INITIATIVE ON
Climate Resilience

Development of Climate Smart Governance Dashboard to support National Climate Action and resilience building

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Affiliation of authors

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Cover photo: IWMI/ClimBeR A snapshot at National launch of CSG dashboard

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CGIAR Initiative on Climate Resilience

The CGIAR Research Initiative on Climate Resilience, also known as ClimBeR, aims to transform the climate adaptation capacity of food, land, and water systems and ultimately increase the resilience of smallholder production systems to better adapt to climate extremes. Its goal is to tackle vulnerability to climate change at its roots and support countries and local and indigenous communities in six low-and middle-income countries to better adapt and build equitable and sustainable futures.

Learn more about ClimBeR here: https://www.cgiar.org/initiative/climate-resilience/

Contents

Abstract

The urgency to address climate change impacts demands innovative approaches to governance to tackle the interconnected climate issues, which traditional governance frameworks often address in a fragmented manner. The development of "climate smart governance (CSG)" responds to the urgent need to integrate climate considerations into decision-making processes. This research report introduces a novel CSG dashboard designed with integrated capabilities to monitor, analyze, and visualize climate information across sectors and administrative levels. Leveraging advanced software architecture for greater user interaction, the dashboard features nine modules: country overviews, adaptation catalogs, climate outlooks, geo-intelligence, project trackers, monitoring and evaluation, and investment planning, nationally determined contribution tracker and development indicators. The suggested case applications demonstrate its versatility, supporting National Adaptation Plans (NAPs), enhancing Nationally Determined Contributions (NDCs) under the Paris Agreement, and facilitating multi-stakeholder collaborations for climate finance mobilization. The dashboard holds the potential to drive transformative adaptation by addressing systemic changes in response to climate impacts, providing comprehensive data on climate risks and vulnerabilities to identify transformative pathways. It supports real-time updates and scenario planning to inspire innovative approaches and foster multiscale collaboration in governance and policy frameworks. Recommendations include the need for data transparency, accessibility, interoperability, and security measures to ensure the dashboard's effectiveness and acceptance. Future directions include CSG's potential to be deeply integrated into national adaptation planning, assess adaptation effectiveness, support capacity building, conduct economic analyses of adaptation investments, and promote sectoral policy integration to enhance CSG strategies.

1. Introduction

In the face of increasing climate change impacts, the imperative for effective adaptation measures has never been more urgent (Gills and Morgan, 2022). Across the globe, communities, governments, and organizations are grappling with the multifaceted challenges posed by changing weather patterns, rising sea levels, extreme heat events, and disruptions to ecosystems (IPCC, 2022; Raihan, 2023). The need to build resilience, not just to withstand these impacts but to thrive in a changing climate, is driving a paradigm shift in governance approaches (Miceli et al., 2022; McHugh et al., 2021).

Traditional governance frameworks, often compartmentalized by sectoral boundaries, are ill-suited to address the interconnected and cross-cutting nature of climate change impacts (Muiderman et al., 2020). Siloed approaches to policymaking and planning can lead to fragmented responses, missed opportunities for synergies, and unintended consequences across sectors such as agriculture, water management, energy, infrastructure, health, and urban planning (Wamsler et al., 2020). Recognizing these challenges, the concept of "climate smart governance" has emerged as a transformative approach to integrating climate change considerations into decision-making processes as demonstrated for forestry (Tognetti et al., 2022) and cocoa (Maguire-Rajpaul et al., 2022).

At its core, climate smart governance seeks to enhance the adaptive capacity of societies by promoting collaboration, innovation, and resilience across sectors. It emphasizes the need for coordinated holistic, and forward-thinking approaches that transcend traditional governance silos. Central to this approach is the concept of "cross-sectoral transformative adaptation," which goes beyond incremental changes to fundamental shifts in policies, practices, and systems to build resilience and sustainability (Neely et al., 2021; England et al., 2018;).

In response to the growing demand for tools that support cross-sectoral transformative national climate action and resilience building, we develop the "Climate Smart Governance Dashboard", a novel and innovative approach to empowering decision-makers with actionable insights, data-driven assessments, and visualization tools to navigate the complexities of climate change governance. The development of the CSG dashboard is motivated by the following rationales:

Interconnectedness of climate change impacts: Climate change impacts are pervasive and interconnected, affecting multiple sectors simultaneously. A drought in one region can have cascading effects on water availability, agricultural productivity, energy generation, and public health. The dashboard recognizes these interlinkages and provides a holistic view of vulnerabilities and opportunities for adaptation.

Need for cross-sectoral collaboration: Effective climate adaptation requires breaking down silos and fostering collaboration across sectors. The dashboard serves as a platform for stakeholders from diverse sectors to come together, share information, align priorities, and co-create solutions. By CSG dashboard facilitating cross-sectoral dialogue and cooperation, it aims to harness the collective expertise and resources needed for transformative change.

Enhanced decision-making support: Informed decision-making lies at the heart of effective climate smart governance. However, the sheer volume and complexity of climate data and information can overwhelm decision-makers. The dashboard streamlines this process by distilling complex data into user-friendly visualizations, trend analyses, and scenario planning tools. It empowers decision-makers with the knowledge and insights needed to make timely and evidence-based choices.

Empowerment of stakeholders: At its essence, the dashboard is a tool for empowerment. It puts the power of data and information in the hands of diverse stakeholders, including policymakers, planners, researchers, community leaders, and citizens. Promoting transparency, engagement, and inclusivity, the CSG enables stakeholders to actively participate in addressing wicked problems and social complexity, that shape climate resilience strategies, that reflect local needs, contexts, and priorities.

Therefore, in this research report, we aim to achieve the following objectives:

1. To introduce the concept of the CSG dashboard including its framework, design principles, and underlying methodologies that capture the core components, indicators, and metrics.

2. To describe the development process and methodology of CSG including the stakeholder consultations, data collection, integration, and visualization techniques.

3. To present possible case applications of the CSG to demonstrate its utility and effectiveness in diverse contexts.

4. To reflect on future research directions and suggest policy recommendations based on insights and lessons learned

Through this research report, we invite readers to explore the possibilities, challenges, and opportunities that the dashboards offer in creating sustainable paths toward a climate-resilient future.

2. Background Review

2.1. Climate Change as a Wicked Problem

According to NASA (National Aeronautics and Space Administration) and NOAA (The National Oceanic and Atmospheric Administration), the year 2023 was by far the world's warmest year on record, and looking ahead, there is a 33% chance that 2024 will be warmer than 2023, with a staggering 99% likelihood that 2024 will secure a spot among the top five warmest years on record (NOAA, 2023). As our planet continues to warm, we must prepare ourselves for the immediate and tangible impacts of climate change. This includes increased occurrences of extreme weather events, which are not only becoming more frequent but also intensifying in severity (IPCC, 2022).

Climate change is therefore increasingly recognized as one of the most pressing challenges of this century, demanding a comprehensive global response that integrates both mitigation and adaptation strategies. It is through this holistic approach that we can avoid the impacts of climate change and work towards achieving sustainable development, while also addressing social equity and the eradication of poverty (IPCC, 2022; Sun and Yang, 2016).

The problem of climate change has been increasingly described as a 'wicked problem' (Incropera, 2016). Climate change presents a multifaceted challenge: it is complex, interconnected, and uncertain. Moreover, the complicated social, political, and cultural diversities across nations and localities add another layer of complexity to addressing climate change at different scales. These differences not only shape how people experience and respond to climate change but also underscore the need for context-specific approaches. The challenges posed by climate change are not isolated; they intersect with broader social and environmental issues, further highlighting the need for integrated and interdisciplinary solutions (Bhandari,2024; Incropera, 2016; Perry, 2015). Levin et al. (2012), argued that climate change qualifies as a super "wicked problem", given that it is characterized by the absence of a central authority to address the issue, the paradox where efforts to solve the problem often inadvertently contribute to it, and the irrational discounting of future consequences in policymaking and the fact that time is of the essence makes it so.

Therefore, as we confront the realities of climate change, responses must transcend geographical boundaries and disciplinary silos to embrace collaborative efforts that bridge science, policy, and society to navigate the climate change challenges.

2.2 Integration of Climate Data and Governance

The integration of climate data into governance frameworks is crucial for effective decision-making and policy formulation in the face of a changing climate. This integration allows policymakers and stakeholders to have a comprehensive understanding of current and future climate trends, vulnerabilities, and risks (Bauer et al., 2012; Fröhlich and Knieling, 2013). For example, Finnessey et al., (2016) discussed how integrating climate data into governance frameworks enables proactive planning and response strategies, inform broader policy efforts, unifying the scientific basis across multiple processes. The authors further report that integration helps identify vulnerable areas, prioritize adaptation measures, and allocate resources effectively.

Moreover, the integration of climate data into governance frameworks enables evidence-based decision-making and policy formulation. Studies have shown that data-driven assessments and visualizations help policymakers understand the urgency and severity of climate change impacts (Berry et al., 2015). Maguire-Rajpaul et al. (2022) discuss how the use of climate data in cocoa governance allows for the development of targeted adaptation strategies. This includes selecting climate-resilient crop varieties, implementing sustainable farming practices, and creating early warning systems based on climate projections.

Wamsler et al. (2020) emphasize that open data policies and platforms contribute to greater transparency, accountability, and public engagement. Integrating climate data into user-friendly platforms, such as the CSG dashboard, ensures that stakeholders have easy access to relevant information for decision-making. This

accessibility empowers communities, policymakers, and organizations to actively participate in climate resilience initiatives, fostering a more inclusive and collaborative governance approach.

2.3 Multi-level Governance for Climate Adaptation

Climate change poses unprecedented challenges that require coordinated efforts across various levels of governance. The concept of multi-level governance (MLG) has emerged as a framework to address these challenges, emphasizing the need for collaboration, coordination, and integration of actions at different administrative levels (Keskitalo,2010).

MLG offers a promising approach to climate adaptation by recognizing the diverse actors and institutions involved in the process (Di Gregorio et al., 2019; Scott, 2011). MLG emphasizes the importance of vertical and horizontal coordination, enabling effective decision-making and implementation of adaptation strategies (Gonzales-Iwanciw et al., 2020). Studies by Bulkeley and Betsill (2005) and Termeer et al. (2010) highlight how MLG frameworks facilitate the alignment of national policies with regional and local priorities, fostering adaptive governance structures.

Despite its benefits, the implementation of MLG for climate adaptation faces several challenges. Institutional fragmentation, conflicting interests among stakeholders, and a lack of clear governance structures often hinder effective coordination (Nilsson et al., 2012; Gupta,2007). Research by Jordan et al. (2012) underscores the complexity of MLG, noting the need for adaptive governance mechanisms that can accommodate diverse perspectives and interests.

MLG offers a pathway to enhance adaptive capacity by leveraging the strengths of different governance levels (Dressel et al., 2020; Brockhaus et al., 2012). By promoting participatory approaches and engaging stakeholders at various levels, MLG frameworks can improve the effectiveness of adaptation measures (Eichhorn et al., 2021; Thaler and Levin-Keitel, 2016). Pahl-Wostl et al. (2007) and Diduck (2010), emphasize the role of learning networks and knowledge-sharing platforms within MLG, enabling the exchange of best practices and building collective resilience.

Several case studies illustrate the successful application of MLG in climate adaptation. The Netherlands provides an example of effective coordination between national, regional, and local authorities through its Delta Program, aimed at addressing flood risks and sea-level rise (Biesbroek et al., 2014). Similarly, the Climate Change Adaptation Strategy in Canada demonstrates the integration of federal, provincial, and municipal efforts to build resilience in vulnerable communities (Feltmate andThistlethwaite, 2012).

MLG therefore plays a crucial role in climate adaptation by fostering collaboration, addressing challenges, and enhancing adaptive capacity. While implementation hurdles exist, lessons from case studies and research provide insights into effective strategies to strengthen MLG to promote sustainable adaptation to climate change.

2.4 Application of digital tools to enhance climate change adaptation

In recent years, due to climate change, the application of various digital tools has emerged as a promising approach to enhance climate change governance and adaptation efforts. These tools harness the power of data analytics, modeling, and communication technologies to inform evidence-based decision-making, facilitate stakeholder engagement, and foster resilience in the face of climate variability and change (Dittmer et al., 2022; Ulibarri et al., 2022; Balogun et al., 2020).

The use of digital tools in climate change governance offers unprecedented opportunities to strengthen policy frameworks, improve transparency, improve decision-making processes to enhance community engagement, and enhance the effectiveness of adaptation measures (Ulibarri et al., 2022). One key advantage of these digital tools is their ability to facilitate the assessment of climate risks and vulnerabilities. For instance, Geographic Information Systems (GIS) enabled tools allow spatial mapping of climate hazards, exposure, and sensitivity, aiding in the identification of high-risk areas (Parker et al., 2019; Cavan et al., 2014; Preston et al., 2011). Also, decision-support tools, such as scenario planning and cost-benefit analysis frameworks, provide stakeholders with valuable insights into the potential impacts of adaptation measures, assisting in the prioritization of actions (Hritonenko and Yatsenko, 2022; Siders and Pierce, 2021). The IMF-World Bank Climate Policy Assessment Tools (CPATs) enable policymakers to assess the coherence, effectiveness, and feasibility of climate policies (Black, 2023). These tools facilitate evidence-based decision-making, helping governments align their policies with climate adaptation and mitigation goals. Additionally, tools such as Climate Action Planning frameworks provide a systematic approach for local governments to develop and implement climate strategies tailored to their specific contexts (Boswell, et al., 2019).

