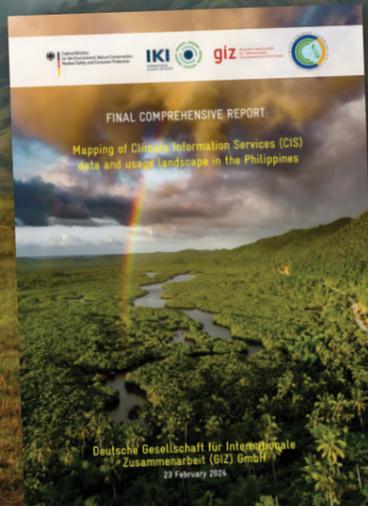**FINAL COMPREHENSIVE REPORT:**

Mapping of Climate Information Services (CIS) data and usage landscape in the Philippines

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

23 February 2024

The cover photo features a typical landscape in the Philippines capturing a unique diametrical weather—cloudy and rainy and sunny highlighted with a rainbow. The climate is an awe-strucking phenomenon, both terrifying and a wonder.

A busy street in the Philippines.

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Executive Summary

Climate Information Services (CIS) are critical in mitigating weather and climate-related risks.

The "Mapping of the CIS data and usage landscape in the Philippines" initiative was conducted to better understand the breadth and scope of available climate data that contribute to CIS initiatives in the country. Key project deliverables include: (1) a comprehensive report with insights and recommendations from interviews and literature, and (2) a data catalog, serving as a reference for essential climate datasets.

The catalog lists 71 of the most useful datasets relevant to the Philippines, categorized by type (atmosphere, land, water, socio-economic) and time period (forecast or historical). It serves as a user-friendly resource containing comprehensive information for each dataset, providing general details, spatial and temporal aspects, technical specifications, and usage insights CIS used in the Philippines come from both international and local sources. The most commonly used sources for meteorological data are: (a) the Philippine Atmospheric, Geophysical, and Astronomical Services Administration's (PAGASA) station data and advisories, and (b) downscaled international models and reanalysis data. PAGASA remains to be the main producer of climate data in the country and their data is translated by specialized institutions for use by local government units and national agencies for policy making and program implementation.

CIS adoption is primarily observed in the agriculture and research sectors, while other sectors lack comprehensive CIS and case studies. Data producers face challenges balancing data quantity and quality due to limited resources. Integrators struggle with varying data quality and localized requirements. Data access is smoother within the government, while accessing data from academia and private institutions is hindered by privacy concerns. Insights point to a unified whole of government approach as a crucial step for streamlining CIS efforts.

Recognizing the interdisciplinary nature of climate action, collaboration among data producers, transformers, users, and sector communities is essential to overcome challenges in mainstreaming effective CIS practices. Institutionalized support to enhance engagement with diverse end users, and building partnerships and advisory networks for comprehensive climate solutions is vital for realizing the full potential of CIS in the Philippines.

List of Acronyms and Abbreviations

ACAP	Agro-Climatic Advisory Portal
AFP	Armed Forces of the Philippines
AI	Artificial Intelligence
AMIA	Adaptation and Mitigation Initiative
APHRODITE	Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation
API	Application Programming Interface
AR5	IPCC's Fifth Assessment Report
AR6	IPCC's Sixth Assessment Report
ASTI	(DOST) Advanced Science and Technology Institute
ATI	(DA) Agricultural Training Institute
BAR	(DA) Bureau of Agricultural Research
BCRUPD	Building Climate Resiliency through Urban Plans and Designs
BFAR	(DA) Bureau of Fisheries and Aquatic Resources
BoatR	Boat Registration
BSWM	(DA) Bureau of Soils and Water Management
C3S	Copernicus Climate Change Service
C4	C4 Ecosolutions
CAR	Cordillera Administrative Region
CC	Creative Commons
CCC	Climate Change Commission
CCI	Climate Change Initiative
CCIMS	Climate Change Information Management System
CCS	(DENR) Climate Change Service
CDP	Comprehensive Development Plan
CDRA	Community-Based Disaster Risk Assessment
CFSR	Climate Forecast System Reanalysis
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CHIRTS	Climate Hazards Group InfraRed Temperature with Station Data
CIS	Climate Information Services
CMIP3	Coupled Model Intercomparison Project Phase 3
CMIP5	Coupled Model Intercomparison Project Phase 5
CMIP6	Coupled Model Intercomparison Project Phase 6
CLUP	Comprehensive Land Use Plan
CMORPH	CPC Morphing Technique
CO2	Carbon Dioxide
CORE	Communities for Resilience
CPC	Climate Prediction Center
CRAO	(DA) Climate Resilient Agriculture Office
CRU	Climatic Research Unit
CRVA	Climate Risk Vulnerability Assessment
DA	Department of Agriculture
DALA	Damage and Loss Assessment
DBMP	Database and Management Portal
DENR	Department of Environment and Natural Resources
DEPDMS	DOE Electric Power Database Management System
DHSUD	Department of Human Settlements and Urban Development
DILG	Department of Interior and Local Government
DOE	Department of Energy
DOH	Department of Health
DOST	Department of Science and Technology
DOTr	Department of Transportation
DPWH	Department of Public Works and Highways
DRA	Disaster Risk Assessment
DRRM	Disaster Risk Reduction and Management
DRR-CCA	Disaster Risk and Reduction and Climate Change Adaptation
DSWD	Department of Social Welfare and Development
DTI	Department of Trade and Industry
EB	(DOH) Epidemiology Bureau
ECMWF	European Center for Medium-Range Weather Forecasts
EID	Emerging Infectious Diseases
ELUPDB	(DHSUD) Environmental, Land Use, and Urban Planning and Development Bureau
EMR	Electronic Medical Records
ERA5	ECMWF Reanalysis v5

List of Acronyms and Abbreviations

ESA	European Space Agency
ESITU	(DOTr) Environmentally Sustainable Initiatives Transportation Unit
ESRI	Environmental Systems Research Institute, Inc.
EWS-FNS	Early Warning System for Food and Nutrition Security
FishR	Fishermen Registration
FishVool	Fisheries Vulnerability Assessment Tool
FOI	Freedom of Information
FRMD	Fisheries Resources Management Division
GCF	Green Climate Fund
GDO	(DENR) Geospatial Database Office
GEF	Global Environment Facility
GEOAGRI	Geographic Information System for Agricultural and Fisheries Machinery & Infrastructure
GHCN_CAMS	Global Historical Climatology Network version 2 & the Climate Anomaly Monitoring System
GHG	Greenhouse Gas
GIS	Geographical Information Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GOCC	Government-owned and Controlled Corporation
GPCP	Global Precipitation Climatology Project
GPM	Global Precipitation Measurement Mission
GRUN	Global Runoff Model
GSM	Global System for Mobile Communication
GSMaP	Global Satellite Mapping of Precipitation
HAB	Harmful Algal Bloom
HLURB	Housing and Land Use Regulatory Board
IMERG	Integrated Multi-Satellite Retrievals for GPM
IP	Indigenous People
IPCC	Intergovernmental Panel on Climate Change
JRA-55	Japanese 55-year Reanalysis
KII	Key Informant Interview
KMP	Knowledge Management Portal
LAMS	Land Administration and Management System
LAWA	Local Adaptation to Water Access
LCCAP	Local Climate Change Action Plans
LDRRMF	Local Disaster Risk and Reduction Management Fund
LDRRMP	Local DRRM Plan
LGA	Local Government Academy
LLDA	Laguna Lake Development Authority
LMP	League of Municipalities of the Philippines
LTO	Land Transportation Office
LULC	Land Use and Land Cover
LUZIS	Land Use and Zoning Information System
LWUA	Local Water Utilities Administration (LWUA)
MaxEnt	Maximum Entropy
MERRA-2	Modern-Era Retrospective analysis for Research and Applications, Version 2
MITHI	Medium-term Information and Communication Technology Harmonization Initiative
MGSP	Microgrid Systems and PVM Provider
MO	Manila Observatory
MOA	Memorandum of Agreement
MODIS	Moderate Resolution Imaging Spectrometer
MOSAICC	Modeling System for Agricultural Impacts of Climate Change
MWSS	Metropolitan Waterworks and Sewerage System
NAMRIA	National Mapping and Resource Information Authority
NASA	National Aeronautics and Space Administration
NCA	National Center for Atmospheric Research
NCCAG	National Color-Coded Agricultural Guide
NCDC	National Climate Data Center
NCEP	National Centers for Environmental Prediction
NDRRMC	National Disaster Risk Reduction and Management Council
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NEA	National Electrification Administration
NEDA	National Economic and Development Authority
NFRDI	National Fisheries Research and Development Institute
NGCP	National Grid Corporation of the Philippines

List of Acronyms and Abbreviations

NGO	Non-government Organization
NHA	National Housing Authority
NHFR	National Health Facility Registry
NHWSS	National Health Workforce Support System
NIA	National Irrigation Authority
NMHS	National Meteorological and Hydrological Services
NNC	(DOH) National Nutrition Council
NOAA	National Oceanic and Atmospheric Administration
NOAH	Nationwide Operational Assessment of Hazards
NSAP	National Stock Assessment Program
NWRB	National Water Resources Board
ODbL	Open Data Common Open Database License
PAGASA	Philippine Atmospheric, Geophysical, and Astronomical Services Administration
PAP4SCP	Philippine Action Plan for Sustainable Consumption and Production
PCIEERD	Philippine Council for Industry, Energy, and Emerging Technology Research & Development
PDP	Philippine Development Plan
PERSIANN	Precipitation Estimation from Remotely Sensed Info using Artificial Neural Networks
PGHGIMRS	Philippine Greenhouse Gas Inventory Management and Reporting System
PhilSA	Philippine Space Agency
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PKT	Passenger-Kilometer Traveled
PNP	Philippine National Police
PRDP	Philippine Rural Development Project
PRiSM	Philippine Rice Information System
PSA	Philippine Statistics Authority
PVM	Photovoltaic Mainstreaming
PZD	(UPLB) Program for Zoonotic Diseases
RAP	Resettlement Action Plan
RBIIMS	River Basin Integrated Information Systems
RCP	Relative Concentration Pathways
REMB	(DOE) Renewable Energy Management Bureau
RIDF	Rainfall Intensity Duration Frequency
RMSE	Root Mean Squared Error
RRL	Review of Related Literature
RRP CCAM	Risk Resiliency Program Climate Change Adaptation and Mitigation
SA-OBS	Southeast Asian Observational Dataset
SAR	Synthetic Aperture Radar
SMS	Short Message Service
SSCIS	South-South Collaboration on Climate Information Services
SSP	Shared Socioeconomic Pathways
StreaMS	Streamflow Management System
SURG	Strengthening Urban Resilience for Growth with Equity
SVPCF	Special Vehicle Pollution Control Fund
SWP	(USAID) Safe Water Project
TCAGP	(UP) Training Center for Applied Geodesy and Photogrammetry
TKT	Ton-Kilometer Traveled
TM	Thinking Machines Data Science, Inc.
TRMM	Tropical Rainfall Measuring Mission
UDEL	University of Delaware Dataset
UN	United Nations
UNDP	UN Development Programme
UNDRR	UN Office for Disaster Risk and Response
UNESCO	UN Education, Scientific, and Cultural Organization
UP	University of the Philippines
UPLB	UP Los Banos
UPRI	UP Resilience Institute
UP-IESM	UP Institute of Environmental Science and Technology
UP-NIH	UP National Institutes of Health
USAID	United States Agency for International Development
UV	Ultraviolet
WCRP	World Climate Research Program
WMO	World Meteorological Organization
ZO	Zoning Ordinance

Introduction
Context and background

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has a joint project with the Philippines' Climate Change Commission (CCC) entitled "Towards South-South Collaboration on Climate Information Services: Building a Knowledge Exchange and Learning Platform for the Philippines and the Climate Vulnerable Forum (SSCIS)". This project aims to develop CIS jointly with key stakeholders to contribute to an expanded knowledge base that may aid in making informed decisions concerning adaptation and mitigation measures on the adverse impacts of climate change. GIZ has engaged Thinking Machines Data Science, Inc. (TM) to deliver a study on the "Mapping of the CIS data and usage landscape in the Philippines" to better understand the breadth and scope of available climate data which contributes to its usage in CIS initiatives. The project, running from October 2023 to March 2024, aims to provide the following deliverables:

1. Comprehensive report- This report synthesizes insights and recommendations gathered through stakeholder engagement activities (i.e., key informant interviews). It also summarizes findings from literature reviews and identifies research activities relevant to climate impact services.

2. Data catalog- The catalog serves as a unified reference for commonly used climate-related datasets. It includes the datasets' corresponding metadata, hardware requirements, access, and other relevant information such as error metrics (compared to ground data) and existing studies where available.

CIS in the Philippines

CIS are crucial decision-support tools that play a significant role in mitigating weather and climate-related risks (Warner et al., 2022). While the term is more often used in agriculture, its applications are not limited to a specific sector. A robust CIS is designed to accommodate the unique requirements and areas of application of its users. In the Philippines, diverse entities have developed an array of CIS products, ranging from localized assessments of climate change impacts and vulnerability to downscaled global climate change scenarios.

While it's widely acknowledged that climate products should be tailored and understandable for end users, there is often a lack of a well-designed system connecting those who produce the data and those
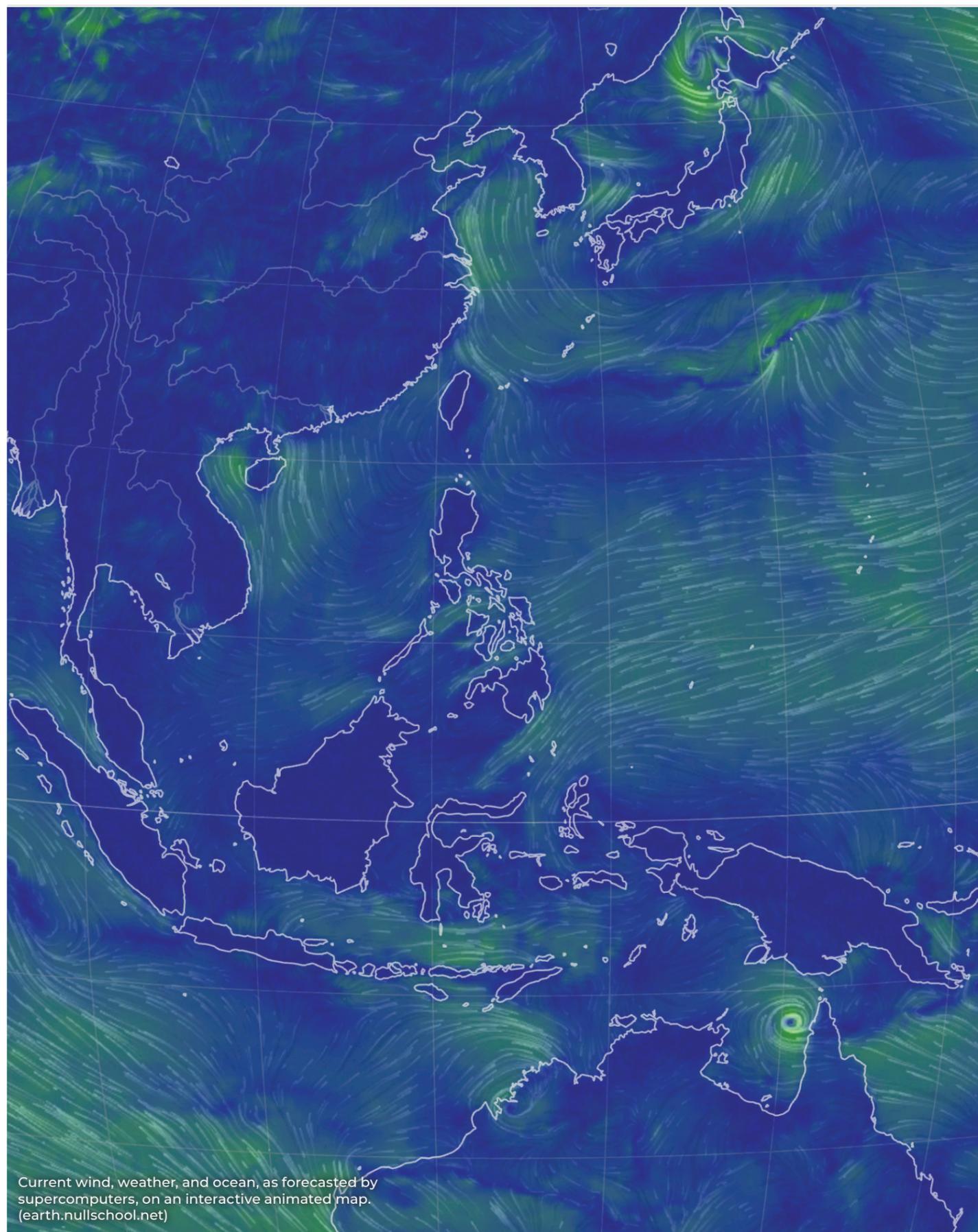
who use it. The primary challenge lies in effectively translating climate information into practical impacts and providing users with suitable application options (Elazegui et al., 2017). Furthermore, issues such as limited internet access in rural areas and the need to enhance the technical skills of local extension agents in handling specific climate data present additional hurdles that must be overcome to establish sustainable CIS use in the Philippines (Paunlagui et al., 2017).

