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Research Article

Enhancing climate change resilience: Assessing adaptation needs, and significance of monitoring and evaluation systems

Çiğdem TUĞAÇ*

Department of Political Science and Public Administration, Ankara Hacı Bayram Veli University, Faculty of Economics and Administrative Sciences, Ankara, Türkiye

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ABSTRACT

Losses and damages from climate change-related extreme weather events and disasters require the development of adaptation measures to increase resilience to the adverse impacts of climate change. In line with the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement's Global Goal on Adaptation, Parties have developed strategies that include adaptation actions, but there are significant gaps in the identification of adaptation needs and the monitoring and evaluation (M&E) of actions to address them. Adaptation M&E systems are critical for measuring the success of adaptation actions, providing feedback from the implementation process, and identifying new actions. There is no global methodology for adaptation M&E. At international climate change negotiations in 2023, it was agreed that countries should operationalize their national adaptation M&E systems by 2030. The study aims to evaluate adaptation M&E methodologies developed by countries at different development levels and to present future policy recommendations for the adaptation M&E system planned to be established in Türkiye. The study reveals the necessity of up-to-date socio-economic data as well as climate data in determining adaptation needs and adaptation M&E systems. In Türkiye, which is vulnerable to the impacts of climate change, for the success of adaptation actions, besides the rapid operationalization of the adaptation M&E system, the establishment of the system with an approach that includes all stakeholders in the process and considers adaptation actions as integrated with disaster risk management actions is an important requirement in the context of Türkiye's international commitments, national security, and development.

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INTRODUCTION

The two key strategies identified by the United Nations (UN) for combating climate change today are mitigation of greenhouse gas emissions and adaptation to the adverse effects of climate change. Adaptation to climate change is becoming increasingly important in today's conditions, where climate-related extreme weather events are increasing. Adapting to climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as "In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" [1]. In addition to determining the needs that require adaptation to climate change and the actions taken towards them, conducting monitoring and evaluation (M&E) that will make it possible to evaluate the effectiveness of these actions and learn from the results is very important in determining forward-looking adaptation strategies [2].

***Corresponding author.**
*E-mail address: cigdem.tugac@hbv.edu.tr

Climate change adaptation efforts, actively pursued through the UNFCCC and the Paris Agreement, specifically aim to achieve the Global Goal on Adaptation (GGA). The main components of the GGA, which are detailed under Article 7 of the Paris Agreement and form the basis of adaptation efforts, include the following [3–5]:

- Enhancing adaptive capacity,
- Reinforcing resilience,
- Mitigating vulnerability to climate change.

The importance of the GGA and its components lies in the escalating frequency, severity, and global scale of climate change impacts, resulting in widespread loss and damage worldwide [1]. Even if countries aim for net-zero emissions, the lasting effects of historical emissions will persist for centuries. This underscores the urgency of conducting studies on adapting to climate change, enhancing climate resilience, and reducing vulnerabilities across sectors to achieve the GGA targets [1, 6].

In this context, there is a growing body of research dedicated to ensuring sustainable and climate-resilient development in economic sectors [7, 8], establishing efficient and flexible heating, cooling, and energy systems [9–12], climate-sensitive urban planning and design [13–15], local climate action [16, 17], public health protection [18], disaster risk management [19, 20], capacity building in legal, human, and administrative systems [21, 22], ecosystem protection, and using nature-based solutions to combat climate change [23, 24], constructing climate-resilient infrastructure [25, 26], ensuring water and food security [27–29], and combating drought [30, 31]. A plethora of studies have demonstrated that the implementation of adaptation actions in order to achieve the GGA objectives not only enhances resilience but also yields considerable environmental, economic, and social benefits by reducing vulnerability [1].

However, assessing the success of adaptation actions involves some difficulties in itself. This is because, while M&E methodologies that show the success of actions to reduce greenhouse gas emissions on a global scale in terms of carbon dioxide (CO_2) equivalents have already been established, there is not yet a global M&E (and Learning-MEL[1]) system or methodology that would enable the monitoring of the adequacy and effectiveness of global efforts to adapt to climate change to achieve the goals of the GGA or that would link national M&E systems. Although efforts are underway to establish such a system, there is a need to improve these efforts [3, 4, 32–34]. The Annual Report of the UNFCCC Adaptation Committee published on 26 October 2023 also emphasized the need for studies and adaptation M&E systems to guide planning for adaptation to climate change. Among these efforts, it was stated that work is underway to prepare a technical document for establishing an M&E system and to support Parties' adaptation actions within the framework of National Adaptation Plans (NAPs) [35].

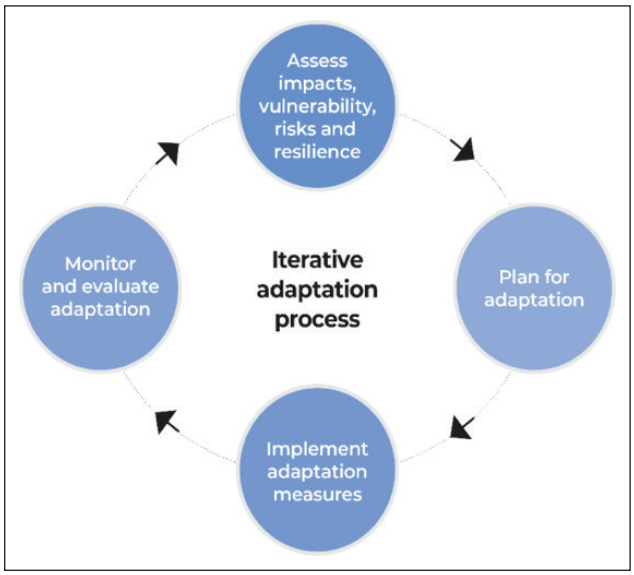

Figure 1. UN adaptation cycle [41].

Establishing adaptation M&E systems was also one of the main subjects of the Adaptation Gap Report published by the UN Environment Program (UNEP) in 2023. The Report emphasized that adaptation M&E systems are relatively underdeveloped due to difficulties in developing systems and methodologies for understanding the effectiveness of planning and implementation of adaptation actions. However, today, the pressure in legal and financial processes that require proving the effectiveness and success of adaptation actions, especially in international climate change negotiations, is increasing, further increasing the importance of adaptation M&E systems [36].

During the 28th Conference of the Parties (COP 28) to the UNFCCC held in Dubai from November 30th to December 13th, 2023, the taken decisions reflected the necessity for M&E systems for adaptation actions. COP28 was the first of the Global Stocktakes (GST), which will now take place every five years. Under the GST, Parties to the UNFCCC and the Paris Agreement are urged to demonstrate their national mitigation and adaptation actions clearly. Hence, the M&E of adaptation actions has become as crucial as their planning. At COP28, the GST Decision-CMA5 document, which outlines the decisions, specifies a timeline for a roadmap defining the adaptation actions that countries need to undertake within the adaptation cycle (Fig. 1) established by the UN [37]. The COP28 decision text encompasses the completion of planning and policy development processes regarding adaptation by all countries by 2025, ensuring their implementation until 2030, and the consolidation of adaptation-related information submitted by Parties in their biennial transparency reports within a synthesis report by the Secretariat (Articles 59 and 60) [38].