Effective climate governance relies on the active participation of diverse stakeholders such as governments, businesses, civil society organizations, and local communities, and digital tools the mechanism for fostering collaboration, dialogue, and knowledge exchange among stakeholders (McIntosh et al., 2023; Welp 2006). For example, multi-stakeholder platforms provide a stage for joint decision-making, ensuring that adaptation strategies are inclusive, equitable, and responsive to local needs (Ambani et al., 2021; Larson, 2020; Djalante,2012). Furthermore, online platforms and digital tools facilitate broader public engagement, enabling citizens to contribute ideas, feedback, and data for climate action planning (Falco and Kleinhans,2019; Lawrence et al., 2017). Digital platforms provide a more accessible means for diverse stakeholders, including marginalized communities and youth, to participate in climate discussions and initiatives (Kretser and Chandler,2020).

Transparency and accountability are essential pillars of effective climate governance, ensuring that actions are transparently communicated, and progress is monitored and evaluated (van Deursen, 2021; Hughes, et al., 2020; Gupta and van Asselt,2019). Tools such as Climate Finance Tracking Platforms (CFTPs) enable governments and stakeholders to track the flow of climate finance, ensuring that funds are allocated efficiently and effectively (Lamhauge and Jachnik, 2018; Donner, 2016; Tirpak et al., 2014). These platforms enhance accountability by providing transparent information on climate finance sources, allocations, and outcomes, fostering trust among stakeholders.

Despite their benefits, many tools require specialized knowledge for operation and interpretation, which may limit their accessibility to certain stakeholders, particularly in resource-constrained settings (Bettini et al., 2020; Berrang-Ford et al., 2019). Moreover, the integration of diverse data sources into tools can pose challenges related to data quality, consistency, and interoperability (Adger et al., 20). Ensuring the long-term sustainability of tools also requires ongoing maintenance, updates, and financial resources, which may present barriers to adoption.

3. CSG Development

3.1 Design and User Choices

The design of the CSG dashboard prioritizes user-friendliness, accessibility, and intuitive navigation to ensure that users can easily comprehend and interact with the information presented. We did so on the premise that a well-thought-out visual design, incorporating clear data visualizations and infographics, can enhance the user experience, making it easier for stakeholders to interpret complex climate-related data.

User choices within the CSG dashboard were carefully considered to empower users to tailor their experience based on their specific needs and interests. CSG dashboard provides customizable features, such as the ability to select and prioritize specific indicators, regions, or timeframes, allowing users to focus on the information most relevant to their concerns or responsibilities. Also, the dashboard incorporates multiple communication channels, such as interactive maps, charts, and textual summaries, and caters to diverse learning styles and preferences, ensuring a broader user engagement.

In the context of climate governance, users' choices extend beyond customization options to include decision-support modules such as investment portfolio planning, and monitoring and evaluation. These modules enable users to simulate the impact of different scenarios, helping policymakers and stakeholders make informed decisions based on projected outcomes. By incorporating such interactive modules, the dashboard serves as a dynamic platform that facilitate easy and proactive decision-making.

Furthermore, the CSG dashboard has built-in continuous user feedback, and iterative design processes for refining and enhancing its content over time. Regular consultations with end-users, including government officials, researchers, and community representatives, provide valuable insights into evolving user needs and emerging priorities. This feedback mechanism ensures that the dashboard remains relevant, responsive, and adaptable to the changing landscape of climate governance, ultimately contributing to more effective and informed decision-making.

3.2 Software Architecture

The software architecture of the CSG dashboard is meticulously designed, leveraging a combination of powerful frameworks, technologies, and tools to create a comprehensive and user-friendly platform for monitoring and analyzing climate and other geo data (Table 1). At its core, the Django REST Framework serves as the foundation for creating robust RESTful APIs. Leveraging the features of Django REST Framework facilitates rapid development and efficient handling of HTTP requests, ensuring a continuous flow of data between the frontend and backend components.

User authentication is a critical aspect of the dashboard, and JSON Web Tokens (JWT) are integrated to provide secure and stateless authentication. This enables users to interact with the system effortlessly while maintaining the necessary security measures. The primary data storage mechanism is implemented using MySQL, offering efficient data management, retrieval, and storage capabilities. MySQL's robust querying capabilities support diverse functionalities within the application, ensuring optimal performance.

The frontend of the CSG Dashboard is powered by HTML, forming the structural backbone of the web pages, while AJAX streamlines and simplifies API calls, facilitating enhanced communication between the frontend and backend. Visualization is a key aspect, and the integration of Leaflet.js and D3.js empowers the frontend with interactive map displays and robust data visualization capabilities. Highcharts is utilized to implement dynamic and visually appealing graphs and charts, providing users with a visually engaging and informative experience.

Data handling tools, such as Sheet.js, are employed to extract and process climate risk datasets from Excel sheets. This enhances the application's predictive capabilities, allowing it to forecast and present future climate trends based on gathered data. Geospatial data handling is optimized through the use of the TopoJSON format for shapefiles, ensuring efficient storage and processing of geographical data. Additionally, a GeoServer instance

manages raster data efficiently, supporting the application's geospatial functionalities and enhancing data visualization.

The CSG Dashboard's software architecture therefore ensures user interaction, effective data visualization, and the handling of varied data types. By integrating a robust set of tools and technologies, the dashboard provides a comprehensive solution for monitoring and analyzing climate-related information, contributing to informed decision-making in the face of environmental challenges.

Table 1: key architectural components and toolkits used for the CSG dashboard

Components	Toolbox	Details
Framework	Django REST Framework	• Utilized extensively for its powerful features in creating RESTful APIs. • Offers a wide range of tools and functionalities, facilitating rapid development and efficient handling of HTTP requests.
User Authentication	JWT (JSON Web Tokens)	• Integrated for secure and stateless authentication. • Enables seamless authentication processes for users interacting with the system.
Database Integration	MySQL	• Acts as the primary data storage mechanism. • Facilitates efficient data management, retrieval, and storage for the application.
Frontend Technologies (Core Technologies)	HTML	• Forms the structural backbone of the application's web pages. • Provides the basis for content layout and organization.
	AJAX	• Streamlines and simplifies API calls, enhancing frontend-backend communication.
	Leaflet.js	• Enables the integration and visualization of interactive maps within the application.
	D3.js	• Empowers the frontend with robust data visualization capabilities.
	Highcharts	• Implements dynamic and visually appealing graphs and charts.
Data Handling Tools	Sheet.js	• Enables the extraction and processing of data from Excel sheets. • Specifically utilized for extracting future climate risk datasets, enhancing the application's predictive capabilities.
Backend Functionality	Django REST Framework Implementation (Functionalities)	• Provides comprehensive functionalities for both general and catalog projects. • Handles various HTTP methods for data manipulation (GET, POST, PUT, DELETE).
User Management and Authentication	JWT Token Usage	• Ensures secure and streamlined user authentication. • Manages user sessions without the need for server-side storage.
Database Operations:	MySQL Integration	• Utilizes MySQL for efficient data storage and retrieval. • Offers robust querying capabilities to support diverse application functionalities.
Interactive UI Elements:	AJAX Integration	• Enhances user experience by facilitating asynchronous API calls. • Enables dynamic content updates without page refreshes.
Visualization Enhancements:	Leaflet.js and D3.js Integration	• Empowers the frontend with visually appealing and interactive map displays and data representations. • Offers users an engaging and informative experience through effective visualization.
Data Management and	Sheet.js Usage	• Extracts and processes climate risk datasets from Excel sheets.

Sources (Climate Risk Data Handling)		• Enables the application to forecast and present future climate trends based on gathered data.
Geospatial Data Handling:	TopoJSON Format for Shapefiles	• Utilizes efficient file formats for geospatial data to optimize storage and processing. • Enhances the performance of geographical data rendering and manipulation.
Raster Data Management:	GeoServer Instance	• Manages raster data efficiently, ensuring seamless retrieval and rendering of spatial information. • Supports the application's geospatial functionalities and data visualization.
Comprehensive Integration and Purpose	User Interaction	• Seamless and intuitive interaction through a well-structured UI.
	Data Visualization and Presentation	• Effective visualization of complex data sets for user comprehension and analysis.
	Handling of Varied Data Types	• Manages and presents diverse data types, from simple HTML content to intricate geographical and climate datasets

Figure 2 highlights the interplay and connection between the backend, frontend, and data handling processes within the software architecture of the CSG dashboard. It illustrates the purposeful selection of tools and frameworks, emphasizing the relationship among components that contribute to the CSG's overarching goal of technological integration.