Currently, end users often rely on general advice from PAGASA. However, there is an increasing need for enhanced and localized CIS to better understand and adapt to the adverse effects of climate change.

Objectives of the project

This project aims to achieve the following objectives:
1. Provide an inventory and mapping of available climate information services in the Philippines through literature review and conduct of key informant interviews with relevant agencies, and
2. Present a summary of findings in relation to the maturity of CIS practices and its use in policy development in different themes in the region.

Scope and Methodology
Phase 1: Inception Planning

The purpose of the Inception Report is to align the project's scope and facilitate its successful execution. It includes a list of the expected project outcomes, along with detailed plans and schedules for each task. Additionally, the document features an initial review of relevant literature, which encompasses a discussion about typical climate data types and the methods employed for their measurement.

The Inception Report also includes: (a) a list of stakeholders targeted for KII, (b) a general KII questionnaire to guide the conduct of interviews, (c) letters of invitation to the target stakeholders, and (d) an initial data catalog. The Inception Report was submitted to GIZ on 27 October 2023.

Current wind, weather, and ocean, as forecasted by supercomputers, on an interactive animated map. (earth.nullschool.net)

Phase 2: Stakeholder Engagement and Structured Desk Review

The Draft Comprehensive Report contains a more detailed review of (a) related literature with preliminary findings on the CIS landscape in the Philippines and (b) best practices and applications in policy and development. The document consolidates essential insights and recommendations derived from desk research and stakeholder interviews, enabling GIZ to conduct a thorough review of the output and integrate any necessary feedback into the Final Comprehensive Report.

A basic visual representation of the roles played by the interviewed stakeholders in terms of the data they use and generate is also provided in the document. The output focuses on the responses of the participants during the interviews. A review of existing literature regarding the predominant applications of CIS across different sectors in the Philippine context is also provided.

For stakeholder engagement, key informant interviews (KII) with CIS-relevant agencies are shown in Table 1. Documentation on the interviews conducted by TM are detailed in Appendix A.

Table 1. Interviewed CIS-relevant agencies

Interviewed by C4	Interviewed by TM
• Department of Health (DOH) • Department of Environment and Natural Resources (DENR) • Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) • Philippine Institute of Volcanology and Seismology (PHIVOLCS) • Philippine Statistics Authority (PSA) • University of the Philippines- Resilience Institute (UPRI) • Oscar M. Lopez Center (OML Center) • Department of Agriculture (DA) • University of the Philippines- National Institutes of Health (UP-NIH) • The League of Municipalities of the Philippines (LMP)	• Department of Science and Technology- Advanced Science and Technology Institute (DOST-ASTI) • DENR Geospatial Database Office (DENR-GDO) • National Mapping and Resource Information Authority (NAMRIA) • Department of Agriculture- Bureau of Fisheries and Aquatic Resources (DA-BFAR) • Department of Agriculture- Agricultural Training Institute (DA-ATI) • University of the Philippines- Institute of Environmental Science and Meteorology (UP-IESM) • University of the Philippines Los Banos- Program for Zoonotic Diseases (UPLB-PZD)

Note: C4 Ecosolutions is GIZ's consultant for the health and agriculture aspect of the SSCIS project.

KIIs were mostly conducted with climate data producers and users in the health and agriculture sectors being the focus of the SSCIS project. Applications for CIS for the transport, housing, energy, water resource, ecology, economics, social development, and disaster risk reduction and management sectors are mostly based on review of related literature.

It is worth mentioning that CCC is also an important stakeholder in climate conversations in the country, but there were difficulties in scheduling a KII. Nonetheless, they remain to be an important agency in the study of CIS and will continue to be consulted throughout the SSCIS project.

Phase 3: Documentation and Handover

The Final Comprehensive Report is a refined version of the Draft Comprehensive Report that exhaustively addresses the list of comments from GIZ's detailed review. It includes additional references and resources depending on further conduct of desk research and extracted insights from KIIs.

The Final Data Catalog contains the complete list of datasets based on the scope of the study. Downloaded data finalized through the dataset prioritization meeting with GIZ is curated and handed over via GIZ-provided hard drives. The final outputs of this study, together with relevant documents and appendices, is likewise included in the hard drives.

Overview of climate variables
Dataset categories
Climate variables are usually organized into four main categories:

■ **Atmosphere**: datasets on various near-surface atmospheric parameters, collected from weather stations, satellites, and atmospheric models. Examples are temperature, rainfall, wind speed, solar radiation, and air quality.

■ **Land**: datasets on terrestrial characteristics that can influence local climate patterns and risk of climate-induced hazards. Examples are land cover, vegetation indices, built-up indices, forest cover, landslide risk.

■ **Water**: datasets on relevant water bodies, their characteristics, and movement patterns, which is influenced by climate effects. Examples are flood risk, sea level rise, water quality, dam level, El Nino index.

■ **Socio-economic**: datasets that describe the exposure and vulnerability of key sectors, which includes demographics, agriculture, and health. These are commonly obtained using surveys, but alternative methods are also currently being explored, such as remote sensing and machine learning. Examples are population, production value for key crops, health facility locations, demographics and health survey data.

Types of climate data
There are different types of climate data. These are initially classified according to the time period it covers: historical and forecast data (Schneider et al., 2023).

■ **Historical climate data** refers to the recorded measurements of climatic variables, from the time when systematic record-keeping began, typically in the late 19th century, up to the present

■ **Forecast climate data**, on the other hand, consists of projections of future climatic conditions based on mathematical models and scenarios, often extending several decades to a century into the future.

Historical Climate Data
Table 2 shows the types of historical climate data, each with its own advantages and limitations.

Table 2. Types and assessment of historical climate data

	Advantages	Disadvantages
Station Data	Weather stations measure the climate variable directly and thereby represents the most accurate, "ground truth" observation	Spatial distribution is sparse and depends on the availability of physical weather stations
Gridded data / Reanalysis	Represents climate data in a gridded form, thereby having higher and almost complete spatial coverage	Datasets can display significant biases compared to station data, depending on the interpolation method
Satellite/ Remote sensing	Measures climate variables using earth observation satellites, thus having global coverage	Dataset are estimates from remote instruments, and thus can also differ significantly from ground conditions as represented by station data

Station Data
Station data refer to measurements of climate variables that are obtained at a specific site ("in situ"), most often using specialized instruments. Typical weather station data include precipitation (most commonly rainfall), wind speed and direction, temperature, humidity, and air pressure. An example is data from PAGASA weather stations. Most weather stations provide data up to sub-daily intervals, which allows users to see a picture of the weather conditions at that particular location from daily to yearly timescales.

Station data is often considered to be the "ground truth", as it is the most direct, physical measurement of the climate variable. The other types of data, which are measured remotely or derived from models and numerical calculations are rigorously assessed by how closely they compare to their station data counterparts. However, station data is sparse and spatially limited to the physical locations of weather stations, thus the need for other types of data to fill in the gaps.

Gridded data
Gridded data utilize numerical methods to interpolate a network of station data into a grid of values, thereby providing a more complete and comprehensive view of the physical parameter across space and time. As such, they are often used as alternatives to station data, especially for use-cases where wider coverage is key. Some examples of gridded datasets include Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation (APHRODITE) and Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) for rainfall.

A *reanalysis dataset* is a special type of gridded data that combines in situ observations with numerical models to generate gridded data for a wider array of climate variables, including wind speed, rainfall, pressure, sea-surface temperatures, at different altitudes.

The use of models ensures physical consistency across these variables and makes it possible to generate data further back in time. An example of this would be the 5th generation European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis Dataset (ERA-5). However, the reliability of a reanalysis dataset varies per variable, as a model can capture some physical phenomenon better than others. Thus, it is important to note the reported biases for reanalysis datasets when using it for research and adaptation purposes.

Satellite/ Remote sensing
Earth-monitoring satellites routinely have instruments on-board that regularly collect data on climate

variables at very high spatio-temporal scales. Using remotely sensed data and sophisticated post-processing algorithms, satellite-based datasets can give us a global and timely picture of key climate variables. Satellite data is similar to gridded data in that they are most commonly provided in grid-referenced form, thus providing a continuous spatial coverage. Examples of variables that can be measured from space include land cover, land surface temperature, and precipitation.

However, it is important to note that these are estimates derived from indirect, top-down measurements of proxy variables, and so these datasets differ from the actual conditions on the ground. For example, rainfall estimates are typically calculated from electromagnetic radiation from the top of clouds, then correlated to temperature and rainfall from in situ measurements. Assessing and improving the performance of satellite datasets compared to station data is an active field of research to this day.

Aside from physical variables, satellite data is also often used to derive useful indexes for monitoring and assessing the environment, such as the normalized difference vegetation index (NDVI) and normalized difference water index (NDWI).

Forecast climate data

Forecast climate data aims to predict long-term conditions across several years and decades, providing an "average" picture of the atmospheric characteristics.

These projections consider the environmental impacts of carbon emissions from long-term human activity. Projections rely on computational models that solve physical equations given a set of environmental boundary conditions. As model-based estimations, they have inherent uncertainties due to a multitude of factors, including but not limited to the model parameters, underlying algorithms, and uncertainties in the input data. Thus, when using these datasets, it is important to take note of the reported biases and

limitations. In practice, it is recommended to refer to an ensemble of models, taking output from many different models run in varying conditions, to properly capture this uncertainty and range of possible scenarios.

In 2014, the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) defined four Representative Concentration Pathways (RCPs), which depict potential future greenhouse gas concentrations based on human actions. Each RCP is labeled with a number at the end (2.6, 4.5, 6.0, 8.5), which indicates the expected additional radiative forcing in watts per square meter (W/m2) by 2100. Radiative forcing measures the change in energy in the Earth's atmosphere and serves as an index of the potential for global temperature change.

Using these RCPs, modelers estimate how the climate would change depending on human behavior in the coming decades. For example, RCP2.6 describes a future with low future concentrations as human efforts greatly succeed in curbing emissions, by shifting to sustainable energy sources and implementing emission capture technologies. On the other end of the spectrum, RCP8.5 describes a future with drastic emissions increase throughout the century, as humans maintain the fossil-fuel-powered status quo, representing the worst case scenario. RCP4.0 and RCP6.0 are intermediate scenarios which model emission peaks at 2050 and 2060 respectively, followed by a drastic decrease until the end of the century. It is important to note that warming will continue beyond 2100 under all RCP scenarios, except in RCP2.6.

In 2021, the IPCC's Sixth Assessment Report (AR6) introduced the Shared Socioeconomic Pathways (SSPs) as a refinement of the previous RCPs, placing a greater focus on socio-economic considerations in projecting future climate scenarios. While SSPs provide a more comprehensive perspective, they are still in the early stages of adoption at the local level. RCPs remain relevant and widely used in many data products available today.

Data catalog

General information

The data catalog is an inventory of metadata of major climate variable dataset availability on a regional scale in Southeast Asia, Asia, and Pacific, with a special focus on the Philippines. In addition to climate data, the inventory also includes key datasets relevant for agriculture and health sectors.

For each dataset, the inventory documents relevant information for end-data users, divided into 6 main sections. Table 3 shows a full list of the included information by section.

■ **General information**: high-level details describing the dataset, including the dataset's name, variable, and owner.

■ **Spatial information**: geographical characteristics and coverage of the dataset

■ **Temporal information**: time resolution and coverage of the dataset

■ **Technical requirements**: information needed by data users in order to access and utilize these datasets, including the download portal, estimated file size, access requirements (ex. account sign-up), and required software (if any)

■ **Assessments**: summary of the dataset's performance against ground truth data and other similar datasets, as reported in literature

■ **Usage information**: key information for responsible use of the dataset, including terms of use, licensing, sharing, and redistribution The data catalog aims to list all relevant and quality datasets, prioritizing local datasets and those most relevant to partner stakeholders and their sector, as possible within the project timeline. Due to the extensive breadth and scope of datasets available from CIS, the data catalog only includes a selection of the most pertinent and relevant datasets.

Table 3. Data catalog schema

Section	Field	Description
General information	Dataset Name	Name of dataset
	Variable	Variable that is being described by this dataset
	Category	See next section
	Type	Type of dataset (measured, derived, model, reanalysis, etc.)
	Owner	Organization responsible for production and/or distribution of data
	File Format	File format (e.g. .csv, .pdf, .netcdf, .geojson)
	Description	Brief overview of the dataset
Spatial information	Resolution / Granularity	Describes the spatial detail captured by the dataset. This can be in terms of gridded scale (ex. 0.1 degrees / pixel) or smallest unit described (ex. Data per barangay)
	Coverage	Extent of area covered by the dataset (ex. Global, SEA, or Philippines)
Temporal Information	Resolution / Granularity	Describes the temporal detail captured by the dataset (ex. 3-hourly, daily, weekly, monthly, yearly)
	Coverage	Years covered by the dataset (ex. 1957 - present)
	Frequency of update	How often the dataset is updated with new data
Technical Information	Estimated Size	Estimated file size of the dataset when downloaded
	Download URL	URL or website for accessing data
	Access details	Requirements for downloading/using the data (ex. User account needed, available upon purchase)
	Software	Software needed for downloading or using the datasets (ex. Google Earth Engine, Google Earth)
Assessments	Error metrics	Relevant metrics on dataset's performance
	Existing Studies	Papers and research work related to dataset
Usage information	Access and Licensing	Relevant access and license information
	Usage and Restrictions	Terms of use and explicit restrictions for using the datasets, as documented by dataset owner
	Data Sharing and Redistribution	Whether or not data can be freely shared or redistributed by third-party users
	Caveats and Limitations	Caveats and limitations not covered above
Other information	Other information	Other relevant information for this dataset

The data catalog is submitted to GIZ in a separate file. Downloaded datasets, which have been identified and finalized with GIZ on 11 December 2023, have accompanying technical documentation in Appendix B that detail how to access and download data. Larger datasets (such as those obtained from processed satellite imagery and reanalysis) also have accompanying Jupyter notebooks that can be run and adjusted using Google Colaboratory.

Currently, the data catalog contains 71 datasets covering a wide range of climate-relevant variables. Many of the datasets listed in the catalog are products of research groups and government agencies, and are freely-available for download online. Common research data formats encountered include netCDF, a multidimensional data format that is standard in climate applications, geospatial TIFF raster images, and vector shapefiles. On the other hand, government datasets are typically provided in Microsoft Excel spreadsheets or as portable document format (PDF) files.

For each dataset entry, the catalog also summarizes key findings and error metrics from the available literature, which informs users on how to use these datasets appropriately. Findings from the team's literature review focused on the Philippines, but literature search was expanded to greater Southeast Asia whenever there were no reported metrics for the Philippines.

Data sharing and redistribution

Datasets in the catalog are covered by different licenses that inform how they can be used, shared, and redistributed. We can categorize these licenses into five main types:

■ **Open government data** refers to datasets and information produced and widely distributed by government entities such as PAGASA, DENR, DOST, the United States' National Aeronautics and Space Administration (NASA), etc. These datasets are accessible for free, either through government websites or electronic Freedom of Information (FOI) access requests, and do not have any imposed restrictions on their use. Datasets in this category include PAGASA's reports, PSA statistics, and Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) and Moderate Resolution Imaging Spectrometer (MODIS) datasets from NASA.

■ **Public domain data** is not protected by copyright or any other intellectual property rights, as the data producer has voluntarily relinquished them. As such, public domain datasets are freely available for anyone to use, modify, and distribute without restrictions. This is often the case for scientific datasets meant for research and analysis, as releasing to the public domain maximizes their adoption and use by the general public. Public domain datasets include the CHIRPS/CHIRTS dataset and contributions to OpenStreetMap. Government datasets in the previous category can be considered public domain data as well.

