ҮНДЭСНИЙ УС, ЦАГ УУР БОЛОН ХӨДӨӨ АЖ АХУЙН АЖИГЛАЛТ, ҮЙЛЧИЛГЭЭНИЙ ЧАДАВХЫН ҮНЭЛГЭЭНИЙ ТАЙЛАН

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МОНГОЛ УЛСЫН ЗАСГИЙН ГАЗАР

National Hydrometeorlogcial and Agrometeorological Services Capacity Assessment Report

The National Agency for Meteorology and Environmental Monitoring (NAMEM)

Information and Research Institute of Meteorology, Hydrology and Environment (IRIMHE)

WORLD METEOROLOGICAL ORGANIZATION

Food and Agriculture Organization of the United Nations

National Capacity Assessment of the Hydrometeorological and Agrometeorological Service of the Mongolia

Foreword

The demand for accurate and reliable weather, climate, and hydrological (hydromet) information has never been higher. Extreme weather events heatwaves, floods, dzud and droughts cause significant economic damage and loss of life. Effective warning systems and improved hydromet services are essential for minimizing these impacts and enhancing socio-economic resilience.

Reliable hydromet services are crucial for sectors like aviation, agriculture, transport, energy, and tourism. As climate change intensifies natural hazards and rapid urbanization increases vulnerability, investments in hydromet services become even more critical.

The World Meteorological Organization (WMO) is providing technical assistance for Food Agriculture organization (FAO) in Mongolia. To guide the project design, the FAO and WMO conduct National Capacity Assessments (NCAT and ACAT) to assess hydrometeorological and agrometeorological service gaps, water resource management, and cryosphere issues. These assessments ensure future project proposal aligns with national priorities. The report provides a snapshot of the current NHMS status, a phased implementation plan, and Concept of operation for the operational hydrological service for a full EWS value chain.

We appreciate the contributions of all stakeholders and look forward to continued collaboration in advancing hydromet services.

Acknowledgments

This report provides as a result, the NCAT roadmap contains a diagnostic of the current stage of hydrometeorological and agrometeorological services, and a phased short-, mid-, and long-term implementation plan, a concept of operations (CONOPS) for EWS, and a SWOT analysis. It is based on various guidelines, including WMO No. 1286 Assessment Guidelines for End-to-End Flood Forecasting and Early Warning Systems, the Global Hydrological Status and Outlook System (HydroSOS), the Multi-Hazard Early Warning System (MHEWS) Checklist, the Guide to Agricultural Meteorological Practices (WMO-No. 134), and Baseline Assessment of Drought Impact Monitoring (WMO No 1355) and other relevant WMO Technical Guidelines. By incorporating data from the WMO Country Profile Database (CPDB) and the WMO Information System, NCAT and ACAT evaluated and verified the existing capacities and capabilities of Hydrometeorological and agrometeorological Services within the MHEWS environment. The report was prepared by WMO and FAO team.

WMO express their gratitude to the management, all specialists of NAMEM, IRIMHE for the materials provided, and the time devoted to assessing the state of the NHMS and ultimately developing recommendations and an implementation plan.

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List of acronyms

AHC	Automated Hydrological Complex
AMS	Automated Meteorological Station
DBMS	Data Base Management System
EWS	Early Warning System
EW4A	Early Warnings For All Initiative
GMAS	WMO Global Multi-Hazard Warning System
GSM	Global System for Mobile Communications
HydroSoS	Hydrological Status and Outlook System
IT	Information Technology
IRIMHE	Information and Research Institute of Meteorology, Hydrology and Environment
NHMS	National Hydrometeorological Service
NWP	Numerical Weather Predictions
MHEWS	Multi-Hazard Early Warning System
NCAT	National Capacity Assessment Tool
NAMEM	National Agency for Meteorology and Environmental Monitoring
SOP	Standard Operating Procedures
SWOT	Strength Weaknesses Opportunities and Threats analysis
UAV	Unmanned Aerial Vehicles
UIP	Unified Information Platform for early warning and notification of the Ministry of Emergency Situations of the Kyrgyz Republic
WMO	World Meteorological Organization

Summary

This report contains the main results of the implementation of the National Capacity Assessment Tool (NCAT) and Agrometeorology Capacity Assessment Tool (ACAT) In relation to the National Hydrometeorological Service (NHMS) of the Mongolia (NAMEM), as well as recommendations and an implementation plan developed on the basis of the assessment, taking into account short-, medium- and long-term planning horizons.

The objective of the assessment is to improve the accuracy, quality and timeliness of hydrological, meteorological, agrometeorological and other environmental services of the NMHS of the Mongolia, with particular attention to the development and operation of an effective and sustainable early warning system.

NCAT and ACAT tools was used to perform the assessment, based on the application of the WMO Assessment Guidelines for End-to-End Flood Forecasting and Early Warning Systems[1] the Guide to Agricultural Meteorological Practices (WMO-No. 134), and Baseline Assessment of Drought Impact Monitoring (WMO No 1355) and other WMO guidelines and manuals. The set of guidelines and assessment tools that make up the NCAT and ACAT are presented in more detail in the section on the NCAT and ACAT methodology below.

An important stage of the assessment was the so-called pre-trip study to the NMHS, during which WMO Secretariat conducted a desktop study by collectingthe necessary information about the current status of the NMHS from pre-existing surveys, reports and other publicly available materials, recent and significant hydrometeorological events/hazards and their impacts in Mongolia, as well as aspects of the current forecasting system . An important stage was the validation of the pre-filled information and completion of missing information (filling in the assessment matrix) by NAMEM, IRIMHE specialists before the mission, which allowed for targeted discussions and actions with the agencies during the mission along with the verification of the information that was provided.

The period of the mission and work with specialists from NAMEM, IRIMHE on December 1-5, 2025 (Fig. 1) consisted of assessing individual components of the operational hydrological and agrometeorological services by analyzing the assessment guidelines together with specialists from the NMHS responsible for the relevant components of the EWS. Based on the results of the assessment which presented the current capabilities and identified the existing gaps, a set of draft recommendations for improving the operational hydrometeorological and agrometeorological services in the territory of the Mongolia was presented.

[1] WMO No. 1286. Assessment Guidelines for End-to-End Flood Forecasting and Early Warning Systems, 2022

Figure 1. - Communication with NAMEM, IRIMHE staff during a visit on December 1-5, 2025.

SOURCE: AUTHORS' OWN ELABORATION

A validation workshop outlining the results of the NCAT and ACAT findings was held in the UN compound in Ulaanbaatar, on 5 December 2025. The workshop also provided the opportunity to work with specialists from the NMMS and other stakeholders, to further refine the recommendations aligning with the needs of the country. These refined assessment results and recommendations, expressed in the form of an action plan for the short, medium and long terms, are presented in this report.

The annex to the report contains additional analysis materials obtained during the assessment, including the results of the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis . Also included in the annex is information on the observation networks of NAMEM, IRIMHE (meteorological, agrometeorology and hydrological), institutional features of NAMEM in relation to the early warning system. A separate section of the annex contains a checklist of the concept of operations foroperational hydrological and agrometeorological services (CONOPS) and the CONOPS of the current and recommended system for operational hydrological services and agrometeorological of NAMEM, IRIMHE.

1. Status of NMHS

The National Hydrometeorological Service (NHMS) of the Mongolia (NAMEM) is a division within the Ministry of Environment and Climate Change.

The organizational structure of NAMEM is presented in Figure 2 outlining the different departments and divisions.

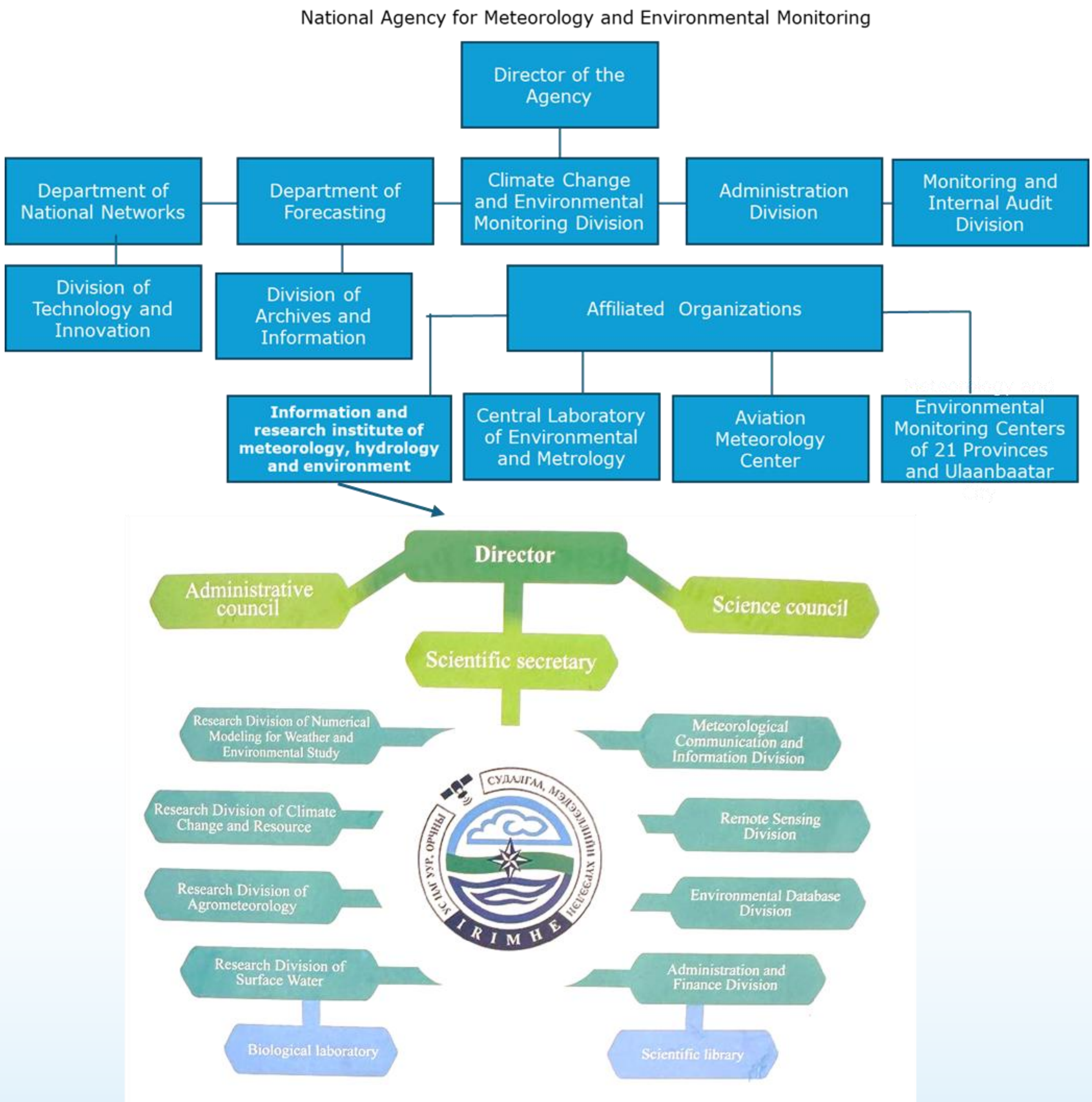

Figure 2. - Structure of NAMEM, IRIMHE

SOURCE: NAMEM, IRIMHE

The results of the assessment are presented in the graph (Figure 3), which gives an indication on the status of NAMEM, IRIMHE and the various components of their early warning system such as observation network infrastructure, data processing, methods and models, forecasting products, dissemination of information to users, and feedback from the users .

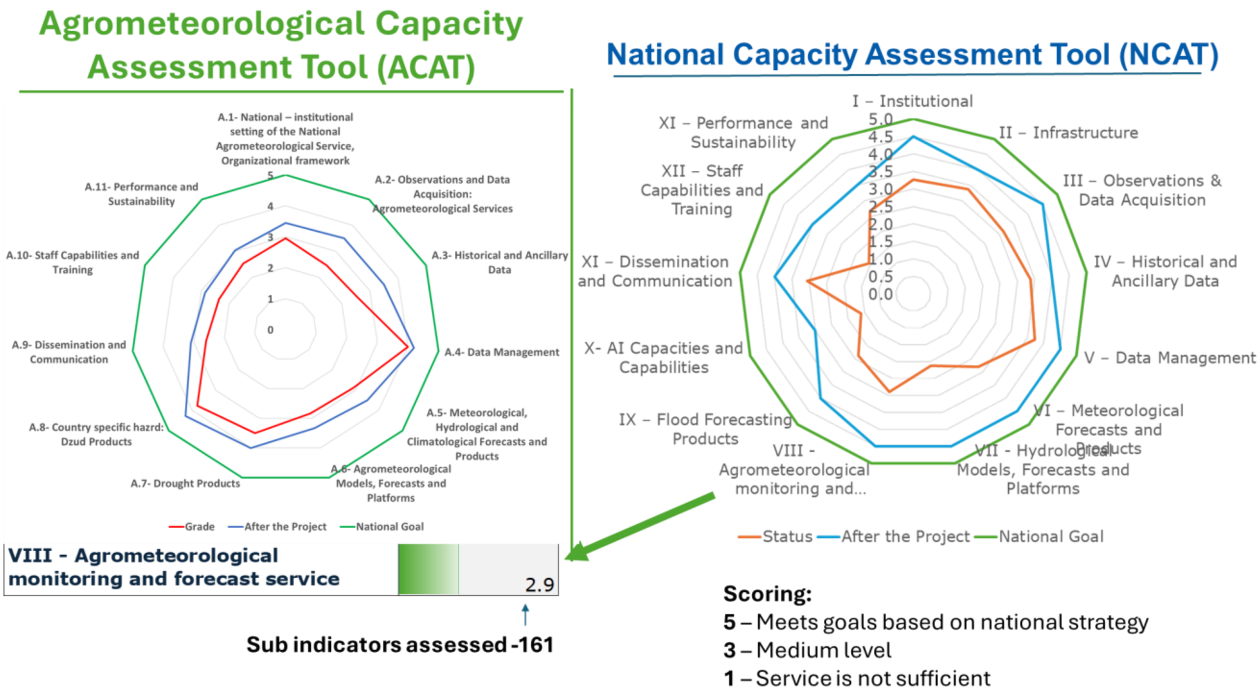

Figure 3. - Status of NAMEM, IRIMHE based on the completed assessment

SOURCE: AUTHORS' OWN ELABORATION

The objective of the report is to highlight the existing gaps within the early warning system value chain of Mongolia across the various components and to provide guidance on improving them.

2. NCAT and ACAT Methodology

2.1. NCAT methodology

NCAT methodology makes use of various assessment tools and guidelines developed by WMO to provide NMHSs with the desired level of performance for their operational hydrological, meteorological and agrometeorological services, as well as to assess the current state of the EWS, identifying weaknesses, areas of potential growth, and EWS sections that require special attention to enhance the level of hydrological services in terms of forecasts and warnings of dangerous floods, inundations, mudflows, drought and other dangerous hydrological phenomena.

Implementation of NCAT enables reporting and support for task completion through the following three stages:

- Stage 1: Assessment of Flood Early Warning Systems: uses national and regional assessments to map and assess the stakeholders and existing capacities of hydrological services within the Multi-Hazard Early Warning System (MHEWS); uses information on NMHSs from various sources with further assessments in line with WMO guidelines; describes and analyses the strengths and weaknesses of Flood EWS at national and transboundary levels along the chain of hydrological product production and delivery to end users.
- Stage 2: Implementation of the WMO Guidelines and Practices for Operational Hydrology, which outline assessment principles for end-to-end flood forecasting and early warning systems[2] and the Guide to Hydrological Practices[3, 4] as well as other guidelines (e.g. MHEWS Checklist; Impact-based Forecasting and Warning Services; Service Delivery; Numerical Weather Prediction).
- Step 3: In addition to assessing compliance with relevant WMO initiatives such as Early Warning for All (EW4All), the principles laid down in the Hydrological Status and Outlook System (HydroSOS) system for assessing the hydrological status of water bodies are used.

One of the main stages of the work within the NCAT assessment is the use of the WMO Assessment Guidelines on End-to-End Flood Forecasting and Early Warning Systems, developed by the WMO Commission for Hydrology and since 2019 with experts from the WMO Standing Committee on Hydrological Services .

This guide covers the assessment of all the main components of the flood EWS, going beyond the NMHS to include end users of flood forecasts and warnings. That is, all actors and organizations involved in the process of issuing operational flood forecasts and warnings, and the users of these products are considered.

An EWS is a chain of actions, that includes the following stages: collection of initial information, its analysis, processing, modeling, use of meteorological forecast products, meteorological forcing of hydrological models, release of operational forecasts and generation of warnings which are subsequently delivered to the end users and their response to these warnings. The main stages of the EWS are presented in Fig. 4.

[2] WMO No. 1286. Assessment Guidelines for End-to-End Flood Forecasting and Early Warning Systems, 2022
[3] Guide to Hydrological Practices, Volume I : Hydrology – From Measurement to Hydrological Information (WMO-No. 168), 2008

[4] Guide to Hydrological Practices, Volume II : Management of Water Resources and Applications of Hydrological Practices (WMO-No. 168), 2009

Figure 4 – Main stages (components) of the EWS on floods

SOURCE: AUTHORS' OWN ELABORATION

The assessment guide should be implemented in the following four chronological stages:

- preparatory stage;
- Application of the Assessment Matrix (Assessment Guidelines Tool);
- performing a SWOT analysis - analysis of strengths and weaknesses, identifying growth points and future risks;
- preparation of the assessment report.

The first step is a preparatory stage which is aimed at gathering information on the activities of the NMHS, defining flood forecasting methods related to the EWS, assembling a group of experts for assessment and planning the strategy for conducting the assessment in the country. At this stage, it is important to understand:

- the structure of the NHMS at the national (and transboundary) level and its interaction with other services involved in the process of producing flood forecasting products (e.g. disaster management authorities, water management agencies, dam, reservoir or facility operators, local authorities and other stakeholders).
- Assessors should document the responsibilities of each organization in terms of: providing data and products; generating forecasts and warnings; interpreting consequences, communicating and disseminating information; and responding to emergency situations.

The second step is to complete the Assessment Matrix (AM). The Matrix is a tool developed as a comprehensive template (Excel sheets) to assist in this process. The Matrix is designed to assist in collecting information for the assessment and contains the following sections (individual sheets with questions). Each of the 11 sections of the Assessment Matrix (listed below) covers a specific link in the chain that makes up the flood preparedness and forecasting process (Figure 5).

(i) Institutional;

(ii) Infrastructure;

(iii) Observations and data collection;

(iv) Historical and supporting data;

(v) Data management;

(vi) Meteorological forecasts and products;

(vii) Hydrological models, forecasts and platforms;

(viii) Flood forecasting products;

(ix) Dissemination and communication;

(x) Staff capabilities and training;

(xi) Performance and sustainability.

In addition to the 11 sections, there are ten supporting tables that contain detailed information to support the assessment. These tables are referred to as follows:

(i) AUX _NHMS structure;

(ii) AUX _Network of meteorological stations;

(iii) AUX _Network of hydrological gauges;

(iv) AUX _Competencies and training;

(v) River Discharge;

(vi) Groundwater;

(vii) Reservoirs Lakes and Glaciers;

(viii) Soil Moisture;

(ix) Hydro Status Products;

(x) Hydro Outlooks Systems.

Each section of the assessment matrix is divided into subsections that address specific topics within that section. Each subsection is provided with guidance for the assessor, possible response options, which are also accompanied by a specific score (for performing a formal quantitative assessment). It should be noted that not all questions within the matrix are graded.

The information captured in the matrix should provide a comprehensive overview of the state of the operational hydrology services. The matrix serves as a basis for further analysis, including the preparation of recommendations for improving the component of the EWS.

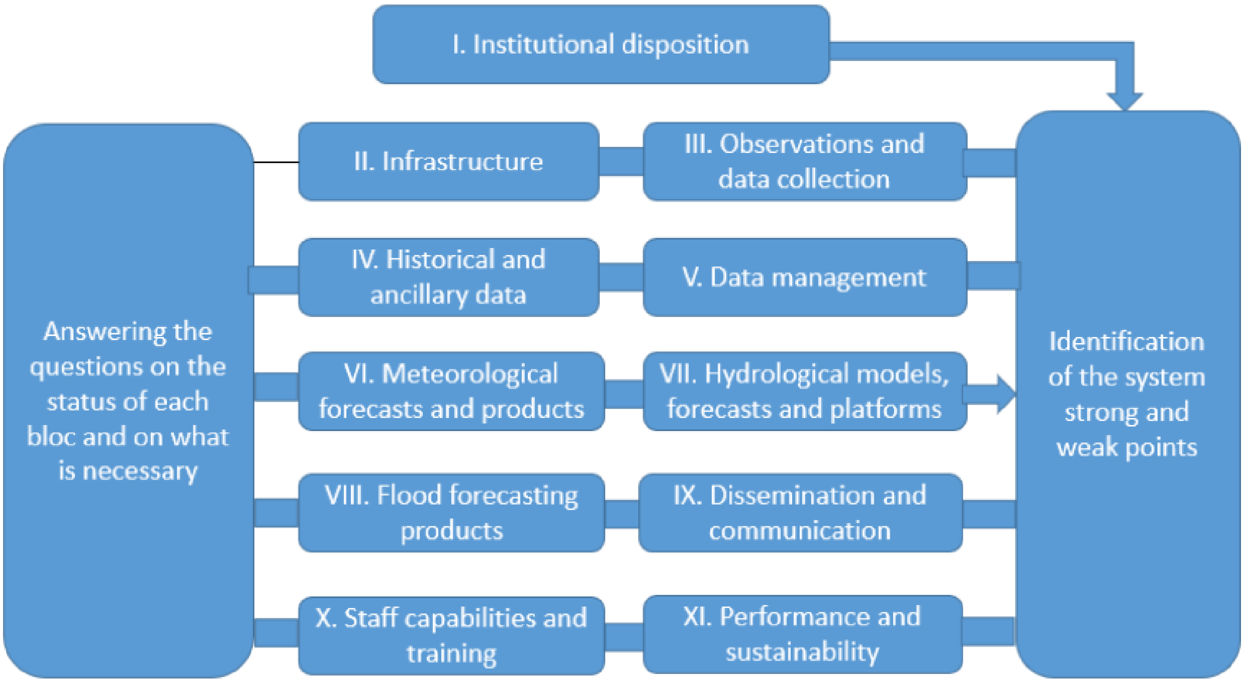

Figure 5 – Sections of the Assessment matrix

SOURCE: AUTHORS' OWN ELABORATION

The next step in implementing the assessment guideline is a SWOT analysis. The purpose of completing this type of assessment is to examine the areas in which the country's SOPs could be improved to better meet the needs of end users. It is believed that using the SWOT analysis tool can assist an organization in setting performance-based objectives and priorities for improving the SOPs.

The SWOT analysis provides important information needed to define a service improvement plan and ultimately a national development plan that will lead to improved flood forecasting and warning services.

To perform the analysis, it is necessary to follow a certain structure.

The final stage of using the assessment guideline is the consolidation of the information from the assessment matrix and the findings of the SWOT analysis into a report that outlines the current status and provides recommendations for improving the existing capacities of the NMHS.

2.2. ACAT methodology

The Agrometeorological Capacity Assessment Tool (ACAT) is a standardized methodology designed to evaluate national capacities for the delivery of end-to-end agrometeorological services. The ACAT methodology builds on a suite of WMO-approved guidelines and good practices, including the Guide to Agricultural Meteorological Practices (WMO-No. 134[5]), the Baseline Assessment of Drought Impact Monitoring (WMO-No. 1355[6]), and related guidance on service delivery, impact-based forecasting, and early warning systems. ACAT aims to assess both the current operational status of agrometeorological services and their readiness to support risk-informed decision-making, climate adaptation, and anticipatory action in the agriculture sector.

ACAT follows an end-to-end service chain approach, covering all key components required for effective agrometeorological service provision. These include institutional arrangements and governance; observation networks and data acquisition; historical and ancillary datasets; data management and quality control; meteorological, hydrological, and climate forecasts; agrometeorological models and platforms; drought and climate risk monitoring; dissemination and communication; staff capacities and training; and performance, sustainability, and financing mechanisms. The methodology explicitly considers linkages between NMHSs, Ministries of Agriculture, extension services, research institutions, and other stakeholders involved in agricultural decision-making.

The assessment is implemented through a structured Assessment Matrix (similar to NCAT), designed as a comprehensive template to guide systematic information collection. The Matrix consists of thematic sections, each corresponding to a specific link in the agrometeorological service chain. Within each section, detailed questions are provided along with guidance notes and predefined scoring options, enabling both qualitative and quantitative assessment. Scores are used to indicate levels of maturity, ranging from limited or ad hoc capacities to fully operational, institutionalized, and sustainable systems.

A core element of the ACAT methodology is the emphasis on use of agrometeorological information for decision support. The assessment examines not only the technical production of data and forecasts, but also how these outputs are translated into actionable advisories, co-produced with users, and disseminated through appropriate channels. Particular attention is given to services supporting drought risk management, crop and livestock decision-making, climate variability, and extreme events, as well as the integration of agrometeorological services into broader early warning systems and anticipatory action frameworks.