[1] In the context of adaptation M&E, integrating insights from action outcomes and experiences enhances the system, integrating the notion of 'Learning' into M&E frameworks. Some sources in the literature refer to these systems as MEL (Monitoring, Evaluation and Learning) [33].

Therefore, transparent reporting of the steps taken on adaptation has become very important. This means that the contribution levels of national actions to global efforts will be determined by developing national M&E systems for adaptation actions reported through National Communications (NCs), Nationally Determined Contributions (NDCs) and/or NAPs to the UNFCCC Secretariat [1, 33, 39, 40]. This is emphasized in the Adaptation section (Article 48) of the COP28 CMA5 document with the following statement: "Notes that there are gaps in implementation of, support for and collective assessment of the adequacy and effectiveness of adaptation, and that M&E of outcomes is critical for tracking the progress and improving the quality and awareness of adaptation action" [38].

Besides the above-mentioned documents, at UNFCCC COP28, as part of the United Arab Emirates Framework for Global Climate Resilience, within the adaptation cycle's defined objectives, the necessity for UNFCCC, and Paris Agreement parties, including Türkiye, to develop national MEL systems for adaptation by 2030 was highlighted. This is stated in the Glasgow–Sharm el-Sheikh Work Programme on the GGA referred to in decision 7/CMA.3 text (paragraph 10/d) as "Monitoring, evaluation and learning: by 2030 all Parties have designed, established and operationalized a system for monitoring, evaluation and learning for their national adaptation efforts and have built the required institutional capacity to fully implement the system" [37].

Another dimension of the need for adaptation M&E/MEL systems is undoubtedly related to adaptation financing. The delay in observing the outcomes of adaptation actions compared to mitigation actions raises discussions about how funds provided by developed countries for adaptation actions in developing countries are utilized, in other words, whether they are effectively used for adaptation actions in developing countries [34, 40, 42–44]. Therefore, the importance of adaptation M&E systems has also increased in the future to collect data for the necessary assessments to use the Loss and Damage Fund established at COP28 to compensate for losses and damage caused by extreme weather events and slow onset events in developing countries, as well as other existing sources of adaptation finance [39, 45].

As mentioned above, efforts to measure the effectiveness of adaptation actions through M&E have been ongoing for some time, mainly under the leadership of the UNFCCC Adaptation Committee. As a result, various approaches have been developed [46]. For example, there are indicators for assessing climate adaptation projects that apply to benefit from the Green Climate Fund, one of the funds under the UNFCCC and the Paris Agreement. However, these indicators are independent of the characteristics of the beneficiaries and are based on numerical results [34]. Most country-based indicator-driven adaptation M&E systems use different methods, with assessments based on fewer than 15 or more than 100 indicators. There is no standardized approach for collecting the data required for these indicators; surveys, workshops, interviews, and literature reviews are often used. In the assessment of adaptation actions, most developing countries do not have the basic data required for adaptation M&E, or there are problems with the quality and reliability of existing data. Another challenge in M&E of adaptation actions is the relationship of some actions with GHG mitigation actions. This situation adds uncertainties to adaptation M&E [1, 47, 48]. Nevertheless, the ongoing evolution of and insights gained from existing M&E methodologies are crucial for both national M&E/MEL systems, and the UNFCCC Secretariat in developing a methodology/system for M&E of global adaptation efforts. In addition, understanding the types of data used in the adaptation cycle and the existing methodologies developed by some countries for the M&E of adaptation actions is also of great importance in the context of reporting the national adaptation M&E methodology/systems requested from the Parties in line with the COP28 decision and the outputs to be obtained from them to the UNFCCC Secretariat.

In this framework, the study seeks answers to the following research questions:

1. What kind of data are used in determining the need for adaptation to climate risks and then determining adaptation actions, is only climate data sufficient?
2. What are the methodologies developed by countries at different levels of development for M&E of the effectiveness and adequacy of climate change adaptation actions and what is the situation in adaptation M&E in Türkiye?

MATERIAL AND METHODS

This study aims to evaluate the adaptation M&E methodologies developed by countries at different levels of development and to provide future policy recommendations for the adaptation M&E system planned to be established in Türkiye.

The study employed a relational research model to address the research questions and examined the relationship between climate change adaptation actions and the methodologies for adaptation M&E efforts (Fig. 2). Various international institutions such as the UN, UNFCCC, IPCC, along with publications, reports, websites related to climate change adaptation from Türkiye and other countries, were utilized as data sources, in addition to academic literature.

This study examines different M&E systems and approaches to climate change adaptation, revealing that this issue has not yet been comprehensively researched in Türkiye and many other countries, and contributes to the literature. The methodologies summarized here cover the elements of the systems and methodologies that the UNFCCC Secretariat requests from Türkiye and other countries to be established by 2030 regarding adaptation in international climate change negotiations. Therefore, Türkiye and other countries can benefit from the content of this study in the processes of developing policies on adaptation to climate change and establishing an M&E system for adaptation actions. The study aims to guide the revisions to be made to Türkiye's National Climate Change Adaptation Strategy and Action Plan (NCCASAP) in the future. In addition, the study aims to lay the groundwork for the establishment of

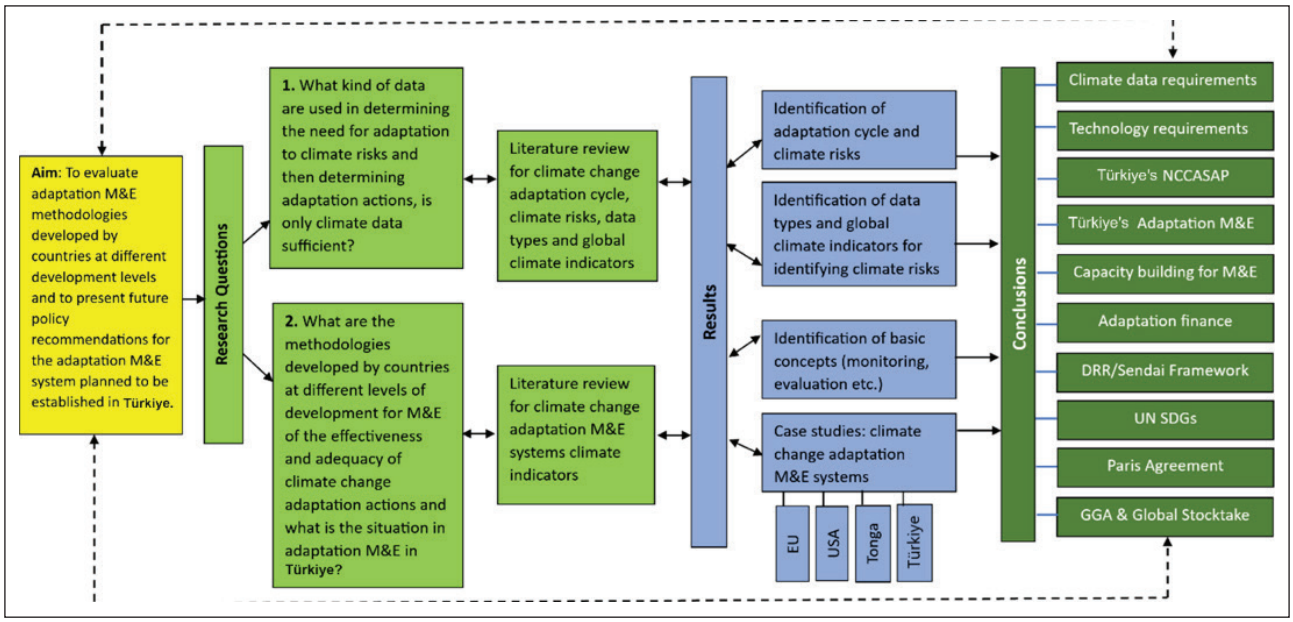

Figure 2. Conceptual method flowchart.

