1 below. It was used to ensure consistency of the learning approach across the studies, and with the intention of producing learning outcomes relevant to the broader hydrometeorological and climate services community. The hydrometeorological and climate services value chain framework consist of the following components: hydrometeorological data collection and management, development and delivery of hydrometeorological and climate information, products and services, and its application to support climate resilient development outcomes.

Figure 1: Climate Services Value Chain Framework (Source: World Bank, 2021)



The hydrometeorological and climate services value chain begins with the production of services which is composed of hydrological and meteorological observations, and data processing and management (Figure 1). Data processing generally encompasses the use of models and other tools to visualize and produce real-time hydrometeorological forecasts and climate information. Subsequently, this information is delivered as hydrometeorological and climate services to users who then take actions that translate into prevented human and economic loss, as well as increased productivity of key economic sectors. A better understanding of weather, water, and climate from more reliable hydrometeorological and climate information can inform long-term planning and investments to mitigate or adapt to climate risks, and help understand the potential impacts of long-term climate.

This hydrometeorological and climate services value chain is operationalized by hydrological and meteorological service providers who are responsible for data collection, management, and processing. They rely on intermediary users to transform and translate the data collected into sector-specific information to produce hydrometeorological and climate information products and services. The intermediary users are different from the final end-users of climate information who frequently do not need hydrometeorological and climate information or data, but a finished useable advisory service or product they can use for their decision-making. The end-users can comprise farmers, fishermen, among other groups, as well as national decision-makers and planners who may need finished hydrometeorological and climate information products (Tall A., 2013).

3) BACKGROUND

3.1) INSTITUTIONAL LANDSCAPE

As stated in section 1.2, the Department of Hydrology and Meteorology (DHM), currently under the Ministry of Energy Water Resources and Irrigation (MoEWRI), is the institution mandated to collect and manage hydrometeorological data, and deliver weather and climate services in Nepal. Various actors including the hydropower developers, development partners, Independent Power Producers Association-Nepal, and universities and research institutes (national and international) have set up their hydrometeorological stations in different locations to privately collect data and use hydrometeorological information for their own benefit. International non-governmental organization such as Practical Action had also established hydro-meteorological station jointly with DHM which is now handed over to DHM.

Other government agencies such as the Ministry of Agriculture and Livestock Development (MoALD) and Nepal Agricultural Research Council (NARC) are responsible for developing and disseminating agrometeorological and agroclimatic services using data from DHM. In the case of disaster risk reduction, the National Disaster Risk Reduction and Management Authority (NDRRMA) coordinates all the activities relating to disaster risk reduction and management in Nepal. That includes relaying water level, discharge information, and early warning messages generated by DHM to the District Emergency Operations Centers (DEOCs), Local Emergency Operation Centers (LEOCs), and Provincial Emergency Operation Centers (PEOCs). International non-governmental organization such as Practical Action has also been working to strengthening community-based early warning system in different river basins of Nepal. A detailed map of institutional relationships is found in Figure 2.

Previous to the implementation of the BRCH project, DHM was mandated to provide hydrometeorological services in the country but the following challenges compromised the effectiveness of its services:

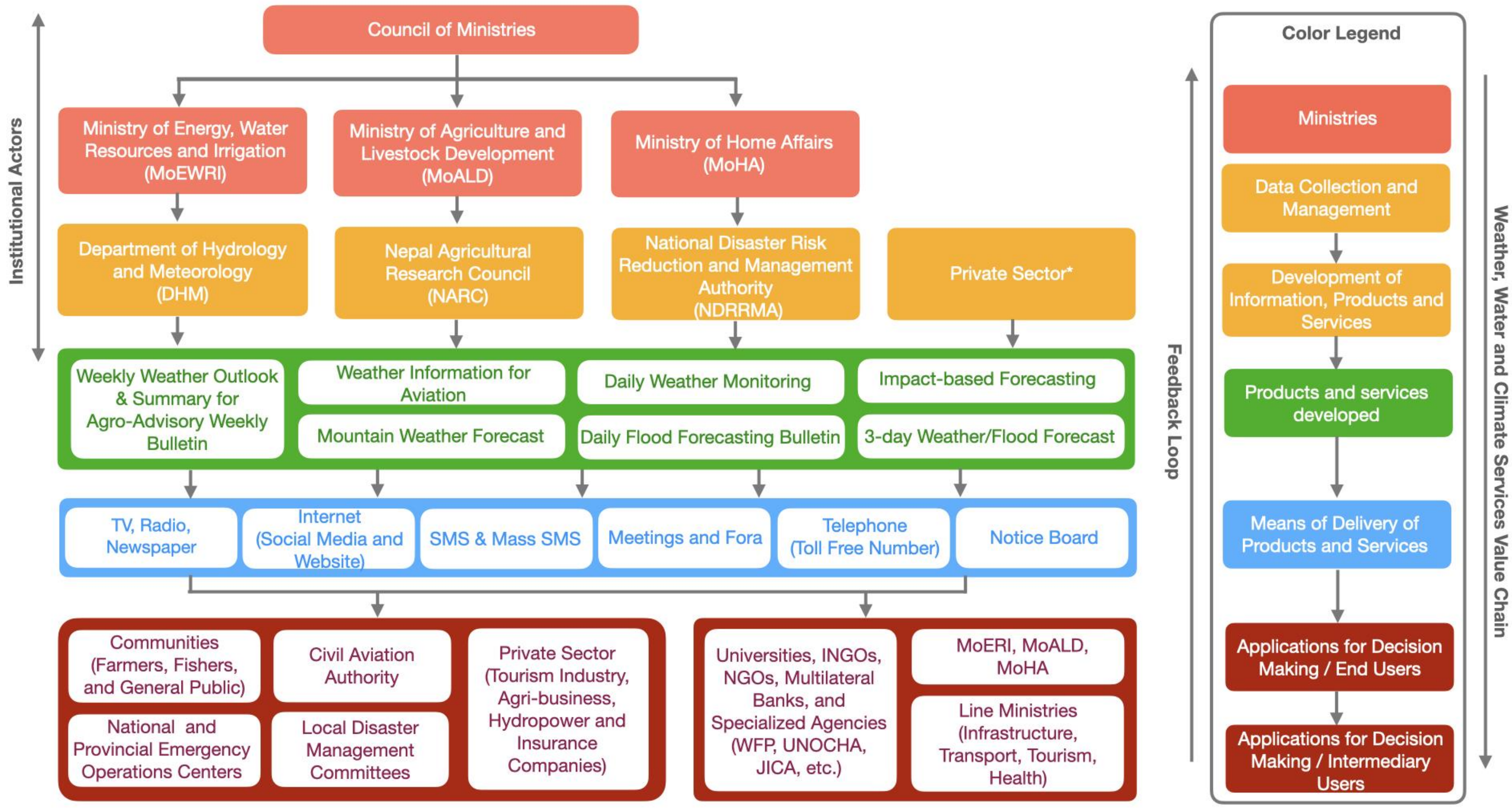
- **Lack of a well-functioning modern hydrometeorological system:** It hindered data collection, transmission, storage, processing, use, and dissemination of hydrometeorological services to the public, government agencies, and targeted user groups.

- **Limited human resources capacity:** The skills profile and staffing of DHM fell far short of the required needs. This human resources challenge limited the capability to provide consistent and quality hydrometeorological services.

- **Constrained financial capacity:** The government's budget was inadequate for the operation, maintenance, and upgrade of the hydrometeorological system despite its significant value to the economy and society.

In addition to the challenges mentioned above, an agroweather and agroclimatic advisory system to deliver information, and climate risk management tools to reduce climate risks was absent in the country.

Figure 2: Institutional landscape of hydrometeorological services in Nepal (Source: Authors)



*In IFC's Promoting Climate Resilient Agriculture Project, mPower, a private sector company, provided weather forecasts and agrometeorological advisory to a group of farmers in Eastern Terai districts

3.2) EXISTING HYDROMETEOROLOGICAL AND CLIMATE SERVICES

Hydrometeorological and climate services provided by different institutional actors in Nepal are described below.

- **Department of Hydrology and Meteorology (DHM):** In terms of **meteorological services**, DHM produces daily, as well as 3-days weather forecasts and climate information, a periodical Climate Bulletin to the public. Moreover, it has the responsibility to provide aviation weather forecasts to Civil Aviation Authority of Nepal (CAAN) for national and international flights in Nepal. It generates special agrometeorological notices to NARC for the AMIS component.

  In terms of **hydrological services**, DHM produces flood forecasts such as a daily service of Flood Forecasting and Early Warning to public and related agencies during Monsoon Season and flood hazard maps of most major river basins in Nepal for any relevant users (DHM, 2020). DHM has the responsibility to provide water level, discharge information, and flood early warnings for the Emergency Operations Center at different administrative levels (DEOCs, PEOCs and LEOCs). The DEOC is responsible for monitoring the flood situation based on the DHM's information and communicating warning and danger levels (Meechaiya et al., 2019). Ministry of Home Affairs (MoHA), National Disaster Risk Reduction and Management Authority (NDRRMA), National Emergency Operation Center (NEOC) and District Emergency Operation Center (DEOC) are also responsible for response after receiving the early warnings from DHM.

  A list of climate and hydrometeorological services provided by DHM (including those developed and distributed under the BRCH project) and relevant details such as the frequency, language, and means of delivery is provided in Appendix 1.

- **Ministry of Agriculture and Livestock Development (MoALD) and Nepal Agricultural Research Council (NARC):** Both institutions develop and disseminate various agrometeorological products and services including: a well-functioning **AMIS portal** duly linked with WMO's World AgroMeteorological Information Service (WAMIS), the **mobile application - "Hamro Krishi" and SMS gateway** for agrometeorological information; the **Agromet Advisory Bulletin (AAB)** providing weather and agriculture summary, the **weather forecast** for different geographical regions, **agriculture advice** (on crops, livestock, fish, and grass farming); **Kisan Call Centers (KCC)** facilitating digital display boards, and timely delivery of agroclimatic and agroweather information under early warning systems (EWS) to farming communities (MoALD, 2018).

  A list of agrometeorological services provided by MoALD and NARC (developed and distributed under the BRCH project) and relevant details such as the frequency, language, and means of delivery are found in Appendix 2.

- **National Disaster Risk Reduction and Management Authority (NDRRMA):** Under the Ministry of Home Affairs, NDRRMA is a coordinating body for all the **disaster risk reduction and management activities** in Nepal. It also plays a specific role in the **overall risk mapping and communication for informed decision-making and response/recovery operations**. For example, NDRRMA manages and operates the National Emergency Operation Center (NEOC), which **disseminates flood early warnings as well as**

hydrometeorological forecasts generated by DHM to Provincial Emergency Operation Centers (PEOCs) and PEOCs to District Emergency Operation Centers (DEOCs). DEOCs disseminate flood early warnings, respond to disasters, and coordinate and mobilize search and rescue and relief operations through Local Emergency Operation Centers (LEOCs) and Local Disaster Management Committees (LDMCs) (See Appendix 3, Figure 3.1 for additional information) (Meechaiya et al., 2019).

4) STUDY APPROACH

This study used qualitative methods to identify promising pathways to transform weather, water, and climate services in Nepal. Climate services refer to all timescales, from short-term weather to long-term climate. The study involved collecting and analyzing empirical evidence through Focus Group Discussions (FGDs), Key Informant Interviews (KIIs) with relevant stakeholders of hydrometeorological and climate services in Nepal, and key documents. These documents included project appraisal documents, progress reports, implementation completion reports and literature on hydrometeorological services, which are listed in the bibliography section.

4.1) DATA COLLECTION

Key Informant Interviews (KIIs)

A list of participants for KIIs was selected in consultation with the World Bank's BRCH team and through a snowball sampling strategy that was used to add additional stakeholders when appropriate. A total of 47 key informants from 12 different agencies (Appendix 4) working in the broader hydrometeorological service area were interviewed. These largely included but were not limited to actors involved in the PPCR investment programme in Nepal.

In-depth interviews were conducted in February/March 2020 to reveal participants' perceptions and feedback on Nepal's climate services value chain. It lasted roughly an hour. A separate set of questions were developed for different stakeholder groups: (i) climate service providers; (ii) climate service intermediary-users; (iii) climate service end-users; and (iv) 'other' direct or indirect climate service users (academic, private sector, civil society representatives). While interview questions were common to all stakeholder groups to permit comparative analyzes, other sections were tailored to the specific stakeholder group's role in the climate services value chain.