Following completion of the Assessment Matrix, the results are synthesized to identify strengths, weaknesses, gaps, and priority areas for improvement. This may be complemented by qualitative analysis, including stakeholder consultations and review of national strategies, policies, and operational practices. The findings form the basis for evidence-based recommendations aimed at strengthening agrometeorological services, improving institutional coordination, enhancing technical capacities, and increasing the impact of climate information on agricultural resilience and food security.

The final output of the ACAT process is an assessment report that documents the current status of agrometeorological services and provides a clear, prioritized roadmap for development. This supports national planning, investment prioritization, alignment with WMO initiatives such as Early

[5] https://wmo.int/guide-agricultural-meteorological-practices-gamp2010-edition-wmo-no134
[6] https://library.wmo.int/records/item/69496-baseline-assessment-of-drought-impact-monitoring

Warnings for All, and integration of agrometeorological services into national climate adaptation, disaster risk reduction, and agricultural development strategies.

2.3. Linking of the NCAT–ACAT–AI checklist

The assessment applies a complementary set of WMO-aligned tools, combining the NCAT, the ACAT, and an AI capacities and capabilities checklist to provide a comprehensive evaluation of end-to-end early warning and anticipatory action systems. NCAT focuses on operational hydrology and flood early warning systems, ACAT assesses agrometeorological service delivery across the agricultural value chain, and the AI checklist examines institutional, technical, and human capacities to apply digital and AI-enabled approaches for impact forecasting and anticipatory action. Together, these tools enable a coherent analysis of governance, data, modelling, service delivery, and innovation readiness, identifying gaps and priorities for strengthening climate and disaster risk services.

2.4. Interpretation of the NCAT and ACAT assessment results and scales:

Interpretation of NCAT and ACAT assessment results is based on a standardized scoring scale applied across all assessment dimensions. Scores reflect the maturity and effectiveness of services relative to national strategies and international good practices.

- A score of 5 indicates that the service meets established goals and aligns with national strategies,
- 3 represents a medium level of capacity with partial functionality,
- 1 indicates that the service is insufficient and requires substantial improvement.

This scoring approach enables consistent comparison across service components and supports prioritization of actions for system strengthening.

3. Diagnostics of NMHS

3.1 Institutional

Maturity score and interpretation: 3 (Established, partially integrated)

A maturity score of **3.3/5** indicates that Mongolia has a clearly established institutional framework for hydrometeorological services and disaster risk management, with defined mandates, operational agencies, and legal recognition. Core institutional functions are operational and broadly understood by national stakeholders. However, the system remains partially integrated, with overlapping roles, uneven coordination mechanisms, and limited formalization of end-to-end service delivery across agencies. The score reflects a system that functions reliably for routine operations but requires structural strengthening to fully support multi-hazard early warning systems, impact forecasting, and anticipatory action at national scale.

3.1.1 Institutional setting and mandates

Mongolia's hydrometeorological and early warning system is anchored in the National Agency for Meteorology and Environmental Monitoring (NAMEM), which holds the national mandate for meteorology, hydrology, climate, and environmental monitoring. NAMEM operates as a government implementing agency and is responsible for policy-level oversight, coordination, and service provision at national level.

The Information and Research Institute of Meteorology, Hydrology and Environment (IRIMHE) functions as the primary technical and scientific arm under NAMEM. IRIMHE is responsible for operational forecasting, climate services, agrometeorological services, hydrological monitoring, research, and product development. During the mission, it was repeatedly confirmed that IRIMHE carries most of the day-to-day technical work, including forecasting, modelling, data analysis, and sector-oriented products.

At the disaster risk management level, the National Emergency Management Agency (NEMA) is the legally mandated authority for disaster preparedness, response, and coordination, operating in line with the Sendai Framework. NEMA relies on hazard information and warnings produced by NAMEM and IRIMHE to support preparedness, contingency planning, and response actions. Under NEMA, a disaster research institute contributes analytical inputs, though integration with hydrometeorological workflows remains limited.

This institutional arrangement is well recognized nationally and was consistently confirmed during meetings with NAMEM, IRIMHE, NEMA, UN agencies. There is no ambiguity regarding which institutions are responsible for hazard monitoring, forecasting, and disaster response. This clarity of mandate is a key strength contributing to the relatively high institutional score

3.1.2 Coordination and role clarity

Despite clear mandates, the assessment identified functional overlap between NAMEM and IRIMHE, particularly in dissemination and external coordination. In practice, NAMEM occasionally undertakes technical dissemination tasks that would typically fall within IRIMHE's operational remit. While this has not caused systemic failure, it reflects institutional blurring rather than a formally defined operational model.

Coordination mechanisms between NAMEM, IRIMHE, and NEMA are largely relationship-based and event-driven, rather than governed by standardized operating procedures or formal Concepts of Operations (CONOPS). During the 2023–2024 dzud event, coordination improved significantly through contingency planning and ad hoc arrangements, including anticipatory action elements. However, these arrangements were not institutionalized following the event.

At sub-national and local levels, disaster risk management plans exist for major hazards, and state-level DRM plans are in place. However, systematic linkage between national hydrometeorological services and local decision-making remains uneven, contributing to gaps in last-mile information flow, particularly for agriculture and pastoral communities.

3.1.3 Legal and Policy Mandates

Mongolia's hydrometeorological services and disaster risk management functions are underpinned by a defined legal and policy framework, which establishes mandates for monitoring, forecasting, warning, and emergency response.

Key instruments include:

- **Law on Meteorology and Environmental Monitoring (1997, amended)** This law establishes the national mandate for meteorological, hydrological, agrometeorological, and environmental observations, data management, forecasting, and information provision. Under this law, the National Agency for Meteorology and Environmental Monitoring (NAMEM) is designated as the competent authority for national hydrological and meteorological services.
- **Law on Disaster Protection (2017)** This law defines the national disaster risk management system and assigns the National Emergency Management Agency (NEMA) as the lead authority for disaster preparedness, response, recovery, and coordination at national and sub-national levels. It also establishes obligations for sectoral agencies to cooperate in early warning and emergency response.
- **National Disaster Risk Reduction Strategy (aligned with the Sendai Framework)** The strategy emphasizes early warning, risk-informed decision-making, and preparedness, including for slow-onset hazards such as drought and dzud.
- **State Policy on Climate Change (2017–2030)** Provides the policy basis for climate monitoring, climate services, and climate risk assessment, including sectoral applications for agriculture and water resources.

Other Relevant Institutions

- Sectoral ministries, particularly agriculture and water-related institutions, use hydromet information for planning and response
- River basin organizations contribute hydrological data and water management decisions
- National Statistical Office (NSO) maintains socio-economic and impact data relevant to exposure, vulnerability, and loss assessment
- Humanitarian partners (FAO, IFRC, UN agencies) operate anticipatory action frameworks, often in parallel rather than fully integrated at national level

3.1.4 Coordination Mechanisms

Current coordination mechanisms include:

- Event-based coordination during major disasters (e.g. dzud, floods)
- Ad hoc technical exchanges between NAMEM/IRIMHE and NEMA
- Project-based coordination under externally funded initiatives (e.g. GCF, ADB, FAO, IFRC)

However:

- There is no nationally endorsed Concept of Operations (CONOPS) defining end-to-end workflows from monitoring to action
- Roles in impact forecasting, trigger definition, and anticipatory action activation are not consistently formalized
- Coordination is person-dependent rather than system-based
- Sub-national institutions receive warnings but often lack clear guidance on interpretation and action

3.1.5 Anticipatory Action and Impact Forecasting

Mongolia has demonstrated practical experience with anticipatory action, particularly during the 2023–2024 dzud, where early measures reportedly reduced losses significantly. However:

- These actions were event-specific, not institutionalized
- No nationally agreed multi-hazard anticipatory action framework exists
- Impact-based forecasting is applied inconsistently and is not yet embedded in routine operations

This represents a strong foundation but incomplete institutional maturity for anticipatory action.

The primary gap is operational integration, not institutional absence.

Current Status	Needs
• National mandates for meteorological, hydrological, agrometeorological, and environmental monitoring are clearly established under the *Law on Meteorology and Environmental Monitoring (1997, amended)*, with NAMEM designated as the competent authority.	• Focus on translating existing legal mandates into standardized operational procedures across institutions rather than introducing new legislation.
• Disaster preparedness, response, and coordination responsibilities are defined under the *Law on Disaster Protection (2017)*, with NEMA acting as the lead disaster risk management agency.	• Stronger operational integration between hydrometeorological services and disaster response mechanisms, particularly for early action.
• NAMEM provides governance and oversight, while IRIMHE functions as the primary technical and scientific institution responsible for monitoring, forecasting, and research.	• Clearer operational delineation between governance, technical production, and dissemination functions to reduce role overlap.
• Coordination between NAMEM, IRIMHE, and NEMA occurs mainly during major hazard events and through informal or project-based arrangements.	• Development and national endorsement of a Concept of Operations (CONOPS) defining end-to-end early warning workflows.
• Impact-based forecasting has been applied in selected cases, particularly during dzud events, using hazard and sectoral information.	• Formalization of impact-based forecasting methodologies, thresholds, and standard operating procedures across hazards.
• Anticipatory action tried during the 2023–2024 dzud through contingency planning and early measures coordinated with partners, but it is not unified nor the national framework exists.	• Institutionalization of a multi-hazard anticipatory action framework aligned across government agencies and humanitarian partners.
• Sectoral agencies, including agriculture and water-related institutions, receive hydrometeorological information on an ad hoc basis.	• Structured protocols for sectoral engagement, including tailored products and decision-support guidance.
• Sub-national authorities (aimag and soum levels) receive warnings but have limited technical tools and guidance to support timely action.	• Strengthening of sub-national capacities through training, simplified guidance, and operational decision-support tools.
• Hydrometeorological products are disseminated to users, primarily through official channels and websites.	• Establishment of systematic user feedback and post-event review mechanisms to improve service relevance and effectiveness.
• Core hydrometeorological and disaster management institutions are stable, though leadership changes periodically affect coordination continuity.	• Documentation of institutional processes and workflows to ensure continuity and institutional memory.

3.2 Infrastructure

Maturity score and interpretation: 3– Established, generally adequate but uneven

A maturity score of **3.4/5** indicates that the core infrastructure components are in place and operational across Mongolia's hydrometeorological system. Infrastructure development has, however, largely occurred incrementally through multiple externally funded projects over time, rather than through a single consolidated modernization programme. As a result, infrastructure systems are heterogeneous, with variable standards, differing equipment lifecycles, and uneven levels of redundancy.

Overall, the existing infrastructure is adequate for current service levels, supporting routine monitoring, forecasting, and dissemination. At the same time, it exhibits limited scalability to accommodate the increasing technical demands associated with high-resolution modelling, impact-based services, anticipatory action, and emerging AI-enabled applications. Targeted modernization and consolidation are therefore required to support future operational requirements and national early warning ambitions.

3.2.1 Physical facilities and operational spaces

NAMEM and IRIMHE operate from established premises that accommodate operational forecasting rooms, technical offices, data handling units, and supporting administrative functions. These facilities enable routine operations during standard working hours and provide a functional base for coordination during hazard events.

The assessment indicates, however, that infrastructure specifically designed for multi-hazard operations remains limited. Dedicated spaces for:

- joint inter-agency briefings,
- integrated situation awareness,
- and sustained surge operations (24/7 staffing during extreme events)

are not yet fully developed. Existing operational spaces are not optimized for integrated decision-support functions, particularly those requiring the visualization and combined analysis of meteorological, hydrological, agrometeorological, and impact information across agencies.

3.2.2 ICT infrastructure and computing capacity

Core ICT infrastructure supports operational workflows, including:

- numerical weather prediction,
- climate modelling,
- data processing,

- and product dissemination.

Computing resources are sufficient for current deterministic forecasting and routine modelling tasks. However, increasing demands are being placed on computing and storage capacity as IRIMHE expands its technical scope, including:

- higher model resolution and expanded domain coverage,
- ensemble forecasting and scenario analysis,
- integration of hydrological and agrometeorological models,
- exploratory use of AI-assisted data processing and quality control.

Network connectivity supports internal operations and external dissemination. The assessment did not, however, confirm consistent redundancy arrangements or guaranteed bandwidth sufficient to support sustained high-demand operations or real-time, multi-agency data exchange during major events.

3.2.3 Power supply and operational resilience

Primary power supply arrangements are in place to support routine operations, and backup systems are reportedly available for critical functions. However, the assessment did not identify a fully documented, standardized, and regularly tested backup power architecture covering all operationally critical systems and spaces.

Given Mongolia's exposure to extreme weather conditions, particularly during severe winter events, continuous and reliable power supply is essential for forecasting, monitoring, and communication systems. Strengthening power redundancy and testing protocols is therefore a critical element of infrastructure resilience and service continuity.

3.2.4 Maintenance, calibration, and technical support infrastructure

Infrastructure supporting equipment maintenance and calibration is available through a central laboratory function within NAMEM, complemented by maintenance activities conducted at regional offices. This arrangement provides a foundational capacity for sustaining observation systems and technical equipment.

Nevertheless, the assessment identified persistent gaps in:

- availability of reference instrumentation for calibration,
- mobile calibration capability,
- capacity to fully support certain key parameters, notably wind, precipitation, humidity, and radiation.

These limitations increase reliance on external support and constrain the ability to systematically verify and maintain diverse equipment introduced through multiple projects and suppliers. As a result, infrastructure for maintenance and calibration has not kept pace with the expansion and diversification of the observation network.

3.2.5 Infrastructure readiness for future service requirements

From an operational perspective, existing infrastructure supports the provision of essential national services. However, to meet evolving requirements related to multi-hazard early warning systems, impact-based services, and anticipatory action, further infrastructure strengthening is required.

Key areas for improvement include:

- scalability of computing and data infrastructure,
- redundancy of power and network systems,
- interoperability across heterogeneous platforms,
- and enhancement of operational environments for integrated, user-oriented, decision-support services.

Key areas include improving scalability, redundancy, interoperability, and the operational environment required for integrated, user-oriented, and decision-support services.

Current Status	Needs Identified
• Established operational facilities support routine forecasting, data processing, and dissemination activities at national level.	• Modernization of operational environments to support integrated multi-hazard coordination, joint briefings, and surge operations.
• Core ICT infrastructure supports deterministic forecasting and routine modelling.	• Targeted upgrading of computing, storage, and network capacity to support higher-resolution models, ensembles, and AI-assisted workflows.
• Network connectivity enables internal operations and public dissemination of products.	• Improved bandwidth reliability and redundancy to support real-time data exchange and sustained high-demand operations.
• Power supply arrangements exist for essential operations.	• A documented, tested backup power architecture covering all critical operational systems and rooms.
• Central calibration and maintenance infrastructure is in place, supported by regional offices.	• Upgraded reference instruments, mobile calibration capability, and expanded capacity for under-served parameters.
• Technical equipment has been procured through multiple projects over time.	• Greater standardization of equipment specifications, maintenance procedures, and lifecycle management.
• Infrastructure supports current service levels and operational demands.	• Strategic infrastructure consolidation and modernization aligned with future service expansion and national early warning objectives.

3.3 Observations and Data Acquisition

3.3.1 Baseline observation system maturity and scope

Baseline NCAT maturity score (Observations and Data Acquisition): 3

A maturity score of approximately 3.1/5 indicates that Mongolia's national hydrometeorological observation system is established, nationally functional, and operational, but not yet fully optimized for advanced forecasting, impact-based (IB) services, anticipatory action (AA), or AI-enabled applications for benefitting from emerging technologies.

Mongolia operates a nationally extensive hydrometeorological observation system covering meteorological, hydrological, agrometeorological, and environmental parameters across a territory of approximately 1.56 million km², characterized by strong climatic gradients and extreme seasonal variability.

Based on the assessment, Mongolia maintains:

- 137 meteorological stations
- 181 meteorological observation posts
- 154 hydrological stations

This represents a relatively dense observational footprint when normalized by population density, but spatial gaps remain in remote mountainous regions and the Gobi Desert, particularly for parameters critical to impact forecasting.

The observation network is operational and nationally functional, but data consistency, parameter completeness, and real-time reliability limit its full effectiveness for advanced forecasting, impact-based services, and anticipatory action.

3.3.2 Meteorological Observation Network

Surface Observations

The national meteorological network includes both **manual stations and Automatic Weather Stations (AWS)**. Automation began in **2003**, with AWS deployment accelerating through donor-funded projects.

However, assessment findings highlight key quantitative and technical challenges:

- The proportion of fully automated stations remains below optimal levels for operational homogeneity (exact percentage varies by region and is not centrally consolidated).
- AWS and manual stations often operate in parallel without a formal transition protocol, leading to:
    - Systematic discrepancies in wind speed, with AWS often reporting higher values

- Lower relative humidity readings from AWS compared to manual observations
- Significant inconsistencies in precipitation measurements, particularly during snowfall and mixed-phase precipitation events

These discrepancies are attributable to:

- Sensor height differences
- Shielding and siting inconsistencies
- Use of multiple AWS manufacturers and sensor models, introduced through different projects

No nationally harmonized bias-correction or homogenization procedure is currently applied operationally to reconcile these differences.

Upper-Air Observations

Mongolia operates **7 upper-air (radiosonde) stations**:

- 4 stations operational
- 2 stations under maintenance
- 1 station non-operational

This results in reduced temporal and spatial coverage of vertical atmospheric profiles. The limited availability of upper-air data constrains:

- Numerical Weather Prediction (NWP) performance
- Medium-range forecast skill
- Seasonal outlook consistency

This limitation was identified as a contributing factor to the low forecast skill (~20%) reported for the 2023–2024 dzud outlooks, particularly during the October–November transition period.

3.3.3 Hydrological Observation Network

Mongolia's hydrological observation network comprises **154 river and water level stations**, monitoring major basins and tributaries.

Assessment findings indicate:

- Most major rivers are monitored, but tributary coverage is uneven, particularly in headwater catchments contributing to rapid runoff.
- High-flow measurements are limited, due to:
  - Insufficient access to ADCPs and modern flow-measurement equipment
  - Logistical constraints during flood events
- Rating curves are available at most key stations, but:
  - Many curves are not updated regularly

    - High-flow segments are often extrapolated rather than measured

These limitations directly affect:

- Flood peak estimation
- Model calibration and verification
- Reliability of flood impact thresholds

3.3.4 Agrometeorological and Environmental Observations

Agrometeorological observation is a recognized strength of Mongolia's system.

Quantitative capacities include:

- Approximately 1,500 soil sampling locations monitored through field-based campaigns
- Land cover and desertification mapping updated every 5 years using remote sensing
- Operational use of SPI and SPEI drought indices

However, critical quantitative gaps remain:

- Snow Water Equivalent (SWE):
    - Measurements are predominantly manual
    - Spatial density is insufficient to capture dzud heterogeneity
- Soil moisture:
    - Limited in-situ continuous measurements
- Evapotranspiration (ET):
    - No operational ET measurement network in place

Satellite products are used for snow cover and vegetation monitoring, but ground-based validation capacity is insufficient, limiting operational confidence

3.3.5 Data Transmission and Reliability

Observation data transmission uses a mix of:

- GSM/mobile networks
- Project-specific communication systems

Assessment findings indicate:

- Reasonable transmission reliability under normal conditions
- Increased data loss during extreme winter events, particularly in remote areas
- Limited redundancy, with few alternative transmission paths available

No centralized performance statistics on transmission success rates were available at the time of assessment.

WORLD METEOROLOGICAL ORGANIZATION

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3.3.6 Suitability for Impact Forecasting and Anticipatory Action

From a quantitative and scientific perspective, the observation system currently supports:

- Deterministic weather and climate forecasting
- Basic flood and drought monitoring
- Seasonal dzud assessment

However, it does not yet fully support:

- High-resolution impact modelling
- Robust anticipatory action triggers
- AI model training requiring homogeneous, quality-controlled datasets

Key constraints include:

- Limited calibration and maintenance reducing quality and reliability
- Inconsistent time series
- Limited high-frequency observations for rapid-onset hazards
- Insufficient parameter coverage for loss modelling

Current Status	Needs Identified
• 137 meteorological stations and 181 observation posts provide national surface coverage.	• Quantified assessment of spatial gaps and targeted infilling in mountainous and arid regions.
• Automation introduced since 2003; AWS widely deployed.	• Harmonized AWS specifications, transition protocols, and operational homogenization procedures.
• 7 upper-air stations exist; only 4 fully operational.	• Restoration of all upper-air stations and sustained maintenance capacity.
• 152 hydrological stations monitor major rivers.	• Increased high-flow measurement capacity and systematic rating curve updates.
• Agrometeorological system includes ~1,500 soil sampling locations.	• Continuous soil moisture and ET observation capability for operational drought and dzud forecasting.
• SWE observations largely manual.	• Deployment of automated SWE sensors and mobile snow-survey equipment.
• Satellite products used for snow and vegetation monitoring.	• Expanded in-situ validation network to improve reliability of satellite-derived products.
• Data transmission generally functional.	• Redundant transmission paths and performance monitoring, especially for extreme conditions.
• Maintenance and calibration capacities are at critical need situation both for in-situ, mobile calibration sets as well as reference measurement devices.	• Renovation and reequipping the calibration capabilities.

Mongolia maintains a nationwide meteorological observation network comprising synoptic stations, climatological stations, and observation posts. Automation has progressed steadily since the early 2000s, with a significant number of Automatic Weather Stations (AWS) now operational.

However, the assessment identified several structural issues:

- **Parallel operation of manual and automated stations** without a sufficiently managed transition period
- **Inconsistencies between AWS and manual observations**, particularly for wind speed, humidity, and precipitation
- Deployment of AWS equipment from **multiple manufacturers and models**, introduced through different projects

These factors contribute to data inhomogeneity and complicate calibration, maintenance, and long-term climate analysis.

Upper-air observations are conducted through a limited number of radiosonde stations. While upper-air capability exists, several stations were reported as under maintenance or non-operational during the mission, reducing the robustness of atmospheric profiling for numerical weather prediction.

3.4 Historical and Ancillary Data

3.4.1 Baseline data maturity and scope

Baseline NCAT maturity score (Historical and Ancillary Data): 3

A maturity score of approximately 3.4/5 indicates that Mongolia possesses substantial volumes of historical hydrometeorological and related ancillary data, but that these data are not yet fully optimized for operational forecasting, impact analysis, or advanced analytics due to gaps in digitization, metadata completeness, consistency, and accessibility.

Historical and ancillary data form the scientific basis for climate analysis, hydrological modelling, impact assessment, and anticipatory action. Mongolia has accumulated long-term hydrometeorological records spanning several decades, reflecting one of the longest continuous observation histories in Central and East Asia.

The assessment confirms that Mongolia possesses substantial volumes of historical meteorological, hydrological, agrometeorological, snow, and environmental data. However, data accessibility, metadata completeness, digitization status, and suitability for advanced modelling vary significantly across data types and regions.

3.4.2 Meteorological and Climate Data Archives

Mongolia maintains long-term meteorological records from its national station network, with some climate stations providing continuous observations since the mid-20th century (1940s–1950s).

Key characteristics include:

- Daily and sub-daily records of temperature, precipitation, wind, humidity, pressure, and snow depth
- Use of climate indices consistent with WMO guidance, including SPI and SPEI
- National climate trend analyses indicating an average temperature increase of approximately 2.5°C between 1940 and 2024

Despite the depth of records:

- Metadata completeness is variable, particularly for older stations
- Station relocations, instrument changes, and automation transitions are not consistently documented in a centralized digital metadata system
- Homogenized climate datasets suitable for trend analysis and AI model training are not yet systematically available

3.4.3 Hydrological Data Archives

Historical hydrological data include:

- River water levels and discharge records from 154 hydrological stations
- Multi-decadal records on major rivers, with shorter or discontinuous series on tributaries

Assessment findings indicate:

- Rating curves exist for most key stations, but documentation of updates and high-flow measurements is incomplete
- Long-term discharge records often contain gaps associated with extreme events, access limitations, or equipment failure
- Cross-sectional surveys exist for selected river reaches but are not systematically updated

These limitations affect:

- Calibration and validation of hydrological and flood forecasting models
- Reconstruction of historical flood events
- Development of reliable impact thresholds

3.4.4 Snow, Cryosphere, and Dzud-Related Data

Snow-related data are critical for Mongolia's dzud risk assessment.

Current datasets include:

- Manual snow depth measurements at meteorological stations
- Limited snow course observations
- Satellite-derived snow cover products used operationally

However:

- Snow Water Equivalent (SWE) data are sparse, largely manual, and spatially limited
- Historical SWE records are insufficiently dense to characterize spatial variability during dzud events
- Metadata on snow course locations and measurement protocols are incomplete

This limits the ability to:

- Reconstruct historical dzud severity
- Calibrate snowmelt and pasture availability models
- Establish robust dzud impact thresholds

3.4.5 Agrometeorological, Environmental, and Land Data

Mongolia maintains a diverse set of ancillary datasets relevant to drought, dzud, and land degradation, including:

- Approximately 1,500 soil sampling locations
- Land cover and desertification maps updated every 5 years
- Vegetation condition indicators derived from remote sensing
- Historical drought assessments based on SPI and SPEI indices

While these datasets are scientifically valuable:

- Temporal resolution is often insufficient for operational early warning
- Spatial resolution varies between products
- Integration with hydrometeorological time series is limited

3.4.6 Impact, Loss, and Socio-Economic Data

Impact and loss data are essential for impact-based forecasting and anticipatory action.