■ **Creative Commons (CC)** refers to data that has been made freely available under a creative commons license. There are a range of creative commons licenses, which explicitly permit others to use data under specified conditions, thus forming a spectrum of openness. The most open CC licenses, such as CC BY, and CC BY-SA require only attribution (giving credit) but otherwise permits nearly any use imaginable. Less open licenses, such as CC BY-NC-ND, include components that limit or prevent commercial reuse and modification. Under this umbrella, other datasets are also provided under modified forms of CC licenses, such as the Open Data Commons Open Database License (ODbL) (i.e. OpenStreetMap) and the Copernicus Products Licence (i.e. ERA5). More information about each CC license can be found here.

■ **Restricted government data** refers to government data that is usable but requires access through official government means. The most relevant restricted climate datasets are PAGASA weather station observations, which must be requested from PAGASA directly. In addition, while PAGASA provides weather data at no cost for research and government purposes, commercial entities are required to purchase these datasets. As another example, DENR maps of land cover and flood susceptibility are also requested and provided on a per regional office-basis.

■ **Commercial data** is collected, processed, and made available for purchase by businesses and organizations. Some examples include high-resolution satellite imagery (MAXAR, PlanetScope) and Google Maps data. As the data catalog focuses on freely-available data, these are currently not included in the catalog.

The Access Type field denotes which of these five categories a specific dataset belongs to.

Technical information

For the catalog, priority datasets up to 2023 were downloaded and stored into external hard drives. Whenever possible, we also used Python to programmatically download and process these datasets. Listed below are recommended hardware and software requirements for using and replicating our work:

■ **Storage**: Up to 400GB of disk space if loading all datasets. TM will provide 4 copies of the data in separate 1TB external hard drives
■ **Internet speed**: 50 Mbps or better
■ **Processing**: Intel Core i7 processor, 16GB of RAM
■ **System**: Python installation >= 3.10
■ **Code**: Jupyter notebooks can be found in the GitHub repository

Table 4 also lists programs for opening and processing these datasets, depending on their file type.

Table 4. Typical climate data formats and recommended software

Format (file extension)	Description	Recommended software
CSV (.csv), XLSX (.xlsx)	Tabular data organized into rows and columns	Excel, Google Sheets (visualization)
NetCDF (.nc)	Multidimensional gridded data	QGIS (visualization and processing) xarray (processing) Climate Data Operators or cdo (processing)
GeoTIFF (.tif)	Georeferenced images	QGIS (visualization and processing) GDAL (processing) rasterio (processing)
Shapefile (.shp), GeoPackage (.gpkg)	Tabular data containing spatial geometries (i.e. points, admin boundaries)	QGIS (visualization and processing) geopandas (processing)

In order to extend or update this work in the future (i.e. regularly refreshing the data), future collaborators must take the following into account:

■ **Increasing disk space requirement**: Acquiring data for more years will lead to a significant increase in the disk space required.
■ **Processing time**: The time needed to process and refresh the data is highly dependent on internet bandwidth (for downloading the data) and compute resources (for processing). The current data catalog was downloaded over a cumulative period of two months using a single laptop with a typical fiber internet connection. Regularly updating the data would thus require much higher internet speeds and ideally multiple computers and servers to process the data.
■ **Regular maintenance**: As datasets get updated, the requirements for accessing and processing them also change, so there would be a recurring need to maintain the code in order to keep it functional and up-to-date.

Comparison of climate datasets

Measurements from weather stations are often regarded as the "gold-standard" for the collection of climate data. It is considered representative of actual conditions, but it can be limited by missing records and the sparse distribution of stations particularly in developing countries. As such, climate reanalysis data is usually applied as pseudo-observations that provide a complete record of various meteorological variables, usually in a global scale and at various spatio-temporal resolutions (Mistry, et al., 2022).

The data catalog provides a list of various climate datasets commonly used in the Philippines. Measurements from weather stations are obtained from PAGASA's website and ClimGridPH platform, while reanalysis data

come from ERA5, CHIRTS, JRA-55[1], MERRA2, and CFSR[2]. A combination of collection from weather stations and some modeling or interpolation is also implemented for CHIRPS, APHRODITE, CPC[3], CRU[4], IMERG[5], and tropical cyclone datasets. A summary of comparisons between these datasets are in Table 5, while further details are shown in the data catalog. It is worth noting that literature is focused mostly on the comparison of datasets for temperature and precipitation.

Table 5. Comparison of climate datasets

Dataset	Variable being compared	Compared with	Findings
ERA5	Temperature	PAGASA stations	Root mean squared error (RMSE) of 1.3°C to 2.1°C and a standard deviation of ±2°C when compared to 26 PAGASA stations (Gulfan, et al., 2021)
CFSR	Precipitation	Other datasets	Better estimate of observed precipitation (RMSE=0.97) compared to eight other reanalysis datasets for East Asian summer monsoon (Huang, et. al., 2018)
CHIRTS	Temperature	Other datasets	CHIRTS improves on daily T_{max} and associated heat wave trends, but performance deteriorates when assessing minimum temperature in Southeast Asia (Li, et al., 2022)
JRA-55	Precipitation	Other datasets	More stable temporal behavior compared to ERA-I when assessing precipitation for Asian monsoons (Ceglar, et al., 2017)
MERRA2	-	-	-
CHIRPS	Precipitation	PAGASA stations	Performed best during dry seasons, observed to be well-correlated with Philippine climate types (Alejo, et al., 2021)
APHRODITE	Precipitation	PAGASA stations & other datasets	Performs best compared to TRMM[6], CHIRPS, and PERSIANN[7] even if it shows consistent underestimation (Peralta, et al., 2022)
	Temperature	Indian weather stations	Good accuracy for North and Northeastern India in a study that spanned 149 weather stations (Bandyopadhyay, et al., 2018)
CPC	Precipitation	Indian weather stations	CPC is more sensitive than CMORPH[8], GPCP[9], PERSIANN, and TRMM compared to gridded reference data produced by the Indian Meteorological Department even if there is overestimation over most of India (Sunikumar, et al., 2015)
CRU	Precipitation	PAGASA stations	Tends to underestimate by an average of 0.89% bias (Salvacion, et al., 2018)
	Temperature	Other datasets	RMSE of 0.4, making it comparable to other observational gridded datasets such as SA-OBS[10], GHCN_CAMS[11], UDEL[12] (Ge et al., 2018)
IMERG	Precipitation	PAGASA stations & other datasets	Strong agreement with rain gauge observations from 66 PAGASA stations during typhoons compared to GSMaP[13] and PERSIANN, also performs well in detecting heavy rainfall in low elevations and under various windspeeds (Aryastana, et al., 2022)

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[6] TRMM: Tropical Rainfall Measuring Mission
[7] PERSIANN: Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks
[8] CMORPH: CPC Morphing technique
[9] GPCP: Global Precipitation Climatology Project
[10] SA-OBS: Southeast Asian Observational Dataset
[11] GHCN_CAMS: Global Historical Climatology Network version 2 and the Climate Anomaly Monitoring System
[12] UDEL: University of Delaware Dataset
[13] GSMaP: Global Satellite Mapping of Precipitation

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[1] JRA-55: Japanese 55-year Reanalysis
[2] CFSR: Climate Forecast System Reanalysis
[3] CPC: Climate Prediction Center
[4] CRU: Climate Research Unit
[5] IMERG: Integrated Multi-Satellite Retrievals for Global Precipitation Measurement Mission (GPM)

Land use and land cover datasets

There are various land use and land cover (LULC) datasets available from various satellites rotating around the globe. Some of the most common datasets used for fine-resolution LULC (10-m) are derived from Sentinel-1 and Sentinel-2 images and include Google's Dynamic World, European Space Agency's (ESA) WorldCover, and Environmental Systems Research Institute, Inc.'s (ESRI) Land Cover. ESRI's Land Cover had the highest overall accuracy (75%) compared to global ground truth data (resolution of 250-m, while ESA's WorldCover had the highest overall accuracy (71%) compared to European ground truth data (resolution of <100-m). This highlights the ability of ESAs WorldCover to resolve landscape elements in a finer resolution compared to Google's Dynamic World and ESRI's Land Cover (Venter, et al., 2022). Another global land cover dataset created with a relatively fine resolution (30-m) is the Global Land Cover and Land Use Change dataset derived from Landsat-5.

The data catalog includes ESA's WorldCover and its coarse-resolution (300-m) predecessor, the Climate Change Initiative's (CCI) Land Cover. ESA's WorldCover has been used in the Philippines for post-disaster recovery assessment of mangrove forests (Gil, et al., 2024), rapid assessment of deforestation (Cho & Lim, 2023), and paddy rice mapping (Sun, et al., 2023).

Maps and visualizations

Some of the most pertinent maps and visualizations displayed in local CIS platforms are summarized in Table 6.

Table 6. Pertinent maps and visualizations from local CIS

Map/ visualization	Source	Description
Hydrometeorological hazards	Project NOAH (UPRI), Monitoring Dashboard (NDRRMC)	Flood, storm surge, and rain-induced landslides
Geophysical hazards	GeoRisk (PHIVOLCS and MGB), Monitoring Dashboard (NDRRMC)	Seismic and volcanic hazards
Climate projections	PAGASA Website and OML Knowledge Center	Statistical and dynamic downscaling (CMIP3 and CMIP5)
Historical climate data	ClimGridPH (PAGASA)	Monthly historical rainfall
Agricultural Guide	National Color Coded Agricultural Guide (DA)	Crop suitability, agro-ecological zones, AMIA villages, groundwater suitability
Non-CIS but relevant to determining risk and vulnerability		
Fisheries information	National Stock Assessment Program (NSAP) Interactive Atlas	Landing sites, catch data by species and gear, fisheries management areas
Select exposure indicators	GeoPortal (NAMRIA)	Land cover, population, critical facilities

Data platforms

This section enumerates the different data platforms encountered while developing the data catalog and during the KIIs.

International CIS

Table 7 shows available and commonly used international CIS. These CIS are usually used across sectors.

Table 7. International CIS

CIS	Description
World Meteorological Organization (WMO) Climate Data Catalog	This contains links to climate datasets at various scales (i.e., global, regional, and national). Datasets are contributed and assessed through the WMO Stewardship Maturity Matrix for Climate Data. Global datasets with relevant info on Philippine CIS include gridded temperature and precipitation data (ClimDex and ERA5).
WMO World Weather Information Service	This contains weather observations and forecasts through the provision of data from National Meteorological and Hydrological Services (NMHSs) in selected cities worldwide. The NMHS in the Philippines is PAGASA and they only provide data for Metro Manila in the World Weather Information Service.
World Bank Climate Change Knowledge Portal	This is a central repository for all climate-related information and tools being used by the World Bank Group. Datasets are available at national, subnational, and watershed scales and may be downloaded using a registered account. The datasets available include Coupled Model Intercomparison Project Phase 6 (CMIP6), CRU, ERA5, and Population/Poverty.
National Oceanic and Atmospheric Administration (NOAA) Climate Data Online	This platform provides access to the United States National Climate Data Center (NCDC) that include variables such as temperature, precipitation, wind, radar, and climate normals. Daily, monthly, and annual summaries for temperature and precipitation are available for selected Philippine stations.
NOAA Global Forecast System	This is maintained by the United States National Centers for Environmental Prediction (NCEP). It is a model that generates forecast data for up to 16 days for temperature, wind, precipitation, soil moisture, and atmospheric ozone concentration with a base horizontal resolution of 28 kilometers between grid points.
National Center for Atmospheric Research (NCAR) Climate Data Guide	This provides information on the pros and cons of various climate datasets. It has several categories ranging from atmospheric, climate indices, cryopshere, land, ocean, paleoclimate, and reanalysis variables.
Copernicus Climate Change Service	Also known as C3S, this is one of the six thematic information services provided by the Copernicus Earth Observation program. It relies on research carried out by the World Climate Research Programme (WCRP) and provides climate adjusted datasets for specific sectors. An account is needed to fully access the data store and to use the toolbox to build workflows and applications. There are a number of datasets with global coverage in the different variable domains (e.g., atmosphere, land, ocean) with varying spatial and temporal coverage. Sector specific datasets and applications that might be of interest are shown in Appendix C.
Accuweather	This is a platform run by a private company that provides weather forecasting services and other climate-related information. They combine climate data sourced from satellites, radar sets, ground observations, and crowdsourcing and use proprietary artificial intelligence (AI) algorithms reviewed by meteorologists to come up with their digital forecast system. Variables available in Accuweather's forecasts include temperature, precipitation, wind speed and direction, air quality, ultraviolet (UV) index, humidity, and cloud cover.

Local CIS

Table 8 below shows available and commonly used local CIS. These CIS are usually used across sectors. CIS used by specific sectors in the Philippines are further elaborated in the section for Discussion (Applications of CIS).

Table 8. Local CIS

CIS	Description
PAGASA Website	This is the source of most, if not all, local climate information in the Philippines. Their website includes a variety of information, all of which are post-processed data intended for general use by the public and specific sectors. Information is divided into various sections namely, weather, flood, tropical cyclones, climate, and agri-weather. More information on the data included for each section is shown in Appendix D. PAGASA's automated weather stations are also listed in the website.
PAGASA ClimGridPh	This provides monthly means for historical and projection data for rainfall and temperature. It is an interactive map with resolutions that can be adjusted by region, province, and municipality. Historical data (monthly mean per municipality) is downloadable via CSV, while PNG maps may be downloaded by request. SHP and NETCDF files showing the same information are not yet available for download. Climate data may also be requested from PAGASA by request on this platform.
MO Panahon	This platform shows (a) current station data for precipitation, temperature, wind speed and direction, and pressure over Manila and a few other stations around the Philippines, (b) five-day forecasts for the entire Philippines for rainfall, temperature, maximum heat index, relative humidity, winds, wind power, and solar power, and (c) climate projections up to 2090 for daily temperature and rainfall under RCP45 and RCP85 scenarios. Links

CIS	Description
	to reports of extreme climate events (drought and typhoons) are also available on the platform, while historical weather station data may be requested via a Google Form.
Weather Manila	This provides local weather information and forecasts as a supplement to PAGASA's forecasts. It is currently being maintained by Dr. Gerry Bagatasa of UP-IESM and includes 3-hour weather forecasts by city and daily forecasts for key areas in the Philippines. Weather forecasts are produced using Japan Meteorological Agency's numerical weather prediction model. Air quality forecasts are still in the works and plans are for it to include a one-day forecast of particulate matter, ground ozone, and SO2 and ash fall (in case of increased volcanic activity).
DA Bureau of Soils and Water Management (BSWM) Agromet program	This was established in 2010 through a Memorandum of Agreement (MOA) between DA (particularly DA-BSWM) and DOST to establish agro-meteorological stations in highly vulnerable agricultural areas. It involved the installation of 100 automated weather stations, upgrading of select PAGASA and ASTI sensors, and installation of 84 standard rain gauges. The tool shows the location of the automated weather stations/sensors and provides interpolations of temperature, rainfall, and pressure for the entire country. It is worth noting that a number of weather stations/sensors are non-operational and/or in need of maintenance. The interface is openly accessible to the public by answering a survey and a Reference ID available for the next 24-hours.
DA National Color Coded Agricultural Guide	This is an interactive map showing various municipal and barangay maps. It is a project supported by the Adaptation and Mitigation Initiative (AMIA) under the DA. Barangay maps include agro-ecological zones, AMIA villages, crop suitability, ground water availability, network of protected areas for agriculture and agro-industrial development, and rice suitability zones. Municipal maps include rainfall and temperature information and Climate Risk Vulnerability Assessments (CRVA) for adaptive capacity, crop vulnerability, and multi-hazards.
National Disaster Risk Reduction and Management Council (NDRRMC) PhilAWARE	This is a customized version of the Pacific Disaster Center's DisasterAWARE platform that seeks to provide hazard monitoring, early warning, advance modeling, and decision support tools to aid in rapid disaster response. Most of the 398 data layers in the platform are geospatial information; however, the platform can only be accessed by a valid and approved account. Kickoff for training on how to use the platform was conducted in October 2022 (Pacific Disaster Center, 2022).
PHIVOLCS GeoRisk	This is a geospatial information management project for hazards and risk assessment in the Philippines. It includes a range of information and tools which include, but are not limited to, hazard maps, risk assessments, early warning systems, and other decision support tools. Data is contributed by various government agencies. The portal has multiple components, namely: (a) HazardHunterPH, (b) GeoAnalyticsPH, (c) GeoMapperPH, (d) Map & Feature, (e) 3D Earth Risk, and (f) PlanSmart. HazardHunterPH and GeoAnalyticsPH are open to the public, while other components need permissions and valid account access. HazardHunterPH is a one-stop shop for hazard assessment and includes climate information in the hydrometeorological, severe winds, climate projection, and typhoon monitoring section. GeoAnalyticsPH, on the other hand, is a tool that generates maps and analytics for hazards and exposure.