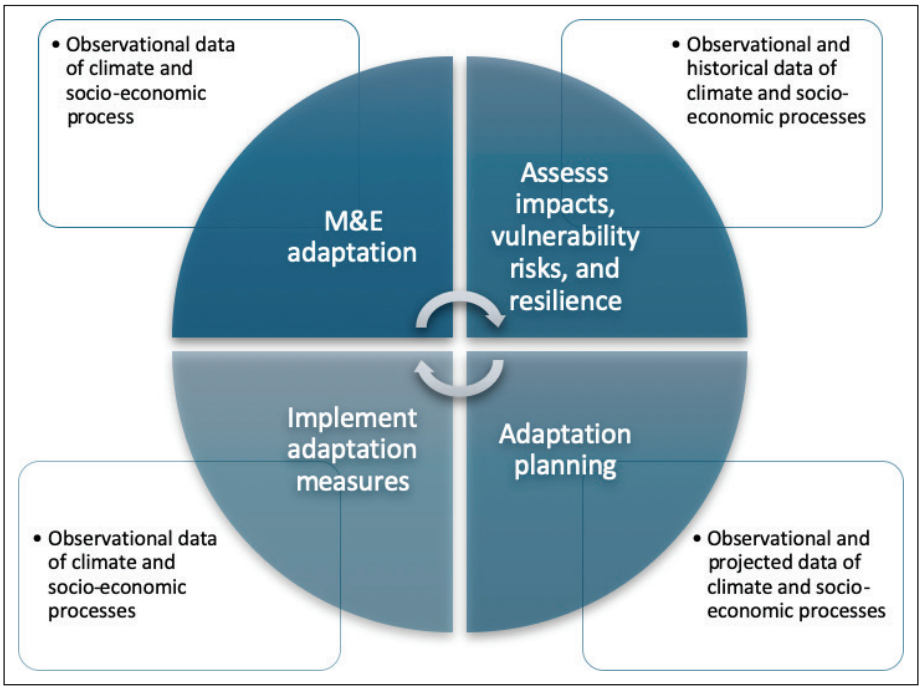

Figure 3. Data requirements in adaptation cycle [39].

an M&E/MEL system for NCCASAP in Türkiye and to facilitate academics to conduct further research in this field.

RESULTS AND DISCUSSION

Types of Data Necessary for Assessing Climate Risks and Adaptation Needs

The need for M&E systems to assess the effectiveness of climate change adaptation is growing. Therefore, data on adaptation is crucial. Article 7 of the Paris Agreement calls on Parties to use the best available science for adaptation. GSTs will assess global progress on adaptation and support the review process. The Cancun Framework for Adaptation provides the basis for strengthening data systems and making climate data available to decision-makers. Research and systematic observation are on the Subsidiary Body for Scientific and Technological Advice (SBSTA) agenda in international climate negotiations [5, 49, 50].

Preparation of adaptation-related communications for the UNFCCC Secretariat involves the use of tools such as NAP, NDC and NC, which highlight the need for different types of data across the four stages of the adaptation cycle (Fig. 3). The actions taken and the data used at each stage can be linked to M&E. The steps in this process are as follows [39, 47, 48]:

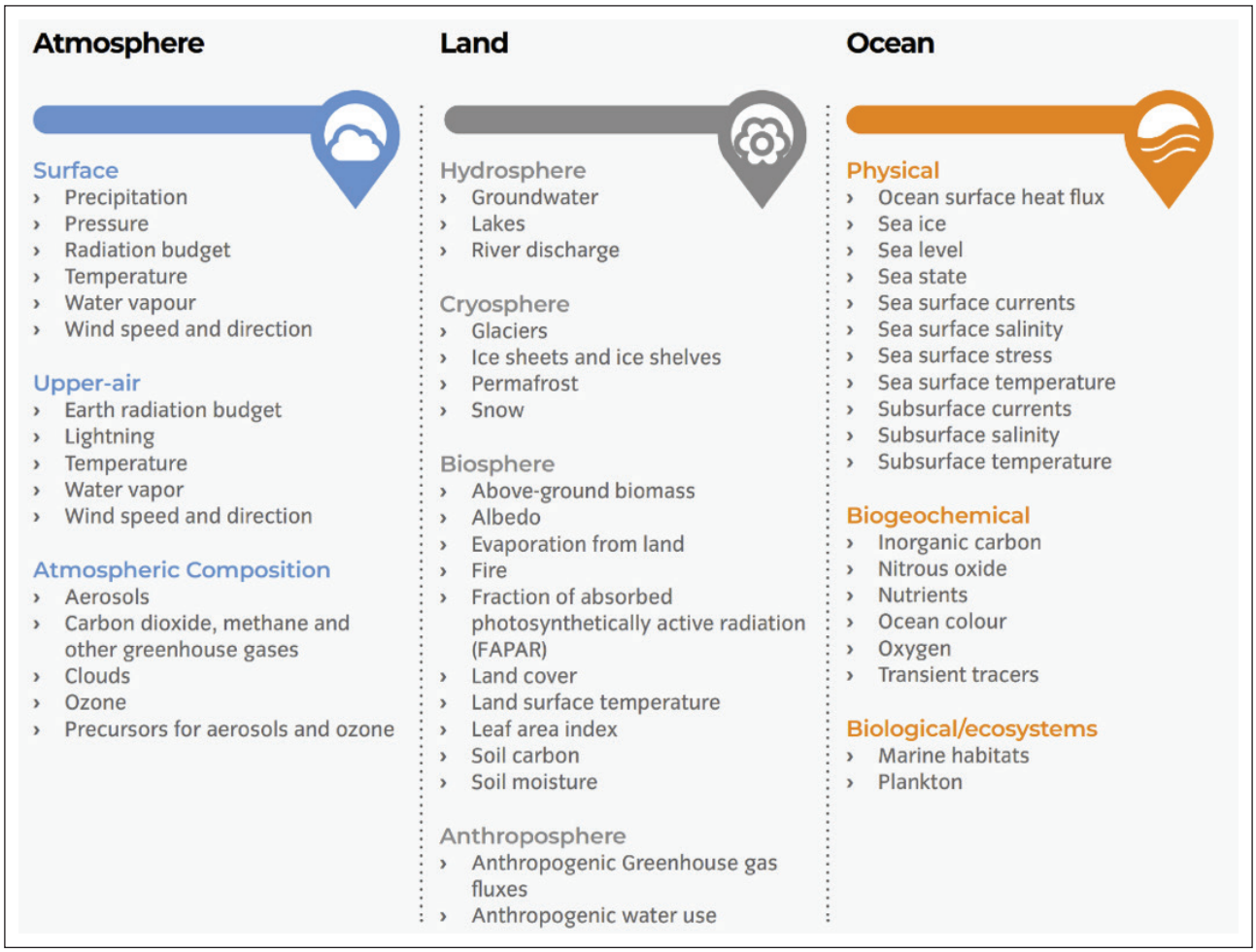

Figure 4. Global climate indicators [39, 52].