Most of the KIIs were conducted in person in the capital city, Kathmandu. At that time, the federal system of government in Nepal had begun its restructuring process but was not fully implemented. Although a small number of key informants were interviewed face-to-face in the districts of Banke, Chitwan, Dang, Pokhara, Bhairahawa, and also virtually, this study did not include KIIs with government agencies at the provincial and local levels. KIIs were conducted in English and Nepali, recorded on hard copy documents and audio recordings, and were transcribed together with those from the focus group (see below) to support the data analysis. An interview protocol is included in Appendix 5.

Focus Group Discussions (FGDs)

Study locations and participants for FGDs were selected in consultation with the World Bank's BRCH team and other stakeholders. A total of six FGDs were carried out in the Nepali language with 71 actors who were expected to use weather, water, or climate services for agriculture and/or for disaster risk management. The groups ranged in size from 4 to 18 people (see Appendix 6). Five out of six groups were farmers and dairy associations, the main beneficiaries of the project, and one was a group of members from a community disaster management committee. The discussions took place at six different locations in Nepal's five western districts, including Banke, Dang, Rupandehi, Chitwan, and Kaski.

FGDs were focused around climate services value chain questions (e.g. awareness, access, accuracy, usage of climate information), behavioral and impact questions (e.g. behavioral changes, livelihood improvements due to the delivery of weather forecasts, suggested improvements to enhance weather and climate services) and project-specific questions (e.g. activities implemented, community engagement, capacity building). The FGDs were audio and video recorded and were transcribed together with KIIs before conducting the data analysis.

4.2) DATA ANALYSIS

As indicated in section 2, the hydrometeorological and climate services value chain and its four different components were used as a guiding conceptual and analytical framework to analyze the data collected, as well as to identify opportunities and bottlenecks to continue transforming weather, water, and climate services in Nepal.

Findings were organized into different categories that are presented in the Results & Discussion section below.

5) RESULTS AND DISCUSSION

Key informant interviews and focus group discussions revealed five themes which are critical to transforming weather, water, and climate services in Nepal. These are: improving data resources; service design and delivery; improving hydrometeorological services through feedback and evaluation; fostering human resources capacity; and strengthening institutional arrangements. These themes are presented and discussed in detail below.

5.1) IMPROVING DATA RESOURCES

With increasing evidence of climate variability and extreme events and their significant impact on economies and societies, high-quality data is crucial to monitor and characterize potential events and plan and build climate-resilient communities (Manton et al., 2010; Vincent et al., 2017). Without high-quality and uninterrupted data, it will not be easy to tailor quality climate information and products that meet the requirements of end-users, planners, and policymakers (Tall et al., 2018). Therefore, improving data resources is essential.

The BRCH project supported investments in improving agrometeorological and hydrometeorological data collection and management in Nepal. Those efforts included:

- Upgrading 88 surface meteorological (of which 21 are in or near the airports to benefit the aviation sector) and 70 surface hydrological observation networks across the country for real-time data collection.

- Improving transmission of data to the WMO Information System (WIS)/ WMO Global Telecommunication System (GTS).

- Installing a Doppler weather radar in Surkhet to detect heavy precipitation and meteorological phenomena, nine lightning detection networks with lightning detection system 'Linet' at various locations and one Upper-Air Sounding station in Kirtipur, Kathmandu. These are now operational and helping the DHM accurately forecast weather and floods throughout the country since the 2020 Monsoon season.

- Supporting the construction of the DHM building in Kathmandu that helps in positioning and operating new IT infrastructures and labs.

- Setting up a remote sensing and GIS lab, as well as modernizing the Information and Communication Technologies infrastructure, hydrometeorological data acquisition system (real time) and a new Database Management Systems (DMS) to support better climate information management.

- Establishing and operationalizing meteorological equipment calibration laboratory to calibrate thermometers, hygrometers, and air pressure gauges.

- Installing high performance computing system.

- Implementing and commissioning of high-resolution local area numerical weather prediction system at DHM.

- Establishing a pilot station for air quality monitoring networks in Nagarkot to monitor the ambient air quality in the vicinity of the Kathmandu valley.

- Digitizing more than 20,000 historical datasets in the agriculture sector. That included annual reports of different agricultural research stations, historical workshop proceedings, journals, and factsheets collected from several research stations under NARC.

Despite the above efforts, there exist several challenges related to data resources in Nepal. FGD and KII participants mainly highlighted challenges and opportunities related to data collection and management and data sharing policy, which are discussed in more detail below.

5.1.1) Data collection and management

Participants of KIIs and FGDs pointed out the challenges below:

Poor quality data collection: There is poor quality data collection, including data errors and gaps from manual stations due to difficult geographical access to set up hydrometeorological equipment, the lack of upgrade/maintenance of existing stations, and the absence of training and financial incentives to local gauge readers and or part-time data observers. Local gauge readers and part-time data observers' wages are low, and they sometimes have to collect data from manual stations three times a day. They often collect data one-time and fill the other two predicted values by themselves, which results in errors and poor-quality data. Weak supervision of local gauge readers and or part-time data observers is a concern. Increasing incentives for supervisors could also help to ensure better supervision. Incentives may include compensation or reward (e.g., supervisory pay, bonus), recognition (e.g., colleague kudos, shout out to supervisors, thank you email/certificate), appreciation (e.g., extra holiday, team lunches), etc. Additionally, capacity building of gauge readers in collaboration with INGOs such as Practical Action already contributing in that area is a potential option.

BRCH project provided a solid foundation for data collection through the installation and operationalization of automated stations thereby avoiding any gaps in data for future information. Although DHM automatized the hydrological and meteorological observation networks, manual data are also important. The manual data helps verify the automated data's correctness, the under or overreading issues, how much-automated data deviated from the manual data, and fix those issues accordingly. Furthermore, manual data also serve as a critical backup during automatized systems failure. Therefore, improving the quality of manual data collection is essential. However, it will be costly for DHM to maintain both automatized and manual data collection. Developing a strategy for keeping some key manual stations and a gradual phasing out of the remaining ones is essential.

Besides DHM's hydrometeorological observation networks, various non-government agencies have set up their stations and collecting data for different uses. Bringing all stations supported by non-government agencies into the DHM system is essential for ensuring quality hydrometeorological data.

***Low spatial density of hydrometeorological stations*:** Microclimate becomes very prominent in Nepal because of the wide altitudinal variation. Currently, the spatial density of the hydrometeorological stations is still low to capture the data of different microclimatic zones and catchments. Moreover, the hydrometeorological stations are almost absent in the hazard-prone high-altitude regions. A high hydrometeorological station density with stations in high altitude regions will be critical. It will help understand microclimatic variability and hydrometeorological events. Furthermore, it will help develop specific weather and climate products for micro or agroclimatic zones; and prepare and respond to hydrometeorological hazards in advance. However, sustaining many stations will be equally challenging given the high operating and maintaining cost. DHM needs to decide the number of stations required across the country and a minimum number of stations in the high-altitude regions considering their importance on the one hand and budget constraints on the other hand.

One of the KII respondents suggested a way to reduce operational and maintenance costs. Department of Environment at MoFE has more than 28 real-time air-quality stations throughout the country. The department is further expanding its stations. There can be collaboration opportunities for DHM and the department of Environment to establish and maintain hydrometeorological, air quality, and or water quality stations in different places across the country. It will help reduce operational and maintenance costs. Nepal can also learn from the interagency collaboration observed in Jamaica, also a least developed country like Nepal trying to transform its Weather, Water, and Climate Services. Water Resources Authority (WRA) and Meteorological Service of Jamaica (MSJ) signed a Memorandum of Understanding (MoU) through the support of the PPCR project (Improving Climate Data and Information Management) in Jamaica. They coordinated and collaborated to locate and expand hydrometeorological stations and facilitate hydrometeorological data sharing. DHM also needs to explore similar collaboration opportunities with other government agencies (e.g., Department of Environment at MoFE, Department of Watershed Conservation, etc.), academic and research institutions for mutual benefits.

Another KII respondent reported that with a new federal system in place and the transfer of staff to province and local levels, there is a reduction in human and financial resources at the central level in DHM. In this situation, central DHM cannot expand and maintain hydrometeorological stations at province and local levels. However, it can provide technical support at lower administrative levels to establish stations and transfer real-time data to the central server.

Besides expanding hydrometeorological stations and services, considering a multi-pronged approach including strategies such as strengthening the adaptation capacity of local people and adopting the mitigation measures is also equally important.

***Poor data management*:** BRCH project supported the installation of a new database management system (DMS) at Government Integrated Data Centre (GIDC) in 2018 and it is in operation since then. With the installation and operation of the DMS, DHM has benefited in managing meteorological and hydrological data through an integrated database, and web-based data entry platform for manually operated hydro-met stations. Importantly the new DMS has auto Quality Control features along with a handy Human Quality Control system and better visualization platform for QC procedure. Despite these improvements, the study participants raised poor data management issues.

DHM's Poor data management is mainly due to the following three reasons. First, the limited number of DHM employees to handle the increasing amount of data coming from automated stations and its management needs. DHM's permanent staff number and human resources plan has remained stagnant since 1988. Second, the lack of DHM staff's technical capacity for data management, which may prevent DHM from utilizing the new data management infrastructure to its full extent. Third, the lack of infrastructure and technical skills to manage publicly available remote sensing and weather data. These types of data could help improve DHM's weather and flood forecasts and services. Poor data management is not just limited to DHM. Respondents pointed out that poor data management is also prevalent in the agriculture sector.

To address some of the above challenges, respondents have reported the following suggestions:

- ***Improve incentives (e.g. increase wages) and provide training to local gauge readers*:** This would help improve the quality of data collected from manual stations. In addition, supervision of local gauge readers through data cross-checks and feedback on data recordings and irregularities in the measurements help ensure good quality data collection (Donauer et al., 2020).

- ***Train and build the capacity of DHM staff on data management*:** This would help strengthen DHM staff's data management capabilities and develop the required skills to cope with the innovation, modernization, and sustainability of the enhanced systems. However, it is equally important to consider ways (e.g., offering more competitive employment packages and a performance-based scheme that remunerates staff based on contributions to tangible outputs) to retain qualified staff (IBRD/The World Bank, 2018).

- ***Establish and maintain hydro and agrometeorological stations in each district:*** This would ensure data availability for all districts to reduce climatic risks in agriculture, water resources, infrastructure development, health sector, etc.

5.1.2) Data sharing policy

Another pressing issue related to Nepal's data resources is data sharing. There is limited policy guidance and a weak hydrometeorological data sharing mechanism at the national and cross-border levels.

Limited data sharing policy at the national level: There is little policy guidance on hydrometeorological data sharing between different ministries and agencies/departments. For example, there is no formal data-sharing mechanism between MoALD and MoEWRI (under which DHM presently resides). While there was a provision of hydrometeorological data sharing during the BRCH project implementation for the AMIS component, before the project started, MoALD and DHM did not share information, and weather information had to be purchased.

Despite the initiation of such an exemplary data-sharing initiative, there was no data-sharing agreement or Memorandum of Understanding (MoU) signed between NARC and DHM. However, during the latter half of the BRCH project, DHM and MoALD-AMIS exchanged letters to discuss and provide historic and Automated Weather Station (AWS) data free of cost with few conditions attached. This was under implementation and should continue beyond the BRCH project, and institutions with the convening power or ability to influence should play a role in ensuring it. The lack of data sharing mechanism or policy also applies to national and international universities conducting research/study in Nepal and projects implemented by donors and development partners.

One of the lessons learned is that data-sharing among different ministries, agencies, and key stakeholders at the national level is essential in fostering the collaboration and development of weather, water, and climate services. In line with this, there was a Ministerial decision in January 2021 to provide hydrological data free of cost to Nepal Government organizations for official use. Additionally, data-sharing by national and international universities, donors, and development partners is also crucial. It helps prevent duplication of data collection and focus efforts towards making data available to relevant stakeholders from the national to the local level.

The data platform could help share and meet the data needs of various sectors such as infrastructure development (hydropower), agriculture, disaster management, etc. NDRRMA has already taken one such initiative on this. They have sent a request letter to the development partners doing DRR and climate change research to upload and share available data in the Building Information Platform Against Disaster (BIPAD) portal. The BIPAD portal is already sharing real-time precipitation and water level data uploaded in DHM's website. Continuous efforts are necessary to bring all relevant data to such a common data platform.