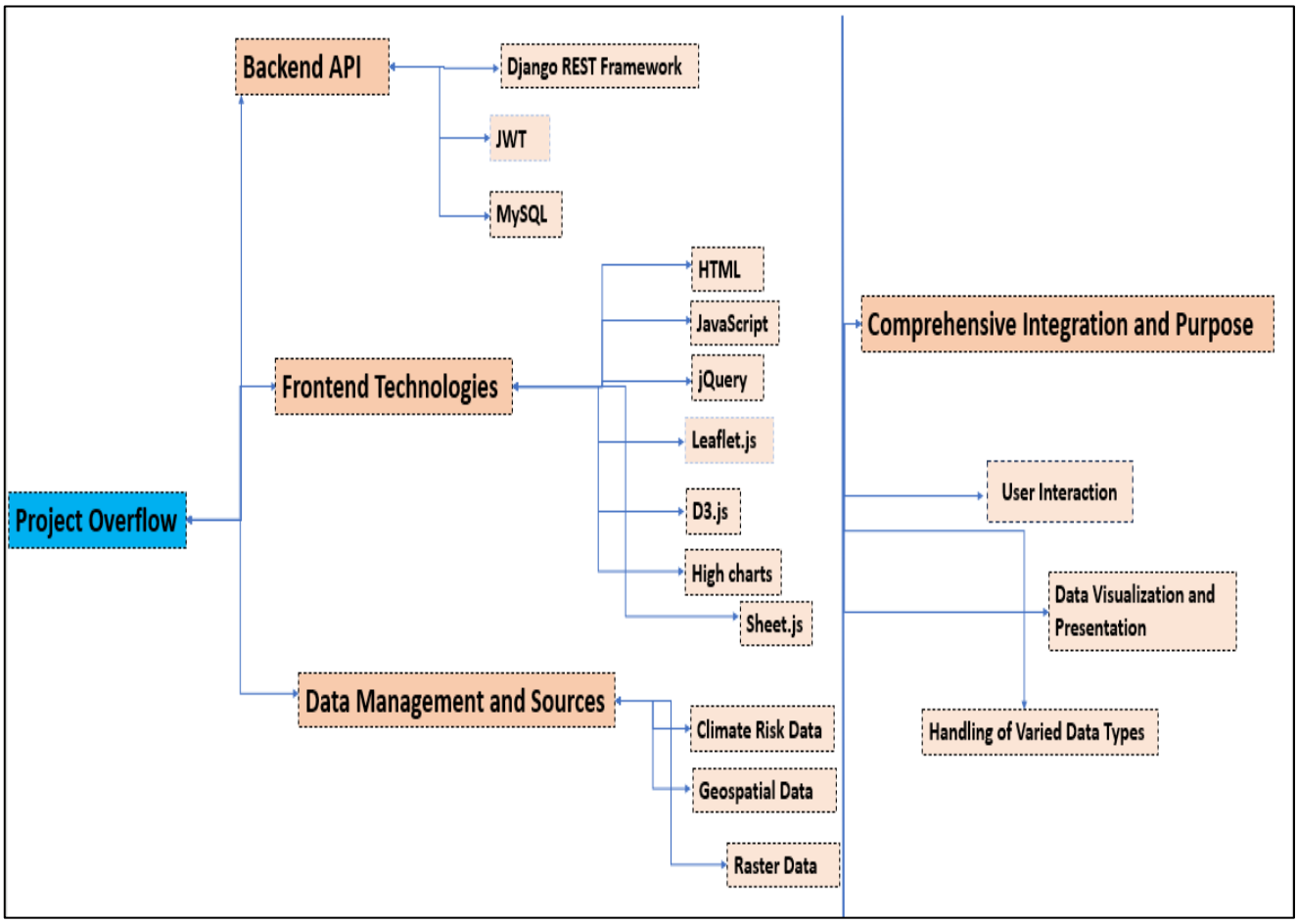

Figure 1:The connectivity of the architectural components of the CSG software

3.3 Data and Processing

Module	Data Requirements	Data sources	Data Processing

Country Overview	• Census and statistics • Historical climate change data.	• Country Census and statistics • Climatology- United States Agency International Development https://www.usaid.gov/climate/country-profiles	• Integration of data from national statistical agencies and relevant government departments. • Geospatial mapping to visualize demographic and economic indicators. • Time-series analysis to track historical climate data trends.
Adaptation Catalog	• Detailed information on each adaptation project (description, duration, and budget location).	• International water management Institute project database	• Standardized templates for consistent data collection. • Categorization of projects based on hazards, scales, themes, approaches, and geographical location.
Climate Outlook	• Climate model outputs and projections • Hazard, exposure, vulnerability and lack of coping capacity data. • Sector-wise climate impact information.	• Climate knowledge portal https://climateknowledgeportal.worldbank.org/.\ • Index for Risk Management https://drmkc.jrc.ec.europa.eu/inform-index • United States Agency International Development https://www.usaid.gov/climate/country-profiles	• Statistical analysis to identify trends and patterns. • Integration of climate model outputs into the dashboard. • Development of user-friendly visualizations for projected climate scenarios.
Geo-Intelligence	• High-resolution satellite imagery. • Geographic Information System (GIS) datasets. • Real-time weather and climate data. • Infrastructure data (roads, buildings, schools).	• Survey Department of Sri Lanka. • The Humanitarian Data • Exchange. (https://data.humdata.org/dataset/hotosm_lka_education_facilities?) • Risk Information http://www.riskinfo.lk/#/ Africa geoportal https://www.africageoportal.com/ • GRID3 https://data.grid3.org/ World bank https://datacatalog.worldbank.org/	• Image processing for satellite data interpretation. • Integration of real-time weather and climate data for dynamic mapping. • Spatial analytics to assess vulnerabilities and risks.
Project Tracker	• Detailed information on climate change mitigation, adaptation, and cross-cutting projects.	• National Ministries • World Bank • African Development Bank • United Nations Development Programme • Asian Development Bank • Green Climate Fund • USAID • Global Environment Facility • Global Green Growth Institute • Nordic Development Fund • International Fund for Agricultural Development • GIZ • Food and Agricultural Organization • Foreign Commonwealth and Development Office Etc.	• Standardized templates for consistent data collection. • Categorization of projects based on standardized templates of questions. • Geospatial mapping and visualization of climate change projects
Monitoring and Evaluation	• Key performance indicators for climate change projects collected for adaptation tracker. • User feedback and community responses.	• Data from other modules of the CSG such as the project tracker	• Comparative analysis of climate change projects. • Quantitative and qualitative assessment of project impacts.

Investment Portfolio Planning	• Historical and projected climate change data • Historical GDP data.	• Climate knowledge portal https://climateknowledgeportal.worldbank.org/.\ • Statista https://www.statista.com/statistics/457737/share-of-economic-sectors-in-the-gdp-in-zambia/	• Analysis of climate change impact on GDP under different scenarios
Development Indicators	• Sustainable Development Goals indicators. • Human Development Index data. • Environmental performance indicators. • Social and economic development metrics. • Climate risk index	•United Nations Sustainable Development Goals (UNSDG) https://unstats.un.org/sdgs/dataportal	• Comparative analysis of national and regional SDG progress. • Composite indices for holistic development assessments. • Integration of real-time data for up-to-date risk indicators.
Nationally Determined Contributions Tracker	• Emissions Reduction Targets • Data on Sector-Specific Targets • Data on adaptation, mitigation and cross-cutting commitments • SDG contribution data	• Data from other modules of the CSG such as the project tracker • United Nations Sustainable Development Goals (UNSDG) https://unstats.un.org/sdgs/dataportal	• Analysis of emission contributions per sector

4.0 Components of CSG

The diverse components within the dashboard collectively contribute to a rich composition, fostering a holistic delivery of climate change governance. CSG has 9 key modules that include country overview, adaptation catalog, climate outlook, geo-intelligence, project tracker, monitoring and evaluation, investment portfolio planning, development indicators and nationally determined contribution tracker. Figure 1 shows an interface of the landing page with all 9 modules of CSG.

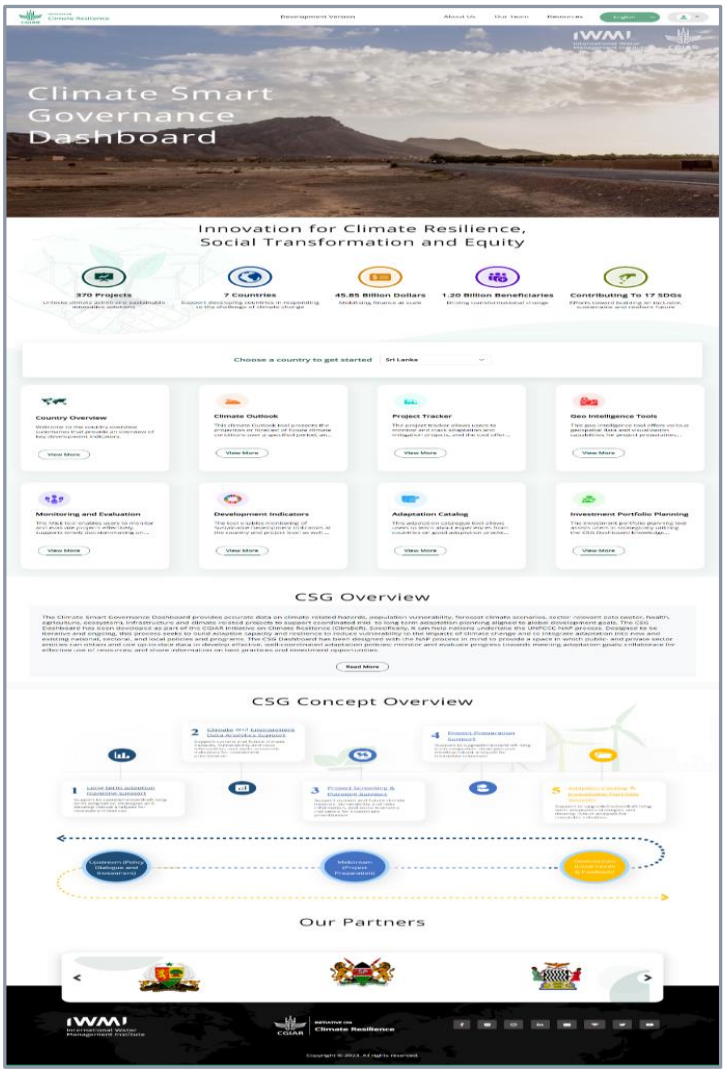

Figure 2:Landing page of CSG dashboard

4.1 Country Overview

The country overview page (Figure 2) presents an overall summary of the country's features. Information about administrative structure, demography, topography, weather and climate, natural hazards and their impacts across the country. A quick description of the fundamental features of the country enables the user to understand the overall status of the country. The information on these features is elaborated across time and space on the dedicated modules of the CSG.

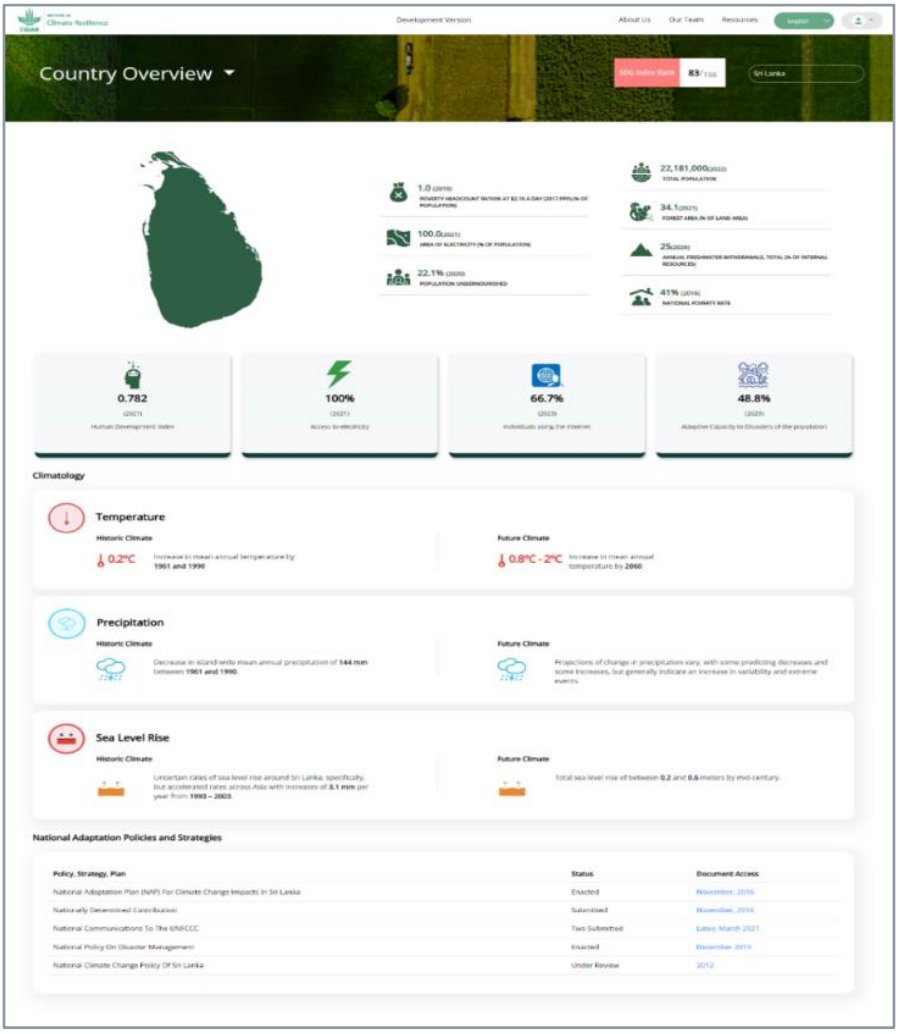

Figure 3:Interface of country overview

4.2 Adaptation Catalog

The Adaptation Catalog (AC) module provides a dynamic space for sharing and learning about climate adaptation initiatives (Figure 3). This module brings together diverse climate change projects and initiatives cataloging best practices and fostering learning to build resilience at different scales and levels. AC transcends geographical boundaries, facilitating global reach and cross-pollination of ideas. Users can draw inspiration and insights from adaptation projects at local, national and regional levels, promoting a shared understanding of diverse climate challenges and solutions. Each adaptation project featured on the platform provides in-depth information on the project descriptions, duration, and budget location, allowing detailed exploration of individual projects and initiatives and encouraging a deeper understanding of their impact.

AC allows individuals to register and upload details about their projects. Projects can be viewed on maps to indicate areas with gaps or clusters of related activities. Users can filter projects according to country, theme, approach, hazards, scale, budget, donors, and duration. AC categorize and organizes different climate adaptation initiatives under hazards, scales, themes, and approaches. This feature ensures that projects are easily accessible and allows users to navigate through a range of strategies, from community-based resilience projects to large-scale infrastructure adaptations. Also, AC has a best practices repository of data and knowledge assembled from successful adaptation projects worldwide, serving as an invaluable resource for stakeholders seeking proven strategies and innovative approaches to climate resilience.

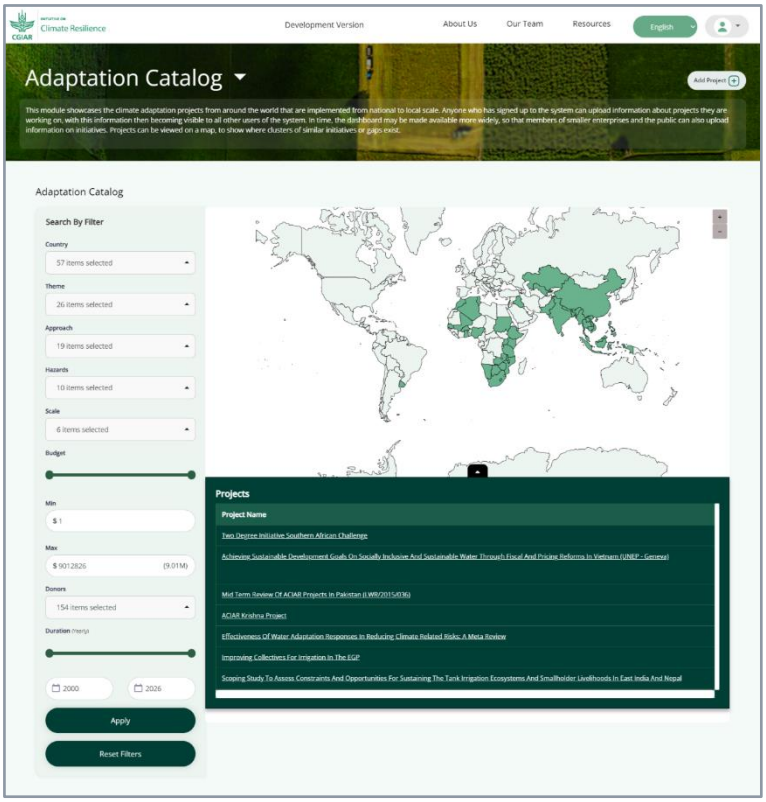

Figure 4:Interface of adaptation catalog

4.3 Climate Outlook

The climate outlook module provides country climate risk information in terms of plausible future changes in climate risk; hazard and exposure, vulnerability, coping capacity indicators, and sector-wise climate change impact. Specific pages are dedicated to climate risk profiles, future climate risk, climate risk visualizer, and sectoral climate impact to help decision makers understand the country's climate risk conditions at a glance to design innovative climate adaptation and mitigation policies.