CIS	Description
UPRI Nationwide Operational Assessment of Hazards (NOAH)	This is a web portal that provides critical information and tools for disaster prevention through the improvement of access to data by various stakeholders. It provides information on weather, flood, landslides, storm surge, inundation, and the identification of local critical facilities. Raw data/maps may be downloaded from Google Drive. NOAH Studio is also available for more granular assessments of natural hazards in wide areas. Climate information available in NOAH studio include weather satellite images from Himawari and rainfall contours.
OML Center Climate Knowledge Portal	This contains regional and provincial information on historical and projected climate. Climate variables include temperature and rainfall. For projected climate, the user can also choose a method (PRECIS and WorldCLIM), time period (2006-2035 and 2036-2076), and time resolution (annual and seasonal).
PhilSA Space Data Dashboard	This contains various datasets derived from our local satellites. It is still being updated, but two of the datasets relevant to climate that have already been released include Land Surface Temperature and Urban Thermal Field Variance Index for the National Capital Region.
ASTI PHILSENSORS	This includes data from ASTI's various sensors in the country. These sensors include, but are not limited to, automated rain gauges, water level monitoring systems, automated weather stations, meteorological buoys, and lightning/thunderstorm sensors. The status of sensors (active or down) are also indicated in the platform. It is worth noting that a number of sensors are down and will require repair and maintenance.
ASTI Deployment of Early Warning System	This is a project implemented by DOST and PAGASA to install hydro-meteorological devices and early warning stations in selected hazard areas in the Philippines. Data is incorporated into PAGASA's system.
Green Climate Fund (GCF) Multi-Hazard Impact Based Forecasting and Early Warning System	This is an ongoing project funded by GCF and implemented by PAGASA from 2019-2027 that aims to develop a nationwide system that communicates what weather "will do" instead of what weather "will be" in order to aid decision making. It will be implemented in the cities/ municipalities of Tuguegarao (Cagayan), Legazpi (Albay), Palo (Leye) and New Bataan (Davao de Oro).

Discussion
Roles and relationships of CIS stakeholders

To better understand the roles of local stakeholders in the sources and usage of CIS, this paper structures them into data producers, integrators and users. Data producers are agencies/institutions involved in the production of raw data such as ground observations (i.e., surveys, sensors, weather stations) and satellite imagery. Data integrators are agencies/institutions involved in the processing of data into forms usable by end-users and implementing capacity building programs to help users interpret climate data. Data end-users are agencies/institutions that use climate data and information systems to make sector-specific decisions and create policies/programs. A summary of identified producers, integrators, and end-users are displayed in Table 9, while a diagram showing their relationships is shown in Figure 1.
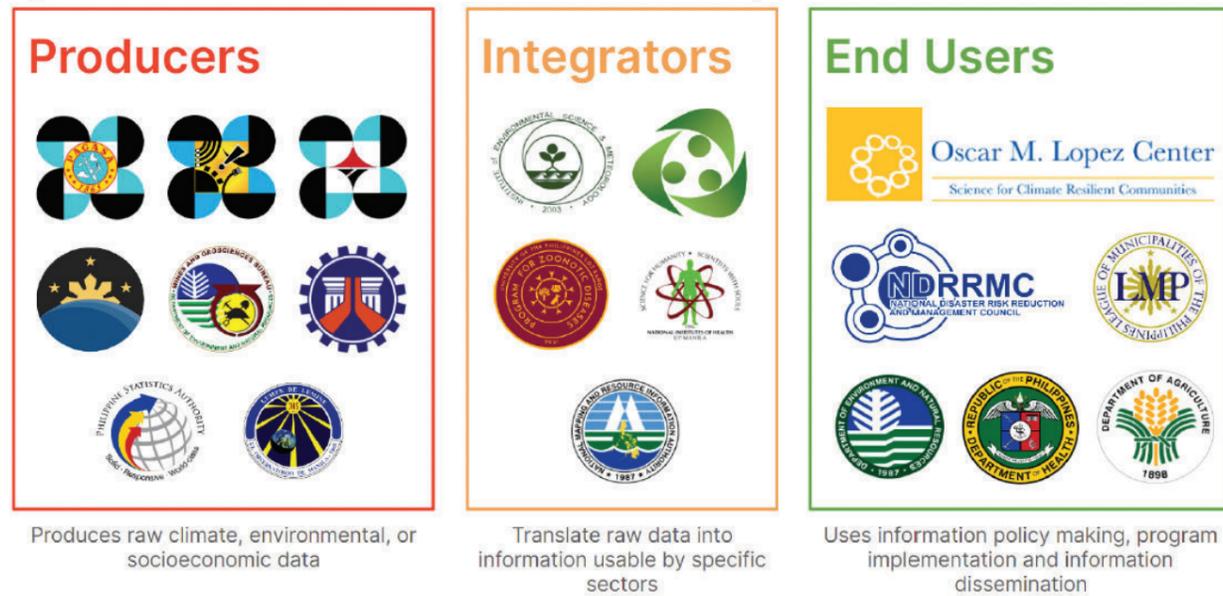
Table 9. Roles of stakeholders in the Philippine CIS landscape

Category	Agency/ Institution	Description
Producer	PAGASA	PAGASA is mandated to provide accurate and reliable weather data and scientific assessments pertaining to disaster risk reduction, climate change, adaptation, and water resources management. PAGASA provides bulletins, advisories, and forecasts for different purposes (general, agriculture, aviation, etc.) and time scales (daily, weekly, monthly, seasonal). They also provide historical and projection data based on observations from ground stations and runs of various climate models. PAGASA usually provides their data in the form of reports and summary tables. Raw data may be requested and given upon PAGASA's approval.
	ASTI	ASTI's role in the collection of climate data is mostly in the design and installment of sensors in automated rain gauges, water level monitoring systems, automated weather stations, and meteorological buoys. Before the creation of PhilSA, ASTI was also the interim agency for the collection of data from remote sensing through the creation of local satellites and processing of satellite imagery. Data from ASTI's sensors are usually sent through Global System for Mobile Communication (GSM) gateways to ASTI's data warehouse and then sent to PAGASA via Application Programming Interfaces (API).
	PhilSA	PhilSA's role in the collection of climate data is in the collection and processing of remote sensing imagery. The agency was established only in 2019 and one of its key development areas is the utilization of space science and technology applications to enhance hazard management, disaster mitigation strategies, and resilience to climate change. PhilSA sources remote sensing observations from sovereign, open, commercial, and charter-activated satellites. The Philippines has two sovereign (local)

Category	Agency/ Institution	Description
		satellites, namely Diwata-2 (an optical imaging satellite) and NovaSAR-1 (a Synthetic Aperture Radar (SAR) imaging satellite). Both satellites were launched in 2018 and have applications in (a) environmental and natural resource monitoring, and (b) disaster response and management. As of current, remotely sensed climate data are sourced mainly from foreign open satellites.
	MGB and PHILVOLCS	DENR's Mines and Geosciences Bureau (MGB) collects mostly geophysical data that indicate a specific area's vulnerabilities and risks to climate hazards. Among the data that they collect and/or process relevant to extreme climate events are flooding and rain-induced landslides. These data are also relevant to PHIVOLCS and are displayed in PHIVOLCS GeoRisk portal.
	DPWH	While the Department of Public Works and Highways (DPWH) is mandated to undertake the planning, design, and construction of major infrastructure systems, their responsibility over the planning for flood control projects makes some of the data they collect relevant to CIS. In particular, DPWH's Streamflow Management System is a source of hydrologic data (e.g., flow duration curves) which are relevant to streamflow, drought, and flood analysis.
	PSA	PSA is in charge of developing policies and implementing programs relevant to the production of the country's official statistics. They collect mostly socioeconomic data that represent the vulnerability of specific populations to climate risks. These data include, but are not limited to, population, vital (deaths), poverty, agricultural, and environmental statistics. The data they produced are usually in aggregates up to municipality or barangay level. Raw data may be requested from PSA or gathered from LGUs with PSA's endorsement.
	MO	In addition to DOST's climate-related agencies (PAGASA and ASTI), MO also owns weather stations in Metro Manila and selected places around the country. They have historical climate data from these stations and create forecasts and projections complementary to PAGASA's data.
Integrator	UP	There are several institutes under the umbrella of the University of Philippines that work with climate data and transform them into formats usable for the specific sectors and local government units. Among those that are of interest to health and the environment are the National Institutes of Health (NIH), the Program for Zoonotic Diseases (PZD), the Resilience Institute (RI), the Institute of Environmental Science and Meteorology (IESM). These institutes are usually equipped with the handling and interpretation of data from raw sources (i.e., PAGASA, satellite imagery) and are involved in developing tools and studies with specific use cases.
	NAMRIA	NAMRIA, being the central mapping agency, depository, and distribution facility for the Philippines, is also equipped to handle geospatial information relevant to climate. They provide baseline information and distribute geospatial data relevant to planning for climate change resilience. They are equipped particularly on the use and processing of geospatial data such as remote sensing imagery and land use/land cover datasets.
	NWRB	The National Water Resources Board (NWRB) is also an integrator of data particularly for the integrated management of water resources. They are also particularly relevant to CIS because they are involved in the release of bulletins and information pertaining to dam levels, particularly during extreme climate events such as droughts and floods.
User	LGUs	Local government units incorporate information from CIS into assessments and strategies for their respective localities such as Community-Based Disaster Risk Assessments (CDRA), CRVA, Comprehensive Land Use Plans (CLUP), Local Climate Change Action Plans (LCCAP), Comprehensive Development Plans (CDP), and Local Disaster Risk Reduction and Management Plans (LDRRMP).
	NGOs	Non-government organizations (NGO) such as the OML Center are involved in developing actionable knowledge and community resilience through tools developed from scientific observations. They translate climate information to materials (films, reports, policy briefs, and almanacs) that are readily understandable to the public. They are also involved in capacity-building initiatives aimed at individuals and organizations working in the field of climate change adaptation and disaster risk management.
	National agencies	Sector specific departments such as DA, DOH, Department of Human Settlements and Urban Development (DHSUD), and DENR are also end users of CIS. The DA and DENR, in particular, are also climate data integrators equipped to interpret raw climate data into usable forms for their respective sectors. They also use climate information to come up with tools and policies which include, but are not limited to, cropping calendars and forecasts for the agriculture sector and various studies linking climate to specific diseases and species of interest.

Figure 1. Main roles of stakeholders in the CIS Landscape

Figure 1. Main roles of stakeholders in the CIS Landscape

Producers
Produces raw climate, environmental, or socioeconomic data

Integrators
Translate raw data into information usable by specific sectors

End Users
Uses information policy making, program implementation and information dissemination

Figure 2. Data sharing network across CIS stakeholders

Directional arrows represent existing instances of data sharing from providers to users, with overlapping arrows denoting mutual sharing. The size of the circles denotes the frequency of involvement of a stakeholder in sharing their datasets. The information in this network combines the KIIs conducted by TM and C4. An interactive version of this figure is available in this link.

While the stakeholders in Figure 1 are labeled according to their main role in CIS, it was also mentioned in the KIIs that some departments within these organizations perform tasks that fall under the other two roles. The complexities of a stakeholder's role in the CIS landscape of the PH, and how each connects to each other via the datasets they share is presented in Figure 2. Based on the network, the DOST agencies PAGASA, PHIVOLCS, and ASTI emerge as the most connected data producers, regularly sharing their datasets to almost all included stakeholders. Meanwhile, other data producers such as PhilSA, NAMRIA, and PSA also contribute data but to a smaller subset. Research institutions like UPRI, UP-IESM, MO, and OML Centre primarily serve as data integrators, with their data being utilized by a select few, often due to established project collaborations and data sharing agreements. On the other hand, agencies focused on specific sectors, such as DENR, DA, and NDRRMC, predominantly function as data users, accessing multiple datasets from various stakeholders. Lastly, stakeholders DENR-GDO, PhilSA and NAMRIA exhibit a relatively equal number of connections both to and from them, indicating their potential suitability as hosts for data sharing initiatives.

In terms of the most utilized datasets, PAGASA's weather reports and tropical cyclone bulletins are used by almost all stakeholders, as shown in Figure 3. Additionally, the GeoRisk and Geoportal platforms are similarly highly utilized. While less-processed data sources such as sensor measurements, weather stations, satellite imagery, and climate models are also mentioned, they are less extensively adopted, and only primarily by data transformers. Finally, data users tend to have their own custom mandate-specific platforms and tools such as FishVool, DALA, NCCAGP, and Nutrition EWS.
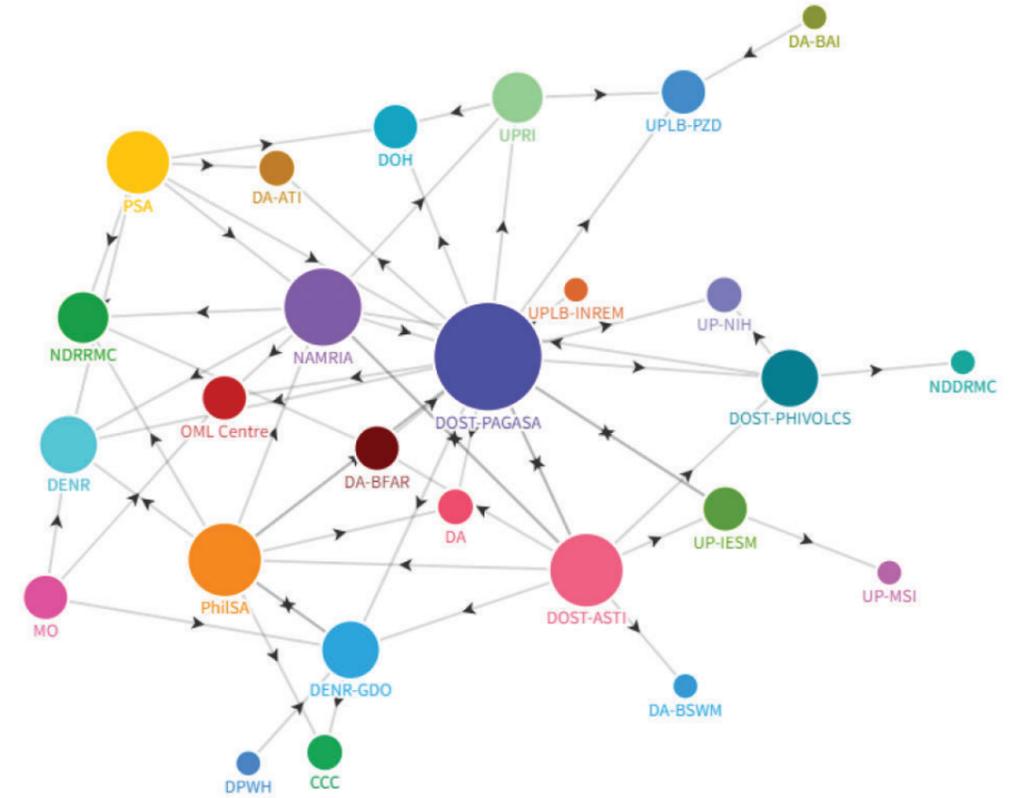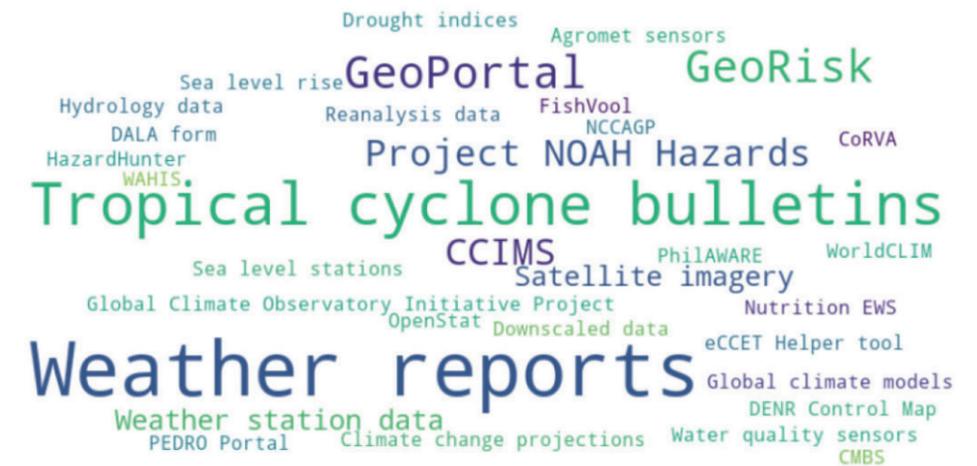
Figure 3. Word cloud diagram of datasets and tools used by the stakeholders

Larger representations indicate higher frequency of usage as mentioned in the KIIs. The information in this diagram combines the KIIs conducted by TM and C4.