Limited data sharing policy at the cross-border level: A weak data sharing policy and mechanism is one reason for the poor data sharing between Nepal and its cross-border (neighboring) countries (India and China). Respondents agreed that Nepal is cooperative and open to sharing hydrometeorological data with cross-border countries. Nevertheless, despite Nepal's open data sharing policy with its neighboring countries, and common climatic hazards such as floods and Glacial Lake Outburst Floods (GLOFs), respondents indicated that there is limited cross-border hydrological data and information sharing between Nepal and its cross-border countries on a frequent basis. For instance, the sharing of data/information on GLOF and Landslide Dam Outburst Flood (LDOF) due to a landslide blocking streams in Tibet occurred few times between Nepal and China at different times.

Additionally, there are also some regional initiatives for data sharing where Nepal participates. Since 2010, Nepal has participated in the South Asian Climate Outlook Forum (SASCOF), organized annually to discuss seasonal climate information. Nepal is also a member of the Regional Integrated Multi-hazard Early-warning System for Africa and Asia (RIMES), an intergovernmental institution. It aims to provide support on disaster risk management through risk assessments, hazard monitoring, among others. Under these initiatives, Nepal shares water, weather, and climate data and information with other countries. However, historical meteorological data of selected stations are shared with RIMES only but not with other countries. RIMES uses historical data to prepare gridded data and verify a forecast. Nepal and other RIMES member countries will soon be sharing additional real-time data with RIMES/ECMWF (the European Center for Medium-Range Weather Forecasts) via RIMES in exchange for additional weather forecast products.

Besides existing initiatives, Nepal can also learn from the hydrometeorology modernization project from Central Asia, which is recognized as an example of good regional collaboration to improving the hydrometeorological services (see Box 1). Similar regional collaboration for data sharing can also be beneficial for South Asia including Nepal.

Box 1: Central Asia Hydrometeorology Modernization Project

A geographically diverse region, Central Asia is prone to different weather-related disasters and climate hazards. In Tajikistan, as much as 36 percent of the country's territory is under threat from landslides. In the Kyrgyz Republic, avalanches, which numbered over 330 between 1990 and 2009, pose a serious risk to communities. These climate vulnerabilities are often exacerbated by poverty and weak infrastructure (GFDRR, 2018).

Climate change is expected to intensify risks and vulnerability in the region. Rising temperatures and changes in hydrological patterns could impact growth levels. For example, in Uzbekistan, increasing temperatures pose a significant threat to the country's agriculture sector, reducing the availability of water for irrigation. 80% of foodstuffs consumed by the population are produced by the agrarian sector, and thus reductions in productivity could seriously threaten food security (CCKP, 2021).

In response to these climate-related hazards, and the need to increase the resilience of communities in the region to future climatic changes, the World Bank, along with the Global Facility for Disaster Reduction and Recovery (GFDRR) and PPCR, supported the implementation of the Central Asia Hydrometeorology Modernization Project. This $28 million initiative had as an objective to generate real-time weather and climate information that can be used to enable EWS, improve emergency response, and highlight critical areas of investment (GFDRR, 2018).

The results of the Central Asia Hydrometeorology Modernization Project include significant progress in strengthening regional hydromet cooperation. Four hydromet agencies (Kazakhstan, the Kyrgyz Republic, Tajikistan and Uzbekistan) have agreed to a common methodology to verify hydromet forecasting accuracy, completed installation of the regional distance learning system, and also reached consensus on guidelines and approaches to regional procedures for emergency prevention (GFDRR, 2018).

This project shows how the combination of country-based programs and a regional component can promote stronger ownership, development of regional common standards, sharing of knowledge and higher coordination among the region's hydromet stakeholders (World Bank, 2014).

Lately, there is also a formal global mechanism like GTS/WIS for regular meteorological data transmission. DHM is receiving weather observations (e.g., SYNOP (surface synoptic observations), METAR (Meteorological Aerodrome Report), Upper Air Data, etc.) regularly from WMO's World Weather Watch (WWW) program through GTS/WIS. DHM not only receives but also shares SYNOP data from 16 stations through the GTS/WIS every 3 hours.

Recognizing the importance of data sharing at the national and regional levels for the development of efficient hydrometeorological and agrometeorological services, study respondents provided the following recommendations for improvement:

- ***Develop a comprehensive data sharing policy at the national level:*** To ensure better access to hydrometeorological data between different government institutions and further develop Nepal's climate services. Moreover, it would also pave the way for establishing agreements between government institutions to define the terms of use for data and metadata (Salack et al., 2019). Signing MoU between DHM and NARC could be a starting point to developing a comprehensive data sharing policy and actual data sharing at the national level.

- ***Strengthen collaboration between cross-border countries***: To discuss and envisage formal data exchange mechanisms/agreements at relevant forums through policymakers, decision-makers (Ministers and possibly advisors to the Ministers), and the technical experts. They can be done through learning exchanges, training activities, workshops, annual technical conferences, etc. Additionally, developing and implementing cross-border hydrometeorological projects could be an option to strengthen collaboration with India and China.

  Moreover, Governments of Nepal and India have already set up three-tier mechanisms called Joint Ministerial Commission for Water Resources (JMCWR), Joint Committee on Water Resources (JCWR) and Joint Standing Technical Committee (JSTC) to implement agreements and treaties and also address water induced problems of flood and inundation. There is also an additional mechanism – Joint Committee on Inundation and Flood Management (JCIFM) to explicitly deal with the issues of inundation, embankments and flood forecasting (GoN, 2021). These mechanisms may also play an important role in facilitating cross-border data sharing.

  Additionally, an experience from Tajikistan and Afghanistan also shows that a cross-border project can play an important connecting role and serve as a principal vehicle for collaboration on hydrometeorological issues. Further, it can provide consistent support to the political and technical dialogue on formal hydrometeorological data exchange mechanisms (Karabanov, 2018).

5.2) IMPROVING SERVICE DESIGN AND DELIVERY

Climate information services have the potential to build resilient livelihoods, protect development gains, and prevent losses that worsen poverty and further increase vulnerability to hydrometeorological hazards and extreme events (Practical Action, 2020). 77% of FGD participants in this study highlighted the importance of climate and weather information for decision making.

The BRCH project tested pilot solutions to improve the development and delivery of tailored hydrometeorological and agrometeorological information (See Appendix 1 and 2 for details). Some key activities included:

- Installing infrastructures to enhance development and dissemination of 24 hours and 3-day weather forecasts, and daily flood forecasting and early warning during monsoon season through SMS, Radio, TV, DHM's website, Facebook, and Twitter.

- Developing and commissioning an end-to-end flood EWS model for Koshi and West Rapti River Basins that provides forecasts of water runoff essential for issuing flood warning to vulnerable communities across eight river basins through mass SMS.

- Developing and disseminating Agromet Advisory Bulletin (AAB) weekly in Nepali and Avadhi languages through AMIS portal, Mobile app, SMS, Radio, National Television, Newspaper, etc. (See Appendix 3, Figure 3.2 for additional information).

- Opening 52 Kisan Call Centers (KCCs) at 52 District Agriculture Development Offices (DADOs) and District Livestock Service Offices (DLSOs) in 26 pilot districts, and 2 KCCs at the central level situated at Nepal Agricultural Research Council (NARC) and Agriculture Information and Training Center (AITC) to timely deliver agroclimatic and weather information under early warning systems to farming communities. DADOs and DLSOs were dismantled in 2018, and Agriculture Knowledge Centers (AKCs) and Veterinary Hospital and Livestock Service Expert Centers (VHLSECs) have been set up as a replacement under a new federal structure.

- Launching the "Hamro Krishi" Mobile Application as a one-stop agriculture and agrometeorological information store for farmers and agriculture extension workers.

- Supporting the distribution of infrastructures such as rain gauges, thermometers, mobile phones with Hamro Krishi app installed, Kisan SIM card, etc., to selected farmers' groups/cooperatives of pilot districts through MoALD. Furthermore, it also built capacity of 16,208 farmers for broader adoption of products and services through roving seminar, inter-district visit and other technical trainings.

The result of these upgrades in hydrometeorological and agrometeorological services was transformational, according to the respondents, as it strengthened the services for the following sectors:

- ***Aviation:*** DHM enhanced its capacity to monitor and forecast weather conditions in real-time using Doppler weather radar-based forecasting, and deliver enroute aviation weather service in timely and usable ways. For instance, in Nepalgunj airport, it helped air traffic controllers to develop better air traffic management strategies taking into consideration weather conditions. It is in line with the

International Civil Aviation Organization's continuous recommendation to significantly improve the timely provision of Significant Meteorological Information reports (SIGMETs), which are critical for aviation safety and efficient operations in Nepal (World Bank, 2012).

- ***Agriculture:*** Famers use hydrometeorological and agrometeorological information (e.g., 3-day weather forecasts) to decide and plan their farming activities. When farmers receive precipitation forecasts, they go for planting paddy from nursery bed paddy field during planting season and harvesting mature crops during harvesting season. However, farmers need lead time or information long in advance to prepare for and change crops in their field.

  Climate information has helped farmers protect their crops from extreme rainfall events. MoALD's user satisfaction survey in 2019 for their services - Hamro Krishi app, Kisan call center, Krishi (agriculture) information SMS, and Agromet Advisory bulletin - showed 79, 73, 89 and 50% of users are satisfied with these services, respectively (See Appendix 7 for additional information). The SMS showed a relatively high score of user satisfaction, likely due to the accessibility of the messages.

- ***The general public*** uses DHM's 24 hour and 3-day weather forecast in their day-to-day decisions. The Composite User Satisfaction Index (CUSI) indicated the DHM services had helped the communities in their way of life. The CUSI is 51% from the End line Survey conducted in 2019.

In addition to the sectors currently benefitting from hydrometeorological and agrometeorological services, respondents from KIIs identified four key sectors to expand Nepal's hydrometeorological services. These four sectors include:

- ***Tourism:*** In October 2014 Cyclone Hudhud caused heavy snow in Central Nepal which resulted in 43 fatalities near Thorung La Pass (5,416 m) on the famous Annapurna Circuit due to the lack of hydrometeorological services. As a result, the MoEWRI acknowledged the need for target weather information for the tourism sector. The Tourism Minister has also expressed strong interest to the Director General of DHM to develop a weather briefing for tourism.

- ***Insurance:*** The lack of necessary weather index-based insurance infrastructure and tools has hindered private insurance companies from entering into insurance markets in Nepal. MoALD has recognized an opportunity in the insurance sector and showed an interest in using weather index-based insurance.

  NARC, with the support of the project, conducted a series of studies on agricultural insurance for Nepal to help the government understand better the available financing risk transfer mechanisms. Under the IFC's Promoting Climate Resilient Agriculture Project implemented by Practical Action Consulting, Shikhar Insurance developed a weather index-based insurance product and pilot rolled it out to 500 farmers in Sunsari District. The insured standing crops qualified for standing crop financing schemes (up to 80%) by the private Easter Sugar Mill. The recommendations from those studies and a pilot project may provide an analytical basis for MoALD's future action in mobilizing private sector/resources to promote sustained efforts in disaster risk management.

- ***Private airlines:*** Almost every year there are aviation accidents in Nepal due to weather conditions which result in deaths and huge economic losses for the aviation industry. Some private airlines in Nepal, such as Yeti and Buddha, have offered to install weather stations in different airports and have noted their willingness to pay for quality weather information. This can be one potential area for DHM to engage with the private sector.

- ***Climate-resilient development:*** With evidence of Nepal's first-ever recorded Tornado event on 31st March 2019 causing damage to different infrastructures in the Bara and Parsa districts, study respondents identified wind information as important for designing guidelines, particularly for building codes in the construction industry. Moreover, hydropower is another key economic sector sensitive to climate change impacts such as GLOF and flash floods. Respondents identified hydrometeorological services' scope in designing hydropower structures to make them resilient to the impacts of climate variability and change.

Additionally, respondents also highlighted the potential use of weather and climate services (e.g., globally and regionally generated modelled climate data and future projections) for climate resilient development including national adaptation plans and other adaptation options. Improvements in climate model downscaling and modelling techniques is critical.

5.2.1) Meeting users' various needs

It is necessary to improve the linkages between the production and supply of information that users need to ensure the climate information is contextual, credible, and understandable (McNie, 2012). Currently, DHM and MoALD's hydro- and agro-meteorological services development is mostly supply-driven rather than need- or demand-driven. There is limited to no information and early warning for flash floods, landslides, and multiple hazards, which people in hilly regions need the most. It is critical to initiate an inclusive, collaborative and flexible co-production process to shift hydro- and agro-meteorological services design and delivery from supply-driven to demand-driven.