Assessment findings indicate:

- Impact information exists for major disaster events (e.g. dzud, floods), often compiled through post-event reports
- Data are not centrally archived in a standardized, machine-readable format
- Loss data are often aggregated at national or aimag level, limiting local-scale analysis

The absence of a structured historical impact database constrains:

- Development of hazard–impact relationships
- Validation of impact forecasts
- Evidence-based trigger design for anticipatory action

3.4.7 Data Digitization Status

Historical data archives remain partially paper-based.

Based on information provided during the mission:

- Approximately 45% of paper-based archives have been digitized
- Current operational data are fully digital
- Digitization progress varies by data type, with older hydrological and snow records particularly affected

This limits efficient access to long-term datasets for modelling and AI training.

3.4.8 Suitability for Modelling, Impact Forecasting, and AI

From a scientific and modelling perspective:

- Many datasets exceed the minimum 6-year record length required for basic model calibration
- However, data gaps, inhomogeneities, and incomplete metadata reduce suitability for:
    - Ensemble and probabilistic modelling
    - AI/ML applications requiring consistent training datasets
    - Robust impact-based forecasting

Targeted investment in data consolidation, homogenization, and documentation would significantly enhance scientific value.

Current Status	Needs Identified
• Long-term meteorological records exist, with some stations operating since the 1940s–1950s.	• Completion and digitization of station metadata, including instrument changes and relocations.

• Climate indices (SPI, SPEI) are produced in line with WMO guidance.	• Development of homogenized climate datasets suitable for trend analysis and AI training.
• Hydrological archives include discharge and level data from 152 stations.	• Systematic updating and documentation of rating curves and cross-sections, especially for high flows.
• Snow depth data and satellite snow cover products are available.	• Expansion and digitization of SWE records and snow course metadata.
• Agrometeorological datasets include ~1,500 soil sampling locations and land cover maps updated every 5 years.	• Improved temporal resolution and integration with hydrometeorological time series.
• Impact and loss data exist in event-based reports.	• Establishment of a centralized, standardized historical impact and loss database.
• Approximately 45% of historical paper archives have been digitized.	• Accelerated digitization of remaining archives, prioritizing hydrology, snow, and impact data.
• Historical datasets support basic modelling applications.	• Data consolidation, homogenization, and quality enhancement to support impact forecasting and AI applications.

3.5 Data Management

3.5.1 Baseline data management maturity

Baseline NCAT maturity score (Data Management): 3

A maturity score of approximately **3.7/5** indicates that Mongolia has successfully transitioned current operational hydrometeorological workflows to digital systems, enabling routine forecasting and service delivery. However, data management remains partially fragmented, with limitations in historical data consolidation, interoperability, standardized quality management, and formal governance.

Data management currently supports deterministic forecasting and routine monitoring, but does not yet fully enable impact-based forecasting, anticipatory action, ensemble-based modelling, or AI-driven analytics, which require consistent metadata, interoperable services, and traceable quality assurance.

Data management is a critical enabling component for Mongolia's hydrometeorological services, supporting forecasting, climate analysis, impact assessment, and anticipatory action. Mongolia has made substantial progress in transitioning operational workflows to digital systems; however, historical data management, interoperability, and quality assurance remain partially developed.

The assessment confirms that current operational data flows are fully digital, while historical archives are still in transition, with implications for data accessibility, verification, and advanced analytics.

3.5.2 Data Storage and Database Systems

NAMEM and IRIMHE operate internal data storage systems to manage meteorological, hydrological, agrometeorological, and environmental datasets.

Key findings include:

- Operational datasets are stored digitally and used routinely for forecasting and analysis
- Multiple databases and file-based repositories coexist, reflecting incremental system development
- Database architectures include relational components, but a single unified national hydromet database does not yet exist

At the time of assessment:

- Approximately 45% of historical paper archives have been digitized
- 100% of current operational data are generated and stored digitally

The coexistence of multiple systems complicates data integration and limits efficient cross-domain analysis.

3.5.3 Data Formats and Interoperability

Data are stored and exchanged in a variety of formats, including:

- Tabular time series (e.g. CSV, spreadsheets)
- Gridded datasets for modelling outputs
- Maps and graphical products for dissemination

However:

- Operational data exchange is not yet aligned with WMO interoperability standards, such as WIS 2.0, WaterML 2.0, or standardized APIs
- Data sharing relies primarily on internal servers and public web portals, with limited machine-to-machine services

This constrains real-time integration with external systems and limits scalability for regional or global data exchange.

3.5.4 Data Quality Assurance and Quality Control (QA/QC)

Quality control procedures are in place for both historical and real-time data, but coverage and automation levels vary.

Assessment findings indicate:

- Automated QC routines are applied to real-time data streams, with checks occurring at approximately 5–8 minute intervals for some automated observations
- Manual review remains an important component of QA/QC, particularly for historical data and manual observations
- Documentation of QA/QC procedures exists but is not uniformly standardized or centrally catalogued

Quantitatively:

- Most real-time meteorological data undergo automated QC
- Historical hydrological and snow datasets have undergone partial QA/QC, with gaps remaining, particularly for extreme event periods

No centralized reliability index or quality flag system is systematically applied across all datasets.

3.5.5 Data Access and User Availability

Hydrometeorological data and products are made available through:

- Internal institutional servers
- Official NAMEM websites and portals
- Data provision on request for specific users and projects

However:

- Data access policies and service levels are not fully formalized
- Access mechanisms vary by data type and user category
- Metadata accompanying datasets are inconsistent, limiting discoverability and reuse

The absence of a unified data catalogue reduces transparency and efficiency for internal and external users.

3.5.6 Data Security and Continuity

Data security and continuity arrangements are partially addressed through internal ICT controls and backup practices. However:

- The assessment did not identify a documented, institution-wide data backup and recovery policy
- Cybersecurity measures specific to hydrometeorological data systems were not comprehensively documented
- Redundancy for data storage and off-site backups was not confirmed for all critical datasets

Given the increasing reliance on digital systems, these gaps represent a growing operational risk.

3.5.7 Suitability for Impact Forecasting, Anticipatory Action, and AI

From a scientific and operational perspective:

- Current data management practices support deterministic forecasting and basic analysis
- Limitations in interoperability, QA/QC standardization, and metadata completeness constrain:
    - Ensemble and probabilistic modelling
    - Impact-based forecasting
    - AI/ML model development and training

Improving data governance, standardization, and accessibility would significantly enhance the value of existing datasets without requiring major expansion of observation networks

Current Status	Needs Identified
• 100% of current operational hydrometeorological data are generated and stored digitally.	• Consolidation of operational datasets into a unified national hydromet data architecture.
• Approximately 45% of historical paper archives have been digitized.	• Accelerated digitization of remaining historical archives, prioritizing hydrology, snow, and impact data.
• Multiple databases and file-based repositories are in use.	• Development of an integrated database system with centralized governance and documentation.
• Automated QC is applied to most real-time meteorological data streams.	• Standardized QA/QC procedures and quality flagging across all data types, including historical datasets.
• Data are shared via internal servers and public web portals.	• Adoption of WMO interoperability standards (WIS 2.0, WaterML 2.0) and machine-to-machine services.
• Metadata exist but are inconsistently documented.	• Completion and standardization of metadata for all datasets to support discoverability and reuse.
• Basic data backup practices are in place.	• Formalized data backup, recovery, and cybersecurity policies covering all critical datasets.
• Data management supports current service levels.	• Strengthened data governance to enable impact forecasting, anticipatory action, and AI applications.

3.6 Meteorological Forecasts and Products

Baseline NCAT maturity score (Meteorological Forecasts and Products):3

Meteorological forecasting and product generation are supported by operational NWP systems and digital data streams. The assessment indicates a moderate overall capacity level (average score: 2.8

in Figure 3) across 20 sub-indicators, with notable gaps between the current situation and national targets. However, data and forecasting platforms remain fragmented, interoperability is limited, and forecast skill—particularly at monthly and seasonal timescales—remains low. Priority needs include a unified national data and forecasting platform, strengthened data assimilation and model resolution, enhanced nowcasting and extreme weather monitoring, and the development of impact, user-oriented meteorological products using combined physical and AI-based approaches.

Status (Current Situation)	Needs (Identified Gaps & Opportunities)
• Agencies maintain digital systems for real-time and historical data, but systems are **not yet unified across institutions** • Data accessibility varies; **APIs and automated exchange systems** are not widespread. • **QA/QC procedures** are present but differ across networks and may benefit from greater automation. • National AI readiness; **interoperability and seamlessness needs improvement** for benefitting from opportunities for improved data governance and interoperability. • **Some datasets** (e.g., AWS, AHS SWE, manual observations) need additional **harmonization**. • Monthly and seasonal **forecast skill and accuracy are low**. • WRF–UM: 5 km (5-day/12-hourly) and 1 km for UB (3-day). Higher resolution needed. WRF-VAR: 9 km (5-day/6-hourly). WRF-GFS, MM5-UM, MM5-GFS: 9 km (5-day/12-hourly). Also uses ECMWF, JMA, NCEP-GFS	• **A unified national** met/hydro/agro data **platform supporting interoperable data and product** sharing. • **Flash** and **urban flood** prediction system; **nowcasting** (AI enhanced remote sensing such as Fengyu etc) • Expand **radar network** for extreme weather detection • Strengthen **data assimilation** tools and training for **NWP** • Strengthen short–medium, monthly seasonal forecast accuracy (physical and AI approaches) • Develop user friendly, impact-based actionable advisories and alert/warning web/app systems

3.7 Operational hydrological capacities

3.7.1 Baseline NCAT maturity score (Operational hydrological capacities):2

A maturity score of **2.1/5** indicates that Mongolia has functional hydrological forecasting capabilities that supports basic river monitoring, seasonal water resources assessments and limited flood forecasting and warning functions. NAMEM is responsible for operating and maintaining hydrological stations, with IRIMHE focusing on the management and analysis of the hydrological data to generate forecasts and warnings.

3.7.2 Hydrological Monitoring and Data Collection

Currently, NAMEM has around 154 hydrological stations nationally, of which only 147 are functional and cover 16 out of the 21 provinces. There are no hydrological stations in the remaining 5 provinces which are in the East and South of the country, due to lack of river basins. All the hydrological stations have proper metadata which are well documented along with regulations in place to monitor and maintain them. At the provincial level, NAMEM has staff who monitor and observe each of the stations. They are further tasked with bringing the station to the laboratory for calibration and a proper report in paper-format is maintained by the provincial staff and further shared with NAMEM.

Almost all of the operational hydrometric stations are manual and the data is taken manually by an observer (mostly at the provincial level) and transmitted by mobile phone to NAMEM who then upload it into a Structured Query Language (SQL) database and generate products. Measurements are typically taken at least once per day during the warmer season, which runs from 1 April to 30 September each year. In the event of flooding, measurements are increased in frequency and may be conducted on an hourly basis as needed. On the other hand. during winter, measurements are not carried out due to ice formation. There are around 110 stations that also send out data on snow depth and river ice depth. In autumn and Spring (Mid October to mid March), one can also observe ice phenomenon. Among all the stations operated by NAMEM, only around 20 stations are covering flash floods and floods (in general). There is a strong need for additional stations to cover flood early warnings. In 2025, NAMEM acquired 17 automatic hydrological stations that will measure water level and discharge and it is planned to install them in 2026 with operationalization planned for June 2026. Initially, the stations will be co-located with existing manual stations and subsequently transitioned to fully automatic stations based on their performance over a period of a few years.

3.7.3 Flood Forecasting and Warning Services

Hydrological forecasts are under the responsibility of IRIMHE which has a clear mandate established formally through various decrees. Currently, most of the hydrological forecasting is done using empirical models. Although IRIMHE is testing different hydrological models such as HBV, SWAT, SRM, HEC-RAS, HEC-HMS and Tank model, they are not yet being operationally used. This is mainly due to a lack of staff with adequate capacity in using hydrological models operationally. Currently, most of the work being done is ad-hoc and on a research basis. This warrants strong training and capacity building effort around transitioning from research to operations phase when it comes to hydrological modeling and forecasting. Although the empirical model has been calibrated and validated, its performance may still vary, particularly under changing climate conditions. At present, the following forecasts are done using empirical modeling:

- Monthly flow forecast
- Forecast of ice depth and phenomena for up to 1 month (from October to April)
- Forecast of complete ice cover and annual ice break for up to 1 month (March and October)
- Water level forecast for up to 1 to 3 days

In relation to flash flood forecasting, there are no existing capacities and it is an area that IRIMHE wishes to improve upon in the coming years.

At the national level, there is a lack of comprehensive, publicly available flood risk maps. Although there have been detailed flood hazard maps that have been generated for high-risk or priority areas in Ulaanbaatar and Khovd province, major parts of the country are still not covered by such assessments. However, flood hazard map of snow melt is being generated. While there are forecast products for different horizons, there is a lack of formal user feedback which means that there is no information that is relayed back to the national agencies on the effectiveness of the forecasts and warnings that were issued. In addition, the hydrological forecasts carry little information on impacts but there is an interest among IRIMHE and NAMEM to move towards impact based forecasting for the priority hazards including floods.

Status (Current Situation)	Needs (Identified Gaps & Opportunities)
• NAMEM operating around **147 hydrological stations** (including in lakes and rivers) – **which are mostly manual** • Multiple steps for observational data verification and quality control but mostly **manual and labour intensive** • **Regular maintenance of hydrometric network** including the update of rating curves (carried out annually) • Hydrological modeling only done on research basis and **not operational** • **Empirical modeling** (based on upstream condition and flood wave propagation) **done for all stations** to develop forecasts • Dissemination of hydrological forecasts and products through multiple channels but **no formal feedback or verification** • Flash flooding occurs in East and South part of country where there are **no basins and no monitoring**	• **Lack of automation** across the observation, monitoring and data processing value chain. Highly labour-intensive means of recording data. • **No specialized staff in hydrological modeling and forecasting** exist with operational experience. • Current **empirical modeling may not be suitable** for extreme events and in changes brought on by land-use and also the climate • There is **no record of any verification studies conducted** post the issuance of a forecast or warning. This limits understanding on whether the produced forecast or warning was useful. Further, these warnings carry no information on the impacts. • **Earth-system approach** for modelling for **seamless and integrated Flood EWS**

3.8 Agrometeorological monitoring and forecast service

Baseline ACAT maturity score (Agrometeorological monitoring and forecast service):3

The agrometeorological services assessment indicates **2.9/5**, a moderate overall capacity level (in Figure 3) across 161 sub-indicators, with notable gaps between the current situation and national targets. Strengths are observed in data availability and selected hazard-specific products (e.g. dzud and drought), while weaknesses remain in impact agrometeorological products, advanced modelling, forecast verification, and user-oriented advisory services.

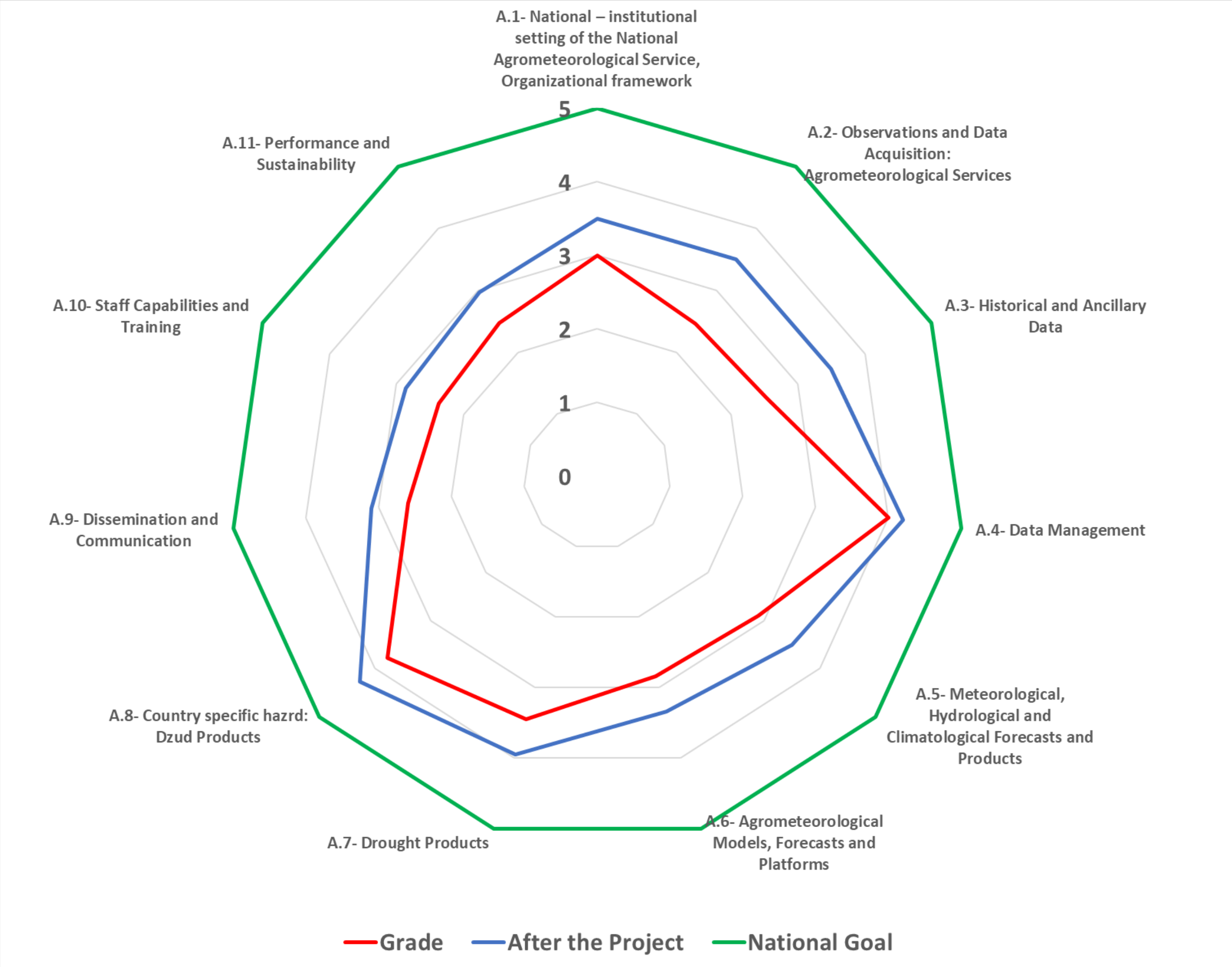

Figure 6 – Sections of the Assessment matrix for Agrometeorological monitoring and forecast service

SOURCE: AUTHORS' OWN ELABORATION

The assessment highlights the need to shift from predominantly hazard- and climate-driven products towards actionable, people-centred agrometeorological advisory services that directly support anticipatory action, particularly for livestock, crop production, and pasture management. Key identified gaps include limited use of impact models (e.g. livestock, crop yield, and pasture biomass), insufficient integration of socio-economic vulnerability data, and limited operational use of AI/ML and downscaled S2S forecasts.

In Mongolia, the NAMEM, IRIMHE is the mandated national authority responsible for the monitoring, forecasting, and delivery of agrometeorological services. Strengthening institutional capacity, data management, forecast verification, and last-mile advisory delivery through these institutions is critical to achieving national goals and enabling effective end to end agrometeorological services.

Status (Current Situation)	Needs (Identified Gaps & Opportunities)
• Around **314 pasture observation** sites **regularly monitor grass type, height, biomass, vegetation condition, and phenology** every **10 days**, with 100 fenced sites for controlled measurements • **1,500 rangeland sites** observed annually in August for pasture condition (same sites used for winter snow-depth measurements) • **Pest and disease** monitoring conducted at **314** sites on a monthly basis • **62 soil-moisture** sites, with automatic sensors (20, 50, 100 cm) providing daily data and manual measurements every 10 days • **44 crop observation** points (potato and wheat) monitored monthly during the growing season • **7 zoo-meteorology** stations, including **2 agrometeorological** stations, monitoring animal–environment interactions • **Decadal agromet bulletin** produced every **10 days**, including **VCI, snow depth/density, soil moisture, THA, biomass, pest and disease maps, livestock weight, and locust monitoring** • **Monthly Dzud risk map** updated and disseminated during winter season	• No automatic **QC system for agromet observations** • **Outdated**/absent **triggering methods** (only drought/dzud 2015; none for floods, fires), and no socio-economic data for **AA** • **No Agromet Workstation/Portal** for monitoring, analysis, forecasting, and automated bulletins • **Lack of feedback channels** for co-production with users • Missing **CONOPS** and **SOPs** for end-to-end agromet services • **Hydrological forecasts not integrated** into agromet service and bulletins • **Limited monitoring/modelling** (water balance, biomass, soil carbon, pests/rodents) • Not exist **cost-effectiveness** or **SEB** tools • Not exist **Crop calendars** • Capacity building needs • **Technical gaps:** lack of modern field instruments; need to upgrade Agromet and zoo-met stations • Impact models (livestock, crop yield and pasture biomass)

3.9 .AI Capacities and Capabilities

3.9.1 Baseline AI maturity and scope

Baseline NCAT maturity score (AI capacities and capabilities): 1

A maturity score slightly below **1.6/5** indicates that Mongolia's hydrometeorological system is AI-aware and AI-adjacent, but not yet AI-enabled in an operational sense. AI-related activities exist primarily at exploratory, analytical, or initial research levels, rather than as systematically embedded components of forecasting, impact assessment, or anticipatory action workflows.

The assessment confirms that AI readiness in Mongolia is constrained less by intent and human capital, and more by data readiness, system integration, and governance maturity. AI is not currently institutionalized as an operational capability within NAMEM or IRIMHE, but several prerequisites for future adoption are partially in place.

Within NAMEM and IRIMHE, forecasting and climate services are predominantly based on deterministic and ensemble numerical models (WRF, ECMWF-based products, regional climate models), combined with classical statistical techniques for climate indices such as SPI and SPEI. These workflows rely heavily on human interpretation, with no operational deployment of machine learning or AI-based models for bias correction, downscaling, impact modeling, or probabilistic decision support. During consultations, it was explicitly confirmed that AI is not currently embedded in operational forecasting chains, either for dzud, drought, flood, or multi-hazard early warning

3.9.2 Institutional and policy context for AI

Mongolia has articulated national ambitions related to digital transformation and data-driven governance, as reflected in broader e-government, digital governance, and innovation strategies reviewed during the assessment. However:

- No hydrometeorology-specific AI strategy currently exists.
- AI is not explicitly referenced in:
  - NAMEM or IRIMHE operational mandates
  - National early warning or DRM regulations
- There is no formal institutional framework governing:
  - Use of AI in forecasting or decision support
  - Accountability for AI-driven outputs
  - Validation and explainability of AI-supported products

The 2023–2024 dzud season exposed a critical limitation of current forecasting approaches: forecast consistency between October–November outlooks deteriorated sharply, with forecast accuracy reported at approximately 20 percent by national authorities. This instability, combined with the lack of transitional forecast coherence across lead times, underscores the absence of AI-supported forecast blending, regime detection, and ensemble calibration, which are increasingly standard in advanced hydrometeorological services.

From an agricultural and impact perspective, agrometeorological services are comparatively strong in Mongolia, supported by over 1,500 soil sampling locations, NDVI-based monitoring, desertification atlases, and periodic land cover mapping (updated every five years). However, these datasets are not systematically integrated into AI-driven impact forecasting pipelines. Impact assessments for drought and dzud remain largely descriptive and retrospective, with limited predictive analytics linking hazard probability to livestock mortality, pasture degradation, or livelihood impacts at actionable lead times.

At the disaster management level, NEMA operates multiple digital platforms (VMS, damage and loss databases, risk portals), collecting thousands of structured data points annually. However, these datasets are used primarily for reporting and coordination, not for AI-based pattern recognition, early anomaly detection, or anticipatory trigger definition. No AI-supported decision engines are currently used to activate anticipatory action protocols or contingency financing.

3.9.3 AI readiness enablers: data, governance, and digital foundations

From a data availability perspective, Mongolia is moderately well-positioned for future AI deployment. Large volumes of meteorological, hydrological, climate, agricultural, and disaster impact data exist, including high-frequency AWS observations, satellite products (Himawari, COMS, MODIS), climate reanalysis, exposure datasets from the National Spatial Data Infrastructure, and detailed disaster loss records disaggregated by sex, age, disability, and location. However, data heterogeneity, inconsistent metadata, incomplete digitization (approximately 45 percent of historical archives), and fragmented system ownership significantly limit AI readiness.

The AI readiness assessment indicates that Mongolia has emerging digital governance frameworks (national digitalization strategies, e-government platforms, data modernization initiatives), but no sector-specific AI governance instruments applicable to hydrometeorology, disaster risk management, or agriculture. There is no formal guidance on ethical AI use, model accountability, data sharing for AI training, or operational validation of AI outputs within national agencies. This creates institutional risk for deploying AI in safety-critical domains such as early warning.

Computational infrastructure remains another binding constraint. While NAMEM and IRIMHE operate operational servers for forecasting and data management, high-performance computing capacity suitable for AI training, ensemble learning, or deep learning applications is not available in-country. Current systems are insufficient for training convolutional neural networks, sequence models, or large ensemble post-processing algorithms. As a result, any AI development would currently depend on external cloud platforms or international partners, raising sustainability and data sovereignty concerns.