Applications of CIS in the Philippines

CIS in the Philippines is mostly for agricultural and general public use. There are limited CIS and even fewer case studies (sometimes none) for other sectors.

Agriculture

Key climate issues in agriculture include drought, extreme weather events, pests and diseases, and sudden temperature changes. Typhoons are particularly highlighted for their impact, not only to crops, but also in aquaculture and mariculture commodities as well (e.g., milkfish, tilapia, and seaweed). For fisheries in particular, sea level rise could affect the inland migration of shorelines and habitats, induce a transition period for fish stocks, and strain fishing industry facilities due to rising water levels (Bigford, 1991). Another effect of sea level rise is the intrusion of saltwater and elevated terrestrial water tables. This reduces crop yields and introduces a need for coastal communities to adopt by rotating between agricultural (i.e., rice) and aquatic (i.e., prawn) crops or by abandoning farmlands entirely (Loc, et al., 2021; Guimond and Michael, 2020; Hingst, et al., 2022).

The DA takes on the responsibility of formulating and implementing policies and programs for the agricultural and fisheries sector in the country. Their main sources of climate data are PAGASA and WorldClim, while the source of field-based agricultural data are their extension offices. A technical working group specific to the Bureau of Agricultural Research (BAR) and BFAR interprets and translates this data for specific applications, disseminating it through extension offices and the ATI. It is worth noting that the Climate Resilient Agriculture Office (CRAO), whose mandate is to mainstream the climate change lens in various programs of DA, is a non-institutionalized office which may be challenged by a lack of resources to implement programs for climate-resilient agriculture. They are implementing the AMIA program which encompasses the creation of AMIA villages (go-to places for climate support services) and agricultural CIS.

CIS commonly used in the agriculture sector are shown in Table 10. There are also other climate relevant tools commonly used by the DA, particularly in the assessment of vulnerabilities, losses, and damages (Table 11).

Table 10. CIS in agriculture

CIS	Description
Weather outlooks and advisories	These are intended for planning farming activities. Seasonal outlooks and advisories are provincial/regional guides for six-month planning periods, 10-day outlooks and advisories are municipal guides for day-to-day farming activities, while special farm outlooks and advisories are specific guides for areas affected by extreme weather events such as typhoons to avoid damage and facilitate recovery efforts. It is worth noting that while these advisories are distributed to regional and extension offices, these offices vary in terms of how they distribute information to their relevant constituents. Not all field offices have outlooks and advisories in a centralized platform accessible to the public but Bicol, in particular, is pioneering one such platform through the Agro-Climatic Advisory Portal Bicol (ACAP-BICOL). This platform is hosted by AMIA and is still a work in progress.
Cropping calendars	This is specific to various commodities and is also still being developed and adjusted by the DA for various provinces and municipalities. The DA notes that in the past 20 years, most typhoons hit the Philippines from September to October and that they are necessitating changes based on these observations in their cropping calendars. ACAP-BICOL already hosts some of these cropping calendars in the platform. A general crop calendar (not yet adjusted to climate scenarios or specific areas) for various commodities is also displayed in the website of the DA's Bureau of Plant Industry.
National Color-Coded Agricultural Guide (NCCAG) map	This was launched in 2017 aims to help farmers boost yield and farm income by showing the suitability of economically important crops, climate risk vulnerability assessments, and hazards for the entire country. The DA is currently conducting training with LGUs on how to use this platform and needs a budget to implement this across the country.
Advisories during emergencies	In emergencies, the DA employs short message service (SMS) blasts through the ATI to alert local farmers. Various modes of information dissemination also include forums, community bulletin boards, social media, weather boards, and radio programs like ATI's School-On-the-Air Program.

Table 11. Climate relevant tools and products in agriculture

Tool/ product	Description
Fisheries Vulnerability Assessment Tool (FishVool)	FishVool assesses the vulnerability of fishery commodities through the administration of key informant interviews and focus group discussions. It was developed by the National Fisheries Research and Development Institute (NFRDI), an agency attached to the DA, to provide insight on the vulnerability of the fisheries sector by gathering data on the sensitivity, exposure, and adaptive capacity of capture fisheries and aquaculture areas. Components include assessments on infrastructure, ecological, financial, and social aspects of an area. Findings are shown in the FishVool website hosted by the DA's Philippine Rural Development Project (PRDP) which also includes a map for fish habitat suitability. A manual on conducting assessments via FishVool has also been published by Aguila, et al. (2021).
Damage and Loss Assessment (DALA)	This form is used to gather data on damage and losses on the field. It includes information on the location, number of fisherfolk affected, particulars and units damaged, and the estimated value of damage. This form is used mainly by quick response teams after typhoons and are passed on to the BFAR's Fisheries Planning and Economics for approval of loans and provisions of assistance for the loss of fish, damaged gears, boats, and infrastructure (e.g., cold storage).
Climate Risk Vulnerability Assessment (CRVA)	This tool aims to assess climate risk vulnerability in DA's AMIA sites to aid in the development of the Provincial Commodity and Investment Plan (PCIP). CRVA data for 44 provinces is currently available on the website. The Hazard CRVA assesses risk on eight climate hazards, while the Adaptive Capacity CRVA addresses vulnerability by determining the capability of a system to adjust to climate variability and extremes.

Farmers, while acknowledging the accuracy of climate forecasts, primarily rely on their own experiences of weather patterns when making decisions. This suggests the need to integrate farmers' experiential knowledge in the development of climate forecasts. The trust farmers place in climate information is influenced by their proximity to meteorological stations and this emphasizes the need for localized data and the role of extension workers in interpreting climate data (Gravoso, et al., 2014).

Television serves as the primary source of information for most farmers, with rice farmers expressing particular concerns about typhoons and corn farmers focusing on wet and dry seasons. Farmers with local leadership positions have a nodal influence by improving the delivery of weather and climate information particularly to farmers that are not reachable by agricultural extension offices. Apart from climate information, farmers also use local ecological knowledge, social circumstances, and market relations to make their decisions. These narratives should also play a role in the development of agricultural CIS (Ruzol, et al., 2020).

Recognizing the limitations of traditional cropping calendars, farmers are turning to localized guides such as those developed by the Bicol Agri-Water Project (BAWP) to provide climate information and extension advisories. It is based on various forecasts from PAGASA and results of crop simulation from modeling decision tools run by state universities and colleges (Faderogao, 2020).

Health

Climate poses significant challenges to the health sector through their impact on disease patterns and outbreaks. Shifts in rainy seasons and increased flooding contribute to the spread of diseases like dengue and leptospirosis, while droughts and dry spells affect nutrition and disrupt supply chains. Modeling disease outbreaks requires consideration of climate variables such as temperature, rainfall, humidity, and the frequency of extreme weather events.

The DOH takes on the responsibility of formulating and implementing policies and programs for the health sector. PhilHealth, an agency attached to the DOH, also provides medical insurance data useful for linking climate and health variables, especially for non-communicable diseases and discharge diagnosis. The main source of climate data is PAGASA, while healthcare facilities and LGUs (barangay and city/municipality level) are the main sources of field-based health data. When combining climate and health data for outbreak modeling, it is important to consider historical health data availability (e.g., past cholera cases) and the spatial resolution of climate data (e.g., barangay level data that cannot be covered by PAGASA stations).

Data gathering for health variables is still largely paper-based and would usually require encoding in the LGU level to transform data in digital format. Rural health unit workers face challenges in transitioning to digital health records, making their engagement in the use of Electronic Medical Records (EMR) selective, partial, and not fully normalized (Macabasag, et al., 2022). In addition, remote rural areas do not have the capability or resources to use online systems.

Collecting health data is also particularly challenging because specific disease cases are typically treated as highly sensitive information. As such, health data are usually aggregated at least on a barangay level. Access to this data needs to be requested from or endorsed by the DOH. Publicly accessible online data products usually only include registries for health facilities and general information pertaining to the health workforce.

CIS used in the health sector are shown in Table 12.

Table 12. CIS in health

CIS	Description
Early Warning System for Food and Nutrition Security (EWS-FNS)	This is run by the National Nutrition Council (NNC) and is a data source for the nutrition surveillance systems and action plans. Data includes historical climate data from PAGASA, however, only 59 LGUs are currently using this system. There is an automated data system for this project integrated with the electronic Operation Timbang Tool (used to track the prevalence of malnutrition in young children). For now, the EWS may be accessed only by the LGUs.
Event-based bulletins	The DOH Epidemiology Bureau (EB) disseminated event-based bulletins for LGUs to interpret for their local health advisories.

DOH and UP-NIH typically obtain climate data from PAGASA's weather stations and apply a distance buffer to determine relevant areas. PAGASA's data lacks the necessary downscaled resolutions for disease outbreak models at the barangay level. As of current, UP-NIH is already in discussions with PAGASA to explore the downscaling of climate data required for health applications. While downscaled data is a crucial initial step, incorporating climate data and health impacts still necessitate additional studies and linked disease models. While not a direct use of CIS, studies linking climate and health have been done in different areas in the Philippines through machine-learning models (Carvajal, et al., 2018; Francisco, et al., 2021, Buczak, et al., 2014) , time-series approaches (Seposo, et al., 2015; Chua, et al., 2022), and species distribution modeling (Recopuerto-Medina, 2024). These studies are more common for heat-related and vector-borne diseases (i.e., dengue) (Chua, et al., 2019).

In addition, compiling health data poses is challenging due to limited and unstandardized information from LGUs. Long-term health data is vital for modeling, but various factors such as typhoons and/or changes in local administration lead to the paucity and discontinuity of data. Health-related disasters are also often deprioritized in disaster risk reduction and management (DRRM) plans that focus primarily on natural and geophysical hazards because of limited information on their integration into DRRM strategies.

There was a pause on climate and health research during the COVID-19 pandemic. Nonetheless, there are pre-pandemic studies examining the influence of climate on health indicators. Research is moving towards establishing the role of climate variables in the onset of both communicable and non-communicable diseases; however, the assumptions made by the DOH and UP-NIH rely mainly on international studies, emphasizing the need to validate these connections within the local context. In addition, the CCC acknowledges the role of the health sector in climate change mitigation. They have already begun an initiative with DOH on making hospitals energy-efficient and climate resilient through the Development of a National Framework and Plan of Action for Philippine Climate-Smart Hospitals (CCC, 2023).

Transport

The commonly referenced connection between climate change and transportation often revolves around the transport sector's contribution to greenhouse gas emissions, but it is also important to note that climate change also affects the planning of transport infrastructure. Most of the research in this topic focuses on emergency evacuation and the effect of weather on road accidents (Suarez, et al., 2005). The impacts of weather on transportation systems become pronounced during extreme temperature and rainfall/flooding events, leading to issues such as pavement deterioration, steel corrosion, and traffic congestion. Additionally, extreme weather events disrupt transportation systems and, consequently, logistics and supply chains.

The Department of Transportation (DOTr) is mandated with the task of promoting, developing, and regulating the comprehensive transportation network in the country. Within DOTr, the Environmentally Sustainable Initiatives Transportation Unit (ESITU) serves as the focal point for climate change and sustainable transport initiatives as it oversees the planning and implementation of the Special Vehicle Pollution Control Fund (SVPCF). DOTr collaborates with external institutions on projects addressing transportation and climate issues, including the ongoing Low Carbon Transport Project with the UN Development Programme (UNDP) and the Global Environment Facility (GEF).

DOTr faces challenges in both institutional and technical capacities concerning climate change mitigation (Asian Development Bank, 2022). As of this writing, we have not come across pertinent CIS for transport, but it is worth noting that there is climate-relevant data being collected in the transport sector through greenhouse gas (GHG) emissions. The GHG Emissions Inventory, which is currently under development by the CCC, is anticipated to be publicly released in 2024 (Gozum, 2023). The Philippine Greenhouse Gas Inventory Management and Reporting System (PGHGIMRS) was launched in 2014 and, since then, various agencies including the DOTr actively participate in documenting GHG emissions and submitting reports to the CCC.

Notable gaps in the integration of climate data in the transport sector include the lack of various transport variables beyond emissions and the disparate collection of relevant data by different agencies (i.e., GHG emissions also collected by the Department of Energy (DOE) and vehicle/fuel taxes collected by the Department of Trade and Industry (DTI)). For instance, essential transport activity indicators like passenger-kilometer traveled (PKT), ton-kilometer traveled (TKT), and passenger occupancy are not officially included in government statistics. In the few cases where this information is gathered, studies are usually limited to Metro Manila and larger metropolitan areas as part of projects for transport modernization (Mejia, et al., 2017). As for the effect of weather on transport systems, studies have also already been conducted in the impact of flooding on truck movement in Metro Manila (Bacero and Fillone, 2023) and disaster response routes in Cagayan de Oro City (Gamboa, et al., 2021).

Housing and Infrastructure

A comprehensive consideration of climate variables is essential when selecting sites for housing and infrastructure. For instance, temperature serves as an indicator of heat island effects in urban areas, with extreme heat events exacerbating temperature impacts on structures. Thermal inversions and frequent episodes of extreme air pollution are also becoming more common in urban areas. Additionally, heavy precipitation and typhoons can result in flooding, particularly in urban road networks where storm drainage systems are insufficient to manage rapid rainfall. Alternating dry and wet spells may also further impact ground surface, potentially destabilizing buildings. (IPCC, 2023).

The DHSUD is the primary housing authority in the Philippines. Within the DHSUD, the Environmental, Land Use, and Urban Planning and Development Bureau (ELUPDB) serves as the focal point for climate related issues. ELUPDB is composed mostly of environmental planners who work on: (a) the development of policies and programs for land use monitoring and urban development, and (b) creating guidelines and offering services to assist LGUs in the creation of land use plans and zoning ordinances.

As of this writing, we have not come across pertinent CIS for the housing and infrastructure sector, but it is worth noting that there is climate-relevant data and tools are being used by DHSUD mainly to manage land use and zoning and aid LGUs in creating climate risk assessments. These are shown in Table 13.

Table 13. Climate relevant tools and products in housing and infras

Tool/ product	Description
Land Use and Zoning Information System (LUZIS)	This features datasets such as CLUP, zoning ordinances (ZO), development projects, and homeowners' associations. It was launched in 2022 and is currently operational for internal use by the DHSUD. It also includes features on monitoring land use change, agricultural land reclassifications, and the status of CLUP submissions. It was developed by DHSUD's ELUPDB in partnership with UP's Training Center for Applied Geodesy and Photogrammetry.
CDRA	This is a methodology to understand and assess the impacts of hazards to people and properties . It aims to incorporate Disaster Risk and Reduction and Climate Change Adaptation (DRR-CCA) into the creation of LGUs' Comprehensive Land Use Plans. The DHSUD has developed supplemental guidelines for this purpose and aims to create training modules through the Strengthening Urban Resilience for Growth with Equity (SURG) Project with USAID. DHSUD plans to put these modules in an online platform to make it accessible to LGUs and the public (USAID, 2021).

Climate change adaptation in the Philippine housing and infrastructure sector often refers to initiatives like green buildings, construction of evacuation centers, shore protection, and flood control projects. They emphasize in integrating risk and resilience assessments into project planning, but a more comprehensive approach should include discussions on standards, information systems, and technological tools (Navaro, 2023).

Climate data is used by DHSUD in financing and capacity building programs. The Inclusive Green Housing Microfinance (IGH) aims to fund resilient housing for low-income families in climate vulnerable areas, while the Building Climate Resiliency through Urban Plans and Designs (BCRUPD) project with UN Habitat aims to enhance the CDRA and facilitate trainings for LGUs (Simeon, 2021; UN Habitat, 2021). As for public infrastructure, DOST initiated the Climate Resilient Infrastructure Initiative with DPWH, the National Irrigation Authority (NIA), and NWRB to form a central repository of LiDAR data and climate information from relevant projects such as NOAH (Ronda, 2016). The program has already updated the science and technology roadmap for infrastructure and identified the top two R&D technologies prioritized for investment until 2025: (a) technologies for upland, coastal, and flood infrastructure, and (b) housing technologies (DOST-PCIEERD, 2023; DOST-PCIEERD, 2021).