4.3.1 Climate Risk Profile

The Climate Risk Profile (Figure 4) presents an overview of temperature, precipitation, and sea level characteristics of the historical and projected periods for each country. This country-level climatological data from various sources offers policymakers and other users an opportunity to understand their likely climate threats and thus informs actions and framing of climate adaptation policies.

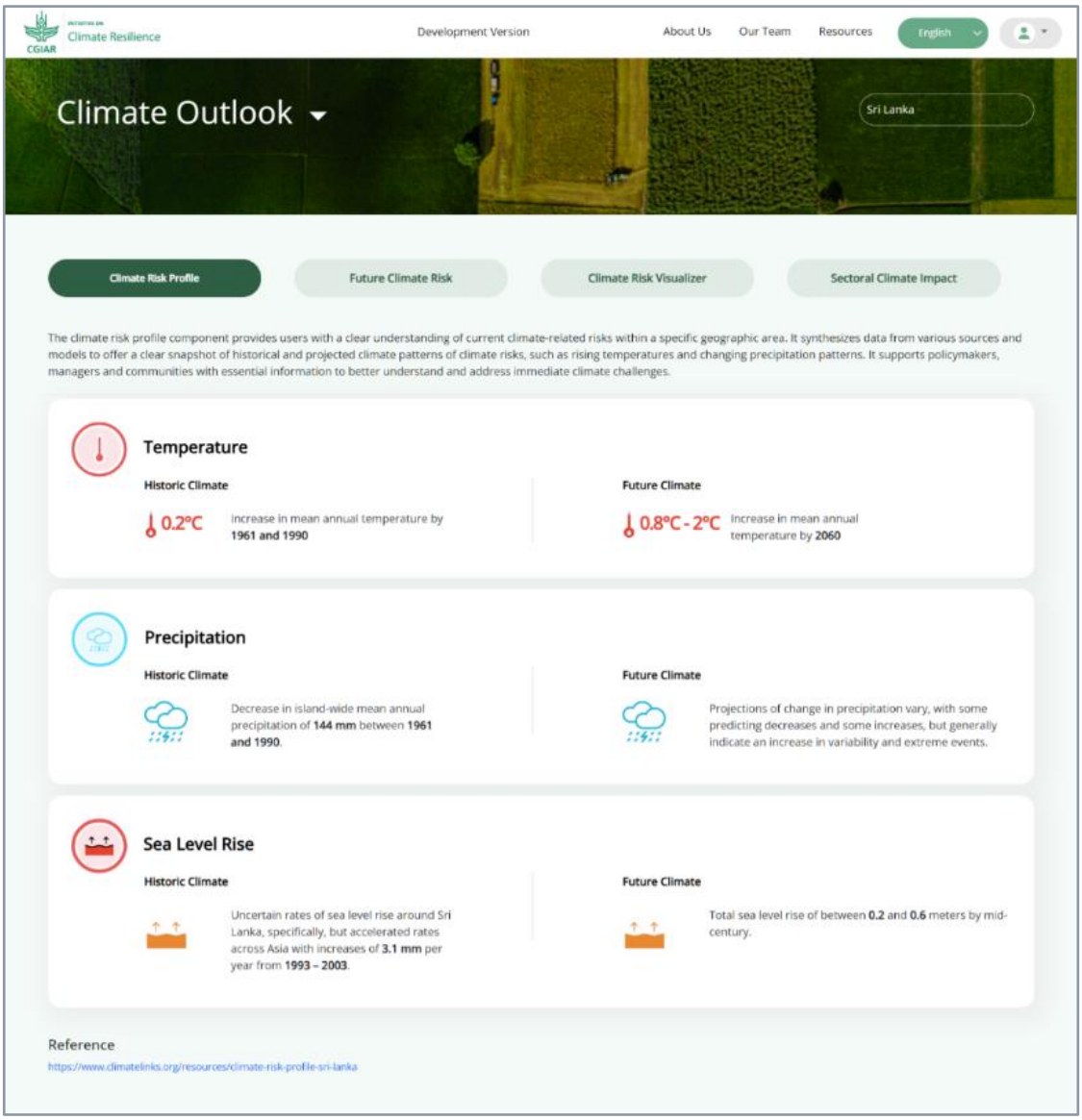

Figure 5:Interface of climate risk profile

4.3.2 Future Climate Risk

The Future Climate Risk (FCR) module (Figure 5) provides a visualization of ensemble climate change projections at the national and sub-national levels. Future climate scenario analysis is used to assess climate risks arising from climate change to capture the unprecedented and uncertain nature of future climate-related events, which assists decision-makers in developing adaptation strategies. Utilizing the recent climate model and its scenario analysis, FCR module offers a glimpse into how climate-related risks are likely to evolve in the coming years and decades based on extreme temperature/rainfall and drought indices. Decision-makers can use this information to assess potential future challenges, such as floods, droughts, or heatwaves, and formulate strategies for adaptation and resilience to ensure long-term sustainability.

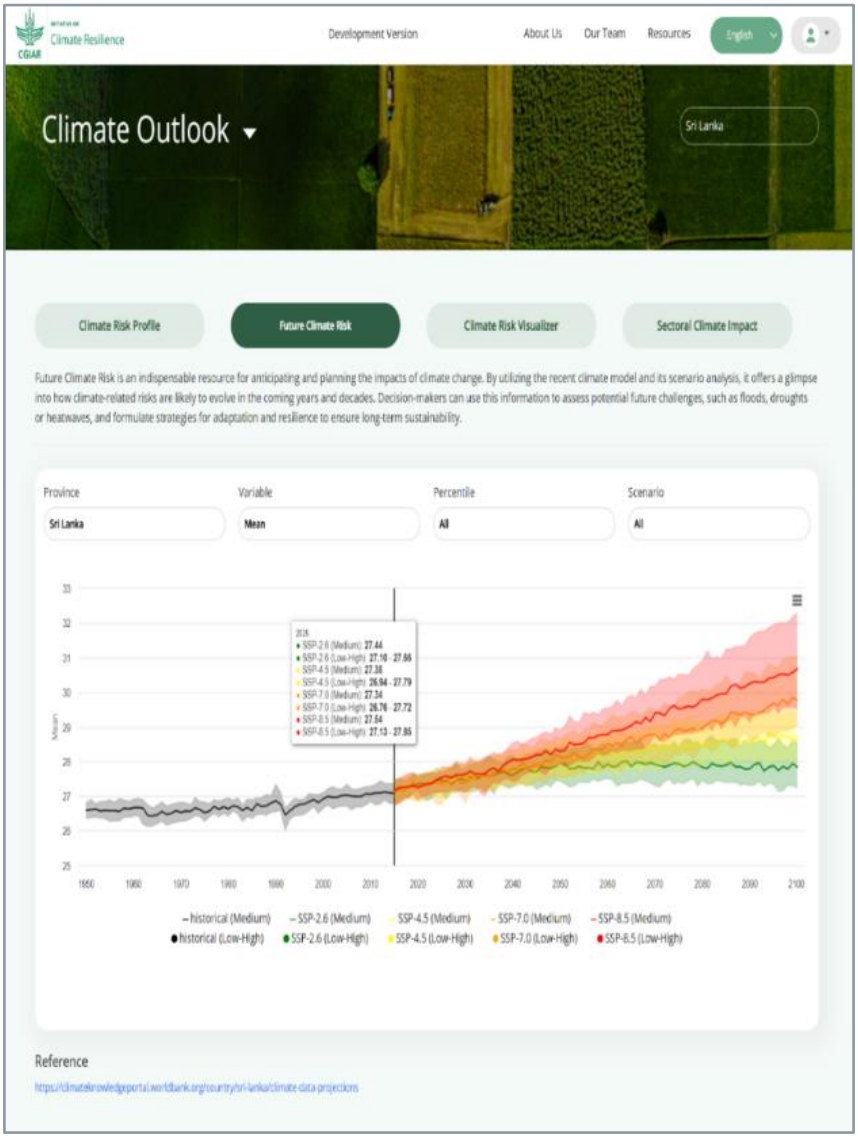

Figure 6:Interface of future climate risk

4.3.3 Climate Risk Visualizer

The Climate Risk Visualizer (CRV) module is a powerful display designed to enhance understanding of climate-related risks and vulnerabilities. It is interactive and enables users to explore and visualize complex climate data in an accessible and user-friendly manner. It leverages advanced data visualization techniques to present a comprehensive picture of climate risks. The climate risk visualizer module (Figure 6) of the CSG dashboard presents the country-level risk. Analysis of risk comprises Hazard, Exposure, Vulnerability, and Adaptive Capacity. The Hazard and exposure dimension reflects the probability of physical exposure associated with specific hazards. The Vulnerability dimension addresses the intrinsic predispositions of an exposed population, and its economic, political, and social characteristics to be affected or susceptible to a hazard's damaging effects, even though the assessment is made through hazard-independent indicators. The adaptive capacity measures the ability of a country to cope with disasters in terms of formal, organized activities and the effort of the country's government as well as the existing infrastructure, which contribute to the reduction of risk.

One key feature of the CRV is its ability to aggregate diverse climate datasets into intuitive visual representations. Users can use maps, charts, and graphs to identify regions and sectors most vulnerable to specific climate hazards such as rising temperatures and extreme weather events. These visuals aid in the identification of hotspots and enable proactive planning for adaptation and

resilience-building measures. The user-friendly interface of CRV allows individuals with varying levels of expertise to interact with and comprehend complex climate data. Additionally, the CRV supports scenario planning to simulate the potential impacts of different climate scenarios. This dynamic feature enables stakeholders to assess the effectiveness of various adaptation strategies and make well-informed decisions based on anticipated climate risks. Thus, developing robust and adaptive responses to the evolving climate landscape.

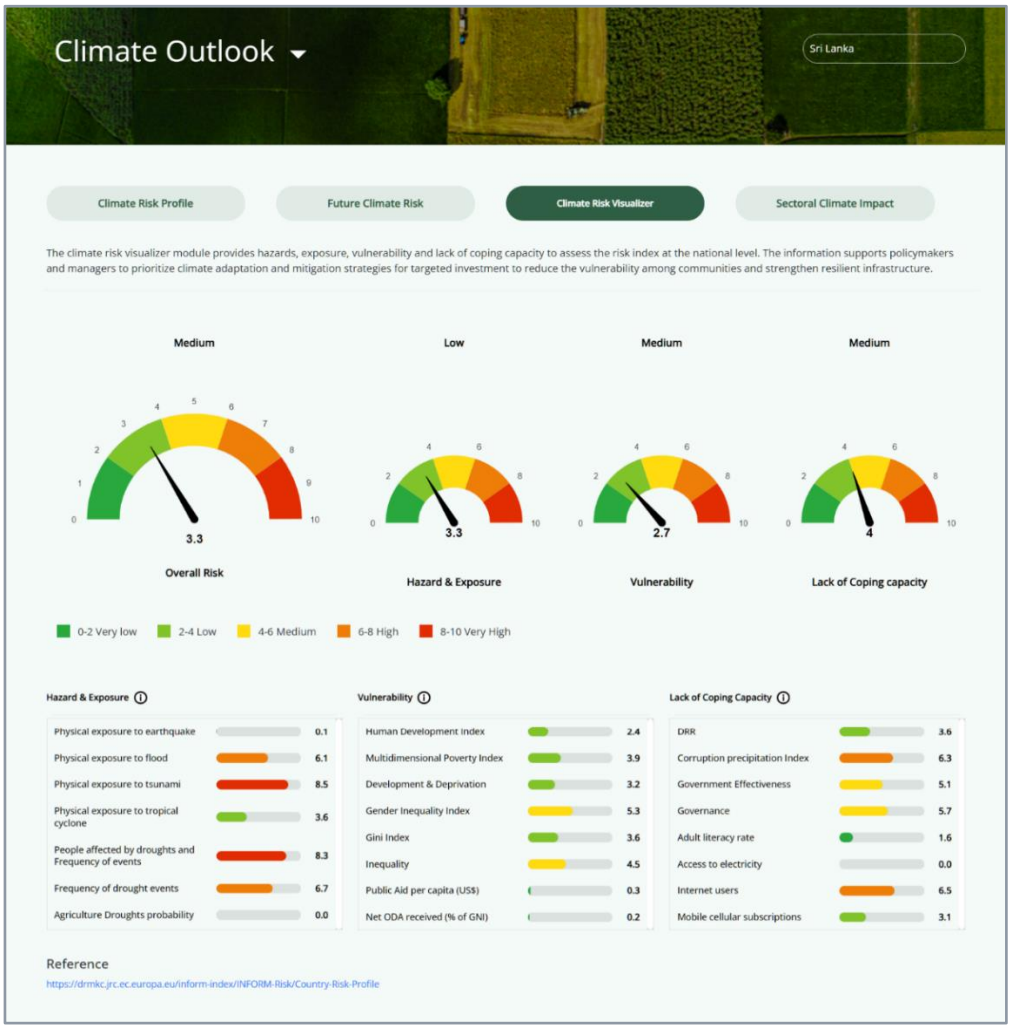

Figure 7:Interface of climate risk visualizer

4.3.4 Sectoral Climate Impact

The Sectoral Climate Impact module (Figure 7) of the CSG dashboard provides a detailed and focused analysis of how climate change affects specific sectors of society, the economy, and the environment. This feature is instrumental in guiding targeted policies and interventions by offering decision-makers insights into the vulnerabilities and opportunities associated with climate change in various sectors such as agriculture, water resources, energy, infrastructure, health etc. For instance, in agriculture, the module showcases the impact of changing precipitation patterns on crop yields or the effects of rising temperatures on livestock. The sector-wise climate change impact information acts as a guide to retrospect the current capabilities of the country to cope with climate change. It further aids in prioritizing finance and investment in each sector for the development of the country by and large.