1. Assessment of impacts, vulnerability, climate risks and resilience (this initial step will also determine the measures to be used for M&E in step 4),
2. Adaptation planning (this step requires the identification of an appropriate set of adaptation measures, considering financial, administrative, and legal aspects. This process will help define other measures for the M&E stage),
3. Implementation of adaptation measures (this stage indicates whether the stages of the cycle are well designed and provides lessons learned from the established M&E system),
4. M&E of adaptation actions (conducting M&E at each stage of the cycle, not just at the end, will positively support the process).

In the IPCC 6th Assessment Report (AR6) Working Group II (WGII) on Impacts, Adaptation and Vulnerability report provides important insights into climate risks and adaptation data. It highlights the interconnected nature of climate risks, which arise from the interplay between climate-related hazards and the exposure and vulnerability of human and natural systems. These risks are shaped by both climate and socio-economic processes, underscoring the need for adaptation strategies to incorporate data from both domains to mitigate climate risks effectively [1].

The Global Climate Observing System (GCOS), supported by key organizations such as UNESCO's Intergovernmental Oceanographic Commission, World Meteorological Organization, UNEP, and the International Science Council, plays a critical role in collecting climate data. GCOS monitors atmospheric, terrestrial, and oceanic conditions and provides critical guidance for improving global climate conditions [51]. The global climate indicators that are essential to support mitigation and adaptation efforts are listed in Figure 4.

Economic and social data, as well as historical climate data, should be considered when conducting analyses at different scales within the four-stage adaptation cycle described above. However, it is only when these data are combined with climate data that consistent projections for adaptation can be developed. In other words, it is essential to make not only observations of the atmosphere, soil and ocean, but also observations of socio-economic processes to obtain the data necessary for the analyses to be carried out to determine adaptation needs. In this way short-, medium- and long-term adaptation plans can be made using the data obtained. Examples of socio-economic data that can be considered in this context are [39],

- Population data (e.g., total population, density, urban population, age and gender distribution, inequalities),
- Economic data (e.g., GDP, annual GDP growth rate, income from sectors such as climate-sensitive industry, agriculture),
- Land cover and land use (e.g., total land area, amount of cropland, rangeland, forest and other land and land uses),
- Water resources and water data (e.g., amount of water per capita, annual water withdrawals for different uses)
- Agriculture and food data reflecting the socio-economic situation (e.g., amount of irrigated land, amount of agricultural employment, total labor force, livestock, economic value of the agricultural sector).

The concept of adaptation needs refers to "the actions and resources required to complete all stages of the adaptation process, from assessing risks and vulnerabilities to planning, implementing, and monitoring and evaluating adaptation measures". The first step in the adaptation cycle is to identify adaptation needs in response to climate change impacts [47, 53].

The availability and accuracy of data is essential for consistent forecasting and adaptation planning. Based on these data, climate models help to make projections of weather, climate and socio-economic conditions. However, there are global challenges to the data used in these studies, such as the lack of observing systems in some regions and/or the unavailability of data in digital formats. Although it is possible to scale global data to local levels, the unpredictable nature of climate change poses some challenges in determining climate impacts. These challenges affect the identification and implementation of adaptation measures, particularly in the areas of food and water security, resilience, and disaster risk management [39]. These challenges arise from the following characteristics of adaptation actions [54, 55]:

- The results of adaptation measures can unfold over a long time period, sometimes several decades.
- While adaptation actions are determined based on local conditions, the unpredictable dimensions of climate change can further complicate local impacts. Measuring these uncertain conditions can be difficult and sometimes impossible.
- The existence, collection and assessment of data related to adaptation sectors can also be challenging and may require the measurement and assessment of events that have not yet occurred.
- There isn't a globally accepted methodology for conducting adaptation M&E, making it difficult to assess the impact of adaptation actions on a global scale.
- At local and national levels, terminology related to adaptation may be used in different contexts.
- There are also shortcomings in linking locally identified adaptation needs and actions to national programs.

Different climate and socio-economic data from observations and forecasts from different stakeholders around the world require standardization by institutions such as national meteorological and water management agencies. These data, supported by local input, are used to meet the data needs of adaptation planning, including the use of high-tech tools such as artificial intelligence and big data. In this context, climate services facilitate the use of scientifically produced data by facilitating collaboration between data producers and decision-makers [1, 2, 33, 39].

Methodologies Focused on the Adaptation M&E

It's critical to conduct M&E of implemented adaptation actions, which marks the fourth step in the adaptation cycle [5, 43]. IPCC's AR6 WGII Report highlights the importance of linking adaptation planning and M&E processes, especially in addressing the limits of adaptation and developing effective responses to climate change risks. According to the IPCC, M&E in adaptation includes activities to track progress, improve effectiveness, and iteratively manage risks. It's critical at all stages to identify effective interventions and manage risks at multiple scales. Adaptation M&E systems are still under development and are not yet fully adequate [1]. Three fundamental aspects that need to be considered in M&E systems for adaptation actions at all scales [56]:

1. Evolving vulnerabilities and risks,
2. Identified adaptation goals and objectives,
3. Adaptation actions implemented.

From the actions within the scope of M&E [1, 33, 57];

- Monitoring aims to track progress in achieving objectives, including using financial resources, during implementing of climate change adaptation measures. It allows for comparison of results achieved with expected results and, if necessary, prompts improvements.
- Evaluation systematically determines the effectiveness of an action. It can be conducted before, during, or after implementation to assess goal achievement and identify success factors. It covers productivity, accountability, results, capacity, impact on groups, lessons learned, and parallels with similar interventions.

Transforming adaptation M&E into a MEL system facilitates leveraging insights from M&E to enhance adaptation actions. This approach aids in detecting the adverse effects of wrong adaptation choices (maladaptation) and identifying new vulnerabilities needing adaptation [44, 48, 58, 59].

Adaptation M&E/MEL systems are notably absent from NAPs worldwide, with only 24% implemented and 19% under development. Existing systems focus primarily on monitoring and neglect the crucial evaluation phase, which is essential for NAP updates. Results-Based Monitoring (RBM), which uses the Logical Framework approach to evaluate indicators, is preferred by many countries and organizations. There are also other methods, such as participatory M&E, and impact assessment, each with its advantages and disadvantages [33, 36, 60, 61].

Key initial priorities for the development of adaptation MEL systems include [48, 62]:

- Policy development and implementation at all levels of decision-making for effective operation of MEL systems.
- Addressing challenges in establishing these systems, including indicator development, long-term uncertainties, data gaps, capacity limitations, financial constraints, and implementation barriers.
- Selecting indicators and criteria that are appropriate for all levels of government to avoid incentivizing inappropriate adaptation actions.
- Establishing MEL systems incrementally, starting at the baseline level and improving over time with new indicators and criteria consistent with progress.
- Ensuring integration with diverse financial resources to sustain the functionality of the MEL system.