Energy

Given the diverse range of energy sources, there are various climate variables that significantly impact the energy sector. Temperature plays a pivotal role in seasonal energy demand and influences energy production and processes (e.g., cooling water and heat-induced incidents). Drought and precipitation influence water availability which is crucial for cooling purposes and flow volumes for hydropower plants. Solar radiation is sensitive to atmospheric and aerosol levels, while wind speed plays a key role in shaping an area's wind and wave energy potential. In regions prone to tropical cyclones such as the Philippines, there's also a heightened risk of damage to energy infrastructure since energy distribution facilities are located mostly above ground (IPCC, 2023).

The DOE is tasked with overseeing activities related to the energy sector in the Philippines. Affiliated agencies such as the National Electrification Administration (NEA) and the National Grid Corporation of the Philippines (NGCP) are likely relevant to climate issues. While DOE does not have a specific climate office, it can potentially integrate climate change mitigation policies into the management and compliance requirements of the energy sector through its various bureaus (DOE, 2023). The Renewable Energy Management Bureau (REMB), in particular, may have use for particular climate data to assess solar, wind, and hydroelectric potential in specific areas.

Climate information in the energy sector is mostly used in long-term energy planning, identifying locations for renewable energy power plants, grid management, and demand forecasting. Maps and datasets on the potential of solar and wind energy (reliant mostly on solar irradiation and wind speed data) are available from international platforms such as SolarGIS and Global Wind Atlas, while specific climate data for grid management and demand forecasting mostly come from downscaling requested data from PAGASA and/ or other open sources of general climate data (i.e., reanalysis and regional climate models) (Acuzar, et al., 2017; Silang, et al., 2014; Lucas, et al., 2021). Project SINAG implemented by UP's Training Center for Applied Geodesy and Photogrammetry (TCAGP) may also be a potential CIS platform used by the Energy sector. It is used to assess the potential power that can be harnessed from Solar PV installations, but data needs to be requested via email. Nonetheless, related publications are linked in the website.

In addition, climate-related data in the energy sector also frequently pertain to GHG and CO2 emissions. Apart from the GHG Emissions Inventory and PGHGIMRS by the CCC, there are also dashboards on GHG Emissions, CO2 Emissions, and Power Generation and GHG Outlook available in DOE's website.

The energy sector relies on granular climate data over prolonged periods of time. There is a gap between the technical requirements required by the energy sector and the data available from existing CIS particularly in the spatio-temporal scales of climate data; therefore, the energy sector utilizes specialized services to maintain weather stations in proximity to current and potential energy assets. Additionally, there is also a growing necessity to integrate forecasts and projections into the planning, design, and capacity/load estimation processes for power infrastructure (WMO, 2022).

Water resource management

The most important climate variable for the management of water resources is precipitation. It is instrumental in the monitoring and prediction of droughts and floods at the local level, enabling the communication of timely warnings to mitigate the impact of water related hazards on vulnerable communities (UNESCO, 2021).

There is no central water agency in the Philippines. Jurisdiction over water resources is split between the following agencies shown in Table 14. While these agencies are actively engaged in policy planning, data monitoring, infrastructure development, regulatory functions, and capacity development, only , but only PAGASA and the Laguna Lake Development Authority (LLDA) are specifically mandated for the scientific modeling of water bodies (Rola, et al., 2015).

Table 14. Agencies with responsibility over water resources

Department/ Agency	Role
DENR	Enforcing water pollution laws and water quality standards. Lead agency in enforcing the Philippine Clean Water Act of 2004 (RA 9275). DENR created a Water Resources Management Office in April 2023.
NWRB	Responsible for the enforcement of the Water Code of the Philippines. They are in charge of (1) policy formulation and coordination, (2) issuance of water permits and resolution of water use conflicts, and (3) regulation of water service providers.
DPWH	Responsible for preparing a national program on sewerage and septage management. They are also responsible for the planning, design, construction, and maintenance of flood control and water resources development systems.
NIA	Responsible for the development of available water resources for the purpose of irrigation
Local Water Utilities Administration (LWUA)	Government-owned and controlled corporation (GOCC) intended as a lending institution of the development and financing of utilities in provincial water districts (except Metro Manila)
Metropolitan Waterworks and Sewerage System (MWSS)	GOCC supervising water supply and sanitation in Metro Manila

CIS commonly used in the water resource management sector are shown in Table 15. There are also other climate relevant data commonly used by the water resources sector, particularly in the monitoring of river basins and modeling runoff (Table 16).

Table 15. CIS in water resource management

CIS	Description
PAGASA Flood Advisories	This contains general flood advisories (updated daily) for 18 major river basins and 4 dams/reservoirs, an interactive map on Metro Manila Flood Monitoring, and dam water level updates. Apart from these openly accessible data, PAGASA also offers other services such as isohyetal, rainfall intensity duration frequency (RIDF), temporal distribution, depth-area duration, and probable maximum precipitation analyses.
Streamflow Management System (StreaMS)	This platform contains water level and discharge measurements data from various water bodies in the country. The data is used to create or update rating curves to convert water level information to river discharge information usable for flood frequency and flow duration analyses.

Table 16. Climate relevant tools and products for water resource management

Tool/ product	Description
River Basin Integrated Information System (RBIIMS)	This central river basin database is created by DENR to integrate information from existing river basin organizations and generate outputs and reports. It contains various data tables which can be imported into GIS. Accessing and updating the database requires necessary permissions and a valid account.
Global Runoff Model (GRUN)	This dataset has been calibrated by the DENR for use in the Philippines and is commonly used for modeling water resources.

Effective water management relies on extensive hydrometeorological monitoring networks for accurate and consistent data to quantify and predict scenarios. One of the difficulties in designing CIS for the water sector is its need to address stakeholders concerned with: (a) the state of the water resources, (b) the water demands of different consumers, and (c) the state of water supply infrastructure. Climate affects not only the resource, but the consumption of water as well (Sharma and Gosain, 2010). Climate variables and water engineering systems also need to be integrated to sufficiently monitor and analyze the condition of critical water sources. There is a resource and time blocker in the conduct of hydrological studies and models (which are often specific to water bodies) to serve as baseline information for water bodies (USAID Water Team, 2021).

Apart from local communities, stakeholders absorbing the impact of extreme climate events in the water sector are water service providers. One notable initiative addressing this challenge is the USAID Safe Water Project (SWP), an ongoing five-year project from 2019-2024. The project is dedicated to enhancing water security in Negros Occidental, Sarangani, and Palawan by adapting climate-resilient designs for water technologies and infrastructure. The project conducts financial stress tests and applies climate risk assessments which include the collection of climate and hydrological data for the comprehensive monitoring and analysis of watershed conditions in the designated target area (USAID Water Team, 2021).

Ecological usage

Both terrestrial and marine ecosystem services are affected mainly by temperature and precipitation. These variables influence the growth and distribution of species, the input of freshwater to saltwater systems, and erosion/sediment regulation (Rawlins, et al., 2017; Ocean and Climate Platform, 2016).

The key agency overseeing ecosystem management is the DENR. DENR primarily relies on climate data sourced from PAGASA, environmental data from DENR's field offices, and hydrology data from DPWH. Within DENR, the offices relevant to CIS include the Climate Change Service (CCS) and GDO. The GDO, in particular, is equipped in sourcing and processing climate-relevant geospatial datasets which they keep in a repository run by ArcGIS Online.

As of this writing, we have not encountered local CIS and climate-relevant products specific for ecology and ecosystem services in the Philippines. Most of the data gathered by DENR are information on critical watersheds, the National Greening Program, and various tenurial instruments. While all files are in a central portal, full datasets and raw data are usually not open to the public due to the need to process and anonymize information.

CIS for ecosystem management is particularly challenging because areas of interest are often remote with poor telecommunication infrastructure and vulnerable communities dependent on land use activities. As such, institutional climate information may not be utilized as much by decision makers from these areas. Additionally, it is also likely that there is a conflict of interests in how ecosystems should be managed, so climate information services need to encompass and inform all relevant parties. Despite the availability of general-use portals like GeoPortal and GeoRisk created by other government agencies for hazard mitigation, the DENR's Geospatial Database office scarcely employs them, citing data mismatches that do not align with the DENR's specific purposes.

One case study of particular interest in the topic of climate and ecosystems is a study on the impacts of climate change on amphibians and reptiles of Southeast Asia (Bickford, et al., 2010). A combination of long-term climate projections, species inventories, and monitoring programs are used for these kinds of studies; however, experimental approaches may also be used to determine the effects of variable temperature and precipitation on specific species or plant/animal groups. DENR has also cited plans to monitor the role of climate variability on the spread of wildlife diseases, but this project is not yet operational.

Economics

There is a strong consensus among economists that climate change is a negative externality of the large-scale emission of GHGs. Therefore, there is a growing focus on accounting for these consequences by putting an appropriate price on these emissions to reflect their social cost, through economic instruments like carbon offsets, taxes, and the like. Climate data becomes relevant in concretizing the negative economic impact of climate change (i.e. crop damage, loss of livelihoods, mortality), which then informs how these economic instruments are designed.

The economic impact of climate change is also especially important in the Philippine context, as research suggests that climate change will disproportionately damage the economies of developing countries (Tol, 2018). PSA has reported that the country has incurred damages totalling to PhP 463 billion from 2010 to 2019 due to climate-related disasters, with agriculture impacted the most at 62.7%. The impact of disasters on the Philippine economy is also expected to accumulate and intensity even further, with the country being the most at-risk to climate disasters worldwide based on the World Risk Index.

There are several CIS products focused on synthesizing carbon pricing policies and outcomes from different countries. The World Bank's Carbon Pricing Dashboard is an interactive web map that visualizes existing and emerging carbon pricing initiatives across 39 national jurisdictions. It is regularly and dynamically updated based on new information and revisions from official government sources, and also provides downloadable graphs and maps for the available data. Similarly, the World Carbon Pricing Database is a data tool that combines interactive graphs on carbon taxes since 1990 with relevant discussion and analysis to aid the user in contextualizing and appreciating the presented trends and insights. A key feature of the database is that the data is presented per country and further disaggregated by jurisdiction and sector level, allowing users to make assessments by country. At present, the data only reflects CO2 emissions, with other GHGs still in development.

At present, there is no explicit carbon pricing policy in effect for the Philippines – at best, the country places a fuel excise tax, which is commonly considered an implicit method of pricing carbon. Thus, the effect of such policies in the Philippines is currently not well understood, but these CIS can support government agencies in getting context from other countries necessary to formulate and enact these policies in the future. In particular, the House Bill No. 7705, entitled "An Act Promoting A Low Carbon Economy, Establishing For This Purpose And Emission Trading System And Implementation Mechanism To Achieve National Climate Targets", which proposes to establish an emission trading system, is currently in deliberation as of writing.

In particular, the National Economic and Development Authority (NEDA) is the country's main authority on macroeconomic programs, responsible for socioeconomic development planning and policy formulation. While NEDA does not have a climate-focused arm, climate action has emerged as a priority in the agency's agenda planning. In 2023, they published the Philippine Action Plan for Sustainable Consumption and Production (PAP4SCP) as a wide-ranging guideline for steering sustainable practices and behavior across sectors and levels of government (NEDA, 2022). NEDA is also the main agency responsible for the Philippine Development Plan (PDP), which is the medium-term and country-wide plan for accelerating the country's economic development and poverty reduction. The latest PDP for 2023-2028 also places special emphasis on the importance of climate adaptation in inclusive socioeconomic growth. (NEDA, 2023)

Social Development

Social development efforts strive to make sure that individuals have the means to their survival needs, physical safety, and human rights. Thus, it is especially important to link climate effects such as extreme weather events and rising temperatures to food security, nutrition, poverty alleviation, migration, education, and other matters affecting social welfare (Achstatter, 2014).

The Department of Social Welfare and Development (DSWD) is mandated to provide assistance to other government agencies, LGUs, NGOs, people's organizations, and all members of civil society in implementing programs, projects, and services that will alleviate poverty and empower disadvantaged individuals, families, and communities to improve their quality of life. While there is no climate-specific office in DSWD, they have introduced the Risk Resiliency Program Climate Change Adaptation and Mitigation Disaster Risk Reduction (RRP CCAM DRR) program, which aims to increase the adaptive capacity of vulnerable communities by providing funding for local programs and infrastructure projects. As of 2022, this program has been implemented in all six provinces of the Cordillera Administrative Region (CAR).

As social development is a multi-faceted process that cuts across multiple sectors, many of the relevant CIS have been discussed in prior sections above (i.e. health, transportation, housing). Especially relevant to social welfare is the EWS-FNC run by NNC for nutrition surveillance systems and action plans. Food security and especially anti-hunger is a key goal for DSWD, driving multiple initiatives such as Enhance Partnership Against Hunger and Poverty (EPAHP) program and the country's first digital food stamp program. PSA also publishes the Compendium of Philippine Environment Statistics, which has a section on Extreme Events and Disasters, summarizing the impact of typhoons and other natural extreme events on infrastructure and human well-being. PSA also publishes statistics on over 155 indicators related to the UN Sustainable Development Goals, quantifying our progress and pace towards these goals. (PSA, 2017)

Downstream, DSWD publishes several knowledge products, such as advocacy materials, how-to guides, reports, and case studies, in their Knowledge Management Portal (KMP). The KMP is envisioned as a dynamic facility for providing learning opportunities within DSWD and its partners. Materials hosted on KMP cover a wide range of topics and sectors, including i) Children and Youth, ii) Family and Community, iii) Indigenous People, iv) Internally Displaced Persons, v) Migrant Workers, vi) Older Persons, vii) Persons with Disabilities and, viii) Women. In 2024, DSWD also launched Local Adaptation to Water Access or Project LAWA, in partnership with the Department of Agriculture and the World Food Program. This project aims to construct vital water reservoirs in select towns, to aid in water access during periods of drought or dry spells.

Disaster risk reduction and management (DRRM)

In disaster risk reduction, is it essential to first quantify possible hazards, exposures, and vulnerabilities of the affected population and assets. Information about the occurrence and severity of extreme weather events such as typhoons, droughts, and landslides is key in properly developing risk management strategies, such as early warning systems, infrastructure development, and risk financing mechanisms. Most especially, prediction models allow agencies to better predict and manage extreme weather and inform decisions on long-term investments.

Since 2011, the NDRRMC has been the cross-agency working group responsible for ensuring the protection and welfare of the people during disasters or emergencies. The council is responsible for the NDRRMC Framework that covers disaster preparedness, response, prevention, mitigation, rehabilitation and recovery. LGUs establish local disaster risk and reduction offices that create local disaster risk management plans based on this framework. In addition, the NOAH is an ongoing program under the DOST established to conduct advanced and high-impact disaster science research and multi-disciplinary assessment of hazards. Most notably, they provide tools for mapping and assessing hazards such as floods, landslides, and storm surges for researchers and policy makers, which has proven instrumental in informing DRRM initiatives.

CIS commonly used in DRRM are shown in Table 17.

Table 17. CIS in DRRM

CIS	Description
NDRRMC Monitoring Dashboard	This informs and alerts the public on upcoming typhoons and the relevant guidelines for proper preparation and response. Its format and information are largely based on PAGASA's website.
Situation Reports	This gives a summary of on-ground situations during major large events and notable disasters on a daily basis.
NOAH Studio	This is an interactive web application that shows flood hazard, landslide hazard, and storm surge hazard, alongside other data layers such as volcanoes, critical facilities (i.e. hospitals, police stations), and precipitation. Local DRRM offices use these hazard maps in assessing flood-prone areas, damaged infrastructure, and affected populations. Citizens can also use this platform to know what hazards are in close proximity and how they can effectively take steps to safety if and when the need arises.

In addition to CIS, statistics on economic loss and damage, such as those published by the PSA in the Compendium of Philippine Environmental Statistics, give stakeholders and the general public a measure of the long-term economic and human impact of disaster events.

At present, while the hazard aspect of disasters is relatively well-understood and represented in data and research, it is a bigger and ongoing challenge to properly quantify the people and assets' risk and vulnerability. For example, there is a lack of standardized methods to measure key statistics such as disaster mortality and ecological losses, which makes it difficult to establish baselines and hinders interoperability between the data currently available. The UN Office for Disaster Risk and Response (UNDRR) also identifies data gaps in economic impacts and protracted events like heatwaves and drought. A key reason for this gap is that disaster-related data is concentrated on the immediate period after an initial disaster, when the full impact of the disaster is still not yet clear (UNDRR, 2023).

Evaluation of CIS Maturity in the Philippines

The following are some of the main insights obtained from the KIIs related to their CIS data practices.