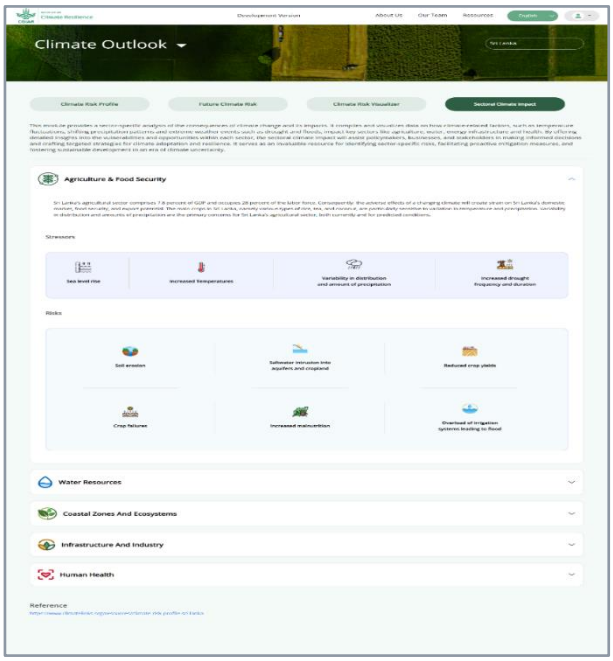

Figure 8:Interface of sectoral climate impact

4.4 Project tracker

The Project Tracker (PT) module (Figure 8) of the CSG dashboard serves as a centralized repository for climate change adaptation, mitigation, and cross-cutting projects. It provides a summarized visualization of all climate change projects at different levels and scales in each country. This module tracks the progress of various projects and programs, offering transparency and accountability in the implementation of climate-related initiatives. The PT contributes to effective governance by aiding the allocation of resources, assessing the impact of interventions, and making data-driven adjustments to enhance the overall effectiveness of climate action strategies.

Typically, PT provides information such as project name, description, duration, location, donor, scale, theme, sector, targeted risk, governance levels, SDGs and SENDAI indicator etc. This allows stakeholders to assess whether projects are on schedule, within budget, and achieving the intended outcomes. Visual representations, such as progress charts and interactive maps, offer a comprehensive overview of the geographical distribution of projects, helping decision-makers identify areas where interventions may be needed or where successful practices can be replicated. By providing a shared platform to access and exchange information on all climate change projects, it enhances coordination between government agencies, non-governmental organizations, researchers, and local communities. Further it offers a holistic understanding of the implemented climate change projects revealing areas where climate action is taken and the state of climate change initiatives revealing challenges and opportunities in climate governance and encouraging a more integrated and synergistic approach to project implementation.

The PT also contributes to adaptive management. As new data becomes available and the climate landscape evolves, decision-makers can use the PT to assess the performance of ongoing projects and adjust strategies accordingly. This adaptive capacity ensures that governance efforts remain responsive to changing climate conditions, emerging risks, and evolving community needs. PT also enhances the overall effectiveness of CSG by providing a comprehensive, real-time overview of the status and impact of initiatives including generating comprehensive reports on project status, achievements, and challenges aimed at building climate resilience and sustainability. These reports can be utilized for accountability purposes, both internally within organizations and externally for reporting to funders, regulatory bodies, and the public. The PT module acts as a centralized repository, consolidating information on climate change projects. This centralized approach facilitates easy access to project details, updates, and documentation, streamlining communication and collaboration among stakeholders.

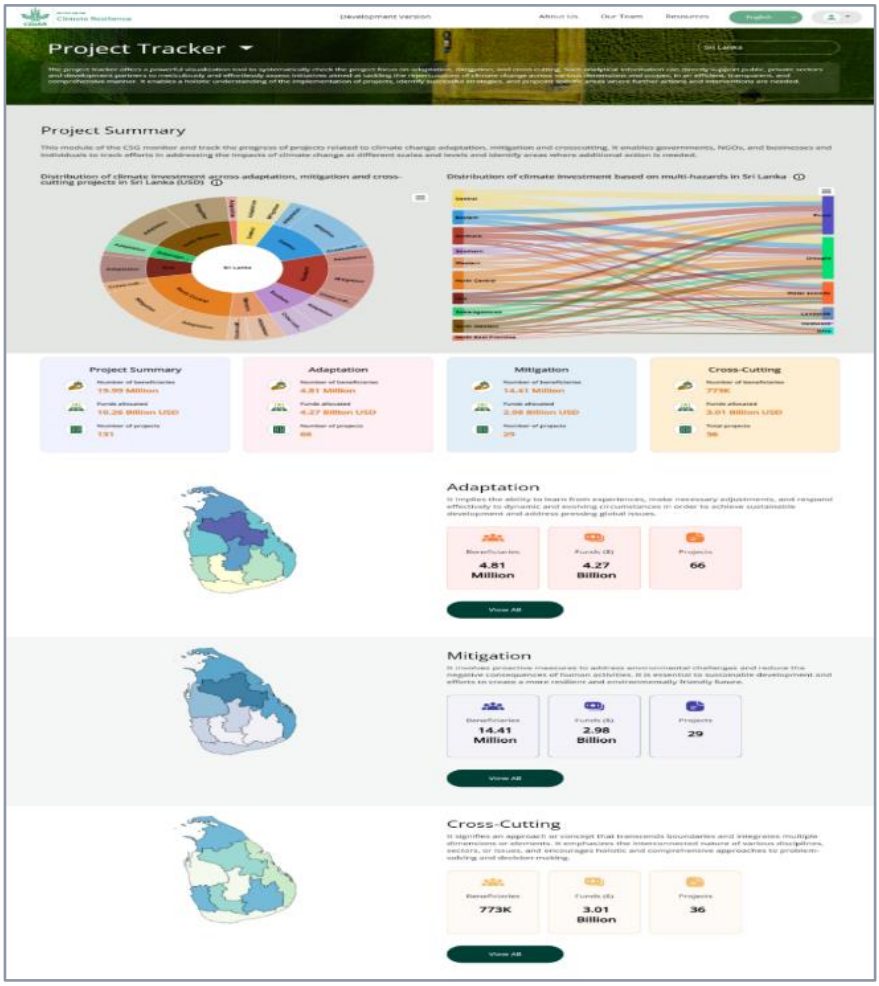

Figure 9:Interface of project tracker

4.5 Investment Portfolio Planning

The Investment Portfolio Planning (IPP) module shown in Figure 9 aligns financial resources with climate-related goals and strategies. This feature integrates financial data such as GDP, risk assessments, and climate impact analyses to facilitate sustainable investments. The module displays how climate change is and will affect national GDP and the prioritization of projects based on their cost-effectiveness. By integrating climate risk assessments and return on investment analyses, decision-makers can identify high-impact, low-risk projects that align with climate smart goals. Thus, enabling governments and organizations to allocate funds strategically to support initiatives that contribute to climate mitigation, adaptation, and overall environmental sustainability.

Furthermore, the IPP module supports long-term planning by incorporating scenario analysis and predictive modeling. Decision-makers can simulate the potential impact of different investment scenarios on climate goals, allowing for strategic adjustments and risk mitigation. This forward-looking approach ensures that investments are aligned with the dynamic nature of climate change, considering future challenges and opportunities. In essence, through data-driven insight, IPP empowers decision-makers to allocate resources efficiently, prioritize impactful projects, and foster collaboration, and contribute to the effective integration of financial strategies with climate-related objectives, promoting a comprehensive and adaptive approach to climate governance.

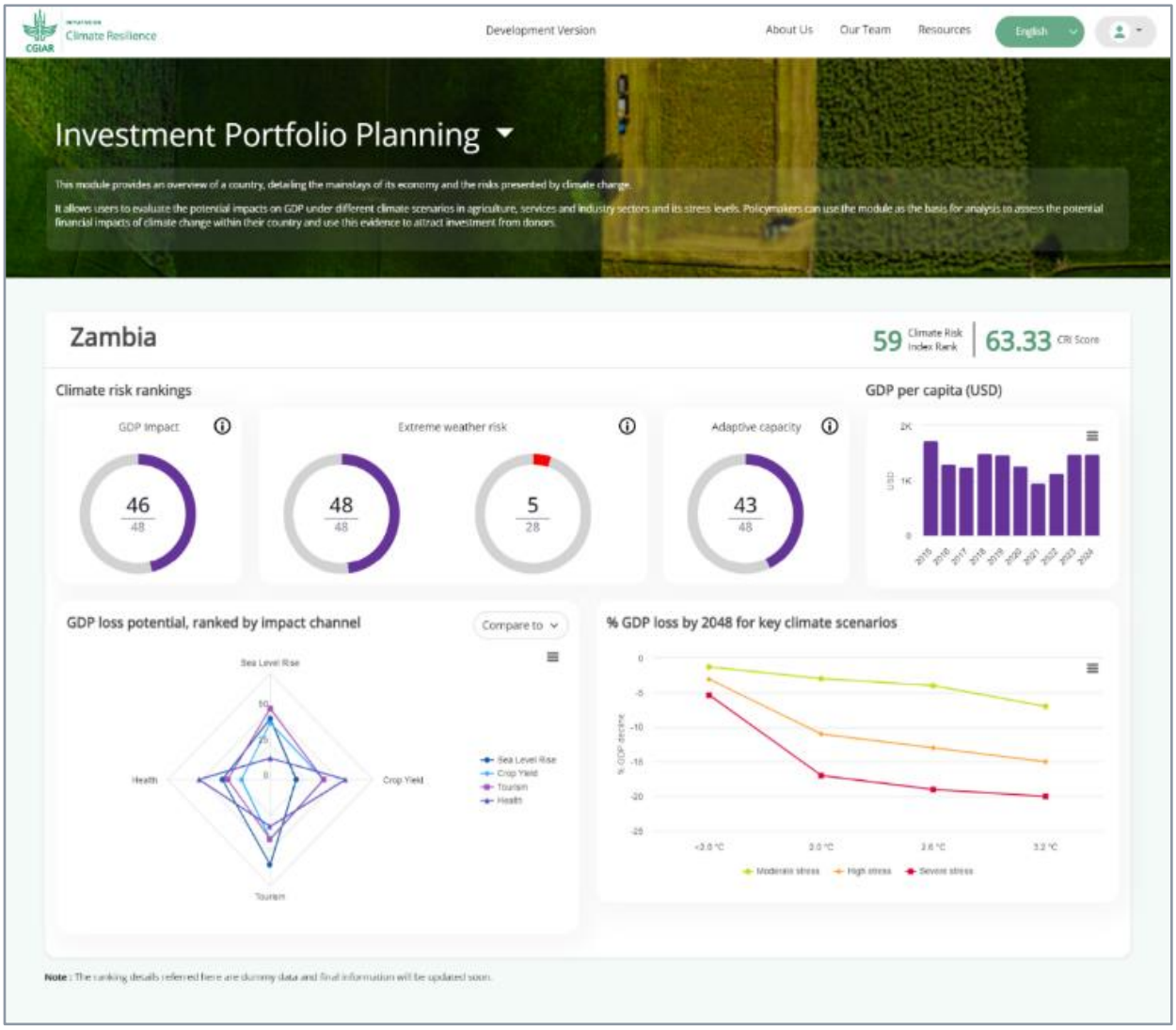

Figure 10:Interface of investment portfolio planning

4.6 Development Indicators

The incorporation of the Development Indicators (DI) module (Figure 10) enhances the capacity to monitor and assess the progress of climate-related initiatives within the broader context of sustainable development. These indicators serve as key metrics that reflect the impact of climate policies on various facets of social, economic, and environmental well-being, reflecting the synergies and trade-offs between climate action and broader development goals.