Following the decision taken at COP28 of the UNFCCC, efforts are underway, led by the Adaptation Committee, to establish systems to facilitate M&E of adaptation actions at the global level through collaborative work involving other relevant UN bodies and participants from the Parties to the UNFCCC [38, 57, 63]. Examples of adaptation M&E/MEL systems established by different countries at different levels of development have been examined as guiding models in the following titles.

United States (US) /Resilience Metrics (Climate Adaptation Toolkit)

The Resilience Metrics approach was developed over 10 years as a result of a collaborative effort of experts from various professions supported by the National Oceanic and Atmospheric Administration (NOAA) in the US. This approach is used in the M&E of climate change adaptation measures [64].

In this approach, the concepts of indicators and metrics are first explained [65]:

- An indicator is defined as 'a sign that shows the desired outcome of adaptation actions'.
- Metrics are defined as the expression of the relevant indicator with both qualitative and quantitative variables (for measurable indicators).

For example, if the indicator is an adaptation to flooding, the metric is the comparison of the monetary value of losses and damages before and after the implementation of these measures. Therefore, in this approach, the terms indicator and target are not used interchangeably. The target is considered only in terms of what is expected to be achieved at a given point in time. However, it was emphasized that the mentioned targets should be detailed through adaptation actions and expressed through indicators and metrics. In the Resilience Metrics approach, it is stated that the success of adaptation actions cannot be measured without M&E. Accordingly, it is stated that local needs, existing data, and the target audience of the implemented actions are important in the selection of adaptation indicators and metrics to be used in the M&E system. The general topics of the indicators and metrics discussed in the toolset of this method are listed below and examples of these are given in Table 1 [65]:

• Economic indicators and metrics

• Environmental indicators and metrics

• Governance indicators and metrics

• Infrastructure indicators and metrics

• Social indicators and metrics

The approach emphasizes the importance of human, financial, and technical capacity, as well as governance processes, in conducting M&E once these indicators have been identified. Within this framework, it's noted that M&E can also identify undesirable outcomes of adaptation actions [65].

Table 1 illustrates that while indicators and metrics exist for economic and environmental dimensions in the US's adaptation M&E approach, a more comprehensive assessment is conducted for the social dimension. This emphasis derived from the recognition that sustainable adaptation requires social ownership, and that socio-economic data are crucial for consistent evaluations. In this framework, while certain quantitative data such as population growth are monitored under headings like Social Aspects, Governance Aspects are integrated into the M&E system separately. Notably, indicators explicitly involving stakeholder participation in processes have been identified. An additional noteworthy aspect of the US's adaptation M&E methodology is the creation of a separate data layer for Infrastructure. This approach ensures that M&E is conducted dynamically and remains current, encompassing not only infrastructure sectors like transportation but also Emergency Action Plans.

European Union (EU)/Adaptation Support Tool (Climate-ADAPT)/M&E Component

The EU is stepping up its efforts to make adaptation efforts more efficient, guided by "smarter, faster and more systematic" approaches [66]. Adaptation policy studies from the Green Paper (2007) to the EU Climate Change Adaptation Strategy (CCAS) of 2013 show continuity in this area. The culmination of these efforts is the new EU CCAS, published in 2021 as part of the European Green Deal. The strategy aims to develop the Climate-ADAPT system, which is the EU's data/information exchange and decision support tool for adaptation, beyond an information tool to a monitoring and reporting mechanism for adaptation [67]. Climate-ADAPT outlines a six-step adaptation cycle [68]:

1. Ground preparation
2. Risk assessment
3. Identify adaptation options
4. Evaluate options
5. Planning for implementation
6. M&E

Table 1. Examples of indicators and metrics in §gy [65]

Adaptation strategy	Indicator	Metric	Process	Capacity	Barriers	Decision-making	Action	Outcome
Economic aspects								
Implement flood mitigation measures	Cost effectiveness	$ saved or $ in damages avoided/$ expenditure						X
Implement adaptation pathways	Cumulative damages	Damage totals/event or /year as triggers for moving to next set of adaptation strategies				X	X	X
Increase economic opportunities and resilience	Economic security/ wellbeing	# of childcare places/ year, employment rate, # of business start-ups/closures		X				X
Environmental aspects								
Improve/maintain water quality	Regulatory change	Width of stream channel buffer in ordinance			X		X	X
Preserve natural assets for flood resiliency	Protected (existing or restored) shorefront areas	Acres of natural shoreline area protected or restored						X
Increase use of green/NBSs	Open/green space	# acres of impervious surface converted to permeable surface; # of green infrastructure projects completed					X	X
Governance aspects								
Connecting short-term decisions with a long-term vision	Cohesive decision-making	Decisions integrate climate projections (yes/no/ partially); Short-term decisions are checked against the long-term vision (yes/no/partially); different government agencies work together on integrated adaptation plan (always/often/ sometimes/not enough/never)	X	X	X	X		
Improve compliance with existing flood mitigation standards	Compliance	% compliant structures within regulated flood risk zones; % houses above base flood elevation		X	X			X
Broaden climate change/adaptation conversation beyond existing stakeholders	Public interest in climate change	Requests for information (#/month or year)	X		X			
Infrastructure aspects								
Secure critical transportation routes	Adjusted/ relocated roads	Critical high-risk road sections elevated or relocated inland (planning/implementation phase); % of funding secured			X		X	X
Update emergency management plan	Up-to-date maps of emergency response routes	Mapping completed/ mapping not begun/ update in progress (regular updates, e.g., every 5–10 years)			X	X	X	
Maintain, elevate, restore and/or relocate (as needed) roads and trouble spots	Flood-related closures or disruptions	# of road or trail closures/year or flood event						X
Social aspects								
Adaptation efforts focus on the most vulnerable/disadvantaged	Improvement for disadvantaged	#of watermains fixed/year; #of trees planted; # of affordable housing unit (increasing over time); $ of investment in economic opportunities		X	X		X	X
Monitor and plan for expected population increase	Land use	Map/% of land use types, distribution, change in acreage over time; #of applications for development permits						X

Table 2. Examples of monitoring indicators for DAS [72]

Cluster	Action area	Impact-indicators-effects	Response-indicators-adaptations
Health	Human health	Heat exposure	Heat warning service
Water	Water management, water regime, coastal and marine protection	Groundwater levels	Water use index
Land	Soil	Soil moisture levels in agricultural soils	Humus content of arable land
Infrastructure	Building industry	Heat stress in urban environments	Recreation areas
Economy	Trade and industry	Heat-related loss in performance	The manufacturing sector's water consumption intensify
Spatial planning and civil protection	Civil protection	Man-hours required to manage damage from weather-related events	Disaster response information
Cross sectoral indicators			Adapting to climate change at the local administrations

In step 6, the EU focuses on generating learning and accountability results in adaptation M&E. This step ensures oversight and stakeholder coordination, learning from successes or failures to improve adaptation strategies and plans. The EU addresses the following subtopics in adaptation M&E [68]:

1 Understanding drivers and targets
2. Identifying stakeholders
3. Definition of monitoring, reporting, and evaluation (MRE) indicators and methods
4. Communicating results to decision-makers
5. M&E of adaptation actions.