Relevance and accessibility

In one part of the KIIs, the interviewees were asked if the following types of data are relevant to their mandate, and if yes, rate their ease of access to each type. Based on Figure 4(a) and (b), climate data is rated as the most accessible and most relevant to their mandate. Most of them noted that it is easy to obtain climate data through PAGASA, whether through the website or through request. Socioeconomic data is the next most accessible, and overall, also easy to obtain through requests in PSA. Agricultural and project-relevant data have the same relevance measure, but lower accessibility ratings due to concerns on reliability when they compare their own data with PSA surveys, and varying access experience depending on their use case. Lastly, most respondents answered that health data is not relevant to their mandate, and they rarely use it. Moreover, those agencies who gave high accessibility ratings to health data are usually looking at reports/maps from DOH and not health data itself. Understanding the varying relevance of CIS data types across sectors is crucial, as it differs widely across sectors.

Figure 4. CIS relevance to mandate and accessibility
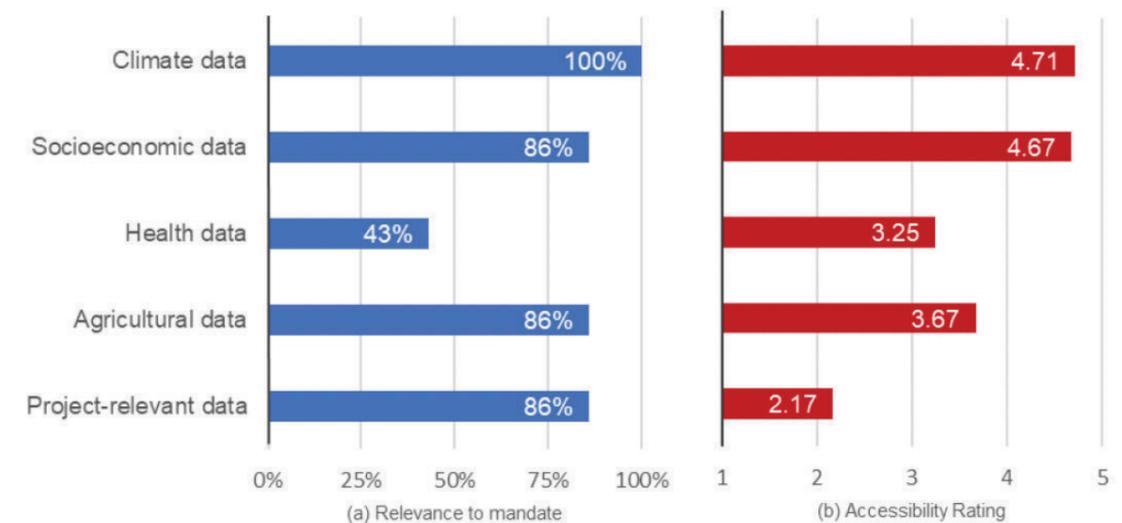
Overall (a) relevance to mandate and (b) accessibility of CIS data across 7 interviewed stakeholders. Relevance to the mandate is represented as a percentage of stakeholders affirming its pertinence. Accessibility, on the other hand, is an average of ratings ranging from 1 (lowest) to 5 (highest) among stakeholders who deemed the data type relevant to their mandate.

Effective data uptake and translation

Stakeholders interviewed for this project recognized the importance of CIS in facilitating the effective uptake and application of climate information across various sectors and purposes. This acknowledgment underscores the importance of these systems as a valuable resource for decision-making in climate-sensitive areas.

To improve data literacy and build technical capacity, various agencies regularly conduct training to their respective sectors. Farmers and fisherfolk receive training on how to interpret climate outlook. Regional offices play a role in disseminating information and services from head office. Initiatives targeting low-income LGUs through data provision and Geographical Information Systems (GIS) training exemplify the commitment to ensuring equitable access to CIS resources. While these capacity building efforts are duly recognized, it has been suggested that occasional top-down training must transition to enduring mentoring partnerships to maximize its impact (Brasseur and Gallardo, 2016).

CIS also plays a role in translation of climate data into actionable policies. But for these policies to be effective, the proponents must understand the beneficiary's decision making process and how and when different weather and climate information is used (Vincent et al., 2015). In the KIIs, the policies mentioned are aimed at mitigating the impacts of extreme weather events, assessing damages, and providing assistance to affected communities. In addition, CIS enabled the issuance of advisories related to safety measures for agricultural activities based on weather forecasts and observations, reinforcing the importance of CIS in safeguarding livelihoods and public well-being.

The monitoring of uptake among CIS users may be reinforced by building on monitoring, evaluation, and learning expertise from the humanitarian, development, and natural science sectors. Weather and climate forecasts may be evaluated by participatory approaches (i.e., users providing feedback on local observations and impacts) to improve models, produce more relevant forecasts, and identify new research questions. Common monitoring and evaluation methods include: Theory of Change, Participatory Impact Pathways Analysis, Key Informant Interviews and Score Cards, Household Surveys, Socioeconomic Benefits assessments,

and Focus Group Discussions. Indicators for measuring the process and principles of CIS co-production may be studied further in Visman et al.'s work on defining metrics for CIS (Visman, et al., 2022).

Defining the target user

Warner et al. (2022) notes that effective use of CIS relies on active user participation and engagement. From the interviews, interactions with sector representatives and LGUs are typically done through a top-down approach. A common example would be providing local users in LGUs with essential baseline data that is crucial for planning and adaptation in climate disaster risk assessments and land use plans. In other cases, funders approach agencies and research institutes to co-develop a proposal to meet the needs of a specific stakeholder, ensuring the relevance and applicability of the information provided.

Knowing the target audience is crucial for the effectiveness of CIS, and the parameters it contains must be tailored to meet the specific needs and contexts (Hackenbrunch et al., 2017). Despite their wide coverage and digital views, platforms external to PAGASA like GeoPortal and GeoRisk, are not yet maximized by all agencies. The core issue lies not in the data itself but in the packaging and tailoring of this information to suit the unique requirements of different users, whether for policy making or project implementation. The one-size-fits-all approach in CIS design often leads to systems that are underutilized, as they fail to address the specific needs of diverse user groups. These shortcomings are recognized by the introduction of targeted CIS, such as DENR's CCIMS, which offers downscaled data specific for municipal-level applications.

Data quality and reliability concerns

PAGASA is widely recognized as the primary source of climate information, utilized by research agencies and various end-user groups. However, there are instances where PAGASA's forecasts fail to accurately reflect the on-the-ground experiences of farmers and fisherfolk. Anecdotes of discrepancies between data and the actual impacts experienced by these local communities have led to diminished trust and pose challenges in maintaining engagement. There's a consensus among the interviewees that the emphasis should be on improving the quality of existing data rather than quantity, especially in understanding production activities and accurately identifying beneficiaries of various programs.

Imprecise climate data, particularly in the case of typhoon forecasts and extreme events, may be due to rapid intensification and/or limited attention to quality assurance and standards (Pulhin, et al., 2023). There is difficulty in making data quality in formats uniform due to the various types of data sources (e.g., different types of stations, ground data vs. remote sensing), paucity of data (e.g., discontinuity due to maintenance and repair), and the different spatiotemporal scales that they operate in. (Veloria, et al., 2021). There is also the question of difficulties in forecasting the locations versus intensity of extreme climate events, where the forecasting of intensity proves to be a more challenging task (MacLeod, et al., 2021). Due to this, there can be mistrust in institutional sources of weather and climate information. Locals would therefore rather rely on local knowledge, personal experiences, and their social networks for information if provided climate advisories are not accurate, timely, and easy to understand (Ruzol, et al., 2020, Tall et al., 2018). While forecast models are continuously improving, there is a need to properly communicate forecast uncertainty and work out a range of data-backed strategies with the community (Vincent et al., 2015). This trust-building effort has to be an ongoing process which providers need to design into their program structure (Warner et al., 2022)

In the attempt to produce more accurate data, there is also a tradeoff in allocating CIS budgets to the development of more accurate downscaled models/datasets over finding the needs of end-users through stakeholder engagement. For example, in agricultural production, there are noted inconsistencies when CIS data is compared with data from surveys, which tends to underestimate due to non-real-time data collection. However, there are logistical challenges to achieving this, such as the limited workforce in agencies and the geographical complexity of the Philippines with its thousands of islands.

Furthermore, while research-grade CIS data is abundant, it often remains inaccessible to the public due to the lack of intermediary steps to transform it into understandable and usable formats. This highlights the gap that governments and communities need to bridge in order to have a successful climate service project (Kolstad et al., 2019).

Data sharing processes

Locally-developed CIS often source data from hydrometeorological sensors and other onsite measurements. This data is often used and shared within agencies to develop early warning systems in various regions in the world (Dugar, 2014). Based on our interviews, there is a trend towards increased digitalization, such as using APIs to streamline data delivery and reduce paperwork. Despite this, many agencies still depend on local government endorsements for data access, which can delay processes. Bilateral MOAs ease the process by facilitating smoother, long-term data exchange and clarifying project responsibilities. These MOAs encompass not just data sharing, but also relevant data platforms and tools for stakeholders.

While processes exist to enable data access, the open data landscape in the Philippines poses unique challenges for a wider audience to avail of CIS. While government entities can get the data with ease, academia and private sectors face restrictions, necessitating partnerships with government bodies for access. Efforts are underway to centralize truly open, publicly-downloadable government data on platforms like Geoportal and GeoRisk, but this is not uniformly applied across all agencies. Mentioned concerns around data privacy and misuse, particularly regarding sensitive information like personal information and land ownership, lead to selective and cautious data release by government agencies. Before release, the agencies need to perform thorough data cleansing and anonymization to safeguard privacy and prevent unintended consequences. Compliance with the Freedom of Information Act and ensuring easier access to data by mainstreaming a culture of openness is recommended to enhance country-wide data sharing and accessibility across sectors.

Apart from technical considerations, social and organization factors must be considered to ease data sharing processes in the Philippines. Historically, the Medium-term Information and Communication Technology Harmonization Initiative (MITHI) was implemented through a Joint Memorandum Circular mandating convening agencies through a steering committee that has the role of coordinating eGovernment initiatives for 2014-2016. One of the key outcomes was the development of the eHealth platform, which has become a model for developing interoperability between sectors. One of the steps was to implement basic technical standards and policies to enable the smooth flow of information between organizations that offer e-services and to facilitate the alignment of administrative producers with technical systems to allow interoperability at the operations level. It also involved the assignment of a Chief Information Officer, allocation funds to a project management office, and the creation of databases for information and terminologies (Alampay, 2013).

Lack of capacity and resources

Hardware requirements for data users are relatively modest, typically requiring standard laptops for spreadsheet and GIS processing. File formats are simple and light, with the exception of climate model data. Although high-performance computing is occasionally needed for certain projects, this is typically addressed through assistance from the DOST and partner groups in academic institutions. However, for data producers, the upkeep of essential components, particularly sensors, is a significant issue, with many being poorly maintained or unavailable. There's also a shortage of personnel skilled in developing and interpreting CIS products, highlighting the necessity for long term robust infrastructure and greater investment in human resources (Lemos et al., 2012).

Climate models, especially long-term forecast scenarios, are essential to disaster planning efforts. While global climate models are freely available, end users face a shortage of downscaled data essential for localized planning. While research agencies can address this, downscaling is costly in terms of human, financial and technical resources, and difficult to sustain long term without institutionalized support (Lemos et al., 2012). They also brought up that budgets for climate training and projects are also often insufficient, typically absorbed into broader programs rather than allocated as distinct resources. This leads to reliance on staff from non-climate departments like administration, diluting the focus on specialized climate tasks. Across different countries, this shortage of dedicated resources and funding severely limits the effectiveness and sustainability of CIS initiatives (Warner et al., 2022).

As echoed by a few stakeholders, a whole of government unified approach is critical for effective management of limited resources (Christensen and Lægreid, 2007). This strategy would reduce overlaps in CIS platforms and streamline efforts that converge to one end result (Nalau, et al., 2015).

Other sector-relevant data platforms and products

Apart from CIS, there are a variety of other local data platforms and products useful for assessments in the different sectors discussed above. These are shown in Table 18.

Table 18. Relevant datasets and products in different sectors

| Sector	Tool/ product	Description
General	GeoPortal	The GeoPortal hosted by NAMRIA is a repository for geospatial data and services. It is an important source of basemaps particularly for exposure indicators such as landcover, critical facilities, and population.
	Open Data Philippines and OpenSTAT	These are data repositories of open data from various government agencies (Open Data Philippines) and the PSA. While data is not necessarily geospatial, these platforms are also an important source of exposure and risk indicators.
Agriculture	Database and Management Portal (DBMP)	These platforms hosted by DA's Philippine Rice Research Institute includes various tools for monitoring, directories, maps, statistics, and services specifically for the farming and harvesting of rice. Another relevant platform is the Philippine Rice Information System (PRiSM).
	Fishermen Registration (FishR) and Boat Registration (BoatR)	This is an internal system within BFAR led by LGUs. The data is compiled by BFAR and specific employees have access, but this cannot be opened to the public due to data privacy issues.
	Harmful Algal Bloom (HAB) monitoring platform	This is hosted by the BFAR's Fisheries Resources Management Division (FRMD) and shows HAB sampling stations, toxin monitoring, and HAB monitoring maps. The platform is also a repository of bulletins (e.g., on the safety of shellfish) but needs an account to access the data.
	National Stock Assessment Program (NSAP) Interactive ATLAS	This is an interactive web application based on data gathered from monitored fish catch. It is accessible to the public at varying degrees of access and includes guidelines on the methods on how to collect fisheries data onsite. It includes interactive maps and downloadable reports from the various landing centers across the country.
	Geographic Information System for Agricultural and Fisheries Machinery and Infrastructure (GEOAGRI)	This is an ongoing project for infrastructure maps that aims to compile information on existing agricultural and fisheries infrastructure (e.g., farm-to-market roads, harvest facilities, fishponds, and cold storage facilities). It is still a work in progress and is accessible within BFAR. It is not certain if this platform will be accessible to the public.

Sector	Tool/ product	Description
	PRDP Planner's Portal	This platform provides links to decision support tools and data relevant to implementing the PRDP. There are guidelines listed for almost each step of the Value Chain Development Flow and links to other tools/products such as FishVool, GeoAgri, NNAG, GeoRisk, and PSA data. A Map Builder is also available where layers relevant to agricultural data may be overlaid with existing infrastructure, protected areas, and ancestral domains.
	NFRDI Knowledge products	NFRDI's website includes publications such as reports, books, manuals, brochures, and posters relevant to fisheries research and development.
Health	National Health Facility Registry (NHFR)	This serves as the national directory of all health facilities in the Philippines. It includes hospitals, infirmaries, rural health units, barangay health stations, and other health and health related facilities.
	National Health Workforce Support System (NHWSS)	This shows data that aim to augment the lack of healthcare workers in the country. It shows the existing data for human resources (e.g., number of physicians and nurses), statistics on the Post-Residency Deployment Program, registered Doctors to the Barrios, available scholarships, and budget trends to implement the program.
Transport	DOTr dashboards	This includes (a) motor vehicle registration and license statistics from the Land Transportation Office (LTO), (b) toll road traffic and cashless transactions from the Toll Regulatory Board, (c) ridership statistics in LRT1, LRT2, MRT3, and PNR, (d) air traffic and passenger statistics, and (e) ports authority statistics.
	Road Traffic Information	This shows the existing road network, annual average daily traffic, number of lanes, kilometer posts, and 2013 volume capacity ratio. It is also searchable by road name and survey site.
	Road and Bridge Information	This shows the length and classification of roads and bridges, together with its existing surface types and conditions (as of October 2022). Road and bridge conditions are based on its Visual Condition Index.
Housing and Infrastructure	Project Map of the National Housing Authority (NHA)	This shows implemented NHA projects, Indigenous People (IP) Housing, Armed Forces of the Philippines (AFP)/ Philippine National Police, PNP Housing, Calamity and Assistance Housing, Evacuation Centers, and housing developments from Resettlement Action Plans (RAP). These locations are overlaid with information on administrative boundaries, protected areas, ancestral domains, and various hydrogeophysical hazards. There are also other maps available from the NHA's Geographic Data Portal that show specific lots for project sites, landholdings, and commercial/industrial

Sector	Tool/ product	Description
		properties, but these require necessary permissions and a valid account to access.
	Land Use Plan Status Dashboard	This contains information on the status of the different cities and municipalities' submission of their CLUP. It also tracks the submission of the PDPFP by provincial governments.
	Project Map of DPWH	This shows ongoing, completed, and terminated projects before 2015 and after 2016. There are also other maps available from DPWH's Geographic Data Portal which include, but are not limited to, road and bridge inventories, sources of construction materials. Some information, such as on the detailed tracking of infrastructure projects, operations and maintenance, feasibility studies, etc. require necessary permissions and need a valid account for access.
Energy	DOE dashboards	This contains information relevant in determining the energy mix in the country. It includes energy supply and demand situations, power consumption by sector, and a summary of general power statistics (e.g., grid generation by fuel and sectoral shares).
	Microgrid Systems and PVM Provider (MGSP)	This portal shows the Philippines' operational microgrid and photovoltaic mainstreaming (PVM) installations. It contains three dashboards for Microgrid Systems, PVM, and project proponents.
	Enerhiyang Atin	This is a repository of policies and programs implemented by DOE.
	DOE Electric Power Database Management System (DEPDMS)	This is a database of information relevant to electric power industry participants which include generation companies, distribution utilities, retail electricity suppliers, and operators. It requires necessary permissions and a valid account for access.
Water resources and management	Irrigation Systems Operation and Maintenance	This shows the target vs. actual areas provided various types of irrigation around the country. The database is arranged by tables and may be sorted by office/region and projects.
Ecological usage	DENR Control Map Portal	This contains information on administrative boundaries, critical watersheds, protected areas, the National Greening Program (NGP), ancestral domains, and various tenurial instruments.
	DENR Land Administration and Management System (LAMS)	This contains land records such as cadastral maps, isolated survey plans, public land applications, patents, and titles. It is also used for processing land transactions and updating land records.