DI provides a comprehensive overview of the current status and historical trends of the Sustainable Development Goals (SDGs) of the targeted countries. The graphical time series of each SDG score gives an idea of the sustainable pathway of a country toward attaining sustainable development. DI together with the PT module gives an idea of the type and extent of development projects needed in the near and long term for the achievement of SDGs. Furthermore, the DI module shows the performance of the indicators of each DDG goal highlighting the gaps to be filled.

Figure 11:Interface of development indicator

4.7 Interface of Monitoring and Evaluation

The Monitoring and Evaluation (M&E) module assesses the effectiveness and impact of climate-related projects and initiatives (Figure 11). It systematically monitors, tracks, and evaluates the outcomes and progress of various climate smart actions implemented, providing decision-makers with real-time, data-driven insights for informed adjustments and improvements to climate governance strategies. The M&E module also aggregates diverse data sources related to climate initiatives from different government agencies, environmental monitoring systems, and community-driven projects, to offer a comprehensive overview of the current state of climate resilience and adaptation efforts. This holistic approach enhances the accuracy of assessments, allowing decision-makers to identify successful interventions, pinpoint areas requiring improvement, and allocate resources more effectively.

Transparency and accountability are inherent features of the M&E module, contributing to a robust climate governance framework. By making performance data accessible to the public, the module encourages active and transparent engagement and scrutiny from stakeholders, fostering a sense of shared responsibility but also promoting collaboration between the government and the community. Also the M&E module ensures that climate governance strategies are grounded in empirical evidence, increasing the likelihood of their success and effectiveness. Citizens can therefore monitor climate initiatives, hold policymakers accountable, and participate in sustainability.

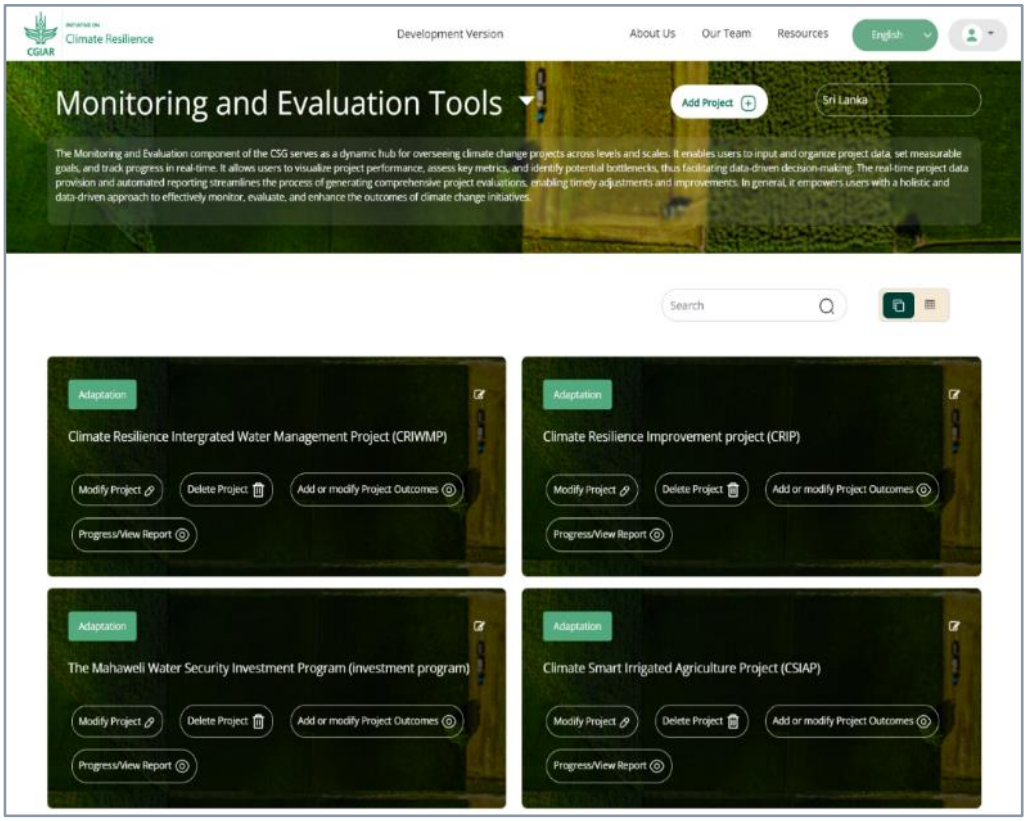

Figure 12:Interface of Monitoring and Evaluation

4.8 Geo-intelligence

Geo-intelligence module offers a strategic integration of geographical information and advanced analytics to enhance climate change decision-making (Figure 12). Through the integration of geographical data and advanced analytics, policymakers can understand the spatial distribution of climate-related factors. This includes mapping vulnerabilities, identifying hotspots, and visualizing the impact of climate change across different regions while understanding, assessing, and addressing the impacts of climate change. The geo-intelligence contributes to effective risk assessment and mitigation by overlaying data on climate hazards, socio-economic factors, and environmental conditions, to gain an understanding of the area's most at risk, including the identification of vulnerable populations, critical infrastructure, and ecosystems.

Embedded within the geo-intelligence module is the Project Feature. This key feature empowers users by enabling them to monitor both implemented and ongoing climate adaptation projects at the provincial level in a particular country. This encompasses a nuanced categorization system, delving into subcategories such as adaptation, mitigation, and cross-cutting initiatives. Geo-intelligence also promotes cross-sectoral collaboration as stakeholders can leverage spatial insights to coordinate efforts and develop integrated solutions. This interdisciplinary approach enhances the effectiveness of climate policies by fostering a holistic understanding of the interconnected nature of climate-related challenges at both local and national scales. Furthermore, Geo-intelligence supports monitoring and evaluation efforts. The integration of geospatial data enables the tracking of climate change indicators, the assessment of the effectiveness of implemented policies, and the measurement of progress toward sustainability goals.

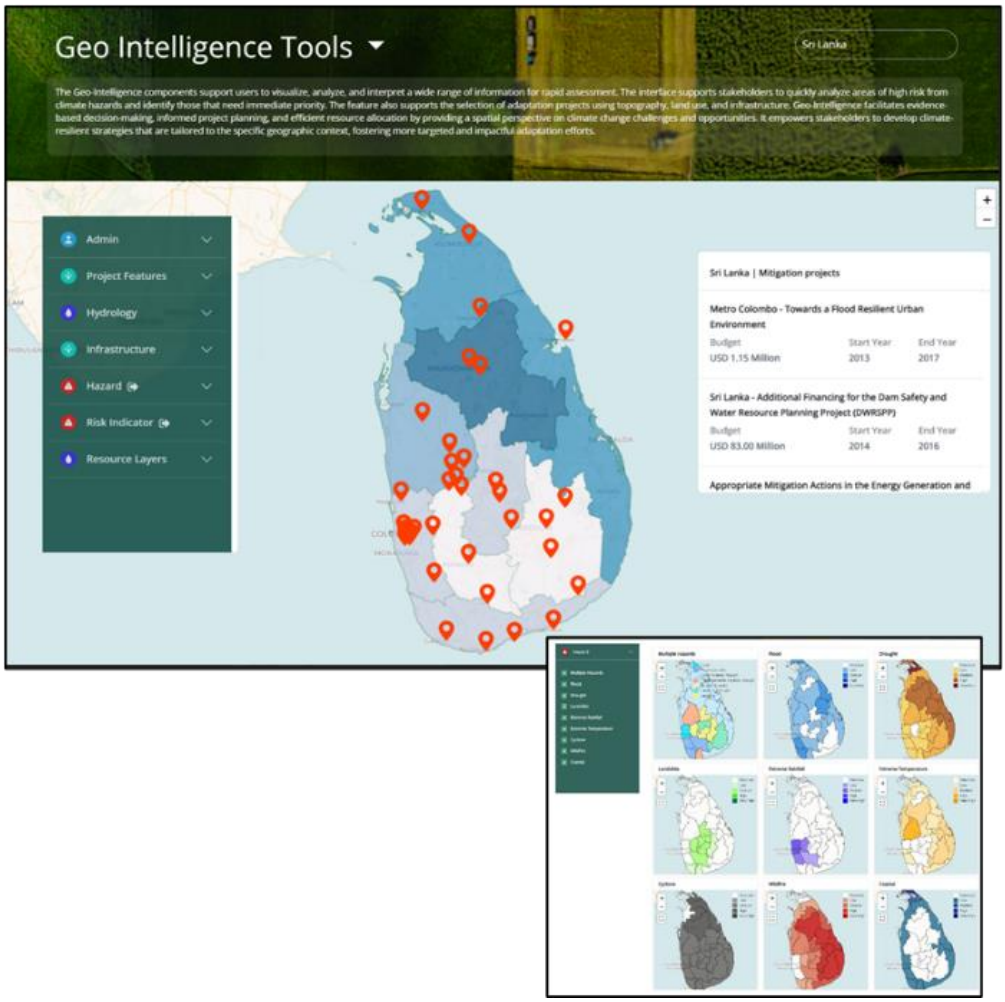

Figure 13:Interface of Geo Intelligence

4.9 Nationally Determined Contributions Tracker

The Nationally Determined Contributions Tracker (NDCT) module monitors and evaluates countries' progress toward their climate commitments under the Paris Agreement. This module provides real-time tracking of Nationally Determined Contributions, offering detailed insights into the pledges and actions of each country to reduce greenhouse gas emissions and adapt to climate change impacts. Combining data on national targets, policies, and measures, the NDC Tracker enable effective assessment of climate strategies, identifying gaps, and promoting transparency and accountability in climate governance.

Integral to the NDCT module is its alignment with the Sustainable Development Goals (SDGs), ensuring that climate actions contribute to broader socio-economic and environmental objectives. The module links NDCs to various sectors such as water, fisheries, tourism, biodiversity, etc. which are critical for achieving SDGs like sustainable cities and communities (SDG 11), and life on land (SDG 15) etc. Mapping NDC targets and actions to specific SDGs highlights co-benefits and synergies, demonstrating how climate policies can drive sustainable development across multiple dimensions. Moreover, the NDCT module facilitates peer learning and best practice sharing by showcasing successful examples of climate-smart initiatives. Users can explore case studies and innovative solutions that have effectively advanced both NDC objectives and SDG targets, fostering a collaborative environment for scaling impactful interventions.

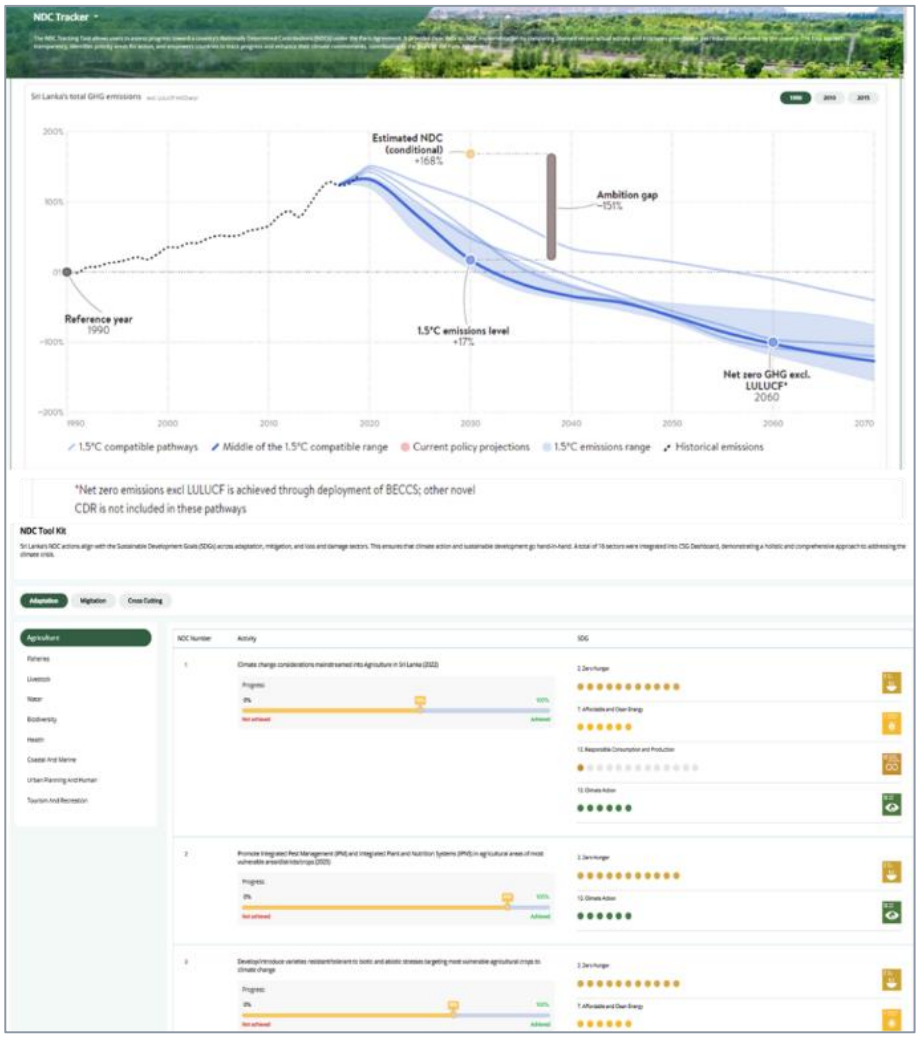

Figure 14:Interface of Nationally Determined Contributions Tracker

5. Reflections

As the Climate Smart Governance Dashboard emerges as a powerful tool to support cross-sectoral transformative adaptation, it becomes apparent that there are exciting possibilities for its application in diverse contexts and avenues for future research. Here, we reflect on the potential case applications that showcase the dashboard's utility.