Under these subtopics, the EEA's approach to indicator development, as outlined by Makinen et al. [69], includes three categories:

1. Climate change indicators to understand the impacts of climate change.
2. Climate change impact indicators to capture impacts.
3. Economic, social, environmental and health vulnerability indicators to identify vulnerability and monitor adaptation strategies.

EEA's methodology for selecting indicators considers how changes in the scope of adaptation actions at different levels, such as national and regional, will affect the approach. At the regional level, a new set of indicators on the impacts of climate change on society and environmental systems is introduced. At national and higher scales, these indicators are categorized within the EEA methodology as input, process, output and outcome indicators. Based on their scope, the indicators are grouped into exposure, adaptive capacity, sensitivity, composite vulnerability, and hazard indicators. Alignment with the Paris Agreement, the Sendai Framework for Disaster Risk Reduction (DRR) and the UN Sustainable Development Goals (SDGs) is a key criterion in the selection of indicators [69].

Despite this approach developed by the EEA, it should be noted that while the EU has an implemented M&E system for greenhouse gas emissions at the Union level, it has an approach for local identification and M&E of adaptation actions. This is detailed in Annex 1 of the Commission Implementing Regulation (EU) 2020/1208, Article 4 on National Adaptation Plans. In the section "Monitoring and evaluation of adaptation actions and processes" it is stated that "Member States shall report on their approaches, systems used, transparency and indicators when M&E relates to reducing climate impacts, vulnerabilities and risks and enhancing adaptive capacity" [70].

As a result of this approach towards local determination and M&E of adaptation actions, it is seen that the successful practices of the Union countries are included in Climate-ADAPT. One of the examples included in Climate-ADAPT is the M&E system created by Germany for its Climate Change Adaptation Strategy (DAS), which includes not only monitoring but also an evaluation system [71]. The indicators addressed in Germany's 2019 monitoring report are considered within different sector and thematic clusters (Table 2) in the context of impact and response [72].

In terms of evaluation, the evaluation of the German Adaptation Action Plan (APA II) covers both strategic and operational levels. While the products and outcomes of the DAS are evaluated at the strategic level, the impact of APA II measures on target groups is evaluated at the operational level. The strategic results cover the short-, medium- and long-term impact of the DAS, while the operational results measure the impact of APA II on the target groups. A three-stage evaluation system assesses the process, implementation status, and overall impact [71].

In line with the EU's policy on local determination of adaptation actions and adaptation M&E systems, it is seen that in the system created to carry out the M&E of Germany's DAS, which is taken as an example within the scope of this study, a sectoral approach is adopted and timeframes for the targets to be achieved are determined. Another feature of the German M&E approach is that a separate M&E layer has been created for horizontally cross-cutting issues and sectors regarding adaptation. In this regard, it is seen that adaptation activities especially in local governments are addressed and local climate action is also evaluated. In this way, it is also possible to carry out M&E of adaptation actions detailed down to the building scale. In this approach,

Table 3. Examples of indicators in the Tonga JNAP2 M&E System Guide [48]

Target area	Process indicators	Outcome indicators (proposed)	Impact indicators
Coasts	Vulnerability baselines developed for coastal sector	Total length of sewer and drainage network at risk from climate hazards	Percentage of wastewater with safe treatment (SDG 6.3.1)
Buildings	Developed a multi-hazard plan to prepare for, respond to, and recover from disasters affecting public and community infrastructure	Number and extent of building-related vulnerability problems perceived by disabled and marginalized groups by gender and age	Percentage of the population living in households with access to basic services (SDG 4.1)
Tourism	Development of resilience indicators (process, outcome and impact) for tourism	Water consumed by tourist facilities	Direct economic losses due to damage or destruction of cultural heritage as a result of disasters (Sendai)
Water	Monitoring system for water, soil and coastal erosion developed	Number of cases of water-borne disasters	Mortality due to unsafe water, sanitation, and hygiene
Community resilience	Development of standard resiliency guidelines forl community engagement activities	Number of people below poverty line living in flood-prone areas	Percentage of people living below the poverty lines, by gender and age (SDG 1.2.1)
Private sector	Developing a costed, gender and social inclusion resilient facility for the private sector	Reduced work productivity due to heat stress	Coverage of essential health services (SDG 3.8.1)

it is seen that the monitoring of disasters and emergencies is included in the adaptation M&E system.

Tonga/Joint Climate Change and Disaster Risk Management M&E System

In Tonga, an integrated approach to disaster risk management and climate change is supported by the Joint National Action Plan 2 on Climate Change and Disaster Risk Management 2018-2028 (JNAP2). An M&E system guide published in 2019 prioritizes learning, accountability, and adaptation management, and integrates local knowledge into adaptation planning. The selection of indicators aligns with Tonga's international reporting requirements, including the Paris Agreement, and emphasizes policy monitoring, implementation evaluation, and impact assessment across management levels. The selection was informed by the UN SDGs and the Sendai Framework for DRR, and Table 3 provides examples of indicators selected with stakeholder input. The system designates specific focal points for data entry, standardized entry procedures, and regular capacity building to ensure its functionality [73, 74].

The M&E system established by Tonga is a good example of tailoring adaptation actions and M&E systems to local needs. This is because the selection of target areas takes into account the sectors in the country and the issues that need to be addressed in adaptation. However, as in other countries' examples, a detailed sector analysis was not carried out. This may be because, as a developing country, Tonga, like many other developing countries, wants to focus scarce financial, technical and human resources and capacity on priority areas. What is striking about Tonga's M&E approach is that all of the adaptation target areas, especially the social resilience layer, are addressed in an integrated manner with the disaster issue mentioned above. In other words, adaptation measures are considered together with the co-benefits of DRR. This approach is in line with the approach of UN agencies, in particular the UNDRR [75], to address adaptation and DRR actions together in recent years, which is also reflected in the linking of impact indicators to the Sendai Framework for DRR and/or the UN SDGs.

Türkiye's NCCASAP and Future Prospects for Adaptation M&E

Türkiye's subtropical Mediterranean climate zone covers a significant portion of its territory, making it highly susceptible to the effects of climate change. As a result, the country is exposed to medium to high climate risks both now and in the future [76]. As one of the Parties to the Paris Agreement, Türkiye currently lacks an active M&E/MEL system specifically dedicated to tracking adaptation actions and the NCCASAP. The relevant ministries in Türkiye have prepared SAPs for various sectors related to climate change adaptation. These sectors include water, agriculture, drought, desertification, capacity building, air quality, waste management, pollutants, and energy. However, separate, and independent M&E systems have been established for each of these sectors, rather than a unified system [77]. In this context, relevant ministries are developing M&E tools specific to their respective sectors, particularly in the project- and investment-based areas related to the following topics [78]:

- Tracking technical progress: Monitoring intervention logic and indicators-Performance evaluation and thematic monitoring
- Physical monitoring, financial monitoring
- Risk management and monitoring
- Early warning systems

However, there is still no system that evaluates environmental parameters together with socio-economic parameters in the context of climate change adaptation. Türkiye's NCCASAP, prepared by the Ministry of Environment and Urbanization (MoEU) for the period 2011-2023, mainly covered the following thematic areas [79]:

1. Water resources management
2. Agriculture and food security
3. Ecosystem services, biological diversity, and forestry
4. Natural disaster risk management
5. Human health

NCCASAP has defined goals and objectives related to the thematic areas, together with outputs and performance indicators, responsible/coordinating bodies and relevant organizations (Table 4).