Human capacity constraints are equally pronounced. While Mongolia has strong meteorological, hydrological, and climate science expertise, formal AI, machine learning, and data science skills within operational agencies are extremely limited. AI-related activities are concentrated in universities and isolated research groups, with minimal exposure among forecasters, agrometeorologists, or disaster managers. No structured training pathways exist to transition staff from statistical methods to AI-enhanced forecasting, nor are there dedicated AI or data science units within NAMEM, IRIMHE, or NEMA.

3.9.4 Implications for impact forecasting and anticipatory action

The current level of AI capacity is insufficient to support next-generation impact-based forecasting or anticipatory action systems. Specifically:

- Dzud and drought early warning lack AI-based multi-source data fusion capable of integrating climate forecasts, pasture conditions, livestock vulnerability, and socio-economic exposure.
- Flood and flash flood forecasting does not benefit from AI-enhanced rainfall–runoff modeling, radar–satellite blending, or probabilistic impact estimation.
- Anticipatory action triggers are defined largely through expert judgment and static thresholds, rather than adaptive, data-driven models that learn from past events.
- Communication products are not personalized or dynamically generated using AI-supported risk profiling, limiting last-mile effectiveness, particularly given that only approximately 35 percent of the population is currently reached by warning information.

Without targeted investment, Mongolia risks widening the gap between increasing climate extremes and the analytical capabilities required to anticipate impacts and act early.

3.10 Dissemination and Communication

3.10.1 Baseline dissemination maturity and scope

Baseline NCAT maturity score (Dissemination and Communication): 3

A maturity score of approximately **3.1/5** indicates that Mongolia has an established and functioning dissemination system for hydrometeorological information and warnings, with multiple operational channels in place. Products are routinely issued, and coordination mechanisms exist, particularly during emergencies.

However, dissemination remains largely hazard-centric, fragmented across platforms, and only partially aligned with impact-based early warning and anticipatory action requirements. End-to-end

Status (Current Situation)	Needs (Identified Gaps & Opportunities)
• AI referenced in Vision-2050 and Digital Nation, but not in hydromet or anticipatory action strategies. Governance bodies exist in principle but lack formal cross-sector coordination. • KHUR, MCloud, and Big Data Repository exist, some sector datasets are connected; historical data available but fragmented, AI-grade computing resources limited. • Roles for AI unclear in agencies; AI not integrated in EOCs or SOPs; coordination mostly project-based and donor-driven. • Limited in-house AI expertise; basic digital literacy, emerging AI research; AI lifecycle management not formalized. • AI use mainly at pilot or concept level; hazard and impact forecasting still physics- and statistics-based, AA triggers manually defined. • Dashboards exist but AI indices not used, limited tailoring for different users, no automatic AA triggers; feedback loops minimal. • Emerging AI ecosystem, project-based partnerships; limited dedicated budget lines; procurement not AI-adapted; MEL frameworks absent.	• Develop a unified AI strategy with sector roadmaps; establish inter-agency AI council; embed AI in hydromet, DRR, agriculture strategies; define ethics and risk management for high-stakes applications. • Integrate hydromet, DRM, agriculture datasets; standardize metadata; provide HPC/GPUs/cloud access; develop cross-sector AI data governance; enable near real-time API access for AI models. • Institutionalize AI roles in agencies; integrate AI into EWS/DRM platforms; codify AI-assisted decision-making SOPs; establish structured community co-design mechanisms. • Build dedicated AI teams; expand advanced AI/data-science training; consolidate multi-year capacity-building plans; promote experimentation culture with hackathons and sandboxes. • Develop operational AI models for hazard and impact forecasting; integrate AI into operational workflows; apply AI for anticipatory action triggers optimization; implement model governance and verification frameworks. • Create AI-enhanced risk dashboards; segment users and tailor outputs; integrate AI triggers into AA protocols and financing; establish continuous feedback loops from users. • Strengthen national AI innovation ecosystem; formalize long-term partnerships; allocate dedicated AI funding; adapt procurement frameworks; develop national MEL system for AI-enabled IF/AA.

communication effectiveness, particularly last-mile reach, user feedback integration, and interoperability across agencies, remains uneven.

Dissemination and communication of hydrometeorological warnings and advisories in Mongolia are carried out under an arrangement of:

- **National Agency for Meteorology and Environmental Monitoring (NAMEM)**, through **IRIMHE**, is responsible for producing and disseminating meteorological, hydrological, agrometeorological, and climate information products.
- **National Emergency Management Agency (NEMA)** is responsible for emergency alerts, coordination of response, and communication through disaster management structures under the *Law on Disaster Protection (2017)*.

While mandates are legally defined CONOPS does not exist to spficify:

- Which institution issues which warning products at each escalation level
- How forecast uncertainty is communicated
- How early advisory, watch, warning, and emergency alert stages are differentiated

3.10.2 Dissemination platforms and technical channels

Official web platforms

NAMEM and IRIMHE disseminate operational products primarily through official web portals:

- NAMEM / IRIMHE main portal
  https://irimhe.namem.gov.mn
  Products include:
  - Daily weather forecasts
  - Severe weather warnings
  - Seasonal climate outlooks
  - Dzud risk maps
  - Agrometeorological advisories

Most products are published in **Mongolian only**, with limited technical metadata or user guidance. No machine-readable warning feeds (API, CAP XML) are provided.

Platforms and Channels Used for Dissemination

- Official IRIMHE and NAMEM websites as the primary dissemination platforms for public-facing products
  https://irimhe.namem.gov.mn
  https://namem.gov.mn
- Television and radio broadcasts used for dissemination of severe weather warnings and emergency-related information
- Social media platforms (primarily Facebook) used for rapid updates, visual products, and public messaging
- Mobile applications and web-based tools providing access to selected weather and environmental information (availability and functionality vary by product)

Mobile and last-mile dissemination

At the time of assessment:

- No national SMS or cell broadcast system is operational for early warning
- CAP-compliant alerting is not fully implemented

- Mobile network-based dissemination is under consideration in future projects (e.g. ADB-supported EWS strengthening from 2026)

NEMA reported that approximately 35 percent of the population is currently reached by warning information. Coverage gaps are most pronounced among:

- Nomadic herder communities
- Remote rural soums
- Seasonal populations

3.10.3 Products disseminated

The main categories of disseminated products include:

Meteorological Forecast and Warning Products

- Daily national weather forecasts covering temperature, precipitation, wind, and general weather conditions, disseminated via the IRIMHE website and media channels https://irimhe.namem.gov.mn
- Severe weather warnings for hazards such as strong winds, heavy snowfall, extreme cold, blizzards, and storms, issued on an event-driven basis and shared through the website, television, radio, and social media
- Short-range weather outlooks and synoptic analyses used internally and partially communicated to stakeholders through summary bulletins
- Aviation meteorological products including METAR and TAF bulletins for major airports, disseminated through the Aviation Meteorological Centre https://amc.namem.gov.mn
- Satellite imagery and weather visualization products (e.g. cloud cover, weather systems), primarily used internally and selectively published during significant events

Hydrological and Flood-Related Products

- River water level observations and status updates for major river basins, disseminated through web-based notices and news bulletins
- Qualitative flood risk information and alerts issued during flood-prone periods, particularly during snowmelt and intense rainfall events
- Periodic river condition summaries providing narrative overviews of hydrological conditions at basin or national scale
- Event-based hydrological updates disseminated to emergency management authorities during active flood situations

Climate and Seasonal Products

- Monthly climate summaries describing observed temperature and precipitation anomalies across the country
- Seasonal climate outlooks providing probabilistic information on expected temperature and precipitation tendencies over upcoming months
- Annual climate reports documenting long-term trends, climate variability, and extreme events
- Climate change assessment outputs and indices prepared for government use and periodically shared through the website

Agrometeorological and Dzud-Related Products

- Dzud risk maps produced prior to and during winter seasons, indicating relative dzud risk levels at soum and aimag scales
- Dzud situation assessments issued during active dzud events, reflecting evolving conditions such as snow cover, ice crusting, and cold stress
- Agrometeorological advisories supporting livestock and crop-related decision-making, disseminated through the website and coordination with sectoral institutions
- Pasture condition monitoring products based on satellite-derived vegetation indices, shared mainly as maps and narrative summaries

Remote Sensing and Environmental Monitoring Products

- Snow cover maps derived from satellite observations, disseminated periodically and during winter seasons
- Drought-related remote sensing products such as vegetation condition indicators and land surface temperature maps
- Forest and steppe fire detection information based on satellite thermal anomaly data, disseminated during fire seasons
- Dust and aerosol monitoring products used to support air quality and visibility assessments
- Environmental monitoring outputs produced by the Environmental Information Centre, including land cover and environmental status products https://irimhe.namem.gov.mn

Air Quality and Environmental Products

- Urban air quality status information derived from fixed and mobile monitoring stations, disseminated mainly for major urban centers
- Environmental quality information products shared through NAMEM platforms and public communications

3.10.4 Coordination with communities and intermediaries

Dissemination to communities relies heavily on intermediaries:

- Aimag and soum authorities
- Disaster management committees
- Media outlets

There is no structured national volunteer-based dissemination network formally integrated into the warning chain. However:

- The Mongolian Red Cross Society maintains a volunteer network of approximately 17,600 volunteers nationwide, supporting disaster preparedness and response
- This network is not formally embedded in hydrometeorological warning dissemination protocols

Community-level feedback mechanisms are informal and not systematically documented.

3.10.5 Feedback, verification, and performance monitoring

No technical system exists for:

- Tracking warning receipt
- Measuring dissemination timeliness
- Assessing user comprehension
- Verifying behavioural response

Post-event reviews are conducted on an ad hoc basis, mainly after major disasters. There is:

- No standardized dissemination performance indicator
- No warning effectiveness database
- No integration of feedback into product redesign

This limits continuous improvement of dissemination services.

3.10.6 Dissemination readiness for impact forecasting and anticipatory action

During the 2023–2024 dzud, anticipatory actions were implemented through contingency planning, but dissemination relied largely on traditional channels without tailored early-action messaging.

Dissemination systems are currently optimized for:

- Short-lead emergency warnings
- Reactive response coordination

They are not yet configured to support:

- Early advisory messaging for anticipatory action
- Communication of forecast uncertainty
- Multi-stage warning escalation
- Pre-agreed early action triggers

Current status	Needs identified
• Dissemination conducted primarily through NAMEM and IRIMHE websites, national TV, radio, and social media platforms	• Development of a unified national dissemination architecture aligned with multi-hazard early warning principles
• Products disseminated as static maps, bulletins, and narrative messages	• Transition toward structured, machine-readable dissemination formats and interoperable services
• Warning messages are predominantly hazard-based	• Integration of impact-based warning content with clear sector- and livelihood-specific implications
• No operational use of CAP or similar international alerting standards	• Adoption of CAP-compliant warning dissemination to support consistency and automation
• Limited integration between NAMEM, IRIMHE, and NEMA dissemination workflows	• Formalized communication protocols and shared operational dashboards between agencies
• Ad hoc communication with emergency responders and sectoral users	• Regularized coordination mechanisms and predefined communication workflows during extreme events
• Social media used informally for rapid updates	• Governance, verification, and monitoring frameworks for digital and social media dissemination
• No systematic collection of user feedback or dissemination performance metrics	• Establishment of post-event review, feedback, and communication effectiveness monitoring
• Last-mile dissemination remains uneven, especially in rural and nomadic areas	• Deployment of mobile-based dissemination solutions, including cell broadcasting and community intermediaries
• No nationally integrated multi-hazard warning display	• Development of an integrated MHEWS visualization and communication platform for decision-makers and the public

3.11 Staff Capabilities and Training

3.11.1 Overview and baseline capacity maturity

Baseline NCAT maturity score (Human Resources and Capacity): 3

A maturity score of approximately **3.2/5** indicates that Mongolia's hydrometeorological institutions possess established technical staff capacity and institutional knowledge, with functional specialization across meteorology, hydrology, climate, agrometeorology, ICT, and research. Core operational functions are staffed and sustained, and there is a demonstrable culture of scientific practice and service delivery.

At the same time, the assessment confirms that human resource capacity is unevenly distributed across domains, and that emerging requirements related to impact-based services, anticipatory action, integrated modelling, and AI place increasing pressure on existing staff profiles. Capacity constraints are not due to absence of expertise, but rather to workload concentration, limited succession planning, and insufficient structured capacity development pathways.

The National Agency for Meteorology and Environmental Monitoring (NAMEM), officially operating as the Meteorological and Environmental Research Agency and designated as a Government Implementing Agency, delivers hydrometeorological and environmental services through a combination of headquarters departments, specialized institutes, and a nationwide operational network. Core scientific, technical, and analytical functions are supported by the Hydrometeorological, Environmental Research and Information Institute (IRIMHE), which plays a key role in research, data analysis, methodological development, and technical backstopping for operational services.

Institutional staffing covers meteorology, hydrology, climatology, agrometeorology, environmental monitoring, forecasting operations, observation network management, data archiving and management, ICT systems, and service delivery. Based on organizational structures and departmental mandates, staffing is distributed across the following functional domains:

- Operational forecasting (meteorology and climate)
- Hydrology and water-related services
- Agrometeorology and sectoral advisory services
- Environmental monitoring and analysis (air, water, soil, radiation)
- Observation network operation, maintenance, and calibration
- Data management, archiving, and information services
- ICT systems, communications, and cybersecurity
- Research, methodological development, and innovation (primarily through IRIMHE)

For verification of operational sustainability and workload distribution, the following workforce indicators should be consolidated and confirmed by the relevant national institutions:

- Total number of staff across NAMEM and IRIMHE (all functions): 65 –NAMEM/IRIMHE
- Number of staff directly involved in operational meteorological forecasting (including shift coverage): 12
- Number of hydrologists engaged in operational analysis and forecasting: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of agrometeorological specialists providing advisory services: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of environmental monitoring and analytical specialists: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

- Number of observation network technicians and field staff: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of ICT, data management, and systems specialists supporting operations and research: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

3.11.2 Education Levels and Qualification Profile

The professional profile of staff within NAMEM and IRIMHE reflects long-standing national investment in meteorological, hydrological, and environmental sciences, including academic training through national universities and international collaboration. Staff are known to hold formal qualifications in meteorology, hydrology, climatology, environmental science, engineering, and related disciplines, supporting both operational and research functions.

To establish a robust evidence base for capacity development and succession planning, education and qualification profiles should be structured along the following lines:

- Distribution of staff by education level (technical diploma, Bachelor's degree, Master's degree, Doctorate): XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of staff with formal qualifications in meteorology and forecasting sciences: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of staff with qualifications in hydrology, water resources, or operational hydrological modelling: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of staff with qualifications in agrometeorology or agricultural advisory services: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of staff with qualifications in data science, statistics, software engineering, or artificial intelligence: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of staff with qualifications in environmental monitoring and analysis- XXX – TO BE PROVIDED BY NAMEM/IRIMHE

3.11.3 Documented Competencies and Operational Skill Base

Evidence from the **EW4All Pillar 2 Rapid Assessment (October 2024)** and the **national verification workshop (July 2025)** indicates that NAMEM and IRIMHE staff demonstrate strong core competencies in:

- Synoptic and short- to medium-range meteorological forecasting
- Interpretation and operational use of deterministic and probabilistic NWP products (including WRF, ECMWF, and JMA outputs)
- Continuous 24/7 forecasting and warning operations

- Operation and maintenance of meteorological, hydrological, and environmental observation networks
- Climate monitoring and production of seasonal outlooks
- Environmental quality monitoring and reporting

At the same time, the assessments confirm that advanced competencies required for next-generation services remain limited or unevenly distributed, particularly in:

- Operational hydrological forecasting and modelling
- Integration of hydrological outputs into warning decision processes
- Impact-based forecasting and use of exposure and vulnerability information
- Ensemble post-processing, verification, and uncertainty communication
- Practical, operational application of AI and advanced analytics

3.11.4 Training Status and Competency Development Approach

Training and skills development within NAMEM and IRIMHE are supported through a combination of institutional learning, professional exchanges, and participation in regional and international initiatives facilitated by WMO, UN agencies, and bilateral partners. Assessment materials define a phased competency development pathway to address identified gaps.

To operationalize this pathway, the following elements should be articulated and confirmed:

- Existing in-house training activities and mentoring mechanisms within NAMEM and IRIMHE: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of staff trained in operational hydrology and hydrological forecasting: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of staff trained in impact-based forecasting and sectoral service delivery: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Number of staff with practical exposure to AI-supported forecasting, post-processing, or data quality control: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Existence of a formal, institution-wide training strategy or annual training plan: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

3.11.5 Strategic Alignment and Future Competency Needs

Staff development priorities for NAMEM and IRIMHE are increasingly shaped by national and international strategic frameworks, including Vision 2050, the draft National Strategy on Big Data and Artificial Intelligence (2022–2030), and the EW4All programmatic framework. These frameworks emphasize the need for strengthened competencies in digital technologies, impact-based services, and multi-hazard early warning systems.

To align workforce capabilities with these strategic directions, the following strategic elements should be clarified:

- Existence of a joint NAMEM–IRIMHE human resource and competency development strategy aligned with EW4All: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Planned career pathways for specialized technical roles (hydrology, modelling, AI, data systems): XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Mechanisms for training-of-trainers and knowledge retention: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

3.11.6 Current status and needs identified

Current Status	Needs Identified
Clear institutional separation between governance (NAMEM) and technical operations (IRIMHE), supporting R2O/O2R	Formal clarification of roles to reduce functional overlap and workload duplication
Strong disciplinary expertise in meteorology, hydrology, climate, and agrometeorology	Targeted capacity development in impact modelling, socio-economic analysis, and decision-support
Presence of advanced academic qualifications within research divisions	Structured career pathways to retain and develop advanced technical expertise
Staff able to sustain routine operations and major events	Surge staffing strategies and workload redistribution for extreme events
Project-based training opportunities exist	Institutionalized capacity development aligned with WMO competency frameworks
Emerging interest in AI and advanced analytics	Dedicated data science and AI roles, supported by training and governance frameworks

3.12 Performance and Sustainability

Baseline NCAT maturity score (Performance and Sustainability): ~2

A maturity score of approximately **2.7/5** indicates that Mongolia's hydrometeorological and early warning services are operationally functional and deliver regular outputs, with demonstrated capacity to perform during major hazard events such as the 2023–2024 dzud. Core services are sustained through a combination of government funding, institutional commitment, and partner-supported projects

Performance and sustainability define sustainable hydrometeorological services as those that are operationally reliable, institutionally embedded, financially viable, and capable of continuous improvement. This section therefore focuses on the ability of NAMEM and IRIMHE to sustain service delivery over time, rather than on individual system components or projects.

However, governance and sustainability mechanisms remain largely project-driven, with limited formalization of long-term financing, performance accountability, and cross-sectoral ownership required for sustained multi-hazard, impact-based early warning and anticipatory acti

3.12.1 Operational Performance and Service Continuity

NAMEM and IRIMHE demonstrate sustained operational performance through the continuous provision of national hydrometeorological and environmental services, including 24/7 forecasting, routine warning issuance for multiple hazards, maintenance of national observation networks, and provision of climate and environmental information to users.

Findings from the EW4All Pillar 2 Rapid Assessment (October 2024) confirm that Mongolia maintains baseline operational capacity across core functions. However, EW4All guidance emphasizes that performance must be evaluated under stress conditions, including high-impact events, cascading hazards, and peak operational demand.

From this perspective, operational performance is increasingly constrained by:

- Limited redundancy in critical systems (ICT, data transmission, power supply)
- High dependence on a small number of specialized technical staff
- Uneven observation coverage in remote and high-risk areas
- Limited system-wide testing of compound and cascading hazard scenarios

In line with WMO good practice, verification of performance sustainability should include confirmation of:

- Backup systems and redundancy arrangements for critical operations: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Frequency and scope of operational stress testing and continuity drills: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

3.12.2 Financial Sustainability and Cost Structure

EW4All and WMO guidance highlight financial sustainability as a cornerstone of long-term performance. NAMEM and IRIMHE operate primarily through national budget allocations, complemented by externally funded projects that support modernization and capacity development.

Hydrometeorological and early warning services in Mongolia are financed through a combination of:

- Core government budget allocations
- Donor-funded and project-based investments

- International climate and development finance mechanisms

The assessment identified that:

- Core operational costs are generally covered, enabling continuity of basic services.
- Capital investments and system upgrades are predominantly project-funded.
- Long-term financing for maintenance, modernization, and capacity development is not systematically secured.

This financing structure limits:

- Predictability of system upgrades
- Lifecycle sustainability of infrastructure and technologies
- Institutional ownership of innovations introduced through projects

To align with sustainable service provision, performance assessment should be anchored in a clear understanding of cost structures, including:

- Annual operational and maintenance costs versus development investments: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Proportion of funding that is time-bound versus recurrent: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Existing or potential cost-recovery mechanisms for specialized services: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

3.12.3 Institutionalization of Innovation

A key sustainability principle under EW4All is the transition from project-based innovation to institutionalized operations. NAMEM and IRIMHE have demonstrated openness to innovation through adoption of NWP systems, automation, probabilistic products, and engagement in AI-related pilots.

However, assessments indicate that:

- Innovation pathways are not yet systematically defined
- New tools and methods are not consistently embedded into standard operating procedures
- Technical evolution is often driven externally rather than through a prioritized internal roadmap

WMO guidance emphasizes the need for clear innovation governance, including criteria for adoption, scaling, and long-term maintenance. Confirmation is therefore required on:

- Existence of an institutional mechanism to operationalize and sustain innovations: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Alignment of innovation priorities with EW4All and national strategies: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

3.12.4 Performance Monitoring, Quality Management, and Learning

Sustainable performance requires systematic monitoring, evaluation, and learning. NAMEM and IRIMHE operate within national oversight and audit frameworks and participate in international data exchange systems.

However, EW4All and WMO maturity frameworks emphasize that performance monitoring should be service-oriented, including:

- Routine forecast verification and skill monitoring
- Evaluation of warning effectiveness and user response
- Feedback loops from preparedness and response actors
- Use of maturity indicators to guide continuous improvement

To align with these principles, the following elements should be clarified:

- Existence and scope of a formal Quality Management System aligned with WMO guidance: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Regular use of forecast verification metrics to inform operational decisions: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- Mechanisms for integrating feedback into service refinement: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

3.12.5 Strategic and Workforce Sustainability

From a sustainability perspective, performance risks extend beyond systems to institutional capacity. The assessment identifies:

- Increasing technical demands without proportional growth in recurrent resources
- Dependence on specialized individuals for critical functions
- Workforce aging and retention challenges in technical disciplines
- Rising expectations for sector-specific and people-centred services

Performance and sustainability are shaped by national and international frameworks, including:

- Vision 2050, emphasizing resilience and digital transformation
- Draft National Strategy on Big Data and Artificial Intelligence (2022–2030)
- EW4All programmatic framework, including maturity monitoring and continuous improvement

To ensure coherence, performance sustainability requires:

- Integration of NCAT and EW4All findings into national planning and budgeting cycles: XXX – TO BE PROVIDED BY NAMEM/IRIMHE
- A medium- to long-term institutional sustainability plan for NAMEM and IRIMHE: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

- Clear pathways to sustain services beyond project lifecycles: XXX – TO BE PROVIDED BY NAMEM/IRIMHE

3.12.6 Alignment with impact-based services and anticipatory action

From a governance and sustainability perspective:

- Impact-based services and anticipatory action are recognized as priorities by national institutions.
- Practical implementation remains largely partner-driven, without a nationally endorsed governance framework.
- Clear institutional ownership of impact thresholds, triggers, and decision authority is not yet fully established.

3.12.8 Current status and needs identified

Current Status	Needs Identified
Clear institutional mandates exist for NAMEM, IRIMHE, and NEMA	Formalization of routine governance and coordination mechanisms beyond emergencies
Alignment with Sendai Framework and EW4All principles	Development of a nationally endorsed end-to-end early warning governance framework
Strong partnerships with UN agencies and development partners	Harmonization of partner-led initiatives under a national framework
Core government funding supports basic operations	Long-term financing strategies covering maintenance, modernization, and capacity development
Successful anticipatory action during dzud events	Policy-level recognition and institutionalization of anticipatory action
Event-based reviews conducted after major disasters	Systematic performance monitoring, documentation, and learning mechanisms

4. Implementation plan

4.1 Institutional

4.1.1 Baseline institutional maturity and intent of improvement

Baseline NCAT maturity score (Institutional): 3

A maturity score of **3.3/5** indicates that Mongolia's institutional framework for hydrometeorological services and disaster risk management is established and functional, with clear mandates and operational agencies in place. However, the system is not yet fully integrated, relies on event-driven coordination, and lacks formalized end-to-end governance mechanisms required for sustained multi-hazard early warning, impact-based services, and anticipatory action.

The objective of the institutional implementation plan is therefore not to create new institutions, but to progressively increase maturity from level 3 toward level 5 by formalizing coordination, embedding impact-based approaches, and ensuring institutional sustainability.

4.1.2 Short-term institutional improvements (1–2 years)

Target maturity progression: 3.4 → 3.8

In the short term, institutional improvements should focus on **formalization of existing practices** that already function but are not documented or standardized. These actions primarily address NCAT criteria that currently score **3** due to partial documentation and informal coordination.