KII and FGD respondents raised various issues related to their hydrometeorological and agrometeorological service needs as discussed below.

Users' need for improved temporal scale: Farmers receive a three-day weather forecast. However, they noted that an increased forecast lead time not just in days but also at sub-seasonal and seasonal timescales would allow them to better prepare for climate events. For example, forecasts that give additional lead time at sub-seasonal and seasonal timescales may allow more efficient farming adjustments by enabling farmers to plan more effectively for fallowing, crop switching or changing, and other water use reduction methods.

In addition, the FGD participants from Community Disaster Management Committee reported that they have been receiving flood information when the flood arrives close to their village. They highlighted the need for early availability of flood information at least a few hours in advance for timely preparation and response. It is also important to consider the timing of the information dissemination. Farmers tend to be busy in their works during the daytime and may not be able to give due attention to early warning messages. So, sharing of early warning message with sufficient lead time in the evening would help reach the message effectively.

Users' need for specific spatial scale: Currently, DHM provides weather forecasts at the province level, flood forecasts, and early warnings at the sub-basin level (for major river basins). Nevertheless, their usefulness is low due to the microclimatic variation within the same province/district.

For instance, different cropping patterns and climate diversity exist between and even within the districts. A KII participant noted there could be rain in the district's northern part but not in the south. Therefore, weather forecast at a specific spatial scale (e.g., district, agroclimatic zone) is meaningful for weather advisory services. DHM can utilize newly installed Doppler weather radar to forecast rainfall at a microclimatic level in Western Nepal. Similar radars should also be installed to cover the remaining parts of the country. It is noteworthy that the government has already allocated budget to procure and install two more weather RADAR to cover the remaining parts and a X-band RADAR for Kathmandu valley.

In terms of flood disasters, besides the major rivers, there are so many rivers that swell up during the monsoon and cause substantial economic damages. DHM's flood forecast should also cover those small but substantive rivers. Another issue related to spatial scale is that that KCCs are initiated at the district level but not yet adopted at lower administrative levels (e.g., municipalities, wards). It is crucial to overcome existing operational challenges and link KCCs at municipality and ward levels.

Impact-based forecast needs: DHM has not provided any impact-based forecast in Nepal until early 2021. From monsoon 2021 (i.e., June 2021), DHM and NDRRMA, with the technical support from the UK Met Office, are piloting impact-based forecasting for landslide vulnerable 36 municipalities of 9 different districts. DHM also initiated Impact based forecasting after Melamchi Flood in early June 2021 to understand how floods impact communities living on the riverside of the Melamchi and Helambu area. But, the forecast information is limited and is shared only with a high-level government official, not even with the local government authorities or DRR focal persons.

Impact-based forecasting focuses on the impact of the weather on lives, livelihoods, and the economy rather than just the expected changes in precipitation or temperature. IFC's Promoting Climate Resilient Agriculture project provided an impact-based forecast to sugarcane farmers in Nepal. See Box 2 for more details on this pilot case. It warned farmers that the temperature would rise in the next few days by approximately 3 degrees centigrade, and fields would get dry. The forecast suggested taking the necessary precautions to control pests and irrigate land to avoid drought impacts. This type of forecast would encourage the public to understand their exposure and vulnerability to hazard risks and act accordingly. However, it is critical to note that impact-based forecast also needs improvement in the disaster risk (vulnerability and exposure) data sources, and involvement of collaborative and flexible co-production process.

FGD participants reported that an impact-based flood forecast that informs the time flood takes to reach their settlement area is essential. It will help them in preparing and alerting the community on time. It indicates users' demand for impact-based forecast needs. A gradual shift from conventional to impact-based forecast is essential. One of the interviewees identified a lack of human resource capacity as a challenge for DHM in developing impact-based forecasts. Training of human resources in this area is necessary.

Regular update of agrometeorological information: Constant update of agrometeorological information in the AMIS portal and Hamro Krishi Mobile app is necessary. Furthermore, the agrometeorological information package could also include some critical variables such as soil fertility/nutrient status to entice greater interest of end users (farmers).

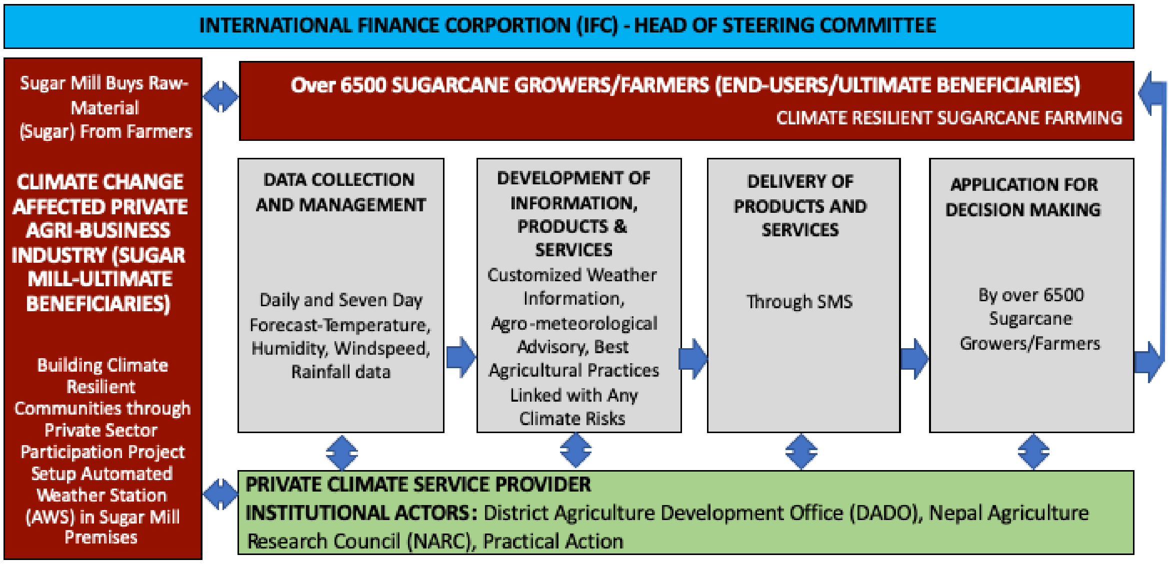
Box 2: A business case from IFC's "Promoting Climate Resilient Agriculture Project" demonstrating private sector engagement in agrometeorological services and contribution to Nepal's climate resilience (CIF, 2018).

The SPCR's private sector component consisted of the three-pronged program "Building Climate Resilient Communities through Private Sector Participation" which was led by the International Finance Corporation (IFC). The Program included the "Promoting Climate Resilient Agriculture Project" which had among its objectives to enhance food security through the adoption of climate-resilient agriculture by farmers and agri-supply chain members, as well as to reduce the vulnerability of farmers to impacts of climate change.

During project preparation, IFC identified key climate-induced risks and other agricultural productivity constraints faced by the farming communities in different regions in the country and analyzed potential solutions where the private sector could play a role. Based on the research findings, the project focused on the Terai region affected by climate risks such as droughts and floods, where sugarcane is one of the major commercial crops.

The project also included a component of the development of ICT-based products to disseminate climate information to better prepare farmers. The climate information was initially designed/envisioned to be achieved through the inputs provided by BRCH as the PPCR program areas were interlinked. However, due to delays in implementation, IFC partnered with different institutional actors, entrepreneurs, and developers operating in this space to support climate-smart agricultural solutions that could be scaled up in Nepal.

As a result, it piloted ICT services that advised small-holders on the possible impacts of weather events on their crops (CIF, 2018) through the use of SMS. See Figure 3 below for more details on the involved agrometeorological value chain process. An institutional actor, Practical Action, undertook climate assessment and projected future scenarios to identify tools, technologies, and practices in each stage of cultivation that reduces the risk of climate change to farmers. The project partnered with a local business (Midas Group) to digitize the Climate Smart Agriculture (CSA) training package in the form of an app and a website in local vernacular for rice, maize, and sugarcane. Further, the project showcased the use of Automated Weather Station (AWS) for the first time in Nepal through a private entity mPower, Bangladesh in sugarcane. It provided weather forecasts and related crop advisory for a group of villages. Midas Group complemented the weather-based advisory messaging initiative through its platform.



NOTES: *# Physical and technical maintenance and operation of AWS by Sugar Mill and Private Climate Service Provider, respectively*
 # Cost for SMS is governed by Sugar Mill
 # An example of Agro-meteorological Advisory: Temperature is going to rise in the next few days by approximately 3 degree centigrade. It is going to get dry. You may start taking precautions to controlling pests and irrigating land to protecting from drought

Figure 3: Agrometeorological services value chain in Nepal through private sector participation

To address some of the above issues, respondents have reported the following suggestions to the DHM:

- ***Improve forecast at temporal scale:*** Increasing lead times of current three days (short-range) forecasts to seven days (medium-range) forecasts and sub-seasonal and seasonal (long-range) forecasts for various climate/weather variables. It may allow delivering crucial weather information such as the timing of the onset of a rainy season and occurrence of drought and flood for agriculture, the risk of extreme rainfall events for potential flood disasters, and heatwaves regarding public health (White et al., 2017).

- ***Improve forecast at spatial scale:*** Improving forecast at spatial scale making them more location-specific will help the general public, farmers, public health, resource managers, and planners make effective decisions based on locally relevant climate and weather information. For example, some climate-related risks (e.g., flooding) are location-specific, and certain places will bear more risk than others. Location-specific flood forecasts with defined impact levels help plan and execute early actions in specific locations.

- ***Shift to an impact-based forecast:*** This will help users know what level of impacts to expect from forecasted weather/climate conditions and take necessary precautions in time to avoid climate impacts. For example, in agriculture, impact-based drought forecasts enable farmers to manage irrigation and maximize yields; in disaster risk management, impact-based flood forecast helps pre-deployment of flood barriers, evacuation of vulnerable communities and their important belongings, pre-position relief packages, etc.

5.2.2) Improving communication and delivery of information and services

Despite some remarkable contributions of the BRCH project, several KII and FGD participants identified the issues below in the communication and delivery of information and services.

Understandability of weather information: Respondents indicated that weather information is not available to the users (e.g., farmers and local level government) in an easily understandable language. Furthermore, local governments in remote landslide-prone hilly districts (e.g., Bajura in Far West Nepal) do not understand what weather forecasts mean and their potential risk to vulnerable people. It indicates the necessity to provide weather information in easily understandable language and increase understanding and awareness to use them through training and awareness raising programs.

Means of delivery of weather information: Most farmers obtain hydrometeorological and agrometeorological services through radio, tv, mobile apps, newspaper, and Junior Agriculture Technicians (JTAs). In some communities, where not all members have a phone, the community leader receives the climate information through his mobile phone and shares it with the community members for their knowledge and action.

In other communities, farmer groups and community members do not have access to mobile phones. Their only means of receiving any agrometeorological and agriculture-related information is through JTAs. However, a considerable number of FGD participants noted that JTAs have not actively and frequently reached out to all of them. As a consequence, many farmers are not benefitting from hydrometeorological and agrometeorological information. Furthermore, many KII respondents also reported that vulnerable and marginalized communities/farmers in remote areas are not getting agro and hydrometeorology information. DHM's collaboration with provincial and local agencies is critical for improved and decentralized service delivery at local levels. Furthermore, engaging community-based institutions and civil society organizations would be advantageous in delivering weather information to vulnerable and marginalized communities.

Study respondents gave the following opinions to improve communication and delivery of climate information and services to users.

- ***Simplify the information and diversify the language of delivery of hydrometeorological information*** to make sure people with different levels of understanding and speaking various local languages can easily understand and use it in their decision making. Furthermore, voice messages in various languages could be an option for differently-abled people (without vision).

- ***Explore and consider multiple service delivery methods*** to make sure information and services reach all target users. Examples include organizing roving seminars, fostering collaboration with extension services/officers (e.g., JTAs), community-based institutions and civil society organizations to reach end-users widely and fostering collaboration between DHM and various (provincial, district, and local) levels of government.

- **Engage private sectors in the delivery of weather and climate services through a Public-Private Partnership (PPP).** The PPP business models can be helpful to sustain the delivery of weather and climate services to end-users. One such model was developed and piloted in Ghana in 2017, which helped deliver climate information services to farmers through mobile phone platforms. It can be one good example to review. Refer to Box 3 for additional details.