As can be seen from Table 4, many responsible institutions and organizations here have become abolished and NCCASAP has expired as of 2023. It is not possible to provide clear information about how many of the actions determined within the scope of NCCASAP have been carried out, because a system regarding M&E of NCCASAP has not been established. All these issues and the need to renew the scope of NCCASAP within the framework of current adaptation needs are also stated in the 8th National Communication of Türkiye submitted to the UNFCCC Secretariat in 2023 [76].

Studies have commenced to revise the NCCASAP as part of the Enhancing Adaptation Action in Türkiye Project. This project is supported by UNDP, with the Ministry of Environment, Urbanization, and Climate Change (MoEUCC) as the beneficiary [80]. It was announced by the Climate Change Presidency (CCP), a subsidiary of MoEUCC, that NCCASAP (2024–2030) was completed in 2023 and was submitted to the Climate Change and Adaptation Coordination Board for approval and accepted [81]. Strategic goals and adaptation actions have been determined in line with the results of vulnerability and risk analyses conducted for 11 sectors within the scope of the current NCCASAP document. Their scope has been explained briefly as follows [82];

1. City (technological actions; Nature-based Solutions (NBS); climate-sensitive urban planning),
2. Agriculture and food security (strengthening institutional capacity for a climate-resilient, technology-efficient, water-efficient and competitive agricultural sector; strengthening the legal framework; raising awareness, protection and sustainable use of natural resources in agricultural production),
3. Water resources management (basin-based water conservation studies; reuse of treated wastewater; access to safe drinking water; increasing the efficiency of agricultural irrigation; rainwater management),
4. Biodiversity and ecosystem services (increasing awareness and capacity on NBS, Ecosystem-based Adaptation issues, strengthening cooperation; reducing habitat fragmentation and overuse pressures; increasing protected areas and ecosystem restoration; researching, monitoring and assessment of climate change impacts on biodiversity and ecosystem services),
5. Public health (monitoring of climate-related diseases; strengthening capacity and cooperation in this area in national and local organizations; development of a list of climate-sensitive diseases; review of occupational health and safety legislation),
6. Tourism and cultural heritage (climate-resilient infrastructure in tourism investments and businesses; development of social infrastructure; ensuring cooperation between institutions by taking climate change adaptation into account in decisions related to tourism and cultural heritage),
7. Industry (conducting vulnerability and risk analyses for the industrial sector; identifying natural technological risks and facilities at risk of major industrial accidents; evaluating investment projects together with their climate impacts),
8. Energy (improving the policy and administrative framework, institutional capacity and cooperation for adaptation of the sector to climate change; strengthening the production, transmission, distribution and storage infrastructure);
9. Transport and communications (ensuring the resilience of critical infrastructure; reducing vulnerability; improving accessibility, communication, and evacuation in case of emergencies),
10. Social development (integrating climate change impacts on social life and actions into policies at all levels and processes in all sectors),
11. DRR (strengthening the understanding and information infrastructure on climate-related disaster risks; adopting a transformative approach to risk management; improving institutional capacity and awareness; making sustainable investments).

It is seen that Türkiye has adopted an approach of making detailed and comprehensive sectoral analysis on adaptation, as in the EU approach. Although it is important that Türkiye's updated NCCASAP has been prepared, what is at least as important is the establishment of an M&E/MEL system specific to NCCASAP. Because, as stated above; In line with the decisions taken at UNFCCC COP28, countries party to the UNFCCC and the Paris Agreement are required to develop national MEL systems for adaptation by 2030. Within the scope of CCP's 2024-2028 Strategic Plan [83], under the title "Goal 2: Increasing the capacity to adapt to climate change at the national and local scale", "H.2.3. "An online monitoring mechanism will be created to monitor the actions of the National Climate Change Adaptation Strategy and Action Plan (2024–2030) and the actions will be monitored." target is included.

The MEL systems can be used in the Biennial Transparency Reports to be submitted to the UNFCCC Secretariat and in the presentations on adaptation actions, and will bring

Table 4. Examples of sectoral objectives, targets, outputs, and performance indicators included in Türkiye's NCCASAP [79]

Actions	Period	Outputs and performance indicators	Responsible/coordinating organization	Relevant organizations
I. Water Resource Management Purpose US1. Integrate adaptation to climate change impacts into water resources management policies. Objective US1.1. Ensure adaptation to climate change is integrated into existing policies, plans and legislation.				
US1.1.7. Orientation of water user organizations by relevant institutions within the framework of irrigation businesses taking into account the impacts of climate change	2011–2014	Improvement of local capacity	General directorate of state hydraulic works (SHW)	Ministry of food, agriculture and livestock (mfal), special provincial administration, local Authorities, water user organizations, NGO's
II. Agriculture Sector and Food Security Purpose UT4. Protect soil and agricultural biodiversity from the impacts of climate change Objective UT4.1. Protect the physical, chemical and biological capacity of soils against the impacts of climate change				
UT4.1.3. Implementation of advanced harvesting systems, and development of agricultural forestr	2012– and onwards	Model practices	MFAL	
III. Ecosystem services, biodiversity and forests Purpose UO1. Integrate climate change adaptation into ecosystem services, biodiversity and forestry policies Objective UO1.1. Review existing policies for adaptation to climate change impacts				
UO1.1.3. Integrating and spreading adaptation to climate change into the existing planning for selected/priority protected areas	2011–2015	Plans for protected areas including adaptation to climate change	Ministry of forestry and water works (MFWW)	
IV. Natural Disaster Risk Management Purpose UA1. Identify threats and risks for managing natural disasters caused by climate change. Objective UA1.1. Identify risks of natural disasters caused by climate change, such as floods, overflows, avalanches, landslides, etc.				
UA1.1.2. Prepare implementation and audit guidance related to flood and landslide risk reduction and management plans.	2011–2015	Relevant plans and guidelines	MFWW, Disaster and emergency management presidency	SHW
V. Public Health Purpose UİS1. Identify existing and future impacts and risks of climate change on public health. Objective UİS1.1. Research on the impact of extreme weather events on public health				
UİS1.1.1. M&E the current and future impacts of extreme weather events such as heat waves, hurricanes, floods and droughts on public health based on climate projections.	2011–2020	Impact assessment reports and monitoring systems	Ministry of health	Governorships
VI. Cross-cutting issues in adaptation OBJECTIVE UYK1. Ensure cross-cutting adaptation to climate change Objective UYK1.3. Organize training, awareness-raising and information activities to develop the capacity to combat and adapt to climate change.				
UYK1.3.2 Ensure participation in the process of adaptation to climate change and prepare programs to raise awareness of the public.	2011–2014	Programs	Ministry of environment and urbanization	Climate change coordination board, universities

important gains that will enable Türkiye to understand and improve the realization and success of its adaptation actions. In addition, the information obtained from this adaptation MEL system will also contribute to the future justification of Türkiye's [84] request to benefit from the Loss and Damage Fund established at COP28.