Key short-term achievements include:

- Development and formal adoption of a **national Concept of Operations (CONOPS)** for end-to-end early warning services, clearly defining:
  - Governance and oversight functions (NAMEM)
  - Technical and scientific functions (IRIMHE)
  - Disaster preparedness, response, and coordination functions (NEMA)
- Establishment of a **standing inter-agency coordination mechanism** for early warning and risk information, with defined terms of reference and regular meetings beyond emergency periods.
- Documentation of **standard operating procedures (SOPs)** for:
  - Routine operations
  - Escalation during extreme events
  - Information sharing between NAMEM, IRIMHE, NEMA, and sectoral ministries

- Clarification of dissemination and coordination roles between NAMEM and IRIMHE to reduce functional overlap identified during the assessment.

4.1.3 Medium-term institutional improvements (3–5 years)

Target maturity progression: ~3.8 → ~4.4

In the medium term, improvements should focus on embedding institutional arrangements into national systems, policies, and planning cycles, addressing NCAT criteria that require demonstrated consistency and sustainability.

Key medium-term achievements include:

- Integration of hydrometeorological early warning services into national and sub-national disaster risk management planning, ensuring systematic use of forecasts and warnings in contingency planning.
- Strengthening of legal and regulatory instruments supporting:
    - Data sharing across institutions
    - Use of hydrometeorological information in decision-making
    - Service provision mandates for NAMEM and IRIMHE
- Establishment of a nationally endorsed Impact-Based (IB) early warning framework, defining:
    - How hazard information is translated into impact information
    - Institutional responsibilities for impact analysis
    - Linkages between impact information and preparedness or response actions
- Formalization of research-to-operations and operations-to-research (R2O/O2R) mechanisms between IRIMHE and operational services, including pilot evaluation and transition criteria.

4.1.4 Long-term institutional improvements (5+ years)

Target maturity progression: ~4.4 → 5.0

Progression to maturity level 5 requires evidence that institutional arrangements are fully integrated, sustainable, and resilient to personnel or political change.

Key long-term achievements include:

- Full institutionalization of multi-hazard, impact-based early warning services as a routine government function, independent of external project support.
- Alignment of early warning governance with national development planning and budgetary processes, ensuring predictable financing and sustainability.

- Establishment of permanent institutional coordination platforms linking NAMEM, IRIMHE, NEMA, sectoral ministries, and national statistical and economic agencies.
- Regular review and updating of CONOPS, SOPs, and IB frameworks based on performance evaluations and post-event reviews.

4.1.5 Impact-Based (IB) early warning and Anticipatory Action (AA)

The assessment confirms that Mongolia has **demonstrated experience with anticipatory action**, notably during the 2023–2024 dzud contingency planning. However, IB and AA practices remain **event-specific and partner-driven**, preventing higher institutional maturity scores.

Institutional improvements required to progress maturity include:

- Clear institutional ownership of Impact-Based (IB) early warning, defining responsibilities for impact analysis, validation, and dissemination.
- Development of nationally agreed impact thresholds and triggers for priority hazards, linked to predefined preparedness or response actions.
- Alignment of IB and AA mechanisms with WMO guidance on impact-based early warnings and FAO anticipatory action principles, while ensuring national ownership.
- Integration of IB and AA into standard DRM planning, rather than treating them as project-based innovations.

4.1.6 Institutional Implementation Actions

#	Action	Details (linked to Section 3 institutional findings)	Responsible agencies
1	Clarify operational roles across the end-to-end early warning chain	Address identified fragmentation between monitoring, forecasting, warning preparation, and coordination by formally documenting operational roles and responsibilities of NAMEM, IRIMHE, and interfacing institutions	NAMEM, IRIMHE
2	Formalize inter-agency operational coordination mechanisms	Move from event-driven coordination to routine operational coordination through agreed seasonal coordination procedures and technical exchange mechanisms	NAMEM, IRIMHE
3	Develop and endorse a national multi-hazard Concept of Operations	Address the absence of a standardized end-to-end operational framework by developing a Concept of Operations defining workflows, handover points, timelines, and decision thresholds	NAMEM, IRIMHE

4	Institutionalize anticipatory action procedures	Transition from project-based early action to institutional practice by defining trigger validation, activation, and coordination procedures linked to forecasts and risk thresholds	NAMEM, IRIMHE
5	Strengthen institutional interfaces with response and sectoral actors	Address weak operational interfaces identified in diagnostics by formalizing information exchange and coordination protocols with disaster management and sectoral stakeholders	NAMEM, IRIMHE
6	Update data-sharing and operational agreements	Address informal or outdated data-sharing arrangements by updating agreements to reflect operational needs, data authority, and interoperability requirements	NAMEM, IRIMHE
7	Introduce routine performance review and learning mechanisms	Address limited institutional learning by establishing post-event reviews focused on operational performance, decision timelines, and service effectiveness	NAMEM, IRIMHE
8	Align institutional planning with EW4All and national strategies	Ensure long-term sustainability by aligning institutional roles and planning cycles with EW4All objectives and national climate and disaster risk strategies	NAMEM, IRIMHE

4.2.Infrastructure

4.2.1 Baseline infrastructure maturity and intent of improvement

Baseline NCAT maturity score (Infrastructure): 3.4

A maturity score of **approximately 3.4/5** indicates that Mongolia's physical, digital, and operational infrastructure for hydrometeorological and early warning services is established and operational, supporting current service delivery requirements. Core facilities, ICT systems, power supply arrangements, and maintenance functions are in place and enable routine forecasting, monitoring, and dissemination activities.

However, the assessment confirms that infrastructure development has largely occurred through incremental, project-driven investments, resulting in heterogeneous systems, variable redundancy, and limited scalability. Infrastructure is not yet fully optimized to support continuous multi-hazard operations, integrated decision-support environments, sustained 24/7 surge operations, impact-based services, anticipatory action, or emerging AI-enabled workflows.

The objective of the infrastructure implementation plan is therefore not to expand infrastructure coverage, but to progressively increase maturity from level 3.5 toward level 5 by improving resilience, coherence, redundancy, and scalability, ensuring that infrastructure reliably supports evolving national early warning ambitions.

4.2.2 Short-term infrastructure improvements (1–2 years)

Target maturity progression: 3.4 → 3.9

In the short term, infrastructure improvements should focus on stabilizing and securing critical operational infrastructure, addressing diagnostic findings related to uneven reliability and limited formalization.

Key short-term achievements include:

- Conducting a comprehensive infrastructure audit covering operational buildings, ICT systems, power supply, network connectivity, and calibration facilities at national and selected regional levels.
- Standardizing backup power arrangements for all operationally critical systems, including forecasting rooms, data processing servers, and dissemination platforms, with documented testing and maintenance procedures.
- Strengthening basic network redundancy and internal connectivity to ensure continuity of operations during peak demand and extreme events.
- Modest reconfiguration and upgrading of operational spaces to better support integrated forecasting workflows, joint briefings, and coordination during hazard events.
- Addressing the most critical gaps in reference calibration equipment, stabilizing observation system performance and data quality.

These actions primarily address NCAT criteria that currently score 3 due to partial coverage, informal arrangements, or inconsistent implementation

4.2.3 Medium-term infrastructure improvements (3–5 years)

Target maturity progression: 3.9 → 4.5

Medium-term infrastructure improvements focus on consolidation, integration, and scalability, enabling infrastructure to support increasing service complexity and coordination demands.

Key medium-term achievements include:

- Modernization of ICT, server, and storage infrastructure to support ensemble forecasting, coupled meteorological–hydrological modelling, and increased data volumes.
- Establishment of dedicated multi-hazard operational and coordination environments, equipped with integrated visualization tools for meteorological, hydrological, agrometeorological, and impact information.

- Strengthening of power resilience to sustain prolonged operations during severe winter events and other extreme hazards.
- Deployment of mobile calibration and maintenance capabilities, complemented by strengthened regional technical support functions.
- Harmonization of infrastructure standards across national and regional offices to reduce heterogeneity introduced by project-based investments.
- Clear separation of operational and development ICT environments, protecting service continuity while enabling innovation.

These actions address NCAT criteria that require demonstrated consistency, redundancy, and system-wide coherence.

4.2.4 Long-term infrastructure improvements (5+ years)

Target maturity progression: ~4.5 → 5.0

Progression to maturity level 5 requires infrastructure that is fully resilient, interoperable, and sustainable, capable of supporting advanced services independent of external project cycles.

Key long-term achievements include:

- Establishment of a high-availability national operations platform integrating monitoring, forecasting, impact analysis, and dissemination functions.
- Full implementation of redundant power, network, and data architectures, supported by routine stress testing and performance monitoring.
- Institutionalization of infrastructure lifecycle management, including asset replacement planning and recurrent budgeting for maintenance and renewal.
- Preparation of infrastructure environments to support operational AI and advanced analytics, including secure data pipelines, scalable computing resources, and governance arrangements.
- Continuous modernization aligned with national digital strategies, WMO technical regulations, and FAO-supported service frameworks.

4.2.5 Impact-Based (IB) early warning and Anticipatory Action (AA)

Infrastructure maturity is a critical enabler for Impact-Based (IB) early warning and Anticipatory Action (AA). The assessment confirms that while Mongolia has demonstrated IB and AA practices during specific events, infrastructure constraints limit systematic application.

Infrastructure improvements required to support IB and AA include:

- Operational environments capable of integrating hazard, exposure, vulnerability, and impact information in near real time.

- Reliable computing and storage capacity to support impact modelling, scenario analysis, and threshold monitoring.
- Resilient power and connectivity arrangements to ensure continuous availability of decision-support tools during extreme events.
- Infrastructure readiness to support automation and AI-assisted processing, including quality control, impact estimation, and alert triggering.

4.2.6 Infrastructure Implementation Actions

#	Action	Details (linked to Section 3 infrastructure findings)	Responsible agencies
1	Assess and prioritize critical operational facilities	Address identified weaknesses in physical facilities by conducting a structured assessment of buildings supporting forecasting, monitoring, and coordination functions	NAMEM, IRIMHE
2	Upgrade operational facilities for continuous service delivery	Improve reliability of 24/7 operations through targeted rehabilitation of facilities, including power supply, climate control, and equipment housing	NAMEM, IRIMHE
3	Strengthen ICT connectivity and internal networks	Address uneven connectivity and internal network limitations by upgrading data links between headquarters, regional units, and operational systems	NAMEM, IRIMHE
4	Improve system redundancy and backup power	Reduce vulnerability to service disruption by upgrading backup power systems and ensuring redundancy for critical operational infrastructure	NAMEM, IRIMHE
5	Upgrade computing and server infrastructure	Address growing computational and data storage demands by expanding server capacity and improving operational system reliability	NAMEM, IRIMHE
6	Separate operational and development environments	Reduce operational risk by establishing clear separation between live operational systems and testing or development platforms	NAMEM, IRIMHE
7	Establish infrastructure maintenance and lifecycle management plans	Address reactive maintenance practices by introducing planned maintenance schedules, asset inventories, and lifecycle costing	NAMEM, IRIMHE
8	Align infrastructure scaling with service expansion	Ensure sustainability by scaling infrastructure investments in line with prioritized service delivery needs rather than ad hoc expansion	NAMEM, IRIMHE

4.3. Observations and Data Acquisition

4.3.1 Baseline observation maturity and intent of improvement

Baseline NCAT maturity score (Observations and Data Acquisition): 3

A maturity score of 3.1/5 indicates that Mongolia's observation and data acquisition system is established, nationally operational, and scientifically credible, but remains monitoring-oriented rather than fully service- and risk-driven. Core meteorological, hydrological, and agrometeorological networks are in place and provide essential inputs for forecasting and climate services. However, limitations persist in spatial representativeness, real-time availability, automation under harsh climatic conditions, and alignment between observed variables and priority decision-making needs.

Diagnostics confirmed that while Mongolia has a long-established national observation network operated by NAMEM and IRIMHE, current configurations do not yet fully support:

- High-resolution impact-based (IB) forecasting
- Robust anticipatory action (AA) triggers
- AI-enabled applications requiring homogeneous, quality-controlled datasets

The objective of the observation implementation plan is therefore not to expand the network indiscriminately, but to progressively increase maturity from level 3.1 toward level 5 by shifting from a primarily monitoring-oriented paradigm to a service- and risk-oriented observation system, explicitly linked to forecasting skill, impact assessment, and decision-making.

Implementation emphasizes:

- Operational reliability under extreme climatic conditions
- Preservation and usability of long-term records
- Systematic integration of in-situ, agrometeorological, hydrological, environmental, and satellite-based observations

4.3.2 Short-term observation improvements (1–2 years)

Target maturity progression: 3.1 → ~3.6

In the short term, observation system improvements focus on stabilizing critical measurements and safeguarding data continuity, particularly for high-impact hazards such as dzud, floods, and droughts.

Key short-term achievements include:

- Securing continuity and quality of priority surface meteorological observations, particularly temperature extremes, wind, precipitation, and snow depth, in line with WMO Guidelines.
- Strengthening calibration facilities and field verification capacity, addressing diagnostic findings related to outdated reference equipment and limited traceability.
- Improving reliability of upper-air observations through targeted maintenance, calibration checks, and operational stabilization of radiosonde stations.

- Reducing data loss during extreme winter conditions by improving station robustness and transmission reliability in climatically harsh regions.
- Introducing systematic metadata documentation and basic quality control harmonization for manual and automated observations.

4.3.3 Medium-term observation improvements (3–5 years)

Target maturity progression: ~3.6 → ~4.4

Medium-term improvements focus on enhancing spatial representativeness, automation, and cross-domain integration, ensuring that observations directly support operational forecasting, IB services, and AA mechanisms.

Key medium-term achievements include:

- Gradual expansion of automated meteorological observations in remote and climatically extreme areas, reducing reliance on manual measurements and minimizing data gaps during severe events, consistent with WIGOS principles.
- Strengthening real-time hydrological monitoring, particularly river stage and discharge observations in flood-prone and snowmelt-driven basins, aligned with WMO-No. 168.
- Improving snowpack and Snow Water Equivalent (SWE) observations, supporting dzud monitoring and spring flood risk assessment through a combination of enhanced in-situ measurements and satellite integration.
- Integrating agrometeorological variables (soil moisture proxies, evapotranspiration indicators, vegetation condition, phenology) into routine national observation planning, aligned with WMO-No. 134.
- Expanding use of remote sensing products (precipitation, snow cover, vegetation indices, land surface temperature) with standardized blending of in-situ and satellite data, including documented uncertainty

4.3.4 Long-term observation improvements (5+ years)

Target maturity progression: ~4.4 → 5.0

Long-term observation improvements aim to achieve a fully integrated, resilient, and service-driven observation system, capable of sustaining advanced forecasting, IB services, AA, and AI-enabled applications.

Key long-term achievements include:

- Institutionalization of service-driven observation network design, where station density, parameter selection, and maintenance cycles are periodically reviewed based on hazard exposure, forecast sensitivity, and user needs.
- Full integration of meteorological, hydrological, agrometeorological, environmental, and cryospheric observations for compound hazard analysis.

- Establishment of mobile calibration and verification units, ensuring consistent data quality across remote and project-diverse station deployments.
- Implementation of advanced quality assurance and quality control (QA/QC) frameworks, combining automated and expert-driven procedures with full traceability.
- Long-term preservation and homogenization of time series to support climate services, loss modelling, and AI training datasets.

4.3.5 Impact-Based (IB) forecasting and Anticipatory Action (AA)

Observation system maturity is a direct limiting factor for IB forecasting and AA. The assessment confirms that while Mongolia has demonstrated AA practices during specific events, observation constraints limit systematic scaling.

Observation improvements required to support IB and AA include:

- Reliable, high-frequency observations for rapid-onset hazards
- Consistent snow, soil moisture, and hydrological data to support impact thresholds
- Integrated datasets enabling translation from hazard intensity to expected impacts
- Homogeneous, quality-controlled archives suitable for AI-supported impact modelling

4.3.6 Observation and Data Acquisition Implementation Actions

#	Action	Details (linked to Section 3.3 findings)	Responsible agencies
1	Secure continuity of priority meteorological observations	Address gaps in data continuity during extreme winter and severe weather events by stabilizing measurements of temperature extremes, wind, precipitation, and snow depth in high-risk regions, in line with WMO-No. 49 and WMO-No. 8	NAMEM, IRIMHE
2	Improve automation in remote and harsh environments	Reduce reliance on manual observations in remote areas identified in Section 3.3 by upgrading and expanding automated weather stations and remote monitoring, consistent with WIGOS	NAMEM, IRIMHE
3	Strengthen upper-air observation reliability	Address limitations in upper-air data availability by improving radiosonde operations, calibration checks, and data continuity, supporting numerical weather prediction and severe weather forecasting	NAMEM, IRIMHE
4	Enhance real-time hydrological data acquisition	Respond to identified gaps in operational hydrology by improving river stage and discharge monitoring in flood-prone and snowmelt-driven basins, consistent with WMO-No. 168	NAMEM, IRIMHE

5	Strengthen snow, frozen-ground, and ice observations	Close gaps in dzud and spring flood monitoring by improving measurement of snow depth, snowmelt indicators, river ice, and freeze–thaw processes using standardized methods	NAMEM, IRIMHE
6	Integrate agrometeorological variables into routine observations	Address limited agrometeorological data availability by introducing systematic observation of soil moisture proxies, evapotranspiration indicators, vegetation condition, and phenology, aligned with WMO-No. 134	NAMEM, IRIMHE
7	Upgrade calibration laboratories and facilities	Address outdated and insufficient calibration facilities identified in Section 3.3 by modernizing national calibration capacity for meteorological and hydrological instruments, ensuring traceability and uncertainty management	NAMEM, IRIMHE
8	Establish mobile field calibration and verification units	Reduce quality degradation in remote stations by establishing mobile units for in-situ calibration and verification, aligned with WMO-No. 8 and WIGOS quality management principles	NAMEM, IRIMHE
9	Strengthen data quality control and quality assurance systems	Address weaknesses in QC and QA by implementing standardized automated and manual procedures, metadata management, and traceability, consistent with WMO-No. 49 and WIGOS	NAMEM, IRIMHE
10	Build technical capacity in calibration and QC	Respond to identified human capacity gaps by providing targeted training on calibration procedures, QC methods, and uncertainty management, aligned with WMO observing standards	NAMEM, IRIMHE
11	Institutionalize service-driven observation planning	Ensure long-term sustainability by periodically reviewing observation network design, calibration cycles, and QC performance based on hazard exposure and service needs, consistent with WIGOS	NAMEM, IRIMHE

4.4. Historical and Ancillary Data Implementation Plan

4.4.1 Baseline data maturity and intent of improvement

Baseline NCAT maturity score (Historical and Ancillary Data): 3

A maturity score of **3.4/5** indicates that Mongolia possesses substantial and scientifically valuable historical hydrometeorological, agrometeorological, snow, and environmental datasets, but that these data are not yet fully consolidated, standardized, or optimized for advanced operational use.

Key limitations relate to incomplete digitization, inconsistent metadata, variable documentation of observational changes, and limited integration of impact and socio-economic datasets.

The objective of the historical and ancillary data implementation plan is not to create new datasets, but to progressively increase data maturity from level 3 toward level 5 by:

- Improving accessibility, consistency, and documentation
- Preserving long-term records while enhancing usability
- Enabling systematic use of historical data for impact-based services, anticipatory action, and AI-enabled analytics

4.4.2 Short-term data improvements (1–2 years)

Target maturity progression: 3.4 → ~4

Short-term actions focus on securing and organizing existing data assets to address NCAT criteria that currently score 3 due to partial digitization, fragmented metadata, and limited operational accessibility.

Priority short-term achievements include:

- Accelerated digitization of remaining paper-based archives, prioritizing:
    - Hydrological discharge and level records
    - Snow depth, snow course, and dzud-related observations
    - Historical event documentation relevant to floods, droughts, and dzud
- Consolidation of station metadata into a centralized digital repository, including:
    - Station relocations
    - Instrument changes
    - Automation transitions
- Systematic inventory and cataloguing of historical datasets across meteorological, hydrological, agrometeorological, and environmental domains
- Establishment of standardized data access procedures for internal operational users, reducing reliance on ad hoc data requests

4.4.3 Medium-term data improvements (3–5 years)

Target maturity progression: ~4 → ~4.5

Medium-term improvements focus on enhancing scientific consistency, interoperability, and analytical value of historical and ancillary data.

Key medium-term achievements include:

- Development of homogenized climate and hydrological datasets suitable for:
    - Trend analysis
    - Extremes analysis
    - Seasonal and sub-seasonal forecasting support
- Systematic updating and documentation of hydrological rating curves and cross-sections, with emphasis on:
    - High-flow segments
    - Snowmelt-driven regimes
- Integration of agrometeorological and land datasets with hydrometeorological time series, enabling:
    - Drought and pasture condition assessment
    - Livelihood-relevant impact analysis
- Establishment of standardized data formats and metadata structures aligned with WMO guidance, improving interoperability with modelling and forecasting systems
- Improved linkage between historical hazard data and emerging impact datasets to support calibration of impact thresholds

4.4.4 Long-term data improvements (5+ years)

Target maturity progression: ~4.5 → 5.0

Long-term progression to maturity level 5 requires that historical and ancillary data are fully integrated, sustainable, and routinely used across forecasting, risk assessment, and decision-support processes.

Key long-term achievements include:

- Completion of digitization and quality documentation of all priority historical archives
- Routine production and maintenance of nationally endorsed homogenized datasets
- Establishment of a centralized, standardized historical impact and loss database, incorporating:
    - Hazard occurrence
    - Exposure
    - Loss and damage information

- Integration of historical data management into institutional planning, budgeting, and performance monitoring
- Demonstrated routine use of historical data for:
    - Impact-based early warning
    - Anticipatory action trigger validation
    - AI and machine-learning model development and evaluation

4.4.5 Impact-Based (IB) services and Anticipatory Action (AA)

The assessment confirms that historical and ancillary data currently limit the full institutionalization of IB and AA, despite demonstrated operational experience during recent dzud events.

Improvements required to support IB and AA include:

- Systematic linkage between historical hazard data and documented impacts
- Development of historical hazard–impact relationships to support threshold definition
- Use of historical datasets to validate and refine anticipatory action triggers
- Alignment with WMO guidance on impact-based forecasting and FAO principles on anticipatory action, ensuring national ownership and scientific credibility

4.4.6 Historical and Ancillary Data Implementation Actions

#	Action	Details (linked to Section 3.4 findings)	Responsible agencies
1	Accelerate digitization of priority historical archives	Address remaining paper-based records, prioritizing hydrology, snow, and impact-relevant datasets	NAMEM, IRIMHE
2	Consolidate and digitize station metadata	Resolve gaps related to relocations, instrument changes, and automation transitions	NAMEM, IRIMHE
3	Develop homogenized climate datasets	Improve consistency for trend analysis, modelling, and AI applications	IRIMHE
4	Strengthen documentation of hydrological rating curves	Improve calibration and flood modelling reliability, especially for high flows	IRIMHE
5	Integrate agrometeorological and land datasets	Enhance drought and dzud impact analysis by linking soil, vegetation, and climate data	IRIMHE
6	Establish standardized data access and cataloguing	Improve operational accessibility and transparency of historical datasets	NAMEM, IRIMHE

7	Develop a historical impact and loss database	Address constraints for IB forecasting and AA trigger validation	NAMEM, IRIMHE
8	Align data management with WMO standards	Improve interoperability, metadata quality, and sustainability	NAMEM, IRIMHE
9	Build capacity in data homogenization and QA	Address technical gaps in advanced data processing and uncertainty management	NAMEM, IRIMHE
10	Institutionalize data lifecycle management	Ensure long-term sustainability through planned maintenance and budgeting	NAMEM

4.5. Data Management

4.5.1 Baseline data management maturity and plan of improvement

Baseline NCAT maturity score (Data Management): 3

A maturity score of **3.7/5** indicates that Mongolia's hydrometeorological data management system is functionally advanced and largely digital, with operational data flows supporting forecasting, climate services, and routine early warning. Core data management functions are in place, and several components already approach good international practice.

However, the system has not yet reached full maturity due to fragmentation across platforms, incomplete interoperability, partial standardization of QA/QC procedures, and gaps in metadata completeness and historical data consolidation. These limitations constrain scalability, machine-to-machine exchange, and advanced applications such as impact-based services, anticipatory action triggers, and AI-enabled analytics.

The objective of the data management implementation plan is therefore to progress maturity from level 3.7 toward level 5 by consolidating existing systems, strengthening governance and standards compliance, and ensuring long-term sustainability, rather than replacing operationally functional components

4.5.2 Short-term data management improvements (1–2 years)

Target maturity progression: 3.7 → ~4.1

Short-term actions focus on stabilization, standardization, and governance, addressing NCAT criteria that currently score between 3 and 4 due to partial implementation.

Key short-term achievements include:

- Formalization of a national hydrometeorological data governance framework, clarifying:
    - Institutional roles of NAMEM and IRIMHE in data ownership, stewardship, and dissemination
    - Responsibilities for operational, research, and public-service datasets

- Consolidation of operational datasets (meteorological, hydrological, agrometeorological) into a logically unified architecture, even if physically distributed, to reduce duplication and inconsistencies
- Standardization and documentation of QA/QC procedures already applied in operations, including:
    - Automated quality control routines for real-time data
    - Manual review protocols for historical and extreme-event data
- Completion and harmonization of core metadata for priority datasets, including:
    - Station histories (relocations, instrumentation changes, automation transitions)
    - Data lineage and processing descriptions
- Formal documentation of data backup and recovery procedures for operational systems, including minimum redundancy requirements for critical datasets.

4.5.3 Medium-term data management improvements (3–5 years)

Target maturity progression: ~4.1 → ~4.6

Medium-term improvements focus on interoperability, automation, and service enablement, addressing NCAT criteria requiring sustained and demonstrable performance.