Box 3: Public-Private Partnership (PPP) model for climate information services in Ghana (Partey et al., 2019)

A private information and communication technology (ICT) company in Ghana, Esoko adopted a Public-Private Partnership (PPP) business model proposed by Climate Change Agriculture and Food Security (CCAFS) to sustain the delivery of climate information services (CIS) to farmers at the climate-smart village sites and reach others in the country. Esoko enhanced its partnership with private companies (Toto Agriculture, aWhere, and Vodafone Ghana) and public institutions (GMet, the Council for Scientific and Industrial Research - CSIR, the Ministry of Food and Agriculture - MoFA) and farmers to design a model of CIS mobile phone platform.

Each partner was assigned specific roles and responsibilities in the PPP. Toto Agriculture, aWhere and GMet provide daily, weekly, and seasonal weather information to Esoko, which is processed and delivered to farmers. CSIR and MoFA train Esoko staff to better understand and interpret CIS to farmers and advising farmers on the climate-smart agricultural options based on weather information. Vodafone provided mobile services and ensured the successful transmission of CIS to farmers.

Esoko delivered processed weather information received from GMet and other sources to farmers using mobile phone platforms during the pilot program. The platform also allowed farmers to access a call center where CIS is delivered vocally in their local dialect. The forecast information included the total rainfall, the onset and end of the rainy season, and a 10-day forecast during the rainy season. In addition to the weather forecast information, farmers received market alerts and agro-advisories intended to help them understand and apply them.

A survey conducted in 2017 showed CIS enabled farmers to make mixed strategic decisions on crop variety selection, time of planting, time of applying fertilizer, time of irrigating crops, time of harvesting, etc. Their decisions contributed to reducing crop failures and increasing household food availability.

5.3) IMPROVING HYDROMETEOROLOGICAL AND AGROMETEOROLOGICAL SERVICES THROUGH FEEDBACK AND EVALUATION

Studies have highlighted that interaction with users and their feedback is crucial in developing and delivering effective services (Roo et al., 2011; Rogers and Tsirkunov, 2011; Vogel et al., 2017). A formal evaluation system of hydrometeorological services can help articulate which services and products are successful, why, and to what extent, as well as guide future investments in hydrometeorological services.

Participants reported feedback collection occurs informally and that there is not an established evaluation system for hydrometeorological and agrometeorological services. These are two key challenges in transforming weather, water, and climate services in Nepal.

5.3.1) Feedback collection from various users

DHM informally collects feedback from various institutions. For example, at the ministerial level, DHM presents work and receives feedback during an inter-ministerial meetings. DHM also receives feedback from government departments (MoALD) and international development organizations and institutions (FAO, WFP, WMO, ICIMOD, RIMES, etc.) through informal meetings, annual workshops, forums (e.g., monsoon forum, Second South Asian Hydromet Forum – 2019), and an interaction program on WMO day. However, there is no formal mechanism (e.g., survey, formal interview, discussion, etc.) to collect feedback from these institutions on the hydro and agrometeorological services that DHM provides. Feedback collection from the local and provincial governments is also critical to assess the usefulness and effectiveness of the provided information and services and communicate available forecasts more effectively.

At the end-user level, feedback collection is through the general public's comments on DHM's climate information posts on Facebook and Twitter; and through NGOs based in the field. For instance, Practical Action receives feedback from the communities in its project area on whether the information is reaching them if they understand it, and in turn, communicates this information to DHM. Establishing a formal mechanism for collecting and incorporating various user's feedback into the design and delivery of the climate services information is essential. The UK Met Office conducts annual and ad-hoc Met Office User Satisfaction Surveys to gain insight into the public's requirements and levels of satisfaction with their forecasts and severe weather warning services. It also conducts National Severe Weather Warning Service (NSWWS) Surveys after selected severe warnings to ensure the Met Office's warnings reach the people who need them and that they find them useful (World Bank, 2019). These surveys can be a good reference for Nepal.

5.3.2) Evaluation of provided weather, water and climate services

A more rigorous evaluation of provided weather, water, and climate services is needed to collect evidence on the value and use of climate services to help inform adaptation decisions and guide future investments (Vaughan and Dessai, 2014). DHM and MoALD did user satisfaction surveys in 2020 and 2019, respectively. Results showed 51% of users were satisfied with DHM's hydrometeorological services. 79, 73, 89, and 50% of users are satisfied with MoALD's Hamro Krishi app, Kisan call center, Krishi (agriculture) information SMS, Agromet Advisory Bulletin, respectively. It indicates there is still some room for improvement.

Evaluating different aspects of hydrometeorological and agrometeorological services such as access to agrometeorological and hydrometeorological information and services; importance, usefulness, reliability, and ease of understanding of that information and services; etc., is critical. To achieve this, building evaluation capacity and exploring potential ways to build it is essential. For instance, DHM may benefit from innovative partnerships with different institutions (e.g., universities), allowing DHM to maintain the evaluation expertise they need. Another model can be to build evaluation capacity at WMO Regional Climate Centers, serving as repositories for evaluation capacity, which can also help serve the needs of DHM (Vaughan et al., 2019).

Based on KII and FGD respondents, DHM and MoALD can continue to improve their hydrometeorological and agrometeorological services in Nepal through:

- ***Develop and strengthen the mechanism for feedback collection from various institutions*** through a formal process. This will further lead to the development of formal monitoring and evaluation protocols, and the involvement of independent evaluators in evaluating feedback and improving hydrometeorological and agrometeorological services (Vaughan et al., 2018).

- ***Develop formal pathways to collect feedback from end-users.*** For instance, at the farmers' level, DHM and MoALD can establish a feedback mechanism by agreeing on potential tools to collect feedback such as soliciting feedback at farmers forums, having agricultural extension officers actively distribute comprehensive, fact-finding surveys, or sharing telephone numbers where users can provide feedback (Rogers and Tsirkunov, 2011; Vogel et al., 2017). This will help to improve the climate services to meet the needs of end-users.

5.4) FOSTERING HUMAN RESOURCES CAPACITY

The provision of meaningful climate services requires a range of capacities from systematic observations to their quality control, data analysis, and monitoring and development of climate information and services, up to the understanding of the sector and user-specific needs (Gubler et al., 2020). AMCOMET (2015) identifies human resources capacity as an essential component to provide specialized hydrometeorological information tailored to particular sectors or decision-makers' requirements.

With the upgrading of the hydrometeorological system, DHM requires fostering human resources capacity to successfully operate and maintain the modernized system, including collecting and managing data, and developing and delivering hydrometeorological and climate services. Additionally, positioning at least one agrometeorologist in each province; and strengthening the capacity of agrometeorologists, agricultural technicians, and scientists at MoALD and NARC in various areas (e.g., weather-based modeling and seasonal forecasting) is equally crucial. It helps developing farmer's need-based agrometeorological information, products, and services.

Respondents mainly identified the following challenges in DHM's technical and administrative capacity to transforming weather, water, and climate services in Nepal.

5.4.1) Technical capacity of DHM

DHM's technical capacity poses challenges in two main areas - equipment maintenance and research and development of climate services.

Challenges in equipment maintenance: Many respondents identified a lack of capacity to maintain modernized infrastructure as a challenge. Without the adequate and required amount of in-house technical capacities/skills, DHM will continue to rely on external expertise for equipment maintenance which can take long international procurement processes. This challenge can hamper data collection and the development of climate services.

There is evidence of the consequences due to the lack of in-house technical capacities. For example, a new radar in Surkhet was hit by lightning six times in the first year of its operation in 2019/2020. Although the installation contract with RTS included a one-year maintenance contract, the radar was non-operational for a couple of months during one of the lightning incidents. It is because the maintenance request processing and deploying the technicians took a very long time. The lightning issue continued even with the proper grounding and seemed related to the area's transmission line.

Similarly, newly automated weather stations at a few locations under the BRCH project also had some technical issues. The DHM field office sent a maintenance request to the central office and then to the suppliers, MicroSTEPs, and RTS. Although there is a two-year full support provision in the contract with the MicroSTEPs and the RTS, they took 15 days to a month to deploy a technician for repairs. It hampered data collection from those stations for many weeks.

There is a risk that radar and automated weather stations may not be operational if technical issues continue after a contract with the supplier expires until DHM gets external help to fix it. An important lesson is that the BRCH project could negotiate a special arrangement with the supplier at the outset that would include an extended period of maintenance services for automated weather stations and radar until the development of an in-house capacity or other sustainable arrangement or approach depending on the institutional culture. Furthermore, considering the spatial density of the hydrometeorological stations, the technical experts need to be trained and stationed in strategic locations (provinces and regions) to reach out for quick maintenance.

Challenges in research and development of climate services: The users' needs and technology preferences keep changing because of many factors, including challenges and opportunities. But the DHM's capacity to research potential challenges, opportunities, and technologies, use forecasting tools/models, and develop specific products and services is weak. Study respondents noted that this is mainly because DHM staff are highly involved in the administrative work rather than research and development of climate services. A limited number of employees and high workloads are also contributing to DHM's weak research component. One of the KII respondents opined that DHM should not be overstretched to put its limited resources to customizing the information for catering to the user's diverse needs. Instead, some relevant agencies could take such responsibilities. For example, NDRRMA could take or share the responsibility of impact-based disaster forecasting with DHM.

Furthermore, the transfer of staff, trained through the BRCH project, from DHM to other departments/ministries as per the government's staff reallocation process impacted DHM's capacity. Unfortunately, DHM does not have any control over this process. Despite those challenges, DHM is trying to establish a research wing and initiate research on climate services. It is a positive step towards improving the research and development of climate services in Nepal.

Addressing the issue of technical capacity is crucial to improving Nepal's hydrometeorological and agrometeorological services. Study participants' key recommendations include:

- ***Develop long-term strategy for DHM's staffing, upgrading skills, and responsibilities:*** DHM has faced long-standing staffing challenges. It is important to map human resources capacity under different themes such as ICT application, data assimilation, data analysis, research, service, and product development, etc., and consequently develop long-term strategy for DHM's staffing, updating skills, and responsibilities through initiatives to recruit, retain, train and support more staff. It needs to be aligned in the technical refurbishment and service delivery strategy context. As of July 2020, DHM developed and finalized the Organizational Structure and Human Resources Plan; however, this plan's operationalization is still in progress.

- ***Invest in capacity building:*** In recent years, a number of training were planned to build DHM human resources capacity under the BRCH project. Nonetheless, some of them were not completed within the project implementation period due to procurement-related issues. The COVID-19 pandemic amplified the delay. It will be important to ensure DHM and MoALD staff's continued capacity building through government or bilateral investments, and internal and external training programmes to achieve efficiency and effectiveness in climate services.

- ***Develop linkage and collaboration with domestic and foreign universities, and research and development organizations*** to strengthen technical capacities to enhance weather forecasts, develop climate services and weather products, and promote research in climate sensitive sectors such as agriculture, water, health, disaster reduction, etc.

5.4.2) Administrative capacity of DHM

In the preparation process of the BRCH project, the project assessed the procurement capacity of DHM and the Ministry of Agriculture and Cooperative (MoAC) (which is now called MoALD). It identified various risk factors such as accountability for procurement decisions in the implementing agency, internal manuals and clarity of the procurement process, staffing, procurement planning, evaluation and award of contract, etc., and identified appropriate mitigation measures. DHM also prepared a project-period master procurement plan, a detailed procurement plan, a checklist outlining the procurement process, key procurement steps, responsible staff, and the expected timeframe for each step.

Despite the initial preparation, KII respondents reported many challenges DHM encountered during project implementation due to the weak administrative capacity. One of the challenges is the lack of dedicated human resources for project implementation. Unlike other agencies, DHM's staff had additional responsibility to supporting project implementation in various roles. A few employees were given multiple responsibilities, at times against their will due to HR limitations. As a consequence, project implementation, monitoring, and supervision were challenging.

The lack of administrative capacity to manage procurement issues is another challenge. DHM's staff do not have proper training and lack large-scale procurement management experience, including the development of precise terms of reference to request proposals and to evaluate bidding documents and reports in a timely and efficient manner. The Nepal government's new policy that prevented using development loan money to send staff for training abroad hampered the capacity-building endeavors. Furthermore, the mismatch between the World Bank's and Nepal government's procurement guidelines for the procurement of consulting packages, especially in areas such as a mode of procurement, lack of approved norm, rate of remuneration, etc., caused delays in the project implementation.

The mid-term review of the project found noteworthy progress in procurement. DHM was able to pull through a few consulting packages. To continue the project momentum, the review team discussed the draft procurement plans and prioritized various actions for DHM. Despite these initial and mid-term strides, review, and close oversight at all stages of the procurement process, the procurement issues continued.