Data is one of the main problems in Türkiye, as in many other countries. In order to determine adaptation needs and measures and to monitor and evaluate them, adequate, reliable and appropriate data in climatic and socio-economic fields should be kept by institutions and these data should be accessible. It is essential to develop policies on this issue and ensure the continuity of the process.

In assessing climate-induced disaster risks, providing sufficient financial resources to conduct impact and vulnerability analyses based on adequate and up-to-date climatic and socio-economic data is another essential issue for adaptation activities in Türkiye. While Türkiye, as a developing country, is already vulnerable to other disaster areas such as seismicity, its vulnerability to climatic disasters makes it necessary to develop policies that utilize resources effectively while allocating the country's financial resources to disaster-related issues. The most important way to achieve this is to shift from crisis management to risk management. A more effective strategy would be to invest in adaptation measures through proactive identification of potential losses and damages. This approach allows for informed decision-making and policy formulation that considers not only the financial implications of disasters but also their social and cultural impacts. This yields positive outcomes for development and national security.

In addition, determining the adaptation actions to be developed, using resources effectively in adaptation-related practices, investing in innovative technologies and supporting R&D studies in this context are very important for increasing the effectiveness of M&E systems. Ensuring regular capacity development of stakeholders who will be entering data is another critical strategy to ensure the sustainability and effectiveness of the adaptation M&E system. Even if appropriate and sufficient adaptation measures are identified and implemented, their correct data entry into the M&E system will directly affect the success of the process.

Adopting a multi-stakeholder approach in conducting studies on the above 11 sectors in the NCCASAP M&E system to be established is essential for the sustainability of the process and the accuracy of the results to be obtained. In this context, Türkiye should receive support and establish cooperation from EU countries with a similar approach to adaptation, as well as from the UNFCCC Adaptation Committee, which has been working on adaptation M&E for a long time. The lessons learned are important for the operation of the adaptation M&E system and benefiting from the experiences of other countries in this context can save time for Türkiye, which is a country vulnerable to climate impacts.

Furthermore, concerning DRR, which is discussed under a separate title in Türkiye's NCCASAP, it is very important to adopt an integrated approach within the framework of the adaptation M&E system to be established and to identify indicators related to disaster resilience in other adaptation sectors.

Considering the magnitude of losses and damages currently caused and projected to be caused by climate-related extreme weather events and disasters in Türkiye, the results obtained from the adaptation M&E system will also be able to provide the necessary information for the establishment of a national insurance system for losses and damages due to climate change.

CONCLUSIONS

Today, the magnitude of the adverse effects of climate change highlights the need for well-planned adaptation measures. This is also a fundamental aspect of the international climate change negotiations under the UNFCCC to realize the goals of the GGA as defined under the Paris Agreement, the Convention's implementing instrument. To ensure the success of current and future adaptation efforts, adaptation actions must be accurately identified and developed through regular review processes. To achieve this, M&E systems for adaptation actions within the UN adaptation cycle are of great importance. Lessons learned from the M&E step not only provide feedback on the adaptation process, but also enable the identification of areas or actions that are failing or working well in the process. In this way, it will be possible to increase the resilience of settlements and infrastructure of all types and levels, prevent disasters, and create opportunities for learning and development in various economic, social, and environmental fields.

The assessment of the research questions at the beginning of the study showed that it is critical to identify climate risks and adaptation needs before M&E of adaptation actions. In this way, the adaptation actions and related indicators for which M&E will be conducted can be accurately determined. This requires good quality and reliable climate and socio-economic data at each stage of the adaptation process.

The nature of climate change poses challenges for M&E in terms of adaptation actions, particularly as the quality of data needed for adaptation processes is limited, incomplete, or unavailable. Innovation in scaling down global data for local use and ensuring that these new technologies are accessible to all countries is crucial both for countries' NAP preparations and for M&E of identified adaptation actions. Although uncertainties may be difficult to eliminate, efforts should focus on developing adaptation actions based on the best available scientific data and on effectively managing uncertainties.

Inadequate M&E during the identification, planning, and implementation of adaptation actions prevents learning from the results of these phases. The provisions of the Paris Agreement, which aim to improve human capacity and achieve the adaptation cycle, call for a GST every five years starting in 2023. At UNFCCC COP28, the first GST, it was decided that all Parties would establish M&E/MEL systems for national adaptation actions by 2030.

Looking at the adaptation M&E systems and methodologies discussed in the study, it is seen that country priorities, level of development, and local conditions for adaptation to climate change affect the sectors covered by adaptation policies, strategies, and indicators in adaptation M&E systems. While developed countries emphasize indicator sets and detailed sector assessments that emphasize governance and infrastructure, developing countries focus on sectors that are prioritized due to scarce resources. In developing countries, there is also a clearer tendency to combine adaptation actions with DRR actions. However, regardless of the level of development, it is also observed that the adaptation M&E methodologies developed generally focus on the objectives of reducing vulnerability, increasing resilience, developing emergency action plans, and ensuring the effective use and sustainable management of financial and natural resources.

Adaptation M&E systems, once established, require continuous improvement. Lessons learned from the successes and shortcomings of adaptation efforts and changing climate conditions, should be used to improve these systems. In this context, the main priorities of M&E/MEL systems in the coming period should be to protect the health of individuals and all ecosystems and to protect and ensure the sustainability and development of all natural and man-made resources.

In Türkiye, one of the Parties to the Paris Agreement, there is no active M&E/MEL system to monitor adaptation actions or NAP. The 8th NC emphasized that efforts to establish such a system are continuing. However, floods and storms that occur especially in cities in Türkiye as a result of extreme weather events due to climate change cause significant loss of life and property, and adaptation measures need to be determined according to new climate norms, and M&E should be carried out especially considering these issues. Not only floods and storms, but also problems such as temperature increases and droughts show the urgency of M&E of adaptation measures in the context of water and food security.

As previously stated, in accordance with the COP28 decision, it is necessary to identify adaptation measures by 2030 and develop an M&E system for these measures. This system will help to understand the adequacy and effectiveness of adaptation measures in Türkiye, a developing country that is highly vulnerable to climate impacts. It will also facilitate the improvement of adaptation efforts, and also support accurate and consistent reporting of adaptation studies to the Secretariat and the contribution of the results of national efforts to global efforts.

In the context of Türkiye's NCCASAP framework, it is of the utmost importance to not only define policies and measures and establish an M&E system, but also to develop the institutional capacity to ensure the continuity of this system. In this regard, Türkiye should cooperate with other countries and the UNFCCC Secretariat.

Consequently, it can be said that adaptation M&E systems represent one of the most pivotal instruments for facilitating the transition from crisis management to risk management in the context of the adverse effects of climate change. Carrying out this last and crucial step of the UN adaptation cycle through established systems in all countries, including Türkiye, and ensuring the integration of M&E systems established by countries will help to understand the adequacy and success of global adaptation efforts, as well as it will make a significant contribution to achieving the goals of the UN SDGs, the Sendai Framework for DRR, and the Paris Agreement's GGA.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

USE OF AI FOR WRITING ASSISTANCE

Not declared.

ETHICS

There are no ethical issues with the publication of this manuscript.

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