Key medium-term achievements include:

- Progressive alignment with WMO information system standards, including:
    - Adoption of WIS 2.0 principles for discovery, access, and exchange
    - Introduction of standardized data services (APIs, machine-to-machine access) for priority datasets
- Establishment of a national hydrometeorological data catalogue, providing:
    - Centralized discovery of datasets across meteorology, hydrology, agrometeorology, and climate
    - Standardized metadata and access conditions
- Expansion of automated QA/QC and quality flagging, including:
    - Application of consistent quality indicators across datasets
    - Improved traceability of data corrections and revisions
- Completion of historical data digitization for priority archives, particularly:
    - Hydrological records
    - Snow and cryospheric observations
    - High-impact event datasets
- Improved integration of impact and loss datasets with hazard and exposure data, enabling:

- Retrospective impact analysis
- Validation of impact-based thresholds and anticipatory action triggers

4.5.4 Long-term data management improvements (5+ years)

Target maturity progression: ~4.6 → 5.0

Achieving maturity level 5 requires evidence that data management is fully integrated, interoperable, resilient, and future-proof.

Key long-term achievements include:

- Full operationalization of a national, interoperable hydrometeorological data ecosystem, supporting:
    - Seamless integration across monitoring, modelling, impact analysis, and dissemination
    - Regional and global data exchange without manual intervention
- Institutionalization of data lifecycle management, including:
    - Planned digitization, archiving, and decommissioning processes
    - Sustainable budgeting for data management operations
- Establishment of trusted datasets suitable for:
    - Probabilistic forecasting
    - Impact-based early warning
    - Anticipatory action decision frameworks
    - AI and machine learning applications
- Regular performance audits of data management systems, including:
    - Data availability
    - Timeliness
    - Quality and usability for decision-making

4.5.5 Impact-Based (IB) services, Anticipatory Action (AA), and AI enablement

The assessment confirms that current data management practices are sufficient for deterministic forecasting, but not yet optimized for systematic IB services, AA, or AI.

Data management improvements required to support these include:

- Structured linkage between hazard data, exposure data, and impact datasets to enable impact modelling

- Improved temporal consistency and homogenization of historical datasets used for trigger calibration
- Standardized, machine-readable datasets suitable for AI model training and validation
- Clear governance arrangements defining which datasets are authoritative for:
    - Impact thresholds
    - AA triggers
    - Post-event verification

4.5.6 Data Management Implementation Actions

#	Action	Details (linked to Section 3.5 findings)	Responsible agencies
1	Formalize national data governance framework	Address fragmented responsibilities by clearly defining data ownership, stewardship, access rights, and dissemination roles	NAMEM, IRIMHE
2	Consolidate operational data architectures	Reduce duplication and inconsistencies by logically integrating operational databases and repositories	NAMEM, IRIMHE
3	Standardize QA/QC procedures and documentation	Build on existing automated and manual QC practices to ensure consistency across datasets	NAMEM, IRIMHE
4	Complete priority metadata documentation	Address gaps in station history, instrumentation changes, and processing lineage	NAMEM, IRIMHE
5	Establish a national data catalogue	Improve discoverability and transparency of hydrometeorological datasets	NAMEM, IRIMHE
6	Align data exchange with WMO standards	Progressively implement WIS 2.0 principles and machine-to-machine services	NAMEM, IRIMHE
7	Accelerate digitization of historical archives	Prioritize hydrology, snow, and impact datasets critical for modelling and AA	NAMEM, IRIMHE
8	Integrate impact and loss datasets	Enable validation of impact-based forecasts and AA triggers	NAMEM, IRIMHE
9	Formalize data backup and recovery policies	Reduce operational risk by ensuring redundancy and continuity	NAMEM
10	Enable data readiness for AI and advanced analytics	Prepare trusted, well-documented datasets suitable for AI and probabilistic applications	NAMEM, IRIMHE

4.6. Meteorological Forecasts and Products

4.6.1 Baseline forecasting maturity and plan of improvement

Baseline NCAT maturity score (Meteorological Forecasts and Products): ~2.8

A maturity score of approximately 2.8/5 indicates that Mongolia's meteorological forecasting system is operationally sound, with routine production of short-, medium-, and longer-range forecasts supported by national observations, global NWP products, and experienced forecasters. Core forecasting functions, including public weather services and hazard warnings, are well established and meet basic service delivery requirements.

However, the forecasting system has not yet reached higher maturity levels due to limited use of advanced data assimilation, incomplete weather radar coverage, early-stage application of AI-based forecasting tools, and partial integration of impact- forecasting concepts. Forecast products remain largely hazard- and parameter-based, with limited systematic linkage to exposure, vulnerability, and sector-specific impacts.

The objective of the meteorological forecasting implementation plan is therefore to progress maturity from level ~2.8 toward level 5 by modernizing forecasting infrastructure, operationalizing AI-enhanced prediction systems, strengthening radar and nowcasting capabilities, and fully integrating impact-based and people-centred forecast products that support anticipatory action.

4.6.2 Short-term forecasting improvements (1–2 years)

Target maturity progression: ~2.8 → ~3.1

Short-term actions focus on operational enhancement, system integration, and foundational capacity building.

Key short-term achievements include:

- **Operationalization of AI-enhanced flash and urban flood nowcasting**, including:
  - Deployment of AI nowcasting software utilizing satellite and existing surface observations
  - Use of open-source, interoperable solutions aligned with WMO-No. 1198 (Nowcasting)
- **Initial strengthening of weather radar operations**, including:
  - Integration of existing radar data into operational workflows
  - Standardized calibration, quality control, and data exchange procedures following WMO-No. 8
- **Improved use of local observations in forecasting**, including:
  - Introduction of basic data assimilation techniques for high-impact weather situations

    - Improved linkage between observational networks and operational forecasting
- **Early application of AI tools for forecast enhancement**, including:
    - Bias correction and post-processing of short- to medium-range forecasts
    - Pilot applications for sub-seasonal and seasonal outlook refinement
- **Initial development of impact-oriented forecast products**, including:
    - Narrative impact statements accompanying hazard warnings
    - Sector-specific advisories for selected priority hazards (e.g. floods, heatwaves)

4.6.3 Medium-term forecasting improvements (3–5 years)

Target maturity progression: ~3.1 → ~4.0

Medium-term improvements focus on automation, interoperability, and impact-based service expansion, addressing NCAT criteria requiring consistent, scalable, and demonstrable performance.

Key medium-term achievements include:

- **Expansion of the national weather radar network**, including:
    - Installation of additional radar units and supporting infrastructure
    - Full compliance with ISO 19926-1:2018 and WMO standards for data exchange
- **Deployment of advanced data assimilation systems**, enabling:
    - Routine assimilation of national observations into high-resolution NWP
    - Improved representation of local-scale weather phenomena
- **Operational use of AI for multi-scale forecasting**, including:
    - AI-supported short- to medium-range forecasting
    - AI-based downscaling and bias correction for monthly and seasonal predictions
- **Development of interoperable impact-based forecast and alert systems**, including:
    - Integration of meteorological, hydrological, environmental, and socio-economic indicators
    - Alignment with WMO-No. 1150 (Multi-hazard Impact-based Forecast and Warning Services)
- **Strengthened institutional coordination**, ensuring:
    - Consistent forecast messaging across agencies
    - Clear roles between forecast production, warning issuance, and emergency response

4.6.4 Long-term forecasting improvements (5 +years)

Target maturity progression: ~4.0 → 5.0

Achieving maturity level 5 requires evidence that meteorological forecasting and product delivery are fully integrated, adaptive, and future-ready.

Key long-term achievements include:

- **Fully operational AI-enhanced forecasting ecosystem**, supporting:
    - Seamless integration of observations, NWP, AI models, and impact analysis
    - Continuous learning and performance improvement of forecasting systems
- **End-to-end impact-based forecasting and anticipatory action support**, including:
    - Forecasts directly linked to agreed triggers and response actions
    - Consistent use across national and local decision-making processes
- **High resilience and redundancy of forecasting infrastructure**, including:
    - Robust backup systems for radar, computing, and data flows
    - Operational continuity during extreme events
- **Routine performance evaluation and verification**, including:
    - Forecast skill assessment across time scales
    - Evaluation of forecast usefulness for decision-making and public action

4.6.5 Meteorological Forecasting Implementation Actions

#	Action	Details (linked to Section 3.6 findings)	Responsible agencies
1	Operationalize AI-enhanced Flash and Urban Flood Prediction	Deploy AI nowcasting software utilizing satellite feeds. Focus on open-source, interoperable code to ensure long-term maintenance, consistent with WMO-No. 1198 (Nowcasting) and WIPPS pilot projects.	NAMEM, IRIMHE
2	Expand National Weather Radar Network	Install radar units, towers, and middleware. Ensure all systems follow ISO 19926-1:2018 and WMO-No. 8 for calibration, site selection, and standardized data exchange.	NAMEM, IRIMHE
3	Deploy Advanced Data Assimilation for NWP	Implement tools to integrate local observations into Numerical Weather Prediction (NWP) models. This bridges the gap between raw data and high-resolution forecasts, aligned with WMO-No. 1311 (High-res NWP).	NAMEM, IRIMHE
4	Deploy AI for Multi-scale Forecast Accuracy	Use AI-based tools for short-to-medium range prediction and monthly/seasonal bias correction (downscaling). Aligns with the WMO AI for Nowcasting Pilot Project (AINPP) and S2S challenge findings.	NAMEM, IRIMHE

5	Develop Impact-Based Forecast and Alert Portal	Build a web portal that moves from "what the weather will be" to "what the weather will do." Integrate socio-economic data for hazard-triggering, following WMO-No. 1150 (Multi-hazard IBFWS).	NAMEM, IRIMHE, NEMA

4.7. Operational hydrological services

4.7.1 Baseline Hydrological Services and plan of improvement

Baseline NCAT maturity score (Hydrological Forecasting and Services): ~2

Although a robust system for hydrological monitoring and data collection is in place, most steps remain manual and highly labour-intensive. For example, rating curves are currently plotted manually by IRIMHE staff. This makes the overall process slow and inefficient. There is therefore a strong need to automate key elements of data collection and management. Doing so would allow hydrological staff at IRIMHE to devote more time to core technical tasks such as data analysis, forecast production, and forecast verification.

There is currently a major gap in lack of operational hydrological forecasting capability, which limits the effective use of available monitoring data for forecasting and decision-making purposes. Addressing this gap requires the deployment of interoperable tools/systems that can effectively integrate the data from different sources to generate user-centric forecasts and products that will enable for timely exchange of data across different stakeholders. At the same, time, there is a need for targeted capacity building to strengthen the staff competencies in hydrological and hydraulic modeling from an operational perspective and to further move towards impact-based forecasting. This can be achieved by leveraging WMO Regional Training Centres and through twinning arrangements with other NMHSs, which will allow for transfer of operational best practices and sustained technical support. To further strengthen and sustain the efforts, it is advisable to institutionalize training support within IRIMHE to ensure continuity of expertise and consistent application of forecasting procedures. With the advent of emerging technologies such as Internet of Things (IoT), AI, Digital Twins and others, the existing system(s) should also be progressively enhanced with the integration of these technologies to improve the hydrological value chain while ensuring operational reliability.

4.7.2 Short-term Improvements (1-2 years)

Target maturity progression:2.1 – > ~ 3.3

Short-term actions will focus on automating some of the data monitoring and collection of hydrological data, laying some of the foundational work around strengthening national/local capacities on hydrological modeling and forecasting and identifying basic training needs.

Some of the main short-term achievements will include:

- **Establish foundations for automated hydrological data workflows**

  - Review existing data collection, transmission and quality control processes
  - Define data standards and basic automated quality control procedures aligned with WMO standards (WIGOS, WIS 2.0, WHOS) and guidelines
  - Initiate pilot deployment of identified stations
  - Training of staff on WMO standards and operation and maintenance of stations

- Develop basin-specific modelling and forecasting concepts
  - Engage stakeholders (disaster managers (NEMA), water authority, agriculture, hydropower etc) to define modelling objectives and operational needs
  - Review of available open-source and freely available hydrological models and platforms making use of WMO inventory of interoperable models, platforms for flood forecasting and early warning systems
  - Conduct operational training of staff on shortlisted model and platform

- Assess capacity gaps and design learning pathways
  - Conduct training need assessments across the hydrological personnel of NAMEM and IRIMHE
  - Identify core competencies around hydrometry, hydrological modeling and forecasting, data management and programming
  - Develop training curricula and capacity building plan for NAMEM and IRIMHE

4.7.3 Medium-term Improvements (2-5 years)

Target maturity progression: **~3.3 – > ~ 4.2**

Medium-term actions will build on the short-term actions outlined above, centering on operationalization of the flood forecasting model and platform, calibration of the hydrometric stations and models, further automation of the remaining network, institutionalizing the training activities within NAMEM and IRIMHE.

- Expansion and integration of automated hydrological information systems
  - Scale up automated data collection and quality control across priority basins
  - Introduce advanced QC procedures, including consistency and anomaly checks
  - Integrate hydrological data with meteorological, agrometeorological and multi-hazard forecasting and warning platforms

- Operational development of integrated hydrological forecasting systems
  - Co-develop hydrological model(s) for priority basins
  - Test model performance for different regimes (low flow, high flow, spring floods etc.)
  - Calibrate and validate models using improved and longer-term datasets
  - Develop plan for expansion of the model to other target basins

- Deliver continued capacity development and generate national expertise
  - Conduct training need assessments across the hydrological personnel of NAMEM and IRIMHE

- Identify core competencies around hydrometry, hydrological modeling and forecasting, data management and programming
- Develop training curricula and capacity building plan for NAMEM and IRIMHE

4.7.4 Long-term improvements (5-10 years)

Target maturity progression: ~4.2 – > 5.0

Long-term actions will consolidate and enhance the systems and capacities developed in the previous phases, transitioning to a fully automated, integrated hydrological and flood forecasting network. Advanced forecasting models, potential integration of technologies such as AI and others and continuous data flows which will assist in timely, accurate and reliable early warnings. Institutionalization of the training and knowledge management will help to sustain technical expertise, transforming NAMEM and IRIMHE into highly responsive, data-driven agencies capable of providing effective and efficient hydrological services to its users.

- Establishment of a resilient and interoperable hydrological data network and system
  - Establish fully automated, end-to-end hydrological data lifecycle management
  - Ensuring interoperability with regional and global hydrological centres and its information systems
  - Potential deployment of AI assisted tools for data quality control

- Embed advanced forecasting capabilities into national operations
  - Establish fully operational, nationally owned forecasting systems
  - Expand hydrological forecasting capabilities from short-term to longer-term incorporating seasonal forecasts and climate-change projections for defining water resource scenarios (aligned with HydroSOS)
  - Enhance the existing modeling framework to ingest new data sources and integrate with emerging technologies

- Institutionalize knowledge, skills and learning capacities
  - Embed continuous professional development within the institutions through potential collaborations with WMO Regional Centres and other NMHSs
  - Develop a national e-learning platform or knowledge portal providing free access to training materials, best practices and case studies
  - Establish mentorship programme and short-term courses for young professionals
  - Setup joint training courses with universities combining theoretical knowledge with vocational training

4.7.5 Hydrological Forecasting Implementation Actions

#	Action	Details (linked to Section 3.6 findings)	Responsible agencies
1	Automation of the hydrological data collection and quality control process	Ensure high-quality data by automating data collection process (replace with automatic hydrometric stations in a phased manner) for water level (river and lake), discharge and other parameters, consistent with WMO-No. 168 (Guide to Hydrological Practices, specifically Volume I: Hydrology – From Measurement to Hydrological Information), WMO Technical Regulations, Volume III: Hydrology (WMO No. 49) which contains standards and high level guidance on hydrological observing networks and observing procedures, and WIGOS metadata standards.	NAMEM
2	Review and identify a suite of freely available (and preferably open-source) hydrological and hydraulic models and platforms suitable for flood forecasting	To support IRIMHE with implementing an operational hydrological model for critical basins in Mongolia to enable them to produce operational forecasts. This will be aligned with the WMO Guidelines on the Inventory of Interoperable Models and Platforms for Flood Forecasting and Early Warning Systems (WMO No. 1345). The guideline provides a set of interoperable solutions to tackle NMHS's needs on flood forecasting models and platforms, and makes use of an inventory that consists of a suite of operational models and platforms that are used for flood forecasting purposes.	IRIMHE
3	Co-design and develop hydrological model and integrated forecasting system for target basins	In collaboration with technical staff from NAMEM, IRIMHE and technical partners (supporting with model and platform development), jointly define modelling objectives, data requirements and operational workflows. The proposed system should make use of basin characteristics, observational data, and also incorporate user needs in the design process. This can be further linked with a visualization and dissemination tool.	IRIMHE, NAMEM
4	Identify training needs and develop training curriculum	Carry out a skill map of operational staff across the hydrological value chain (hydrometry, data management, hydrological modeling, forecasting and communication). A structured training curriculum will be developed with support from WMO Regional Training Centres (RTCs) and other NMHSs that will include a mix of desktop studies and operational hands-on training.	IRIMHE, NAMEM

5	Institutionalize structured training in hydrometry and hydrological modelling and forecasting	To ensure sustainability, training is embedded within the institutional processes and a dedicated training department is setup that can develop training schedules, curriculum and deliver trainings tailored to the needs of the national agencies.	IRIMHE

4.8. Agrometeorological monitoring and forecast service

4.8.1 Baseline agrometeorological maturity and plan of improvement

Baseline ACAT maturity score (Agrometeorological Services): 2.9

A maturity score of **2.9/5** indicates that Mongolia's agrometeorological services are partially established, with operational monitoring and periodic advisory production, but remain fragmented, labour-intensive, and insufficiently integrated across data, modelling, and service delivery components. Core agrometeorological observations and expertise exist, and agromet information is used in selected decision-making contexts, particularly for drought and dzud monitoring.

However, the agrometeorological system has not yet reached functional maturity as an **end-to-end, people-centred service**. Key constraints include limited automation of quality control, insufficient spatial coverage of agromet and zoo-meteorological observations, underdeveloped modelling capacity for pasture, crops, and soil processes, and weak integration with hydrological forecasts. Advisory products remain largely descriptive rather than impact- or action-oriented, with limited use of socio-economic indicators, anticipatory action triggers, or AI-enabled analytics.

The objective of the agrometeorological implementation plan is therefore to progress maturity from **level 2.9 toward level 5** by strengthening agromet services as a fully integrated system—linking observations, modelling, forecasting, impacts, and user engagement—to support anticipatory action for drought, dzud, floods, fires, and other climate-related risks.

4.8.2 Short-term agrometeorological improvements (1–2 years)

Target maturity progression: 2.9 → ~3.4

Short-term actions focus on stabilization, automation, and service foundations, addressing ACAT criteria currently scoring below 3 due to manual processes, limited coverage, and weak standardization.

Key short-term achievements include:

- **Deployment of automated quality control (QC) across agromet observations**, including:
    - Automated QC for soil moisture, temperature, and phenological observations
    - Alignment with WMO-No. 134 (Guide to Agricultural Meteorological Practices) and WIGOS metadata standards

    - Reduced manual workload, allowing staff to focus on analysis and advisory development

- **Expansion of agromet and zoo-meteorological observation networks**, including:
    - Procurement of low-cost, robust stations (e.g. 3D-PAWS) for remote pastoral areas
    - Improved spatial coverage in drought- and dzud-prone regions
- **Initial strengthening of agrometeorological modelling capacity**, including:
    - Basic water balance and evapotranspiration modelling
    - Preliminary pasture biomass and pest/rodent monitoring models
- **Early integration of hydrological information into agromet services**, including:
    - Use of snowmelt and runoff indicators in drought and seasonal outlooks
- **Development of site- and crop-specific calendars**, reflecting:
    - Changing climate conditions
    - Regional agro-ecological zones

4.8.3 Medium-term agrometeorological improvements (3–5 years)

Target maturity progression: ~3.4 → ~4.2

Medium-term improvements focus on system integration, modelling depth, and anticipatory action enablement, addressing ACAT criteria requiring consistent, scalable, and decision-oriented services.

Key medium-term achievements include:

- **Strengthened modelling for pasture, crops, and soil processes**, including:
    - Integrated modelling of water balance, biomass, soil carbon, and pests (including rodents)
    - Improved decision support for livestock and crop management
- **Operational integration of hydrological forecasts into agromet products**, enabling:
    - Improved assessment of water availability for agriculture
    - Early warning of compound drought–water stress conditions
- **Development of impact- and socio-economically informed triggering methodologies**, including:
    - Objective thresholds for drought, dzud, floods, and fires
    - Use of AI to fuse meteorological, agromet, hydrological, and socio-economic data

- Alignment with the WMO Early Warnings for All (EW4All) initiative

- **Establishment of an Agrometeorological Workstation or Portal**, providing:
    - Integrated monitoring, modelling, and forecasting
    - Automated bulletin and advisory generation
    - Interoperability with national hydrometeorological systems
- **Strengthened advisory services at grid and local levels**, including:
    - More frequent, tailored advisories for herders and farmers
    - Improved coordination with extension services

4.8.4 Long-term agrometeorological improvements (5+ years)

Target maturity progression: ~4.2 → 5.0

Achieving maturity level 5 requires evidence that agrometeorological services are fully operational, user-driven, and sustainably embedded within national decision-making processes.

Key long-term achievements include:

- **Fully integrated, end-to-end agrometeorological service system**, supporting:
    - Seamless linkage from observations to impacts and actions
    - National and local anticipatory action frameworks
- **Routine use of AI across agromet service delivery**, including:
    - Advisory generation
    - Advanced modelling and downscaling
    - Automated quality control and anomaly detection
- **Institutionalized user feedback and co-production mechanisms**, ensuring:
    - Continuous input from herders and farmers
    - Iterative improvement of services based on user needs
- **Formalization of operational frameworks**, including:
    - Approved CONOPS and SOPs for agrometeorological service delivery
    - Clear roles across NAMEM, IRIMHE, and sectoral partners
- **Sustained evaluation and learning**, including:
    - Routine socio-economic benefit (SEB) and cost-effectiveness assessments

- Use of evidence to guide investment and service refinement

4.8.5 Agrometeorological Implementation Actions

#	Action	Details (linked to Section 3.8 findings)	Responsible agencies
1	Deploy automatic quality-control (QC) for agromet observations	Ensure high-quality data by implementing automated QC protocols for soil moisture, temperature, and phenology, consistent with WMO-No. 134 (Agromet Guide) and WIGOS metadata standards. It will save agromet team work and they can spent in analyze more time.	NAMEM, IRIMHE
2	Procure low-cost agromet/zoo-met stations (e.g., 3D-PAWS)	Expand network density in remote pastoral areas using 3D-Printed Automatic Weather Stations to fill spatial gaps at a lower cost, aligned with WMO/IOM Report No. 136.	NAMEM, IRIMHE,
3	Develop AI-driven triggering for Anticipatory Action (AA)	Create objective thresholds for drought, dzud, and floods by fusing weather data with socio-economic indicators using AI, supporting the WMO Early Warnings for All (EW4All) initiative.	NAMEM, IRIMHE,
4	Strengthen modeling for pasture, crops, and soil carbon	Improve decision support for livestock and farming by upgrading modeling for water balance, pests (rodents), and biomass, in line with WMO-No. 134	IRIMHE, NAMEM
5	Integrate hydrological forecasts into agromet products	Bridge the gap between water availability and farming by incorporating river runoff and snowmelt data into agromet bulletins, consistent with WMO-No. 168 (Hydrology).	NAMEM, IRIMHE
6	Develop and update site-specific crop calendars	Standardize agricultural timing by creating calendars that account for climate shifts, helping farmers optimize planting and harvest cycles as per WMO-No. 134 standards.	MOFALI, IRIMHE
7	Establish a digital Agromet Workstation/Portal	Centralize monitoring and forecasting into a single platform using AI for automated analysis and bulletin generation, aligned with WMO-No. 1241 (Compendium of Services).	NAMEM, IRIMHE
8	Launch AI-based Chatbot for herder/farmer feedback	Address the "last mile" communication gap by providing interactive, header-centered actionable advisories via mobile, supporting the WMO Strategy for Service Delivery.	NAMEM, MOFALI

9	Develop CONOPS and SOPs for service delivery	Define clear operational roles (Concept of Operations) and procedures to ensure end-to-end reliability of agromet services, consistent with WMO-No. 1292.	NAMEM, IRIMHE, MOFALI
10	Introduce SEB evaluation and cost-effectiveness tools	Quantify the Socio-Economic Benefit (SEB) of agromet information to justify investments and improve service design, using the WMO SEB Toolbox.	NAMEM, IRIMHE
11	Design and deliver specialized training packages	Build staff capacity in agromet modeling, AI application, and user-centric communication, aligned with WMO-No. 258 (Guidelines for Education & Training).	NAMEM, IRIMHE

4.9. AI Capacities and Capabilities

4.9.1 Baseline AI maturity and intent of improvement

Baseline NCAT maturity score (AI capacities and capabilities): 1

A maturity score of **1.6/5** indicates that AI capacities within Mongolia's hydrometeorological, agrometeorological, and disaster risk management system are largely pre-operational. AI is not yet embedded in routine forecasting, impact analysis, or anticipatory action workflows, and there is no institutionalized framework governing AI development, validation, deployment, or accountability.