Another challenge in DHM's administrative capacity which obstructed project implementation is penalization on decision-makers/DHM employees. Office of Auditor General has raised audit observations for several procurement packages which received due approval from the World Bank and recommended penalization on decision-makers. It has created a risk aversion mentality in the decision-makers hampering the project implementation.

Study participants suggested two key priorities to address some of the above issues:

- ***Build in-house expertise*** to develop precise terms of reference to request proposals and evaluate bidding documents and reports quickly and efficiently.

- The Government of Nepal shall ***address mismatches in its regulations and procurement processes when implementing the World Bank or other Development Financial Institution's projects*****.**

5.4.3) Capacity of the user community

A challenge in fostering weather, water, and climate services in Nepal is the limited use of modern weather forecasting and climate information systems among many farming communities. Despite recognizing the importance of climate and weather information in decision-making, only 27% of FGD participants use DHM's climate and weather information. 16% of them use both DHM's information and Traditional Knowledge (TK), while 47% solely rely on their TK to make weather-related decisions for their farming activities. TK includes know-how, skills, and practices developed, sustained, and passed on from generation to generation within a community. Many farmers do not get agrometeorological services. Currently, weather information from DHM does not provide direct agrometeorological advisory needed in their farming activities whereas, DHM's past weather forecast was not as accurate as it is now. Therefore, even when DHM's climate and weather information is available, they feel more comfortable following the traditional practice of using traditional knowledge for farming, informing flood levels in the river, etc.

An important lesson to learn is that fostering an informed climate service user community is essential to increase the use of climate information and services together with traditional weather and climate knowledge in climate-related decision-making. A hybrid approach of using traditional weather knowledge and formal weather and climate information will enable a system that benefits both from the local relevance of indigenous techniques and the increased accuracy and efficiency of modern techniques.

Fostering an informed user community is also critical before collecting the end-user's feedback. Informed users can better understand and use available climate information and services, assess gaps, and provide constructive feedback to improve them further. DHM and MoALD need to improve public outreach to foster an informed user community. That can include climate information, education, communication campaigns; awareness-raising activities; and training programs.

The selection of farmers not based on their ability to learn is another issue in user capacity development. Although MoALD attempted to build community capacity through the BRCH project by distributing thermometers and rain gauges to farmers and training them in using those instruments. One of the KII respondents reported a high value in providing rain gauges considering heterogeneous rainfall distribution in the country but a low value in distributing thermometers as the temperature being a homogenous parameter. Additionally, thermometers are globally banned if they use mercury. It takes some effort to install thermometers in a correct enclosure, read and maintain them. It will be crucial to consider these points when distributing thermometers and rain gauges to farmers.

A few respondents reported that farmers were unable to operate these simple instruments and use information from them. It did not help them improve their on-farm decision-making, which undermined the benefit of BRCH's investment in hardware. So, the lesson learned from the BRCH project is selecting appropriate farmers for training is equally essential to providing instruments and training to use them. The training should focus on local farmer's needs, local conditions, and other realities.

5.5) STRENGTHENING INSTITUTIONAL ARRANGEMENTS

Study participants identified several gaps in the institutional arrangements that impede the transformation of weather, water, and climate services in Nepal. Addressing those gaps is paramount to strengthening hydrometeorological and agrometeorological services in Nepal. These gaps and related priorities include: 1) ensuring financial sustainability, 2) strengthening hydrometeorological policy landscape, 3) fostering national collaborations, 4) improving engagement with WMO and 5) issues related to the governance system.

5.5.1) Ensuring financial sustainability

Many study respondents raised concern over the financial sustainability of the hydrometeorological services value chain in Nepal after the BRCH project. DHM requires significant financial resources for the operation and maintenance of the upgraded automatic stations, renewal of expanded observation networks, and research and development of weather, water and climate services based on users' needs. The automation of stations has solved the issue of reliance on data observers. Nevertheless, it requires maintenance (e.g., cutting grass and keeping the surrounding area open, cleaning a solar panel or the sensors, calibration, equipment maintenance, etc.) which significantly increase operating costs.

In recent years, DHM's expenditure has been steadily increasing. However, the recurring budget has remained stagnant or even reduced over the years. DHM, without enough financial resources, will not be able to generate and deliver high-quality hydrometeorological services at the different levels of the new federal setup. In addition to the government budget, it is important to explore potential means to ensure financial sustainability. The review of the draft hydromet bill shows some positive signs. It defines when DHM can collect service fees and how it can spend them. It also supports the establishment and operation of the Hydromet Service Development Fund, which may receive funds from the Nepal government, foreign government, international organizations, and any other sources or as fees for its services. DHM can use this fund as per the fund operation board's decision. The bill, thus, opens opportunities to generate some financial support for the DHM.

Study respondents have provided the following suggestions for managing the financial needs necessary to continue improving Nepal's hydrometeorological and agrometeorological services.

- ***Develop customized hydrometeorological and agrometeorological services for specific users*:** DHM, private, or academic sectors can work together to develop and sell non-public customized *hydrometeorological and agrometeorological* services for specific users such as tourism, insurance, private airlines, and climate-resilient infrastructure development. An agrometeorological services business model piloted by IFC in Nepal can be one potential example of a customized service for the agribusiness sector (See Box 2 above for more information).

- ***Access external financing***: It will be important to access financing from donors and funds such as the Green Climate Fund (GCF). A second phase of the BRCH project could enhance the achievements to date with the support of the World Bank or the PPCR. External financing could help expand the hydrometeorological observation network, scale-up hydrometeorological and climate service development and delivery. DHM needs to have a plan based on the new services' social and economic benefits to justify the demand for weather, water, and climate products and sustainability of financial investments.

Additionally, Nepal may also consider a list of good practices identified in Box 4 below through different country case studies for the development of a sustainable hydromet value chain or of successful public-private engagement (International Bank for Reconstruction and Development/The World Bank, 2019).

Box 4: Good practices that foster the development of a sustainable hydromet value chain and successful public-private engagement (International Bank for Reconstruction and Development/The World Bank, 2019)

The good practices are broadly categorized into governance, funding of public service, capacity building, infrastructure, and development support, reflecting the design of development projects.

Good Practices	**Area**
Prioritize hydromet services as strategic public service by government	**Governance**
View the role of NHMS as an enabler for a well-functioning hydromet market	
High awareness in the government of the benefits of public hydromet services	
Recognizing the need for a clear legal frame	
Investment project controls are scaled adequately for the hydromet domain	
Sufficient and sustainable budget Funding of public service	**Funding of public service**
Realistic expectations of what a low-maturity NMHS can deliver outside its core competencies	
Minimize non-public service by NMHS	
NMHS is empowered to hire its own staff	**Capacity building**
Create attractive career paths	
Capacity building Provide sufficient training	
Build fit-for-purpose infrastructure	**Infrastructure**
Create a standard for lower-cost weather stations	
Focus development activities on the entire hydromet value chain instead of just the NMHS	**Development support**
Keep the investment budget at an appropriate level and include an appropriate maintenance and operations budget that covers transition to sustained operations	

	Flexible development project design with adequate technical specification capacity		

5.5.2) Strengthening hydrometeorological policy landscape

A strong hydrometeorological policy landscape is important to establish DHM, a hydrometeorological agency as the legally authorized agency for hydrometeorological service in the new federal **set-up**. It provides the essential legal and regulatory framework for the operation of the DHM. Furthermore, it also enables financial support mechanism for operations and maintenance of hydrometeorological infrastructure, which is critical to ensure the sustainability of the development outcomes of the hydrometeorological project.

A national hydrometeorological policy would help DHM clarify its goals and mandate and would give it authority for monitoring and regulating hydrometeorological activities, and facilitate allocation of resources. To achieve this, the BRCH project has supported the development of the hydromet bill in Nepal, which is currently under the enactment process. To speed up the enactment process, DHM has already addressed the comments twice but the bill is returned again with additional comments. DHM plans to have focused discussion with the ministerial authorities to come to common understanding in order to move the bill for further processing, but the frequent change in ministerial authorities is hampering this effort. Respondents flagged that the enactment of the hydromet bill should be prioritized to pathways to transform weather, water, and climate services in Nepal.

Interview respondents identified the pending enactment of the hydromet bill as one of the key challenges in strengthening the hydrometeorological policy landscape. The enactment of the hydromet bill is vital as it provides the legal basis for operation, service delivery and regulates and supervises hydrometeorological activities in Nepal. A review of the draft hydromet bill has further revealed that it helps define special hydrometeorological services and service fees, aeronautical meteorology-related tasks, license requirements for external parties, and eligible hydromet works. Thus, the bill sets the way to issuing licenses and enhancing private sector participation in the area of hydrometeorological services.

5.5.3) Fostering national collaboration

Several respondents identified a lack of communication and collaboration at different government and key stakeholders (e.g. civil aviation) levels regarding ownership of hydrometeorological stations, data collection, data sharing, hydrometeorological services development, and dissemination as a major challenge.

There has been significant progress in collaboration between DHM and different levels of Emergency Operation Centers on the development and dissemination of timely flood early warning at the local level in Nepal. As a result of the BRCH project, an inter-agency initiative, the Working Group of Agricultural Meteorology (WOGRAM), comprising officials from DHM, MOALD, and NARC has been established. The WOGRAM meets regularly, shares information and issues, and enables the three agencies to work closely on the generation and issuance of weekly AABs. This is an excellent example of inter-institutional coordination and collaboration between service providers and users at the national level and it could help continue the AMIS beyond the PPCR project.

The example above shows that it is essential to appreciate the interdependencies and establish strong coordination and collaboration between different stakeholders to build, deliver and capitalize on effective services rather than seeing weather and climate services as a series of individual parts. However, there remains room for improvement in fostering national collaboration.

Study participants identified several areas where better communication and collaboration could transform hydrometeorological and agrometeorological services in Nepal. This includes *strong communication and collaboration at the following different levels of government*:

- ***Between Ministries:*** For instance, communication and collaboration between the Ministry of Agriculture and Livestock Development and the Ministry of Energy, Water Resources, and Irrigation, will help coordinate efforts towards better agrometeorological services in Nepal. Similarly collaboration with Ministry of Culture, Tourism and Civil Aviation will help in better services related to quantity and quality of meteorological services/data required for aviation and ownership and maintenance of hydrometeorological stations located in the premises of airports.

- ***Between Ministries and Departments:*** For example, improvement in the frequency of communication and progress sharing on hydrometeorological services between DHM and Ministry of Finance will help develop a stronger understanding of hydrometeorological services' importance and develop strong collaboration on future investments in hydrometeorological services. Such efforts between the DHM and Ministries (e.g., the Ministry of Forests and Environment, climate change management division) will help develop an understanding of climate change data needs, initiate meaningful coordination for data exchange through proper channels in timely manner and establish a strong collaboration on climate change management in Nepal.

- ***Between different federal government levels:*** For example, improvement of communication and collaboration between central, provincial/district, and local level of DHM, Agriculture Knowledge Centers (AKCs), Veterinary Hospital and Livestock Service Expert Centers (VHLSECs), and Emergency Operations Centers will ensure clarity of roles and responsibilities and will improve communication and coordination on disseminating agro and hydrometeorological services, including early warning services at the grassroots level.

After identifying different levels of government where better communication and collaboration are important in Nepal, establishing strong communication and collaboration at those different levels remains an important question. Hewitt et al. (2020) recognized National Frameworks for Climate Services (NFCS) as an effective way to establish institutional mechanisms to coordinate, facilitate and strengthen the collaboration among national institutions to improve the production, tailoring, communication, delivery, and use of climate services for national and local communities. There are already examples of enhanced national collaboration as a result of launching NFCS in Ivory Coast, China, and the UK**.**

Under the BRCH project, the Asian Disaster Preparedness Center (ADPC) helped Nepal government to prepare preliminary draft of NFCS in November 2020. The NFCS required improvements and consultations for subsequent draft development and finalization. The GoN should keep establishment of NFCS as a priority to foster national collaboration for transforming hydrometeorological and agrometeorological services in the country.

5.5.4) Improving engagement with WMO

A KII respondent highlighted that engagement of DHM as a National Meteorological and Hydrological Services (NMHS) with WMO has significantly declined after the release of DHM's Director General from the role of the WMO's Permanent Representative during the implementation of the BRCH project. In the past, direct engagement with WMO has provided various platforms and opportunities to foster regional and global collaboration; and capacity building, which has substantially declined recently. Therefore, improving DHM's engagement with WMO is critical to enhancing hydrometeorological services in general.