Risk and vulnerability assessments

Climate risk and vulnerability assessments are incorporated into the Philippine Rationalized Planning System through the Comprehensive Development Risk Assessment (CDRA) (Figure 5). The CDRA may be applied to the creation of a LGU's Comprehensive Land Use Plan (CLUP), Local Climate Change Adaptation Plan (LCCAP), and Local Disaster Risk Reduction and Management Plan (LDRRMP).

Figure 5. Relevant steps from the Rationalized Planning System (LGA and DILG, 2017) and Climate Disaster Risk Assessment (HLURB, 2015)
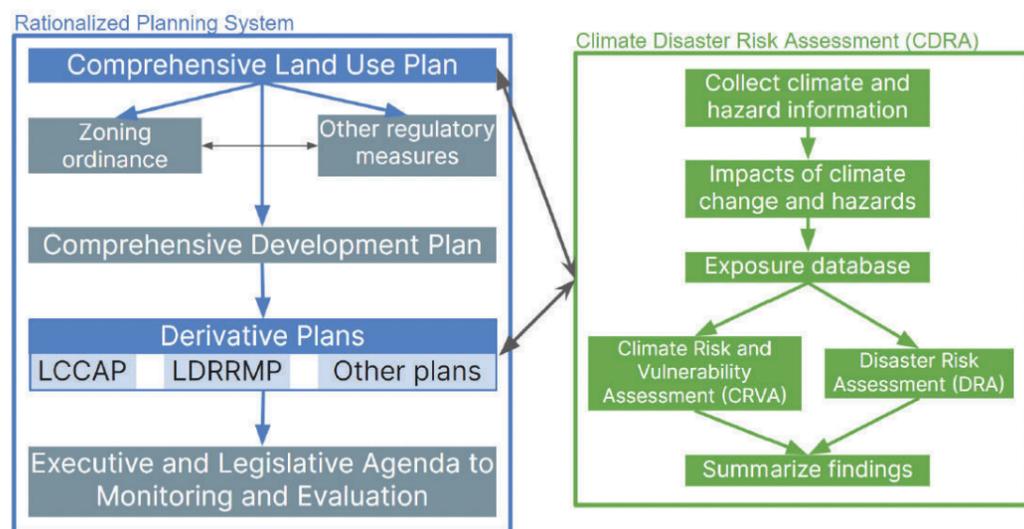
Rationalized Planning System

Comprehensive Land Use Plan

CLUPs aim to enable LGUs in the formulation of development goals, objectives, and alternatives in order to arrive at sound policies, programs, and projects. This document is usually the basis for the effective regulation of land, resources, and investments. As such, it is important for the CLUP to assess risks and vulnerabilities in the city/municipal and barangay levels.

Local Climate Change Action Plan

The LCCAP is intended to specifically address climate change concerns by focusing on mainstreaming adaptation and mitigation programs into development plans. LCCAPs are usually derived from CLUPs and Comprehensive Development Plans, but it is acknowledged by DILG that LGUs are in different stages in terms of the preparation of plans and, as such, there are scenarios where LCCAPs are developed along with the CLUP and CDP as a stand-alone document. There are various tools and resources that LGUs may apply in this process, but the document itself usually follows a basic outline containing: (a) background, (b) climate information and situation analysis, (c) objectives of the plan, (d) programmes, projects, and activities, and policy requirements, (e) monitoring and evaluation, and (e) appendices.

Local Disaster Risk Reduction and Management Plan

The LDRRMP is different from the LCCAP as it has legal provision for budgetary allocations from the DBM and NDRRMC, whereas the LCCAP has to be funded out of the regular budget of the LGU (NDRRMC and DILG, 2013). The LDRRMP needs to contain information that will become the basis for allocating the Local Disaster Risk and Reduction Management Fund (LDRRMF) of which 30% shall cover the Quick Response Fund and 70% shall cover disaster prevention and mitigation, preparedness, response, rehabilitation, and recovery.

Climate Disaster Risk Assessment

The CDRA is adopted into the Rationalized Planning System, particularly in the creation of the CLUP, LCCAP, and LDRRMP. It usually covers sectors such as population, natural resources, urban ecosystem, critical point facilities, and lifelines. CDRA is implemented in six steps (HLURB, 2015), where CIS and information on exposure variables are particularly relevant to Steps 1 to 3.

1. Collect climate and hazard information - This involves the gathering of climate information and characterization of hazards. Particularly important in this step is the collection of climate scenarios developed and updated by PAGASA. Apart from PAGASA, LGUs may also look at other sources of climate information such as reanalysis datasets, projections by other institutions, and studies from universities and research institutes. As for hazards, information can be gathered from various national and local level agencies. A sample output from this step may include climate-adjusted flood hazard maps for a river system within the LGU.

2. Impacts of climate change and hazards - This identifies high-level impacts on key areas and sectors that may be affected by climate change and hazards. This is just an initial scoping on hazards which may result from changes in climate variables and may be obtained from relevant studies and/or getting feedback from stakeholders.

3. Exposure database - This involves a baseline map and attribution of data on exposure, vulnerability, sensitivity, and adaptive capacity. Datasets relevant to this step include population, assets, structures, economic activities, and environmental resources as they identify areas that are most exposed to the impacts of climate change. These datasets may be obtained from both ground truth (e.g., PSA surveys, building inventories) and open data (e.g., WorldPop, Google Open Buildings). Ideally, elements are referenced in geospatial format so that it is easy to overlay with hazard and other relevant maps.

4. Climate Risk and Vulnerability Assessment - This is a detailed identification of vulnerable areas and sectors by analyzing exposure, sensitivity, and adaptive capacity to various climate stimuli. It uses a qualitative approach in establishing the level of vulnerability based on exposure, sensitivity, and adaptive capacity obtained from the previous step. This step usually involves the development of a map scored by a matrix that measures the degree of impact, adaptive capacity, and vulnerability index of a specific area.

5. Disaster Risk Assessment - This is a detailed identification of risk areas by analyzing hazards, exposures, and vulnerabilities. Whereas CRVA is a function of exposure, sensitivity, and adaptive capacity, DRA is a function of likelihood of occurrence and the severity of consequence. This usually involves a scoring system establishing the likelihood of occurrence of certain events (i.e., return period and likelihood scores) and the severity of consequence using the magnitude of the hazard, extent of exposure, and vulnerabilities of the exposed elements. The DRA also involves the identification of risk reduction measures which are usually categorized into risk avoidance/elimination, risk mitigation, risk sharing/transfer, and risk retention/acceptance.

6. Summarize findings - This step identifies priority decision areas/sectors based on the combined level of risks and vulnerabilities, identification of risk management options, climate change adaptation and mitigation options. It also harmonizes findings with various DRR and CCA interventions so that LGUs can identify policy interventions.

Other relevant studies

CDRA is a framework one follows to create risk assessments, but specific steps may be implemented and supported through various methods and/or models specific to the needs of the LGUs and their priority sectors. Some of the most common methodologies in creating risk and vulnerability assessments for the agriculture and health sectors are detailed below.

Modeling

There are various modeling approaches that can be implemented for risk and vulnerability assessments. The Maximum Entropy (Maxent) model is usually used for assessing crop sensitivity by determining baseline crop suitability and predicting the locations for optimal environmental conditions. Sample studies applying Maxent in the Philippines include a CRVA for major crops in Agusan del Norte (Apdohan, et al., 2021) and Bukidnon (Paquit, et al., 2018). Maxent may also be used in identifying suitable fishing grounds using nightlight data and fishing gears (Geronimo, et al., 2018). Another model commonly used to determine the impacts of climate change in agriculture is the Modeling System for Agricultural Impacts of Climate Change (MOSAICC). It combines statistical downscaling of climate projections, yield simulation of crops, hydrology simulations, forest landscape models, and a macroeconomic model (Kanamaru and Fujisawa, 2019). This model has been applied to determine the projected impact of climate change on hydrological regimes in the Philippines (Tolentino, et al., 2016). The EcoCrop model, which is used to predict suitable areas for specific crops, has also been used in determining Sago Palm suitability (Makinano-Santillan and Santillan, 2015) and creating a CRVA for Iloilo (Bito-onon, 2020).

Participatory approaches and multi-criteria analysis

Participatory approaches are usually built around building rubrics for non-specialists but relevant stakeholders in assigning scores for sensitivity and adaptive capacity. Participatory tools have been applied for risk and vulnerability assessments in tropical coastal communities (Licuanan, et al., 2015; Paz-Alberto, et al., 2021) and high-risk flood areas in Cabanatuan (Brucal, et al., 2020). Other participatory tools also include FishVool and the multi-criteria decision analysis.

For the coastal and fisheries sector, NFRDI has developed a specific tool for determining the vulnerability of capture fisheries and aquaculture. It can be modified and used to target different fish species and enables the identification of places that are highly vulnerable to climate change impacts. Computation of scores is straightforward and does not require complex mathematical methods. It incorporates mostly expert judgment and locally relevant knowledge to assess vulnerability (Aguila, et al., 2021). FishVool has been applied to the tuna and sardine sectors in the Philippines (Jacinto, et al., 2015), shrimp (Macusi, et al., 2022), small pelagics and milkfish (Macusi, et al., 2021), and giant squid (De Chavez, et al., 2021).

In the health sector, risk and vulnerability usually come from the emerging infectious diseases (EIDs) and heat-related phenomenon. A variety of socioeconomic and demographic factors, weather variables, animal hosts, and wildlife-livestock-human interfaces are considered for such assessments, but scoring and indexing are nonetheless applied to determine specific areas at high risk of an outbreak or heat-related diseases. Vulnerability scores using the Global Moran's I and Getis-Ord General G statistic were used to determine vulnerable barangay for EIDs in Davao (Damgo, et al., 2023), while the calculation of a heat health risk index was done for selected Philippine cities using a combination of remote sensing data and socio-ecological indicators (Estoque, et al., 2020). A sample of a multi-criteria vulnerability assessment for dengue and malaria is also provided in the Vulnerability and Risk Assessment Manual created by the CCC for the Communities for Resilience (CORE) program (CCC, 2017).

Summary

The "Towards South-South Collaboration on Climate Information Services" (SSCIS) project by GIZ seeks to develop Climate Information Services (CIS) in collaboration with key stakeholders. Among the project's initiatives is the "Mapping of CIS data and usage landscape in the Philippines," which aims to enhance our understanding of the breadth and scope of available climate data contributing to CIS initiatives in the country. The main deliverables for this project include (1) a comprehensive report consolidating insights and recommendations from KIIs and RRL, and (2) a data catalog, serving as a unified reference for commonly-used climate datasets. The project was conducted in three phases: (a) Inception Planning, (b) Stakeholder Engagement and Structured Desk Review, and (c) Documentation and Handover. The data catalog lists the most pertinent and high-quality datasets, prioritizing local datasets most relevant to partner stakeholders in the agriculture and health sectors. For each dataset, this catalog provides general information, as well as spatial and temporal information, technical requirements, assessments from existing studies, and usage information. These climate datasets are categorized according to type (atmosphere, land, water, and socio-economic) and to the time period that it covers (historical and forecast). Technical documentation detailing how to access and download selected datasets are included in the Appendix. The success of the project relies heavily on understanding the roles played by various CIS stakeholders. These stakeholders can be effectively categorized into three key groups: data producers, integrators, and users. Data producers represent agencies or institutions responsible for generating raw climate and exposure data. Integrators, on the other hand, manage data processing and translation. Users, often the decision-makers in specific sectors, use this transformed information to inform the development of policies and programs. PAGASA remains to be the main producer of climate data in the Philippines, while other specialized institutions take on the task of transforming their data along with other sector-specific datasets, and lastly, LGUs and national agencies use the translated information for their decision-making. An examination of the current data sharing network among agencies indicates that DENR-GDO, PhilSA and NAMRIA are well-positioned to host central platforms, given their volume of incoming and outgoing data in various stakeholder use cases. CIS used in the Philippines come from both international and local sources, but is currently well-adopted only in the agricultural and research sectors. There are limited CIS and even fewer or no mentioned case studies for other sectors. Most sectors rely on PAGASA's station data and advisories, together with downscaled international models and reanalysis data. While there are advisories for some sectors, only the agriculture sector produces periodical outlooks and advisories that are concurrent with the frequency of PAGASA's data. It is also only the agriculture sector where there are studies supporting the uptake and usage of CIS by farmers and vulnerable communities. In contrast, CIS and climate-relevant datasets in other sectors are sometimes hosted in nontargeted data platforms and cater to few use cases at the national level.

Stakeholders recognize the importance of CIS in facilitating the effective uptake and application of climate information across various sectors. To improve this effectiveness, a CIS must have a well-defined goal with a well-defined target end user. On the part of end-users, there is a need to improve data literacy, build technical capacity, and gain a deeper understanding of their internal decision-making processes. For data producers, the ongoing trend toward data digitization is met with challenges related to balancing quantity and quality data, mainly due to limited financial resources. For integrators, key challenges in translating climate data for CIS include varying data quality from different sources, and mismatch of available climate information with localized requirements and experiences by sectors. In terms of data access, sharing within government is generally smoother than accessing data from academia, private institutions, and the general public, primarily due to concerns regarding data privacy and misuse. Given the diverse data services available, adopting a unified whole of government approach is critical for streamlining efforts and minimizing overlaps in CIS platforms.

Overall, the effective implementation and mainstreaming of CIS in the country depends on active engagement and collaboration from data producers, transformers, users and the sector communities. Achieving cohesion among these entities is crucial to overcoming the diverse challenges faced by CIS and ensuring their effective utilization in various sectors. Institutionalized support remains pivotal for realizing the full potential of CIS.

Recommendations

To enhance the effectiveness and utility of Climate Information Services (CIS), the results suggest that it would be beneficial to consider a shift from a top-down consultation model to a collaborative, two-way process with end users. This involves engaging a diverse range of users with varying needs and systems in long-term partnerships. Workshops and surveys throughout the CIS development process, could offer a platform for active participation from end users. This enables users to not only to express their requirements but also to contribute to the co-production of knowledge. Additionally, incorporating non-scientific knowledge in this collaborative approach can strengthen legitimacy among specific stakeholders (Vincent, et al., 2018).

While CIS has traditionally centered on the application of climate science for impact assessments, there is a compelling need to adapt to a broader set of societal benefits by acknowledging the interdisciplinary nature of climate issues and this can be facilitated by "translators" who have experience in multiple disciplines. Additionally, the establishment of partnerships and networks overseen by an advisory council could foster a broader range of benefits from CIS, ensuring a more comprehensive and collaborative approach to addressing climate challenges. (Jacobs and Street, 2020).

Finally, the sustainability of CIS is needed especially in high priority vulnerable areas. This would require standardized data from various sources, quality control, and the calibration of weather instruments. The collection of information, if feasible, could be centralized within a data management system and customized to suit the specific scale required by the target sector, with due consideration for timely advisory delivery. While real-time data remains essential, it is also worth pondering the insights that may emerge from the analysis of comprehensive historical data, as these insights could potentially determine probabilities and contribute to the development of tools like cropping calendars (Elazegui, et al., 2017).

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