At this maturity level:

- AI-related activities are exploratory or conceptual, not operational
- AI use is not systematically linked to forecasting skill, impact analysis, or decision-making
- There are no formal CONOPS, SOPs, or governance mechanisms for AI-assisted services
- Data quality, consistency, and interoperability are not yet sufficient to safely support AI model training at scale

The objective of this implementation plan is therefore to progressively raise AI maturity from level 1.6 toward level 4+, by first establishing foundational enablers, then introducing validated AI-assisted applications, and finally embedding AI into impact-based services and anticipatory action in a controlled, accountable, and user-oriented manner.

4.9.2 Short-term AI capacity improvements (1–2 years)

Target maturity progression: 1.6 → ~2.5

Short-term implementation focuses on foundational readiness, addressing NCAT criteria currently scoring 1–2 due to absence of formal processes, limited data preparedness, and lack of institutional ownership.

Key short-term achievements include:

Data infrastructure and readiness

- Introduction of automated quality control routines for meteorological, hydrological, and agrometeorological datasets, building on existing QC practices but extending them to support AI-readiness.
- Identification and documentation of AI-ready datasets, including minimum requirements for:
    - Temporal consistency
    - Metadata completeness
    - Quality flags and uncertainty indicators
- Alignment of data management practices with WMO guidance on data stewardship and interoperability, ensuring future compatibility with AI workflows.

Exploratory AI applications (non-operational)

- Development of pilot AI models in sandbox environments for:
    - Short-range weather nowcasting
    - Data gap-filling and bias correction
    - Pattern recognition in drought and dzud indicators
- Explicit separation of experimental AI outputs from operational forecasting to avoid unintended use.

Human and institutional capacity

- Introductory training for technical staff in:
    - AI fundamentals for hydrometeorology and agriculture
    - AI limitations, uncertainty, and ethical considerations
- Designation of AI focal points within IRIMHE technical divisions to coordinate pilots and liaise with ICT and data teams.

4.9.3 Medium-term AI capacity improvements (3–5 years)

Target maturity progression: ~2.5 → ~3.8

Medium-term implementation shifts from experimentation to controlled operational use, addressing NCAT criteria related to reproducibility, validation, and integration with service workflows.

Key medium-term achievements include:

AI-enabled forecasting and modelling

- Introduction of AI-assisted nowcasting and short- to medium-range forecasting, complementing (not replacing) NWP and hydrological models.
- Development of AI-supported models for:
    - Water balance and runoff sensitivity

- Pasture biomass and vegetation stress
  - Soil moisture proxies and drought evolution
- Systematic use of AI for post-processing, bias correction, and ensemble interpretation.

Impact-based (IB) services and anticipatory action (AA)

- Development of AI-supported impact forecasting tools linking hazard indicators to exposure and vulnerability datasets.
- Use of AI to support anticipatory action trigger analysis, particularly for:
  - Dzud severity escalation
  - Drought onset and persistence
  - Flood risk thresholds in snowmelt-driven basins
- Clear documentation that AI informs triggers but does not autonomously activate decisions.

Governance and validation

- Establishment of model evaluation, verification, and version control procedures for AI-assisted systems.
- Formalization of R2O/O2R mechanisms, allowing research prototypes to transition into operations only after validation against defined criteria.
- Documentation of AI-assisted workflows within institutional SOPs.

4.9.4 Long-term AI capacity improvements (5+ years)

Target maturity progression: ~3.8 → ≥4.5

Long-term maturity reflects institutionalized, accountable, and trusted AI use embedded within national early warning and decision-support systems.

Key long-term achievements include:

- Full integration of AI-assisted components into:
  - Impact-based early warning services
  - Anticipatory action planning
  - Multi-hazard decision-support platforms
- Establishment of national AI governance arrangements covering:
  - Accountability and transparency
  - Model auditability and explainability
  - Ethical use and risk management
- Sustained human capacity development, ensuring AI expertise is retained institutionally and not dependent on external consultants.

- Alignment of AI-enabled services with WMO and FAO guidance, ensuring international interoperability and credibility.

4.9.5 AI implementation actions

c	Action	Details (linked to Section 3.9 findings)	Responsible agencies
1	Establish AI readiness criteria	Define minimum data, metadata, and QC standards required before AI model development	NAMEM, IRIMHE
2	Introduce automated QC pipelines	Extend existing QC practices to support AI training and validation	IRIMHE
3	Develop AI sandbox environments	Enable experimentation without affecting operations	IRIMHE
4	Pilot AI-assisted nowcasting	Support short-range forecasting under analyst supervision	IRIMHE
5	Develop AI-supported impact tools	Link hazards to impacts for dzud, drought, and floods	IRIMHE
6	Support AA trigger analysis	Use AI to explore trigger sensitivity, not autonomous activation	NAMEM, IRIMHE
7	Establish AI CONOPS and SOPs	Define roles, limitations, and validation requirements	NAMEM, IRIMHE
8	Build staff capacity in AI	Training in AI use, verification, and uncertainty	NAMEM, IRIMHE
9	Institutionalize R2O/O2R for AI	Ensure safe transition from research to operations	IRIMHE
10	Embed AI into IB services	Integrate AI into impact-based workflows once validated	NAMEM, IRIMHE

4.10. Dissemination and Communication

4.10.1 Baseline dissemination maturity and intent of improvement

Baseline NCAT maturity score (Dissemination and Communication): 3

A maturity score of **3.1/5** indicates that Mongolia's dissemination and communication system for hydrometeorological and early warning services is established and operational, with multiple dissemination channels, routine product delivery, and functional coordination during emergencies.

At this maturity level:

- Warnings and information are regularly disseminated
- Multiple communication channels are used (web, TV, radio, social media)
- Coordination with disaster management authorities occurs, particularly during high-impact events

However, dissemination remains:

- Predominantly hazard-based rather than impact-based
- Fragmented across platforms, with limited interoperability
- Weak in systematic user feedback, performance monitoring, and last-mile verification
- Not yet aligned with CAP-enabled automation, anticipatory action triggers, or AI-supported dissemination

The objective of the dissemination implementation plan is to progressively increase maturity from level 3 toward level 5, by strengthening end-to-end communication logic, embedding impact-based messaging, formalizing coordination, and enabling scalable, people-centred dissemination.

4.10.2 Short-term dissemination improvements (1–2 years)

Target maturity progression: 3.1 → ~3.6

Short-term actions focus on formalizing and standardizing existing dissemination practices that already function but lack documentation, consistency, or interoperability.

Key short-term achievements include:

- Formal documentation of end-to-end dissemination workflows, clearly defining:
    - Handover points between forecast production (IRIMHE), warning authorization and dissemination (NAMEM), and emergency coordination (NEMA)
- Standardization of dissemination schedules and escalation procedures for:
    - Routine forecasts
    - Watches, warnings, and alerts
- Introduction of basic impact descriptors within warning products, linked to:

- Expected impacts on livestock, agriculture, transport, and communities

- Development of template-based warning messages, including:
    - Clear hazard description
    - Geographic scope
    - Timing and confidence
    - Recommended protective actions agreed with NEMA
- Establishment of a structured post-event review mechanism to document:
    - Dissemination timelines
    - Channel performance
    - Communication gaps

4.10.3 Medium-term dissemination improvements (3–5 years)

Target maturity progression: ~3.6 → ~4.3

Medium-term improvements focus on embedding dissemination within an impact-based, interoperable early warning framework, demonstrating consistency, coordination, and user relevance.

Key medium-term achievements include:

- Operational adoption of an Impact-Based (IB) warning framework, ensuring:
    - Systematic translation of hazards into expected impacts
    - Clear linkage between warnings and preparedness or early actions
- Introduction of Common Alerting Protocol (CAP) for warnings and alerts, enabling:
    - Standardized message structures
    - Automated dissemination across multiple platforms
    - Interoperability with national and international systems
- Strengthening coordination with NEMA and sectoral actors through:
    - Regular joint planning and review meetings
    - Agreed communication protocols for high-impact events
- Development of user segmentation strategies, tailoring dissemination for:
    - Pastoralists and rural communities

    - Agricultural services
    - Local authorities
- Establishment of formal user feedback channels, including:
    - Digital feedback mechanisms
    - Periodic surveys and consultations
    - Integration of feedback into service improvement cycles

4.10.4 Long-term dissemination improvements (5+ years)

Target maturity progression: ~4.3 → 5.0

Progression to maturity level 5 requires evidence that dissemination and communication systems are fully integrated, automated, user-centred, and resilient, independent of individual projects or personnel.

Key long-term achievements include:

- Full integration of dissemination systems into a national multi-hazard early warning platform, linking:
    - Observations
    - Forecasts
    - Impact assessments
    - Alerts and response coordination
- Automated, CAP-enabled dissemination across:
    - Web platforms
    - Mobile and broadcast channels
    - Institutional interfaces
- Routine use of performance metrics to evaluate:
    - Timeliness
    - Reach
    - Comprehension
    - Actionability of warnings
- Institutionalization of continuous improvement mechanisms, using post-event analysis and user feedback to update dissemination practices.

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4.10.5 Dissemination in support of Impact-Based Early Warning and Anticipatory Action

The assessment confirms that Mongolia has demonstrated capacity to disseminate warnings during major events, including dzud. However, dissemination for anticipatory action remains limited.

Improvements required to raise maturity include:

- Predefinition of communication triggers linked to impact thresholds and early action plans
- Dissemination of early advisories and watches with longer lead times, enabling preparedness and early response
- Alignment of dissemination content with national anticipatory action frameworks, ensuring consistency between forecasts, decisions, and actions
- Clear differentiation between:
    - Information products
    - Watches
    - Warnings
    - Activation notices for early action

4.10.6 Dissemination Implementation Actions

#	Action	Details (linked to Section 3.10 findings)	Responsible agencies
1	Formalize end-to-end dissemination workflows	Address fragmentation by documenting roles, timelines, and handover points between IRIMHE, NAMEM, and NEMA	NAMEM, IRIMHE, NEMA
2	Standardize warning formats and schedules	Improve consistency and clarity of warnings using agreed templates and escalation logic	NAMEM, IRIMHE
3	Introduce impact-based warning content	Address hazard-centric dissemination by systematically including expected impacts and protective actions	NAMEM, IRIMHE
4	Establish routine coordination and review mechanisms	Move from event-driven to routine coordination through regular meetings and post-event reviews	NAMEM, IRIMHE, NEMA
5	Adopt CAP for warning dissemination	Improve interoperability and automation by implementing CAP-compliant alerting	NAMEM, IRIMHE
6	Strengthen user feedback mechanisms	Address lack of feedback by establishing structured channels for user input and evaluation	NAMEM, IRIMHE

7	Tailor dissemination to priority user groups	Improve last-mile effectiveness through targeted messaging for pastoral, agricultural, and local authority users	NAMEM, IRIMHE
8	Align dissemination with anticipatory action	Enable early action by linking dissemination triggers to predefined preparedness and response actions	NAMEM, IRIMHE, NEMA
9	Monitor dissemination performance	Introduce metrics for reach, timeliness, and effectiveness to support continuous improvement	NAMEM, IRIMHE

4.11. Staff Capabilities and Training

4.11.1 Baseline capacity maturity and intent of improvement

Baseline NCAT maturity score (Human Resources and Capacity): 3

A maturity score of approximately **3.2/5** indicates that Mongolia has established and functioning technical and scientific human capacity across hydrometeorology, climate, agrometeorology, and related domains. Core operational services are sustained, institutional knowledge is strong, and disciplinary expertise is clearly embedded within IRIMHE and supported by NAMEM's governance structure.

However, this maturity level also reflects structural and strategic limitations:

- Capacity is uneven across emerging domains such as impact-based services, anticipatory action, integrated risk analysis, and AI
- Workload concentration and reliance on a limited number of senior experts reduce institutional resilience
- Capacity development is not yet systematically aligned with competency frameworks or long-term workforce planning

The objective of this implementation plan is therefore to progressively raise human capacity maturity from level ~3.2 toward level 5, by strengthening workforce sustainability, formalizing competencies, and enabling staff to support impact-based and anticipatory services at scale.

4.11.2 Short-term capacity improvements (1–2 years)

Target maturity progression: ~3.2 → ~3.7

Short-term actions focus on stabilizing and optimizing existing human resources, without major structural expansion. These actions primarily address NCAT criteria that currently score 3 due to partial formalization and uneven capacity distribution.

Key short-term achievements include:

- Formal documentation of functional roles and competency expectations for:
    - Operational forecasting

- Climate and agrometeorological analysis
- Hydrological monitoring and modelling
- Data management and ICT support

- Mapping of existing staff skills against WMO competency frameworks, identifying priority gaps in:
  - Impact analysis
  - Multi-hazard risk interpretation
  - Decision-support communication
- Introduction of structured internal knowledge-sharing mechanisms between IRIMHE research units and operational teams to reinforce R2O/O2R practices.
- Targeted short courses and applied training focused on:
  - Impact-Based (IB) early warning concepts
  - Anticipatory Action (AA) logic and trigger interpretation
  - Operational use of probabilistic and ensemble products

4.11.3 Medium-term capacity improvements (3–5 years)

Target maturity progression: ~3.7 → ~4.4

Medium-term improvements aim to institutionalize capacity development and reduce dependence on individuals by embedding competencies into organizational systems.

Key medium-term achievements include:

- Establishment of formal career pathways and role differentiation within IRIMHE and NAMEM, distinguishing:
  - Operational forecasters
  - Applied analysts (impact, risk, agrometeorology)
  - Research and innovation specialists
- Integration of competency-based training and certification into human resource planning, aligned with WMO guidance.
- Development of dedicated capacity in:
  - Impact modelling and loss analysis
  - Socio-economic data interpretation
  - Cross-sectoral advisory services (agriculture, water, DRM)

- Introduction of structured mentoring and succession planning for critical technical roles, particularly in calibration, modelling, and system integration.
- Strengthening of surge capacity arrangements to support sustained 24/7 operations during extreme events.

4.11.4 Long-term capacity improvements (5+ years)

Target maturity progression: ~4.4 → 5.0

Progression to maturity level 5 requires that human capacity systems are fully sustainable, adaptive, and resilient, independent of external projects or individual staff.

Key long-term achievements include:

- Full institutionalization of competency-based workforce planning across NAMEM and IRIMHE.
- Stable staffing structures that support:
    - Multi-hazard impact-based services
    - Anticipatory action
    - Advanced analytics and AI-enabled workflows
- Permanent integration of R2O/O2R mechanisms into institutional mandates, with clear pathways for innovation to transition into operations.
- Alignment of workforce development with national education and research institutions to ensure a continuous pipeline of qualified professionals.
- Routine evaluation of staff capacity against evolving service requirements and technological advances.

4.11.5 Impact-Based (IB) services, Anticipatory Action (AA), and AI-related capacity development

The assessment confirms that Mongolia has demonstrated event-based anticipatory action experience, particularly during dzud events, but that these practices are not yet fully supported by institutionalized human capacity.

Capacity improvements required to progress maturity include:

- Training staff to translate hazard information into impact-relevant insights using standardized methodologies.
- Building multidisciplinary teams combining meteorological, hydrological, agrometeorological, and socio-economic expertise.
- Developing foundational data science and AI literacy among technical staff, focusing on:
    - Data quality requirements
    - Model validation and verification

- Ethical and operational governance of AI tools

- Ensuring that AI applications complement, rather than replace, expert judgment and established scientific workflows.

4.11.6 Human capacity implementation actions

#	Action	Details (linked to Section 3.11 findings)	Responsible agencies
1	Formalize competency profiles	Define competency requirements for key technical and operational roles using WMO frameworks	NAMEM, IRIMHE
2	Map existing skills and gaps	Conduct institutional skills mapping to identify priority capacity gaps in IB, AA, and analytics	NAMEM, IRIMHE
3	Institutionalize R2O/O2R mechanisms	Formalize research–operations exchange through structured pilot evaluation and transition processes	IRIMHE
4	Strengthen impact and risk analysis capacity	Build applied expertise in impact modelling and loss analysis to support IB services	IRIMHE
5	Develop anticipatory action competencies	Train staff on trigger design, forecast interpretation, and action coordination	NAMEM, IRIMHE
6	Introduce structured training pathways	Move from ad hoc training to competency-based capacity development plans	NAMEM, IRIMHE
7	Improve workforce sustainability	Implement mentoring, succession planning, and workload redistribution mechanisms	NAMEM, IRIMHE
8	Build AI and data science literacy	Develop foundational AI skills aligned with operational needs and governance principles	NAMEM, IRIMHE
9	Strengthen surge capacity	Establish staffing arrangements to support sustained operations during extreme events	NAMEM, IRIMHE
10	Align capacity planning with national strategies	Ensure workforce development supports EW4All, national DRM, and climate strategies	NAMEM, IRIMHE

4.12 Performance and Sustainability

4.12.1 Baseline performance and sustainability maturity and intent of improvement

Baseline NCAT maturity score (Performance and Sustainability): ~2

A maturity score of approximately 3.0/5 indicates that Mongolia's hydrometeorological and early warning services are operationally functional and deliver regular outputs, with demonstrated capacity to perform during major hazard events such as the 2023–2024 dzud. Core services are sustained through a combination of government funding, institutional commitment, and partner-supported projects.

However, performance management and sustainability mechanisms are not yet systematic or fully institutionalized. Service effectiveness is not routinely measured against defined performance indicators, lifecycle sustainability is uneven across systems, and long-term financing remains highly dependent on external projects.

The objective of the performance and sustainability implementation plan is therefore to progress maturity from level 3 toward level 5 by institutionalizing performance monitoring, strengthening service verification and learning, and ensuring long-term technical, human, and financial sustainability.

4.12.2 Short-term performance and sustainability improvements (1–2 years)

Target maturity progression: ~2.7 → ~3.5

Short-term actions focus on making existing performance visible and measurable, and on stabilizing sustainability foundations without disrupting ongoing operations.

Key short-term achievements include:

- Definition of a core set of service performance indicators covering:
    - Forecast timeliness
    - Warning lead time
    - Data availability during extreme events
    - Dissemination reach
- Introduction of routine post-event technical reviews following major hazards (dzud, floods, severe weather), focusing on:
    - Forecast accuracy and uncertainty
    - Decision timelines
    - Information flow across institutions
- Documentation of operational dependencies (critical systems, staff roles, infrastructure) to identify sustainability risks.
- Initial integration of performance findings into annual planning and reporting cycles of NAMEM and IRIMHE.

4.12.3 Medium-term performance and sustainability improvements (3–5 years)

Target maturity progression: ~3.0 → ~4

Medium-term actions focus on embedding performance management and sustainability into routine operations and planning, addressing NCAT criteria related to consistency, resilience, and institutional learning.

Key medium-term achievements include:

- Establishment of a formal performance management framework for early warning services, aligned with WMO guidance on service delivery and verification.
- Systematic application of forecast verification and service evaluation across:
    - Meteorological forecasts
    - Hydrological forecasts
    - Impact-Based (IB) products
- Integration of lifecycle cost considerations into planning for:
    - Observation systems
    - ICT and data infrastructure
    - Modelling and dissemination platforms
- Strengthening of staff retention and skills sustainability through structured training pathways and knowledge transfer mechanisms.

4.12.4 Long-term performance and sustainability improvements (5+ years)

Target maturity progression: ~4 → 4.5

Achieving maturity level 5 requires evidence that performance management and sustainability are fully institutionalized, continuously applied, and resilient to external shocks.

Key long-term achievements include:

- Continuous performance monitoring linked directly to service improvement and investment decisions.
- Demonstrated ability to sustain high-quality services independently of short-term project cycles.
- Predictable financing for operation, maintenance, and modernization embedded in national planning and budgeting.
- Institutional culture of learning, with routine incorporation of evaluation results into system upgrades, training, and service design.

4.12.5 Performance and sustainability of Impact-Based (IB) services and Anticipatory Action (AA)

The assessment confirms that Mongolia has demonstrated event-specific performance in anticipatory action, particularly during dzud events. However, sustainability of IB and AA remains limited by the absence of routine performance tracking and long-term resourcing.

Improvements required to increase maturity include:

- Definition of performance indicators specific to IB and AA, such as:
    - Accuracy of impact thresholds
    - Timeliness of trigger activation
    - Effectiveness of early actions
- Routine evaluation of IB and AA outcomes following hazard seasons.
- Integration of IB and AA performance results into service refinement and funding justification.

- Alignment with WMO impact-based early warning guidance and FAO anticipatory action evaluation principles.

4.12.6 Performance and sustainability implementation actions

#	Action	Details (linked to Section 3 findings)	Responsible agencies
1	Define core performance indicators	Establish measurable indicators for forecasting, warning, dissemination, and decision support performance	NAMEM, IRIMHE
2	Institutionalize post-event reviews	Move from ad hoc reviews to routine, documented technical and service evaluations	NAMEM, IRIMHE
3	Strengthen forecast verification practices	Apply systematic verification for meteorological, hydrological, and IB products	IRIMHE
4	Integrate performance into planning	Use performance evidence to inform annual planning and prioritization	NAMEM
5	Address lifecycle sustainability	Incorporate maintenance, replacement, and upgrade costs into system planning	NAMEM
6	Strengthen human resource sustainability	Develop structured training, succession planning, and knowledge transfer mechanisms	NAMEM, IRIMHE
7	Evaluate IB and AA effectiveness	Establish evaluation protocols for impact forecasts and anticipatory actions	NAMEM, IRIMHE
8	Reduce project dependency risks	Transition successful project-based innovations into routine operational budgets	NAMEM

Annex:

Annex 1 - SWOT analysis

Strengths	Weaknesses
• Well-established national institutional mandates for meteorology, hydrology, DRR, and agriculture . • Strong governmental commitment to multi-hazard early warning (EW4All) and the Sendai Framework . • Significant progress in expanding ICT facilities, including recently established HPC server rooms for high-resolution modelling . • Extensive monitoring networks, including 314 pasture observation sites and 147 hydrological stations . • Functioning early warning dissemination covering various hazards like Dzud.	• Lack of operational data exchange between organizations and a unified national data platform . • No formalized Concept of Operations (CONOPS) for operational hydrological, agrometeorological services. • Heavy reliance on manual, labor-intensive data recording and verification . • Low accuracy and skill in monthly and seasonal forecasts . • Inconsistent data performance due to heterogeneous AWS/AHS vendors.
Leveraging AI and machine learning for improved S2S forecasts, actionable advisories, and automated QA/QC . • Integration of hydrological forecasts into agromet products and bulletins . • Expanding the radar network for better extreme weather detection . •Formalizing interagency data-sharing arrangements and establishing a shared geospatial platform . • Development of "people-centered" advisory services with structured feedback from herders and farmers	• Increasing demand for advanced modelling capabilities exceeding current infrastructure and staff. • Risks to data integrity from insufficient regular maintenance of sensors and lack of automated QC systems . • Gaps in specialized staff for hydrological modelling and forecasting . • Vulnerability to flash floods in regions lacking monitoring basins.
Opportunities	**Threats**

Annex 2 - Concept of Operations (CONOPS) of the End-to-End Hydrometeorolgical and Agrometeorolgical Services in Mongolia

NOTE: The CONOPS below are in draft form and will be finalized and adjusted during project implementation.

A. CONOPS: Integrated End-to-End Hydrometeorological Monitoring and Forecasting Service for Mongolia

A.1. Introduction

Mongolia's hydrological cycle is characterized by rapid spring snowmelt and intense summer rainfall, leading to frequent flash floods and riverine flooding. In urban centers like Ulaanbaatar, poor drainage systems exacerbate flood risks, causing significant infrastructure damage and loss of life. Simultaneously, meteorological hazards such as dzud and extreme temperature fluctuations directly threaten the nation's livestock-based economy.

Need for the System: The current system relies on threshold-based alerts which are not dynamic and do not account for changes brought on by land-use, climate change. A critical illustration is the Ulaanbaatar Flash Flood of July 2023, where standardized meteorological warnings were issued, but the lack of localized hydrological inundation modeling prevented effective neighborhood-level evacuations. There is an urgent need to bridge the gap between the meteorological information and the hydrological impacts.

Proposed System Overview: The proposed system integrates meteorological and hydrological monitoring into a unified Multi-Hazard Early Warning System (MHEWS). It covers the entire chain from automated 3-hourly observations to high-resolution NWP (WRF/ECMWF) and hydraulic flood modeling, focused on high-risk basins and urban centers.

A.2. Background

a. Institutional Responsibilities: NAMEM holds the legal mandate for meteorological and hydrological monitoring, while IRIMHE (under NAMEM) is responsible for hydrological research and forecasting. NEMA is the accountable authority for public alerting.

b. Current Limitations: The NCAT assessment highlights a score of 2.1/5.0 for Hydrological Modeling. Critical gaps include the absence of nowcasting tools, limited hydrological modeling and flood forecasting capacity, and outdated dissemination infrastructure (sirens/signboards) primarily located in the capital.

c. Proposed Capabilities: National Hydrometeorological Data Hub: A WIS2-compliant platform for real-time data exchange.

- Flood forecasting system: Integration of open-source hydrological model(s) for priority river basins in Mongolia and generation of user-centric forecast products
- Urban Flash Flood Tool: High-resolution hydraulic modeling for Ulaanbaatar and provincial centers.

- National Sensor Calibration Facility: A formalized laboratory and mobile unit for the 147 hydrological and 135 meteorological stations.