5.5.5) Issues related to the Governance System

In a country like Nepal, where the federal system is in place, there should be a delineation of roles and responsibilities between DHM and provincial and local entities to providing efficient climate services at all levels. However, there exist several issues.

A KII respondent noted that roles and responsibilities for the Hydrology and Meteorology offices at the regional level are more or less clear from DHM's perspective. But, whether those roles and responsibilities best suit the federal setup or not is a question. It indicates that planning, coordination, and clear communication need to happen at all levels of a federal government for well-functioning and sustainable data collection and management; development; and delivery of hydrometeorological information, products, and services. Furthermore, the 2015 constitution gives the mandate of disaster risk management to provincial and local governments. However, significant gaps exist between the needs and current financial and technical capacity to manage hydrometeorological disasters.

6) CONCLUSIONS

Nepal has significantly improved its weather, water, and climate services through the BRCH project since 2013. Despite significant improvements, this study revealed improving data resources, improving service design and delivery, improving hydrometeorological services through feedback collection and evaluation, fostering human resources capacity, and strengthening institutional arrangements as five different thematic areas critical to transforming weather, water, and climate services in Nepal. Furthermore, this study, guided by the analytical Climate Services Value Chain framework, identified the following priority actions for a range of stakeholders under each thematic area to transform weather, water, and climate services in Nepal:

1. <u>IMPROVING DATA RESOURCES</u>

Service provider - DHM

- Improving incentives (e.g., increasing wages) and providing training to local gauge readers to raise the quality of data collected from the manual stations
- Negotiating a special arrangement with the supplier of modern observation networks and forecasting technologies at the outset to include an extended period of maintenance services until the in-house technical capacity increases or other sustainable arrangements in place depending on the institutional culture
- Increasing the number and technical capacity of DHM staff to ensure good hydrometeorological data management and increase the benefits from available data resources

- Improving data sharing at the national, provincial, local, and cross-border levels by developing appropriate policy guidance and hydrometeorological data sharing mechanisms

2. <u>IMPROVING SERVICE DESIGN AND DELIVERY</u>

Service provider - DHM

- Further improving and expanding existing climate services in aviation, agriculture, disaster risk reduction, and potential sectors such as tourism, insurance, private airlines, infrastructure (for example, construction industry and hydropower), and climate-resilient development
- Focusing on hydrometeorological services design and delivery based on user needs such as impact-based forecasts and location-specific mid and long-range weather forecasts at an improved temporal and specific spatial scale
- Identifying and collaborating with appropriate agencies at different levels to facilitate the communication and dissemination of climate information from DHM to a local level

Service provider - DHM and Intermediate users - MoALD, NARC, and NDRRMA

- Continuing inter-institutional and intra-institutional coordination and collaboration between the provincial, district, and local level government to improve the hydrometeorological and agrometeorological services in agriculture and disaster risk management throughout the country

Intermediate users - MoALD and NARC

- Assigning permanent agrometeorologists in Agriculture ministry, department, and NARC to interpret weather and climate data in the agriculture and livestock sector

Donors

- Investing in projects (for example, a second phase of BRCH) to scale up hydrometeorological and climate service development and delivery to willing non-public buyers/users in potential sectors such as tourism, hydropower, private airlines, etc.

Government of Nepal

- Attracting and accessing potential financing such as Green Climate Fund (GCF) sources and or PPCR funding if available to scale up development and delivery of demand- and need-based hydrometeorological and climate services

3. <u>IMPROVING HYDROMETEOROLOGICAL SERVICES THROUGH FEEDBACK COLLECTION AND EVALUATION</u>

Service provider - DHM and intermediate users - MOALD and NARC

- Setting up a formal mechanism (e.g., survey, formal interview and discussion) to collect feedback from different users' levels to continuously upgrade agrometeorological and hydrometeorological services
- Interacting with various institutions and end-users to collect their feedback and collaborate with them to develop demand-based climate services such as impact- and location-based services

4. <u>FOSTERING HUMAN RESOURCES CAPACITY</u>

Service provider - DHM

- Developing long-term strategy for DHM's staffing, updating skills and responsibilities through initiatives to recruit, retain, train and support more staff

- Collaborating with universities, research, and development organizations to foster human resources capacity and enhance climate services development and dissemination in climate-sensitive sectors such as agriculture, water, health, disaster reduction, etc.

Intermediate user - MoALD

- Training farmers with adequate learning capacity to operate the instruments such as thermometers, rain gauges, and smartphones and to interpret data for decision making

Intermediate user - NARC

- Strengthening the capacity of agricultural scientists to developing farmer's need-based agrometeorological information, products, and services through training, participation in seminars and conferences, etc.

Service provider - DHM and Intermediate user - MoALD

- Improving public outreach services such as climate change education, communication campaigns, awareness-raising activities, and training programs and continue building the capacity of the user community to foster an informed user community and increase the use of climate information and services in weather, water, and climate-related decision-making

Donors

- Investing in capacity development projects to build human resources capacity to operate and maintain the modernized system, collect and manage data, and develop and deliver the demand-based hydrometeorological and climate services

5. STRENGTHENING INSTITUTIONAL ARRANGEMENTS AND GOVERNANCE

Service provider - DHM

- Collaborating with private sectors to develop and sell non-public customized *hydro*meteorological *and agro*meteorological services for specific users to improve the financial sustainability of hydrometeorological services
- Strengthening communication and collaboration between ministries, key stakeholders, and different federal government levels to foster national collaboration to transform **hydromet**eorological **and agromet**eorological **services in the country**

Government of Nepal

- Addressing the mismatching of acts and regulations and procurement processes when implementing the World Bank or other Development Financial Institution’s projects
- Enacting the hydromet bill to foster pathways to transform weather, water, and climate services in Nepal
- Defining clear roles, responsibilities, mandates of DHM offices to facilitative coordination and clear communication at all levels of the new governance system

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APPENDICES

Appendix 1. List of Hydrometeorological Products and Services Offered by Department of Hydrology and Meteorology (DHM), Nepal

(Source: Primarily based on information from DHM respondents and DHM website (DHM, 2021)[1])

S.N.	Weather and Climate Information, product or service	Means of delivery	Language of delivery	Targeted users
1.	Periodical climate bulletin	Public web service, Email, Social media (Facebook and Twitter)	English	General public, Students, Researchers, Different user sectors such as Water resources, DRRM, Agriculture, Media, etc.
2.	24 hour and 3-day weather forecast, Special weather bulletin, Weekly weather outlook*	DHM website, Social media (Facebook and Twitter), Telephone call, Radio, TV, and by Email through workstation on special cases (Mobile application in near future)	English (Maps with symbols)	General public, Agriculture ministry and agriculture-related sectors (agriculture sector specific use during locust invasion), Different other user sectors such as Civil aviation, Mountaineering, Tourism, Disaster management (Nepal Disaster Risk Reduction and Management Authority (NDRRMA), Army and Police, Ministry of Home Affairs (MoHA), Norwegian Refugee Council (NRC), etc.), Media, Transportation, Construction, Energy, etc.
3.	Flood forecast and early warning service**	Radio, Mass SMS (through mobile network operators NCELL and Nepal Telecom (NTC)), TV, DHM's website, Social media (Facebook and Twitter), Email message to selected user through workstation	Nepali	General public and those in the affected areas, Related Government and Non-Government agencies such as disaster management authority - NDRRMA
4.	Agro-weather forecasts***	Email, Website, Social media (Facebook and Twitter)	Nepali	Ministry of Agriculture and Livestock Development (MoALD) and Nepal Agricultural Research Council (NARC) - for Agro-advisory Weekly Bulletin**** and other agricultural purposes, General public concerned with agriculture
5.	High altitude forecasts	DHM website	English	Mountaineering, Tourism and aviation sectors
6.	City forecast	WMO website	English	General public and other relevant users
7.	Flood hazard maps	Mobile app, DHM website (App yet to be integrated)	(Maps)	Relevant users from disaster management sector
8.	Real time water level, rainfall	DHM website	English	District Emergency Operations Center (DEOC), General

[1] DHM 2021. DHM, an Introduction. Retrieved 7 January 2021, from http://www.dhm.gov.np/contents/about-us

				public and other stakeholders
10.	Historic water level, rainfall and discharge data/information	Purchase from DHM offices	Mostly Number data in English	Insurance agents, Students, Non-Governmental Organizations (NGOs), International Non-Governmental Organizations (INGOs), Water resource planners, Developers, Researchers and Data seekers
11.	Certification for insurance	Purchase from DHM offices	Nepali and English	Insurers, Insuring companies
12.	Climate services (Seasonal forecast; Daily, Monthly and seasonal temperature and Precipitation monitoring of major cities)	DHM website and Social media (Facebook and Twitter)	Nepali and English	General Public, Government agencies and other stakeholders (e.g., News media for wider dissemination of climate services)
13.	Aviation weather service (Meteorological Aerodrome Report (METAR), Terminal Aerodrome Forecast (TAF), Significant Meteorological Information (SIGMET), Enroute forecast)*****	Hard copy, Mobile app for pilots, Automatic Message Handling System, Aviation meteorology in website in near future	Code / Maps in English	Aviation related stakeholders (e.g., Airport authority, Pilots, Airlines, etc.)
14.	Numerical Weather Prediction (NWP) products	DHM website	Image/grid data in English	General public, Researchers, Experts, Institutions and NGOs in agriculture sector and other relevant users at the local level

Note:

* Graphical icon based three-day forecast is available in mobile app as well as website (Global Forecasting System (GFS) and Weather Research and Forecasting model (WRFDA)), Can be extended to 7 days.
Special bulletin and weather forecast can also be shared with general public and Airport authorities via the display system
24 hour weather forecast in Nepali and English, 3-day weather forecast in Nepali only

** Issued daily only during monsoon season and at other times (outside monsoon season) only when an event is very likely to occur

*** For Agro-advisory Weekly Bulletin, DHM provides weekly weather outlook and map of previous week's max/min temp and rainfall.

**** Developed and distributed under the BRCH project

***** METAR, TAF available in aviation app. SATELLITE image, Significant Weather (SigWX) charts, and SIGMET are also available.

Appendix 2. List of Agrometeorological Products and Services Offered by Ministry of Agriculture and Livestock Development (MoALD) and Nepal Agricultural Research Council (NARC), Nepal under the BRCH project

(Source: Primarily based on information from MoALD and NARC respondents, and MoALD's report (MoALD, 2018)[2])

List of Agrometeorological Information, Product and Services Developed and Distributed by MoALD and NARC, Nepal							
S.N.	**Agrometeorological Information, product and service**	**Means of delivery**	**Language of delivery**	**Frequency of delivery**	**Targeted users**	**Number of users as of (2019)**	**Partners in delivery**
1.	Nepal Agriculture Management Information System (NAMIS) Web Portal (www.namis.gov.np) (Also includes market information, weather information, drought monitoring, fertilizer calculation)	Web portal	Nepali & English	Daily	Farmers, Officials and extension workers of MoALD and NARC	150,000 visits	Project Management Unit (PMU), NAMIS
2.	Mobile app (Hamro Krishi)	Information Communication Technology (ICT)-based mobile app	Nepali	Daily	Farmers, Community representatives, Officials and extension workers of MoALD, NARC, Non-Governmental Organizations (NGOs), and International Non-Governmental Organizations (INGOs)	>40,000 downloads	PMU
3.	Brochures on using Hamro Krishi mobile app, how to operate rain gauge and thermometer	Web portal, Printed copies	Nepali & English	Yearly	Farmers, Community, Extension workers	-	PMU, NARC, District level offices
4.	Hamro Krishi SMS Service	Mobile phone, Text message	Nepali	2-3 times per week	Farmers, Officials and extension workers of MoALD and NARC	>40,000	PMU, Nepal Telecom (NTC), NCell
5.	Kisan Call Center (KCC) service with	ICT, Phone-based	Nepali	Daily from	Farmers and concerned	54 offices	Agriculture

[2] Ministry of Agriculture, Livestock and Development (MoALD). 2018. Progress status report fiscal year (2017/2018) on Agriculture Management Information System Component D, Nepal Pilot Program for Climate Resilience (PPCR), Building Resilience to Climate Related Hazards project (BRCH). Kathmandu, Nepal: Government of Nepal, Ministry of Agriculture, Livestock and Development.