5.1 Case applications

Given that climate change is characterized as a wicked problem, requiring comprehensive and collaborative responses that transcend geographical boundaries and disciplinary silos. The CSG dashboard facilitates the integration of climate data into governance frameworks and fosters inclusive, accountable, and transparent engagement in climate governance and decision-making processes. The CSG can contribute to addressing the complexity of the climate change problem by providing easy access to comprehensive climate data that enables evidence-based decision-making and policy formulation. It allows for the identification of current and future climate trends, vulnerabilities, and risks, thereby enhancing adaptive capacity and resilience. This integration of climate data into governance frameworks aligns with the principles of multi-level governance, emphasizing the importance of collaboration and integration of actions at different administrative levels.

Furthermore, the CSG dashboard facilitates cross-sectoral collaboration and integration of adaptation and mitigation measures. It allows stakeholders to assess the interactions and synergies of adaptation and mitigation strategies across different sectors, enabling the prioritization of actions and the prevention of unintended consequences. This holistic approach to climate governance is essential for addressing the interconnected impacts of climate change and maximizing the effectiveness of adaptation efforts. The application of the CSG dashboard therefore represents a significant step towards enhancing climate change governance and adaptation efforts in the face of climate variability and change. However, addressing implementation challenges and ensuring the long-term sustainability of the dashboard is critical in realizing its full potential in addressing the complex challenges of climate change. The usefulness of the CSG dashboard as identified with and by stakeholders in Sri Lanka are:

1 Development of National Adaptation Plans (NAPs): The CSG dashboard can play a pivotal role in the development, implementation, and monitoring of NAPs. By providing a centralized platform for data collection, analysis, and visualization, countries can assess climate risks, identify adaptation priorities, and allocate resources effectively. For example: In Sri Lanka, the dashboard is seen to have the potential to be used to map climate vulnerabilities across sectors such as agriculture, water resources, and infrastructure to inform the formulation of sector-specific adaptation strategies and the prioritization of actions in the country's NAP.

2. Enhancement of Nationally Determined Contributions (NDCs): Countries can utilize the dashboard to enhance the ambition, transparency, and implementation of their NDCs under the Paris Agreement. By tracking progress towards NDC targets, analyzing mitigation and adaptation synergies, and engaging stakeholders in NDC implementation, the dashboard supports a comprehensive approach to climate action. For example, Sri Lanka aims to utilize the dashboard to align its NDC targets with sectoral adaptation priorities identified through data analysis. The dashboard is seen as a platform with the potential to monitor progress on emissions reduction, renewable energy deployment, and resilience-building measures. This data-driven approach will enable the country to update its NDC with more ambitious and evidence-based targets.

3. Multi-stakeholder collaboration for climate resilience: The dashboard can facilitate multi-stakeholder collaboration and partnerships for climate resilience at the national level. By bringing together government agencies, local authorities, civil society organizations, academia, and the private sector, countries can foster dialogue, share knowledge, and co-design climate-smart policies and programs. For example, Zambia, Senegal, and Sri Lanka see the potential of the dashboard as a central hub for a national climate resilience coalition where stakeholders from diverse sectors will collaborate on initiatives such as sustainable land management, disaster risk reduction, and climate-smart agriculture.

4. Supporting climate finance: The application of the CSG dashboard to mobilize climate finance is instrumental in ensuring strategic and impactful acquisition and allocation of resources. Data and information from the dashboard will enable policymakers and stakeholders to identify priority areas for investment based on empirical assessments of climate risks and vulnerabilities. This data-driven approach enhances the credibility and transparency of funding proposals, thereby increasing the likelihood of securing financing from climate funds. The dashboard facilitates the tracking and monitoring of climate finance flows, ensuring that funds are disbursed efficiently and effectively to support mitigation, adaptation, and resilience-building initiatives.

Despite its potential benefits, a need for capacity building and technical expertise among users, ensuring data quality, consistency, and interoperability, and securing long-term financial resources for maintenance and updates are vital to improving its useability. Addressing these challenges will require continued research, capacity-building efforts, and policy support.

5.2 CSG contribution towards a transformative adaptation

The CSG dashboard holds significant potential to contribute to and advancement of transformative adaptation across various dimensions by addressing key issues of *systemic changes* in response to climate change impacts. The dashboard provides comprehensive data and information on climate risks and vulnerabilities, enabling stakeholders to gain an understanding of the complex challenges posed by climate change and identify transformative adaptation pathways that go beyond incremental changes to existing practices. It achieves these by, *restructuring:* the dashboard can empower decision-makers to identify areas necessitating substantial structural changes, such as transitioning from traditional land use practices to more resilient alternatives like agroforestry or sustainable water management. By providing comprehensive data analytics and visualizations, the dashboard can facilitate the recognition of ecological shifts and prompt strategic restructuring efforts to align with changing climate conditions and enhance resilience.

The dashboard can also play a significant role in facilitating *path-shifting* by guiding stakeholders towards alternative trajectories better suited for climate resilience. Through real-time data updates and scenario planning capabilities, it can empower decision-makers to explore and implement innovative strategies, redirecting pathways towards more adaptive practices and mitigating vulnerability. This capacity to inform strategic decision-making enables communities and policymakers to proactively adapt to evolving climate challenges and seize opportunities for transformative change. *Innovation* is at the core of transformative adaptation. CSG serves as a repository of best practices, emerging technologies, and adaptive solutions, it inspires stakeholders to embrace innovative approaches tailored to their specific contexts. CSG through knowledge exchange nurtures a culture of experimentation and learning, driving continuous innovation in climate adaptation strategies and fostering resilience in the face of uncertainty.

Furthermore, the *multiscale* capability of the dashboard ensures that adaptation efforts transcend local boundaries and address challenges at various administrative levels. By facilitating collaboration and coordination among stakeholders across different scales – from local communities to national governments and international organizations, CSG promotes integrated, multi-level governance approaches to climate adaptation. This holistic perspective fosters synergies, minimizes trade-offs, and maximizes co-benefits, enhancing the effectiveness and scalability of adaptation efforts. CSG's capability to influence governance structures and policy frameworks at all levels demonstrates its *Systemwide* impact contribution to transformative adaptation. The dashboard's role in mainstreaming climate considerations into decision-making processes and promoting the integration of adaptation priorities across sectors drives systemic changes that endure over time. This systemic approach ensures that adaptation efforts are embedded within broader development agendas, promoting sustainability and resilience across socio-ecological systems. Finally, the *persistent* influence of the CSG dashboard lies in its capacity to sustainably transform socio-ecological systems, driving enduring change towards climate resilience and sustainability. Through its dynamic interface, actionable insights, and collaborative features, the dashboard empowers stakeholders to navigate complex adaptive pathways, adapt to changing conditions, and build resilient communities that thrive in a rapidly changing climate.

5.3 Future research directions

Future research directions to improve CSG useability include *first,* Integration of the dashboard into the development and implementation of national adaptation plans (NAPs) and Nationally Determined Contributions (NDCs). This includes exploring how the dashboard can facilitate the identification of adaptation priorities, the assessment of vulnerabilities, and the monitoring of progress toward NAP and NDC goals. *Second,* studies could assess the effectiveness of the dashboard in improving the efficiency and effectiveness of adaptation measures. This may involve evaluating its role in enhancing adaptive capacity, reducing vulnerability, and promoting resilience at national and sub-national levels.

Third, research could explore the design and implementation of capacity-building programs to empower stakeholders in utilizing the dashboard effectively. This includes developing training materials, workshops, and online resources to enhance data literacy and decision-making skills. *Fourth,* economic studies could investigate the cost-effectiveness of adaptation interventions guided by the dashboard. This may incorporate assessing the return on investment of climate-resilient infrastructure, ecosystem-based adaptation measures, and risk reduction strategies. Fifth, future research should delve into the policy integration and coherence facilitated by the dashboard across different sectors. The analysis should cover how the CSG helps align climate adaptation policies with broader sustainable development goals, national strategies, and sectoral plans.

5.4 Recommendations

The CSG dashboard is a promising development in the pursuit of effective climate change mitigation and adaptation strategies. Reflecting on the policy suggestions for the CSG dashboard, we recommend data transparency and accessibility as critical elements in fostering accountability but also for informed decision-making, enabling tracking progress and adjusting strategies based on the most up-to-date information.

Policies on climate governance should include strategies for effectively communicating complex environmental data to the public, fostering a sense of shared responsibility in the fight against climate change. By making relevant climate data and information accessible to the public in an easily understandable format, the dashboard can empower citizens to take an active role in advocating for sustainable policies. Informed and engaged citizens are more likely to support and participate in government initiatives aimed at addressing climate change.

Interoperability and integration with existing government systems are essential considerations for the successful implementation of the CSG dashboard. To maximize its impact, the dashboard should be integrated with other relevant databases and systems across different government agencies. This integration will ensure that policymakers have a holistic view of climate-related activities and can coordinate efforts more effectively. Additionally, interoperability facilitates a streamlined approach to data collection and reporting, reducing duplication of efforts and enhancing overall efficiency.

Security and privacy concerns about CSG must be addressed. Given the sensitivity of climate-related data, robust security measures must be in place to protect against unauthorized access and potential misuse. Clear guidelines on data privacy and protection should be established to build public trust and confidence in the use of the dashboard. Striking the right balance between transparency and data security is crucial to ensure the successful adoption and acceptance of the dashboard by both government agencies and the public.

Continuous improvement and adaptability are key principles that should be embedded in the CSG. The dashboard should not be static but rather evolve with advancements in technology and changes in the climate landscape. Regular assessments and updates to the dashboard's features and functionalities will ensure its relevance and effectiveness in supporting government efforts to combat climate change. As a dynamic tool, the dashboard can contribute significantly to the ongoing commitment to building a sustainable and resilient future.

6. Conclusion

In a world where climate change presents a wicked problem of unprecedented complexity, the Climate Smart Governance (CSG) Dashboard holds immense potential for guiding climate actions at national and sub-national levels. The dashboard emerges as a transformative tool, embodying the principles of climate smart governance by fostering collaboration, innovation, and resilience across sectors. Through its design and user choices, the dashboard empowers stakeholders with actionable insights, data-driven assessments, and visualization tools to make informed decisions. It facilitates cross-sectoral collaboration, enabling diverse stakeholders to come together, align priorities, and co-create solutions. By enhancing decision-making support, the dashboard equips policymakers, planners, and communities with the knowledge needed to build resilience and sustainability.

The software architecture of the CSG Dashboard, meticulously crafted with powerful frameworks and tools, ensures data integration, effective visualization, and user interaction. Leveraging technologies such as Django REST Framework, MySQL, Leaflet.js, and D3.js, the dashboard provides a dynamic and interactive platform for monitoring and analyzing climate-related information. The diverse components of the CSG Dashboard, from country overviews to investment portfolio planning, contribute to its holistic approach to climate governance. By integrating real-time data, fostering stakeholder collaboration, and providing tools for monitoring and evaluation, the dashboard catalyzes informed decision-making and adaptive strategies.

The future research directions outlined reveal the vast potential for the CSG dashboard to integrate deeply into national adaptation planning, assess adaptation effectiveness, support capacity building initiatives, conduct economic analyses of adaptation investments, and promote policy integration across sectors. These avenues of exploration hold the promise of enhancing the dashboard's utility and effectiveness in advancing climate smart governance strategies.

The presented case applications offer concrete illustrations of how the dashboard can be applied in diverse real-world scenarios. From its role in shaping National Adaptation Plans (NAPs) to strengthening Nationally Determined Contributions (NDCs) under the Paris Agreement, and facilitating multi-stakeholder collaborations for climate resilience, the dashboard demonstrates its versatility and profound impact. These case studies underscore the transformative potential of data-driven decision-making, technological innovation, and collaborative partnerships in addressing the complex challenges of climate change.

Finally, the recommendations emphasize critical factors essential for the successful implementation and adoption of the CSG dashboard. Key considerations such as data transparency, accessibility, interoperability with existing government systems, and robust security measures are vital to ensure its effectiveness and widespread acceptance. By promoting informed citizen engagement, fostering efficient coordination among governmental bodies, and adapting to evolving technological and climate landscapes, the dashboard can emerge as a cornerstone of climate-smart governance.

References

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global environmental change*, *15*(2), 77-86.

Ambani, M., Gbetibouo, G. A., & Percy, F. (2021). Multi-stakeholder dialogue to co-design anticipatory adaptation: lessons from participatory scenario planning in Africa. *Handbook of Climate Change Management: Research, Leadership, Transformation*, 1-25.