A. 3. Operation and Information Flow

a. Description of Operations: Current Workflow: 135 met stations and 147 hydromet stations report data (often manually checked for semantic errors). IRIMHE runs basic gauge-to-gauge correlations for river and lake levels.

- Proposed Architecture: Integrated AI weather forecasting, data assimilation for NWP and Hydrological models will ingest real-time data from automatic weather and hydrometric stations and remotely sensed precipitation data (satellite, weather radar) to produce inundation maps.

A.4. Staff Operational Responsibilities

Current staff includes ~20 provincial hydrological engineers and 6 national-level forecasters at IRIMHE. Responsibility Chart:

- Observation (NAMEM): data acquisition and field maintenance.
- Forecasting (IRIMHE): Running NWP and hydrological models.
- Calibration (Technical Dept): Ensuring sensor accuracy and traceability.

A.5. Proposed Future Responsibilities

a. NFC (NAMEM): Focus on severe weather (nowcasting) and heavy precipitation alerts. b. IRIMHE: Operation of the Hydrological Status and Outlook System, providing information on the status of the water resources when compared with the normal and long term information on water availability enabling decision makers to manage water resources effectively. c. Regional Offices: Responsible for local gauge maintenance and "River Watch" activities during flood season. d. NDMC (NEMA): Coordinating the inter-agency response and issuing "Take Action" orders. e. Calibration Unit: A new centralized unit to manage the Calibration and Maintenance Schedule for the entire network.

A.6. Responsibilities of Support Structures

- IT & Communications: Maintaining the internal LAN and ensuring 24/7 server uptime for the WRF/ECMWF modeling clusters.
- Calibration & Maintenance: Establishing a National Calibration Lab to perform annual sensor validation (temperature, pressure, water level) to WMO standards.

A.7. Routine Operations

a. Hours: Transition from working-hour monitoring to 24/7 operational shifts during the "Warm Season" (May–September) and "Dzud Season" (November–March). b. National Meteorological Operations:

- Observations: 135 stations (134 automated) reporting every 3 hours.

- Models: WRF and ECMWF at 80-90% accuracy for 1–3 day leads. c. National Hydrological Operations:
- Observations: Daily water level readings; discharge measurements 5–6 times per month in summer.
- Calibration: Introduction of Mobile Calibration Kits for field-testing pressure transducers and radar level sensors.

A.8. Service Delivery and Dissemination

- Standardized Products: Daily weather bulletins and decadal hydrological outlooks.
- Channels: SMS, TV, Radio, and specialized NEMA Geoportals for emergency managers. AI-driven alerts will segment users by basin.

A.9. Strengthening Warnings through Impact Forecast

The system will move from "Level 3 - Threshold-based alerts" to Impact-Based Forecasting.

- Trigger Matrix: Combining rainfall intensity with soil moisture and urban drainage capacity to predict flood depth.

A.10. Proposed System Training Needs

- Hydrological Modeling: Training for the 6 IRIMHE engineers in HEC-RAS or similar software.
- Sensor Calibration: Specialized WMO-certified training for technical staff on laboratory and field calibration procedures.
- IT/GIS: Data management for the National Spatial Data Infrastructure (NSDI).

A.11. Outreach

Regular coordination with the Water Authority and MoFALI for water-resource planning. Public awareness campaigns focused on interpreting "Inundation Maps" rather than just "Rainfall Totals."

A.12. Validation, Sustainability, and Monitoring

Implementation of a Measurement, Reporting, and Verification (MRV) system for sensor accuracy. Annual performance reviews will evaluate forecast lead times and accuracy against actual flood events.

B. CONOPS: End-to-End Agrometeorological Actionable Advisory Service for Mongolia

B.1. Introduction

Mongolia’s agricultural sector, dominated by nomadic pastoralism, is highly vulnerable to extreme climate events. The primary agrometeorological hazards include dzud, drought, and flash floods. These events lead to massive livestock mortality, pasture degradation, and reduced crop yields (primarily wheat and potatoes). Livestock losses directly impact the livelihoods of over 190,000 herder households, threatening national food security and the rural economy.

The current system focuses on hazard monitoring but lacks "actionable" advisory—specific instructions for herders on when and where to move or how much fodder to prepare. The 2023–2024 Dzud serves as a critical illustration; despite early warnings of a "harsh winter," livestock losses exceeded 7 million head because the information was not sufficiently local or impact-based to trigger timely anticipatory action.

The proposed system will transition Mongolia from a "forecast-based" to an "Impact- Forecasting (IF)" model. It integrates satellite data, AI-driven pasture models, and a user-feedback loop to provide herder-centered advisories. The scope includes national-level modeling by IRIMHE and local-level dissemination via NEMA and MoFALI extension services.

B.2. Background

Institutional Responsibilities: The landscape is led by NAMEM (meteorological monitoring) and IRIMHE (research and agromet modeling). MoFALI provides livestock and crop data, while NEMA is the accountable authority for official disaster warnings. Telecom companies and media are critical for the "last mile" delivery to herders.

Current Limitations: Assessment scores reveal critical gaps: Staff Capabilities (1.5/5.0) and AI Capacities (1.6/5.0) are the lowest. Current models (like the Sibelius/Drought watch) are often too coarse (25km resolution) for farm-level decisions. Data sharing between NAMEM and MoFALI remains largely ad-hoc and project-driven rather than institutionalized.

Proposed Capabilities: The new system will feature:

- Automatic QC and integrated data management.
- AI-enabled chatbots for two-way communication with herders.
- An integrated Agromet Workstation for automated bulletin generation.

Financial Feasibility: Feasibility is supported by the "New Revival Policy" and "Vision-2050," which prioritize digital transformation. Funding is anticipated through a blend of national budget and international climate finance (WMO/FAO/ADB).

B.3. Operation and Information Flow

Description of Operations: Current Workflow: Data is collected from 135 met stations and 314 pasture monitoring sites. Forecasters manually interpret these into bulletins, which are sent to provincial offices and then disseminated via radio/TV.

Proposed Architecture: Data from existing and the 3DPAWS (low-cost stations) zoo met staions and satellites will flow into an AI-based processing hub. This hub generates "Impact Advisories" (e.g., "High mortality risk in Soum X; move to Aimag Y").

B.4. Staff Operational Responsibilities

Existing staff includes approximately 22 agromet engineers across provinces. While 86% of IRIMHE staff have specialized degrees (PhDs/Masters), there is a high turnover and a lack of training in Python, Machine Learning, and IBF.

Responsibility Chart:

NAMEM/IRIMHE: Observation, Data QC, and Agromet Modeling.

MoFALI: Providing "Vulnerability Data" (livestock numbers, fodder stocks).

NEMA: Triggering emergency response for "Extreme Dzud" levels.

B.5. Proposed Future Responsibilities

a.NFC (NAMEM): Focus on 24/7 monitoring of severe weather and providing the technical "Hazard" layer for IBF. **b .National Agromet Service (IRIMHE/NAMEM):** Accountable for the "Agromet Workstation," generating decadal pasture and crop advisories.**c. Regional Offices:** Responsible for "ground-truthing" and localized advisory adaptation for specific Aimag conditions.**d. NEMA:** Dissemination of high-impact alerts through cell-broadcast systems.**e. MoFALI/Provincial Centres:** Extension workers will use the advisories to provide direct training to herder groups on "Anticipatory Action."

B.6. Support Structures

IT and Technical: A dedicated unit will manage the transition from manual databases to WIS2-compliant automated systems.

B.7. Routine Operations

a. Hours: Transition from "Working Hours" to 24/7 monitoring for hazard-specific periods (Winter/Spring).b. Meteorological Ops: 135 met stations reporting every 3 hours; WRF and ECMWF models providing 1–10 day forecasts at 80-90% accuracy.c. Agromet Ops: Collection of agromet data. Future operations will include automated quality control and daily satellite-derived ET (evapotranspiration) maps.

B.8. Service Delivery and Dissemination

Transition from generic TV/Radio broadcasts to a Segmented Product Suite:

Herders: SMS/Audio messages and "Agro-ChatGPT" for specific soum-level questions.

MoFALI/Policy: High-level GIS dashboards for drought/dzud risk mapping.

Emergency Services: API-based triggers for early warning.

B.9. Strengthening Warnings through Impact Forecast

The system will use a Trigger Matrix combining hazard levels (e.g., snow depth/temp) with vulnerability (e.g., lean livestock/low hay stock).

Ground Truth: Utilizing herders as "spotters" to report real-time pasture conditions via mobile app.

B.10. Proposed System Training Needs

Priority areas identified in the ACAT report:

- AI and Python: For IRIMHE researchers to build local models.
- IBF Communication: For NEMA/Media to translate technical data into "plain language."
- Field Equipment Maintenance: For provincial observers managing 3DPAWS stations.
- SEB analysis for agromet services.
- Triggering methodology and modeling of agromet hazards.

B.11. Outreach

Regular "Aimag-level" stakeholder meetings and public awareness campaigns to build trust in AI-driven advisories. Use of "Mobile Herder Schools" to demonstrate how to interpret new impact-based warnings.

B.12. Validation, Sustainability, and Monitoring

A feedback loop will be established where herders report back on advisory accuracy. An annual "Dzud/Drought Performance Review" will involve all agencies to update thresholds and SOPs.

Annex 3 - Interoperability Framework

When implementing the project, at the next stage it is necessary to ensure that the implemented technical, scientific and operational solutions of absolutely all components of the system are functionally compatible, that is:

- the ability to function freely without technical support from the software manufacturer,
- the use of the software must not be limited by a commercial contract,
- the software must allow technical support to be provided by IT specialists of NAMEM, IRIMHE or another third-party organization,

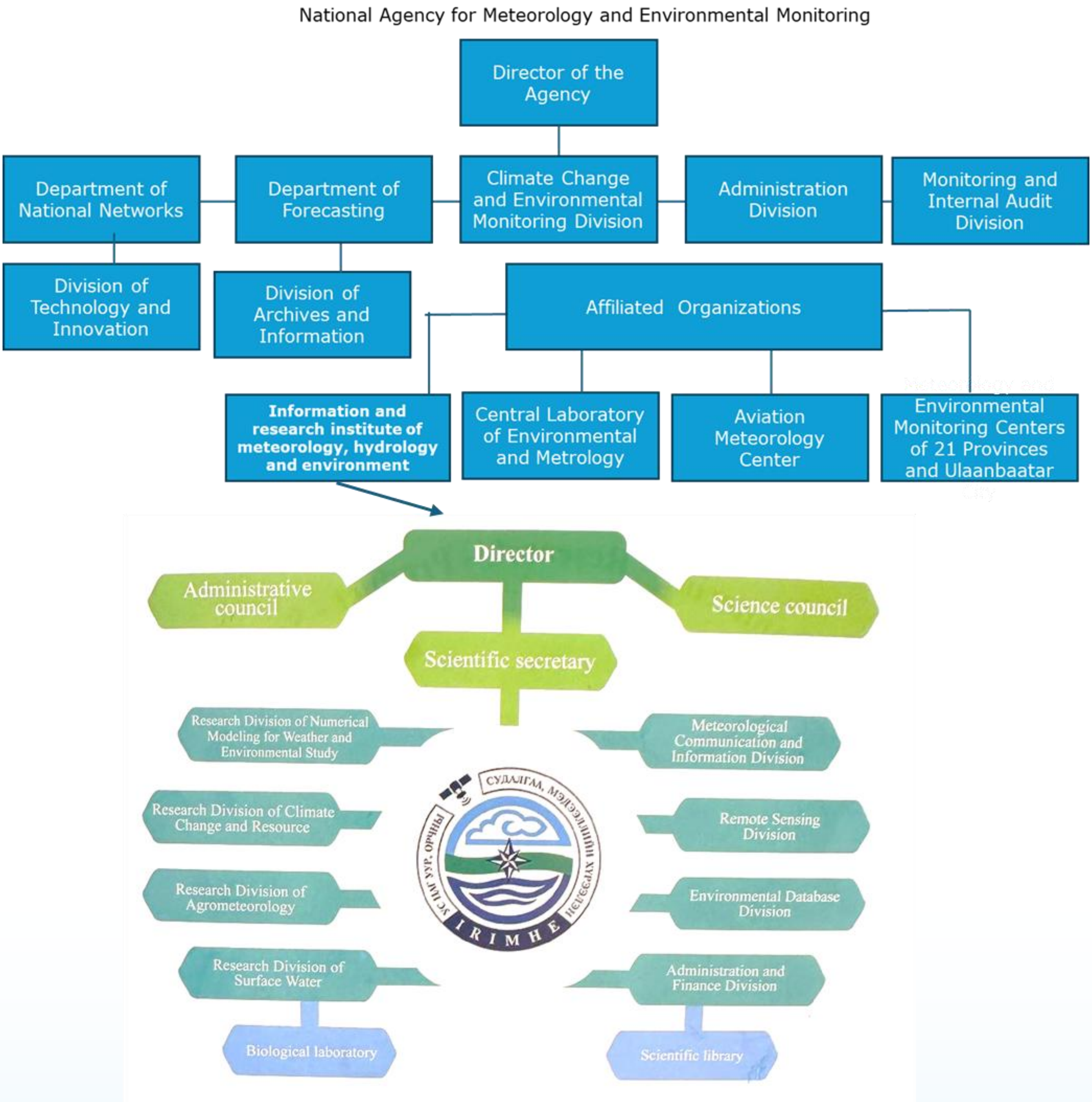
The program code (or modular structure) of the software must allow a specialist to make changes if necessary, that is, there must be either open program code or a modular structure that provides the user with various options for using the software.

The basic principles of interoperability for methods, models and platforms used to solve operational hydrological problems have been formulated by the WMO Standing Committee on Hydrological Services and are presented in the Manual on an Inventory of Interoperable Models and Platforms for Flood Forecasting and Early Warning[7]. According to this manual, the basic criteria for the use of models and platforms for flood forecasting and early warning are:

- Used in operational practice of hydrological forecasts,
- Freely available (non-commercial products),
- Competitive organizations with the computing resources they require,
- Availability of training materials,
- Technical support is available if needed,
- There is an interface for interaction with other software tools,
- Reliability and stability of operation
- There are quality control results and examples of software implementation.

[7] WMO-No. 1345. Guidelines on the Inventory of Interoperable Models and Platforms for Flood Forecasting and Early Warning Systems, 2023

Annex 4 - Institutional structure



Structure of NAMEM, IRIMHE

SOURCE: NAMEM, IRIMHE

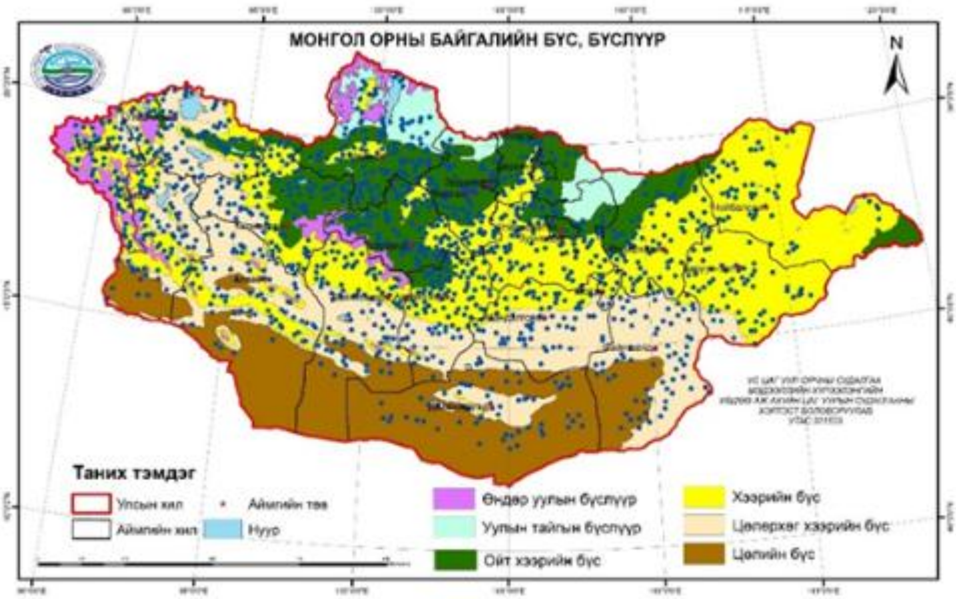
Annex 5 - Meteorological network

SOURCE:

Annex 6 - Hydrological network

SOURCE:

Annex 7 - Agrometeorological network



Monitoring Variable	Start Year	Status	Format	Frequency	Number of Stations/Sites	Notes
Pasture Observation (Fenced)	1980	Ongoing	Digital	Every 2 days (vegetation stage); Every 10 days (biomass/coverage)	132	Data quality significantly improved and missing values decreased after 1995.
Pasture Observation (Unfenced)	1980	Ongoing	Digital	Days 9, 19, & 25 of the month (warm season)	314	Monitoring includes grass type, height, biomass, and phenology.
Rangeland Health	2011	Ongoing	Digital	Annually (August)	1,500	Quality improved starting in 2013; sites also used for winter snow measurements. [3]
Pests and Rodents	2002	Ongoing	Digital / Paper	Days 9, 19, & 25 (warm season)	314	Includes grasshopper monitoring; rodent distribution maps are currently on paper. [4]
Soil Moisture (Manual)	1980	Ongoing	Digital	Days 8, 18, & 28 (thawing to freezing period)	32	Manual measurements taken every 10 days. [5]
Soil Moisture (Automatic)	1994	Ongoing	Digital	Continuous	30	Uses ZL.60 sensors; data reliability improved from 1995–1996 onwards. [6]
Crop Monitoring	1981 / 1985	Ongoing	Digital	Decadal (every 10 days) during warm season	29	Focuses on potato and wheat; monitoring frequency varies slightly by station. [7]

Zoo-Meteorology	1980 / 1999 / 2011	Ongoing	Digital	Every 10 days; Annually	7	Monitoring animal-environment interactions across Forest Steppe, Steppe, and Gobi regions. [8]
Pasture Carrying Capacity	2001	Ongoing	Digital	Annually (End of August)	1,500	Integrated with rangeland health assessment sites. [9]
Dzud Risk Mapping	2015	Ongoing	Digital	2–3 updates throughout winter (starting late Nov)	1,500	Maps are disseminated monthly during the winter season to support anticipatory action. [10]

SOURCE: IRIMHE

Annex 8 - Staff skills and training

NOTE: To be Filled by NAMEM, IRIMHE

Background and experience for National Meteorological and Hydrological Services						
Work areas	Expertise	Academic degree	Position	Number of staff	Years of experience in the institution	Indicate the areas where staff turnover is high
Guidance	Area of training or study	Phd, Master, Engineer, Technician, etc.	Director, technical director, supervisor, others	Total according to the field	Total years of working within the institution across the different areas	
Hydrology	Hydrologist					
	Hydrometeorologist					
	Hydraulic engineer					
	Civil engineer					
	Other					
IT	Systems engineer					
	Informatician					
	Database technician					
Hydrological network and observation	Electronics engineer					
	Technician in electronics					

Research and capacity	Mechanical technician					
	Observer					
	Maintenance					
	Researcher					
	Publications and translation					
Meteorology	Meteorologist					
	Meteorological technician					
	Mathematician					
	Air traffic controller					
	Forecaster					
Climatology	Climatologist					
	Geographer					
	GIS technician					
IT	Systems engineer					
	Informatician					
	Database technician					
Meteorological network and observation	Electronics engineer					
	Technician in electronics					
	Mechanical technician					
	Observer					
	Maintenance					

Agrometeorology	Agrometeorologist	1 phd, 3 phd studen		8	2 M. leave, 1 study leave abroad	agromet
	Climatologist	-	-	-	-	-
	Geographer	-	-	-	-	-
	GIS technician	-	-	-	-	-
	Observers		22 agromet engineers in each province			

Annex 9 - Implementation plan matrix

Implementation plan	Term			Draft Estimated Budget, USD
	Short (1-2 years)	Medium (3-5 years)	Long (6-10 years)	
1. Institutional				
Develop and adopt national CONOPS for E2E EWS (incl. IB, AA)	☑			200,000
Formalize inter-agency coordination mechanisms (NAMEM–IRIMHE–NEMA)	☑	☑		150,000
Institutionalize IB and AA governance (roles, triggers, SOPs)	☑	☑		300,000
Update legal and regulatory instruments for data sharing and services		☑		250,000
Integrate EWS into national DRM and development planning cycles		☑	☑	150,000
2. Infrastructure				
Upgrade operational forecasting rooms and situation spaces	☑			700,000
Strengthen ICT backbone, internal networks, and redundancy	☑	☑		1,000,000
Upgrade backup power systems for critical facilities	☑			400,000
Scale computing and storage for ensemble and AI workloads		☑	☑	1,800,000
Establish lifecycle maintenance and asset management systems		☑	☑	200,000
3. Observations and Data Acquisition				
Secure continuity of priority meteorological observations	☑			1,000,000
Expand AWS in remote and high-risk areas		☑	☑	2,000,000

Strengthen upper-air observation reliability	☑	☑		600,000
Enhance hydrological monitoring in priority basins	☑	☑		**3,500,000**
Improve snow, SWE, freeze–thaw observations	☑	☑		900,000
Upgrade calibration laboratories and mobile calibration units	☑			1,500,000
Enhance the radar coverage for radar mosaic (additional 10 more radars): • Radar units and towers • Communication links and integration middleware • Radar calibration and maintenance packages	☑	☑	☑	20,000,000
4. Historical and Ancillary Data				
Digitize remaining hydrology and snow archives	☑			400,000
Complete station metadata and homogenized datasets	☑	☑		350,000
Establish national impact and loss database		☑		500,000
Consolidate land, agromet, and socio-economic datasets		☑	☑	600,000
			☑	
5. Data Management				
Consolidate data architecture into national hydromet framework	☑	☑		600,000
Implement WIS 2.0 and WaterML 2.0 compliant services	☑	☑		500,000
Standardize QA/QC and quality flagging systems	☑			300,000
Formalize data backup, recovery, and cybersecurity	☑	☑		350,000
6. Meteorological Forecasts and Products				
Acquire and operationalize a Flash and Urban Flood Prediction System, including: • AI-enhanced nowcasting software (compatible with Fengyun and other satellite feeds) • Real-time remote-sensing data ingestion modules, all module open source open code and iteroperable	☑			150,000
Deployment Data Assimilation Systems for NWP, including: • Advanced data assimilation tools • Forecaster and technician training programs	☑			100,000
Procure tools to enhance forecast accuracy, including: • Short–medium range AI model deployment	☑			450,000

• Monthly/seasonal forecasting systems (AI-based bias correction and downscaling)				
7. Operational Hydrological service				
Automation of the hydrological data collection and quality control process (covered under section 4.3. Observation and Data Acquisition Section)	☑	☑		-*
Co-design and develop hydrological model and integrated forecasting system for target basins	☑	☑		350,000
Identify training needs and develop training curriculum	☑	☑		100,000
Institutionalize structured service specific capacity packages across the operational hydrology and value chain as well as integrated water resources management.	☑	☑	☑	250,000
8. Agrometeorological monitoring and forecast service				
Develop/Deploy an automatic quality-control system for all agromet observations (covered under section 4.3. Observation and Data Acquisition Section)	☑	☑		-
Enhancing secondary and tertiary measurements and field observations with the provision of the low-cost (e.g. 3DPAWS) stations for farmers and herders. These stations will compliment primary measurements of the NAMEM.	☑	☑		100,000
Develop **triggering methodologies** (drought, dzud, floods etc.) incorporating **socio-economic indicators** for anticipatory action (AA) with AI tools.	☑	☑		100,000
Strengthen modelling systems for water balance/ET, pasture biomass, soil carbon, pests/rodents, and crops.		☑		250,000
Integrate hydrological forecasts (river levels, runoff, water availability) into agromet products.		☑		100,000
Develop crop calendars.	☑			90,000
Develop an Agromet Workstation/Portal for monitoring, analysis, forecasting, and automated bulletin generation with AI support.	☑	☑		300,000
Develop **AI based Chatbot** for header centred actionable advisories, and feedback channels with herders, farmers.	☑	☑		300,000
Develop CONOPS and SOPs for end-to-end agromet service delivery.	☑	☑		80,000
Introduce tools for cost-effectiveness and SEB evaluation.	☑	☑		100,000
Develop training packages for agromet services and train staff.	☑	☑	☑	120,000
9. Dissemination and Communication				
Strengthen multi-channel dissemination systems	☑	☑		500,000
Implement CAP-aligned warning dissemination	☑			250,000

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Improve last-mile delivery and feedback mechanisms		☑	☑	600,000
		☑		
			☑	
10. Staff Capabilities and Training				
Training on IB, AA, and AI fundamentals	☑			100,000
Advancing institutionalized capacity building mainstream and parnthersip (e.g. Academia, Service Sectors such as Insurance, programmes for observation, data processing, quality management, modelling, hydrology, agromet training and user services.	☑	☑		550,000
Establish structured R2O/O2R programmes		☑	☑	350,000
Long-term staff development and retention pathways, platform and materials			☑	500,000
11. Performance and Sustainability				
Define service performance indicators	☑			120,000
Institutionalize post-event reviews and verification	☑	☑		220,000
Integrate lifecycle costs into planning		☑	☑	200,000
Transition project innovations into core budgets			☑	300,000
Define service performance indicators	☑			120,000
Budget Distribution across short-mid-long terms	10,000,000	15,000,000	20,000,000	
			Total	45,000,000