	digital display board, computer, toll-free number			district level and 3 days in a week from central level	stakeholders		Knowledge Center (AKC), Veterinary Hospital and Livestock Service Expert Center (VHLEC), NARC, Agriculture Information and Training Center (AITC)
6.	Agro-weather advisories, Weekly Agro-Advisory Bulletins (AABs)	Web Portal, Mobile App, SMS, Local FM Radio, National television, Newspaper, Printed copies	Nepali, Avadhi	Weekly	Farmers, Farmers group, Cooperatives, Extension workers	175,000	PMU, NARC, AKC, VHLEC, AITC
7.	Climate Vulnerability area maps focusing on agriculture sector (18 pilot districts) (E-copy)	E-copy, Web portal	English	One time	MoALD, NARC, District level offices, Agro-advisory committee	-	PMU
8.	District Profile of 25 districts	Web portal	English	One time	Farmers, Extension workers, Agro-advisory committee	-	PMU
9.	Package of Cultivation Practice (POCP) of 18 districts only (E-copy)	Manual	English	One time	Farmers, NARC, Agro-advisory committee	-	PMU
10.	Climate Smart Agriculture manuals	Printed copies, Web portal	Nepali	One time	Farming communities, Extension workers and other stakeholders	-	-
11.	Weather and climate change induced Disease/Pest Occurrence and their Management practices in Crops and Livestock covering 7 districts (E-copy)	Web portal, Mobile Apps	English, Nepali	One time	NARC agro-advisory committee, Extension workers	-	-
12.	Videos, Jingles, Documentaries, FM/Radio Program and bulletins, Public service announcements on	TV, web portal, SMS, YouTube, Facebook, FM radio, Mobile	Nepali and with English subtitles	One time	Farmers, Extension workers	-	PMU, National Television

	climate change impacts in Agriculture and use of ICT in climate change adaptation & early warning system	application					
13.	Posters, Leaflet, Booklet, Factsheets, Agro-advisory Books	Web Portal, Printed copies	English, Nepali	Yearly	Farmers, Extension workers	-	PMU
14.	Integrated Crop calendar of major crops (cereals, cash crops, spices) cultivated in Nepal	Printed calendar	Nepali	One time	Farmers, Extension workers	-	PMU
15.	Frequently Asked Question and Answer (FAQs) on major cereals and legumes (mustard, lentil, soybean, sunflower, chickpea, cowpea), vegetables (seasonal and off-seasonal, capsicum, broccoli, chamsoor, garden cress, mushrooms, coriander, chayote, squash, bitter gourd, spinach, pointed gourd, turnip), livestock management and diseases for big and small livestock, fruits (tropical, subtropical and temperate), and spices (ginger, large cardamom, tea and coffee, fenugreek), fisheries, and poultry	Book printed, E-copy, Web Portal, Mobile apps	English, Nepali	One time	Farmers, Extension workers, Agro-advisory committee	-	-
16.	Collection and compilation of irrigation canal data/information covering 25 pilot districts.	Book printed, E-copy, Web Portal, Mobile apps	English	One time	Farmers, Extension workers, Agro-advisory committee	-	-
17	Locally adapted climate resilient technologies in agriculture and livestock	Web Portal	English	One time	Farmers, Extension workers, Agro-advisory committee	-	-

Appendix 3. Different Hydrometeorological and Agrometeorological services value chain examples from Nepal

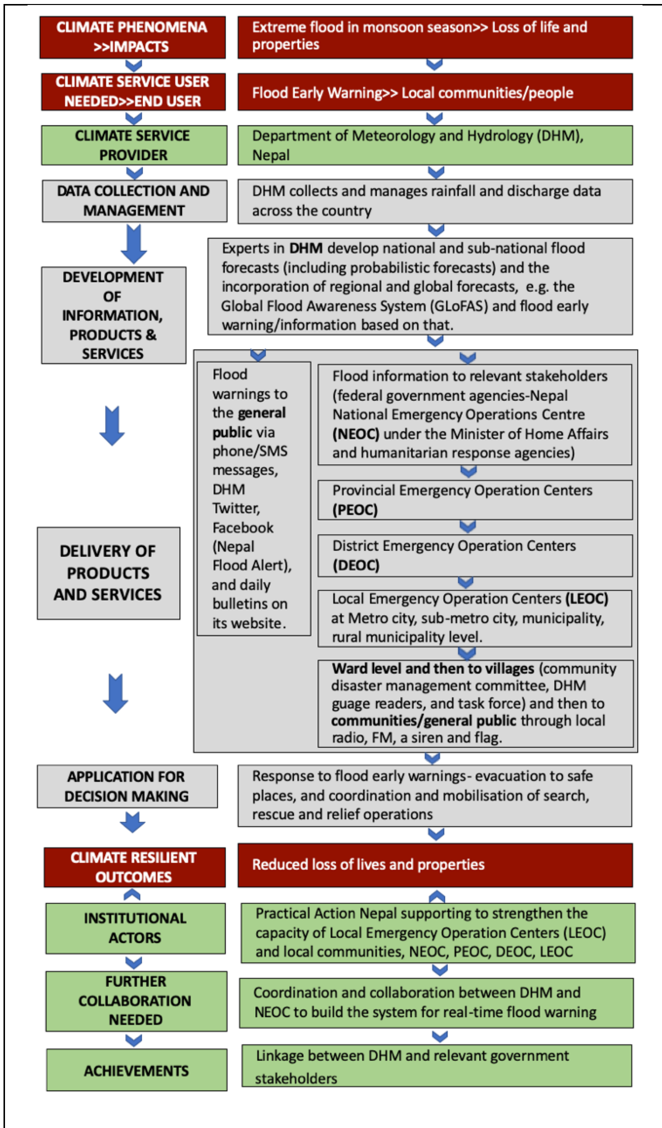

Figure 3.1: DHM's flood early warning service value chain in Nepal

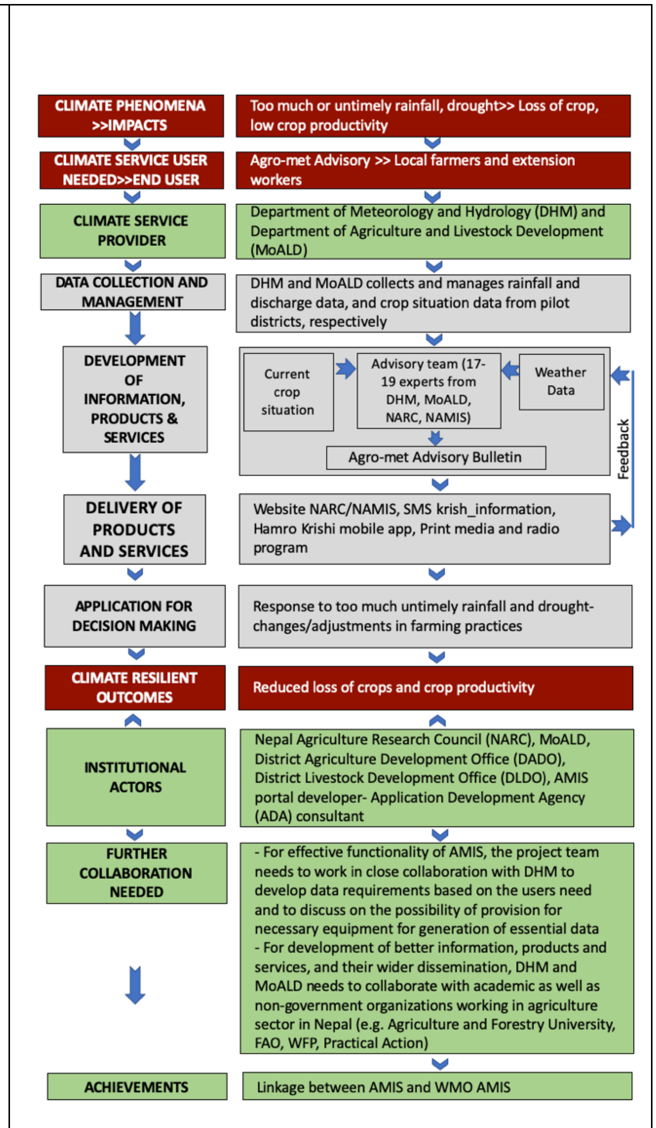

Figure 3.2: MoALD's Agromet Advisory Bulletin (ABB) product value chain in Nepal

Appendix 4. Full list of stakeholder agencies participated in Key Informant Interview (KII)s

S. No	Stakeholder Type	Stakeholder Agency	Number of Key informants
1	**Service providers**	DHM-Kathmandu	1
		DHM-Banke	5
		DHM-Dang	1
		DHM-Chitwan	2
		DHM-Pokhara	6
		DHM-Bhairahawa	6
2	**Intermediary user**	NARC-Kathmandu	5
3		NVC	1
4		MoFE	1
5		NDRRMA	1
6		MoALD	3
7	**Field experts**	Finnish Meteorological Agency	1
8		WFP	3
9		Practical Action	3
10		ADB	1
11	**WBG staff**	World Bank	6
12		IFC	1

Appendix 5. Interview protocol

1. Role of agency: Describe the role of your agency in the value chain
2. Weaknesses of VC: Which elements of the hydromet and climate service system are weakest, and which present the greatest challenge
3. Strengths of VC: Which elements of the hydromet and climate service system are strongest, and which present the greatest challenge
4. Importance of user-provider collaboration: Would you consider collaboration between providers and users in data collection and management important to the successful functioning of the hydromet climate services system in your country?
5. Types of products/services: Which types of hydromet and climate information, products and services are delivered (do you deliver) to your organization, and how is this done?
6. Areas of improvement for data collection and management: What would you suggest are the most important areas where improvements in data collection and management?
7. Areas of improvement for delivery and development of products/services: What would you suggest are the most important areas where improvements in development and delivery of hydromet information, products and services are needed? What improvements would you recommend?
8. Collaboration with stakeholders: Which stakeholders – internationally (including other national NMHSs) and/or nationally (such as local communities) – does your agency collaborate with during development of information, products and services? How important are these partners?
9. Technology influence: Is technological advancement influencing the operation (positively/negatively) of different phases of the value chain (i.e. data collection and management, and development and delivery of information, products and services in any way? If so, how?
10. Utility for decision-making: For the information, products and services that you receive, is content useful for decision-making? Are the information reaching the intended users?
11. Feedback: Do you provide feedback to hydromet and climate information providers and do you receive feedback from users (if you play a role in development and delivery that is)? If so, how is feedback provided and what are the key areas from which improvements are regularly highlighted? (please see list below for guidance). If not, why not?
12. Institutional landscape: How does the wider institutional landscape in your country affect the ability of your organization to deliver or receive a quality service? e.g. institutional leadership, institutional capacities, budgets relationship with key non-government actors, legal frameworks, etc.)
13. Coordination of international actors: How would you describe the coordination of international actors (e.g. WMO, donors, UN agencies, etc.) with respect to hydromet and climate information, products and services in your country? (Excellent; Very good; Good; Poor; Very Poor; Don't Know)

Appendix 6. Demographic characteristics of FGD participants

FGD No.	**FGD Participants *(and Location)***	**Number of Participants**
1	Farmers *(Rapti Sonari Rural Municipality-1, Khaskushma, Banke District)*	11
2	Farmers *(Ghorahi Sub-Metropolitan City-8, Katuki, Dang District)*	18
3	Farmers *(Marchawari Rural Municipality-3, Madhubaniya, Rupendehi, District)*	13
4	Farmers *(Bharatpur Metropolitan-23, Jagatpur, Chitwan, District)*	9
5	Farmers *(Pokhara Metropolitan-33, Bharatpokhari-Dadagaun, Kaski District)*	6
6	Community Disaster Management Committee *(Rapti Rinal Municipality-6, Bagrapur, Dang District)*	14
	Total Number of FGD participants	**71**

Appendix 7. User satisfaction on various sources of agrometeorological information provided by Ministry of Agriculture and Livestock Development (MoALD)

Sources of agrometeorological information	Highly satisfied users (%)	Moderately satisfied users (%)	Neutral (undecided) users (%)	Not satisfied users (%)	Highly not satisfied users (%)	Overall satisfaction level (%)
Hamro Krishi App	22	57	16	6	0	**79**
Kisan call center	14	59	24	3	0	**73**
Krishi (Agriculture) information SMS	28	61	9	2	0	**89**
Agromet Advisory Bulletin	33	17	33	17	0	**50**
Note: This data is based on AMIS project end line survey conducted in 2019 (Source: MoALD, 2019)						