Balogun, A. L., Marks, D., Sharma, R., Shekhar, H., Balmes, C., Maheng, D., ... & Salehi, P. (2020). Assessing the potentials of digitalization as a tool for climate change adaptation and sustainable development in urban centres. *Sustainable Cities and Society*, *53*, 101888.

Bauer, A., Feichtinger, J., & Steurer, R. (2012). The governance of climate change adaptation in 10 OECD countries: challenges and approaches. *Journal of Environmental Policy & Planning*, *14*(3), 279-304.

Berrang-Ford, L., Biesbroek, R., Ford, J. D., Lesnikowski, A., Tanabe, A., Wang, F. M., ... & Heymann, S. J. (2019). Tracking global climate change adaptation among governments. *Nature Climate Change*, *9*(6), 440-449.

Berry, P. M., Brown, S., Chen, M., Kontogianni, A., Rowlands, O., Simpson, G., & Skourtos, M. (2015). Cross-sectoral interactions of adaptation and mitigation measures. *Climatic Change*, *128*, 381-393.

Bettini, G., Gioli, G., & Felli, R. (2020). Clouded skies: How digital technologies could reshape "Loss and Damage" from climate change. *Wiley Interdisciplinary Reviews: Climate Change*, *11*(4), e650.

Bhandari, P. (2024). Building Resilience for an Uncertain Climate Future. *Ecology, Economy and Society–the INSEE Journal*, *7*(1), 161-164.

Biesbroek, G. R., Termeer, C. J., Klostermann, J. E., & Kabat, P. (2014). Rethinking barriers to adaptation: Mechanism-based explanation of impasses in the governance of an innovative adaptation measure. *Global Environmental Change*, *26*, 108-118.

Black, M. S., Parry, I. W., Mylonas, M. V., Vernon, N., & Zhunussova, K. (2023). *The IMF-World Bank Climate Policy Assessment Tool (CPAT): A Model to Help Countries Mitigate Climate Change*. International Monetary Fund.

Boswell, M. R., Greve, A. I., & Seale, T. L. (2019). *Climate action planning: a guide to creating low-carbon, resilient communities*. Island Press.

Brockhaus, M., Djoudi, H., & Kambire, H. (2012). Multi-level governance and adaptive capacity in West Africa. *International Journal of the Commons*, *6*(2).

Cavan, G., Butlin, T., Gill, S., Kingston, R., & Lindley, S. (2014). Web-GIS Tools for Climate Change Adaptation Planning in Cities. *Handbool of Climate Change Adaptation. Springer Verlag, Berlin Heidelberg, Germany*.

Di Gregorio, M., Fatorelli, L., Paavola, J., Locatelli, B., Pramova, E., Nurrochmat, D. R., ... & Kusumadewi, S. D. (2019). Multi-level governance and power in climate change policy networks. *Global environmental change*, *54*, 64-77.

Diduck, A. (2010). The learning dimension of adaptive capacity: Untangling the multi-level connections. *Adaptive capacity and environmental governance*, 199-221.

Dittmer, K.M., Wollenberg, E., Burns, S., Shelton, S.W. (2022). Digital tools for climate change adaptation and mitigation. Agroecological TRANSITIONS: Inclusive Digital Tools to Enable Climate-informed Agroecological Transitions (ATDT). Cali, Colombia: Alliance of Bioversity & CIA

Djalante, R. (2012). " Adaptive governance and resilience: the role of multi-stakeholder platforms in disaster risk reduction". *Natural Hazards and Earth System Sciences*, *12*(9), 2923-2942.

Donner, S. D., Kandlikar, M., & Webber, S. (2016). Measuring and tracking the flow of climate change adaptation aid to the developing world. *Environmental Research Letters*, *11*(5), 054006.

Dressel, S., Johansson, M., Ericsson, G., & Sandström, C. (2020). Perceived adaptive capacity within a multi-level governance setting: The role of bonding, bridging, and linking social capital. *Environmental Science & Policy*, *104*, 88-97.

Eichhorn, S., Hans, M., & Schön-Chanishvili, M. (2021). A participatory multi-stakeholder approach to implementing the Agenda 2030 for sustainable development: theoretical basis and empirical findings. *A Nexus Approach for Sustainable Development: Integrated Resources Management in Resilient Cities and Multifunctional Land-use Systems*, 239-256.

England, M. I., Dougill, A. J., Stringer, L. C., Vincent, K. E., Pardoe, J., Kalaba, F. K., ... & Afionis, S. (2018). Climate change adaptation and cross-sectoral policy coherence in southern Africa. Regional Environmental Change, 18, 2059-2071.

Falco, E., & Kleinhans, R. (2019). Digital participatory platforms for co-production in urban development: A systematic review. *Crowdsourcing: Concepts, methodologies, tools, and applications*, 663-690.

Feltmate, B., & Thistlethwaite, J. (2012). Climate change adaptation: A priorities plan for Canada. *Climate Change Adaptation Project (Canada)*.

Finnessey, T., Hayes, M., Lukas, J., & Svoboda, M. (2016). Using climate information for drought planning. *Climate Research*, *70*(2-3), 251-263.

Fröhlich, J., & Knieling, J. (2013). Conceptualising climate change governance. *Climate change governance*, 9-26.

Gills, B., & Morgan, J. (2022). Global climate emergency: After COP24, climate science, urgency, and the threat to humanity. In *Economics and climate emergency* (pp. 253-270). Routledge.

Gonzales-Iwanciw, J., Dewulf, A., & Karlsson-Vinkhuyzen, S. (2020). Learning in multi-level governance of adaptation to climate change–a literature review. *Journal of Environmental Planning and Management*, *63*(5), 779-797.

Gupta, A., & van Asselt, H. (2019). *Transparency and Accountability in Multilateral Climate Politics* (pp. 37-62). Cambridge, MA: MIT Press.

Gupta, J. (2007). The multi-level governance challenge of climate change. Journal of Integrative Environmental Sciences, 4:3, 131-137, DOI: 10.1080/15693430701742669

Hritonenko, V., & Yatsenko, Y. (2022). Sustainable adaptation and mitigation in regions and cities: Review of decision-support methods. *Resources, Conservation & Recycling Advances*, *13*, 200066.

Hughes, S., Giest, S., & Tozer, L. (2020). Accountability and data-driven urban climate governance. *Nature Climate Change*, *10*(12), 1085-1090.
Incropera, F. P. (2016). Climate change: a wicked problem: complexity and uncertainty at the intersection of science, economics, politics, and human behavior. Cambridge University Press.
IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–33, doi:10.1017/9781009325844.001.
Jordan, A. J., van Asselt, H., Berkhout, F., Huitema, D., & Rayner, T. (2012). Climate change policy in the European Union: Understanding the paradoxes of multi-level governing. *Global Environmental Politics*, *12*(2), 43-66.
Keskitalo, E. C. H. (Ed.). (2010). *Developing adaptation policy and practice in Europe: multi-level governance of climate change* (pp. 1-38). Dordrecht: Springer.
Kretser, J., & Chandler, K. (2020). Convening young leaders for climate resilience. *Journal of Museum Education*, *45*(1), 52-63.
Lamhauge, N., & Jachnik, R. (2018). Tracking climate finance: Progress and challenges. *Organisation for Economic Cooperation and Development. The OECD Observer*, 1-3.
Larson, A. M., & Sarmiento Barletti, J. P. (2020). *Designing for engagement: Insights for more equitable and resilient multi-stakeholder forums* (Vol. 280). CIFOR.
Lawrence, S., López Ventura, J., Doody, L., & Peracio, P. (2017). Polisdigitocracy: Citizen engagement for climate action through digital technologies. *Field Actions Science Reports. The journal of field actions*, (Special Issue 16), 58-65.
Maguire-Rajpaul, V. A., Sandbrook, C., McDermott, C., & Hirons, M. A. (2022). Climate-smart cocoa governance risks entrenching old hegemonies in Côte d'Ivoire and Ghana: a multiple environmentality analysis. *Geoforum*, *130*, 78-91.
Maguire-Rajpaul, V. A., Sandbrook, C., McDermott, C., & Hirons, M. A. (2022). Climate-smart cocoa governance risks entrenching old hegemonies in Côte d'Ivoire and Ghana: a multiple environmentality analysis. *Geoforum*, *130*, 78-91.
McHugh, L. H., Lemos, M. C., & Morrison, T. H. (2021). Risk? Crisis? Emergency? Implications of the new climate emergency framing for governance and policy. *Wiley Interdisciplinary Reviews: Climate Change*, *12*(6), e736.
McIntosh, O. B., Burnett, A., Feldman, I., Lamphere, J. A., Reuter, T. A., & Vital, E. (2023). The role of sustainability knowledge-action platforms in advancing multi-stakeholder engagement on sustainability. *Data & Policy*, *5*, e33.
Miceli, A., Hagen, B., Riccardi, M. P., Sotti, F., & Settembre-Blundo, D. (2021). Thriving, not just surviving in changing times: How sustainability, agility and digitalization intertwine with organizational resilience. *Sustainability*, *13*(4), 2052.
Muiderman, K., Gupta, A., Vervoort, J., & Biermann, F. (2020). Four approaches to anticipatory climate governance: Different conceptions of the future and implications for the present. *Wiley Interdisciplinary Reviews: Climate Change*, *11*(6), e673.
Neely, C. L., Bourne, M., Chesterman, S., Vågen, T. G., Lekaram, V., Winowiecki, L. A., & Prabhu, R. (2021). Inclusive, cross-sectoral and evidence-based decision-making for resilience planning and decision-making in a devolved context. *The European Journal of Development Research*, *33*(4), 1115-1140.
Nilsson, A. E., Gerger Swartling, Å., & Eckerberg, K. (2012). Knowledge for local climate change adaptation in Sweden: challenges of multilevel governance. Local Environment, 17(6-7), 751-767.
NOAA (2023). Monthly Global Climate Report for Annual 2023. National Centers for Environmental Information published online January 2024, retrieved on March 4, 2024 from https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202313.
Parker, L., Bourgoin, C., Martinez-Valle, A., & Läderach, P. (2019). Vulnerability of the agricultural sector to climate change: The development of a pan-tropical Climate Risk Vulnerability Assessment to inform sub-national decision making. *PloS one*, *14*(3), e0213641.
Perry, J. (2015). Climate change adaptation in the world's best places: A wicked problem in need of immediate attention. *Landscape and Urban Planning*, *133*, 1-11.
Preston, B. L., Yuen, E. J., & Westaway, R. M. (2011). Putting vulnerability to climate change on the map: a review of approaches, benefits, and risks. *Sustainability science*, *6*, 177-202.
Raihan, A. (2023). A review of the global climate change impacts, adaptation strategies, and mitigation options in the socio-economic and environmental sectors. *Journal of Environmental Science and Economics*, *2*(3), 36-58.
Scott, J. (2011). Multi-level governance of climate change. *Carbon & Climate L. Rev.*, 25.
Siders, A. R., & Pierce, A. L. (2021). Deciding how to make climate change adaptation decisions. *Current Opinion in Environmental Sustainability*, *52*, 1-8.
Sun, J., & Yang, K. (2016). The wicked problem of climate change: A new approach based on social mess and fragmentation. *Sustainability*, *8*(12), 1312.
Thaler, T., & Levin-Keitel, M. (2016). Multi-level stakeholder engagement in flood risk management—A question of roles and power: Lessons from England. *Environmental Science & Policy*, *55*, 292-301.
Tirpak, D., Brown, L., & Ronquillo-Ballesteros, A. (2014). Monitoring climate finance in developing countries: challenges and next steps. *World Resources Institute. Washington, DC*.
Tognetti, R., Smith, M., & Panzacchi, P. (2022). An Introduction to Climate-Smart Forestry in Mountain Regions. *Climate-Smart Forestry in Mountain Regions*, 1-33.
Ulibarri, N., Ajibade, I., Galappaththi, E. K., Joe, E. T., Lesnikowski, A., Mach, K. J., ... & Global Adaptation Mapping Initiative Team. (2022). A global assessment of policy tools to support climate adaptation. *Climate policy*, *22*(1), 77-96.

van Deursen, M. B. (2021). *Capacity Building for Climate Transparency as de Facto Governance*. WAGENINGEN UNIVERSITY.
Wamsler, C., Schäpke, N., Fraude, C., Stasiak, D., Bruhn, T., Lawrence, M., ... & Mundaca, L. (2020). Enabling new mindsets and

transformative skills for negotiating and activating climate action: Lessons from UNFCCC conferences of the parties. *Environmental science & policy*, *112*, 227-235.

Wamsler, C., Wickenberg, B., Hanson, H., Olsson, J. A., Stålhammar, S., Björn, H., ... & Zelmerlow, F. (2020). Environmental and climate policy integration: Targeted strategies for overcoming barriers to nature-based solutions and climate change adaptation. *Journal of Cleaner Production*, *247*, 119154.

Welp, M., de la Vega-Leinert, A., Stoll-Kleemann, S., & Jaeger, C. C. (2006). Science-based stakeholder dialogues: Theories and tools. *Global Environmental Change*, *16*(2), 170-

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