

Research Report

Combined Impacts of Transformative Adaptation and Multiscale Polycentric Governance for Enhancing Climate Resilience: A Case Study from Sri Lanka

Upali A. Amarasinghe, Giriraj Amarnath, Sachini Ukwattage, Kaushika Seelanatha, Priyanka Sivananthan, Upali Imbulana, Niranga Alahacoon, and Sewwandhi Chandrasekara

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Summary

In recent years, several donor-funded grants and loan programs have targeted the rehabilitation of tank cascade systems in Sri Lanka to address climate-related risks through transformative adaptation options (TAOs). This study, as part of the CGIAR Initiative on Climate Resilience (ClimBeR) and the CGIAR Climate Action Program, assesses the ex-ante impacts of combining multiscale polycentric governance (MPG) to enhance the effectiveness of TAOs' contribution to food, water, and livelihood security policy goals. The analytical framework was designed to identify the interactions between MPG elements, TAOs, and impact transmission factors via impact pathways, with the aim of improving policy goals.

The analysis, conducted across four river basins in Sri Lanka's North Western, North Central, Northern, and Eastern provinces, focused on three key TAOs: river basin planning with a climate change focus, forming cascade management committees with tank rehabilitation, and diversifying to high-value crops with climate-smart practices. The study used perception data of 178 stakeholders, including farmers and officials from different sectors and scales.

The major finding of the analysis is that diversifying into high-value crops positively influences many impact transition factors in the impact pathway leading to policy goals. However, the impacts can be enhanced with detailed river basin plans that consider climate variability alongside the effective functioning of cascade management committees. The policy implication is that CMCs with comprehensive land use and water availability plans for the cascade and individual tanks are critical for maximizing crop diversification benefits.

The other policy strategies that emerged from the study are as follows:

1. **Enhancing collaboration across institutions** (at different sectors and scales) to strengthen TAOs

and their influence on impact transmission factors (ITFs) for advancing sustainable water, food, and livelihood security.

2. **Strengthening the role of private actors** by enhancing value chains, creating opportunities for rural service providers, and increasing corporate sector participation, to facilitate transformative changes through TAOs and support multiple impact transmission factors.
3. **Considering structural institutions**—such as land tenure, traditional practices, and livestock composition—as vital for the success of transformative adaptation options for climate change.
4. **Reforming existing agricultural wage structures, land tenure systems, and food policies** that influence several ITFs to enable the transformative changes required to modernize agriculture in the face of climate change.
5. **Enhancing water infrastructure in parallel with improving collaboration among water institutions** to maximize impacts on ITFs such as water availability and supply.
6. **Designing interventions that target impact transmission factors** to amplify the effects of both MPGs and TAOs and the impacts along downstream transmission pathways. Key transmission factors include climate investments and water availability; cropped area, cropping patterns, land and soil health; land, water, and labor productivity; commercial and industrial crop production; livestock production; and rural employment and wages.

The level of vulnerability, resource availability, and development needs can change the priority of implementation of these policy options.

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Introduction

The convergence of climate change impacts on water, land, and the environment is placing immense pressure on agriculture and food systems worldwide (Brown et al. 2015; Suresh et al. 2022; Saleth et al. 2023). Climate-related disasters—floods, droughts, storms, and extreme temperatures—are responsible for most of these impacts. Zhang et al. (2023) highlight rising cropland exposure to flooding, particularly in South Asia. In Asia, agricultural losses from natural disasters account for about 23% of total economic losses, with global damages to crop and livestock production estimated at USD 3.8 trillion (FAO 2023).

Sri Lanka, an island nation in the Indian Ocean, is frequently ranked among the high climate-risk countries by the Global Climate Risk Index—13th in 2016 and 23rd in 2021 (Kreft et al. 2016; Eckstein et al. 2021). The most common hazards are floods, droughts, and extreme temperatures. Between 2000 and 2022, Sri Lanka experienced 50 major floods, 5 droughts, and 15 storms, with losses exceeding USD 3 billion (EM-DAT 2018). Though less frequent, major droughts can be severe, such as in 2016–2017, when 20 of 24 districts were affected and large areas of paddy land were damaged over consecutive seasons (WFP 2018). Climate change also accelerates coastal erosion and salinity intrusion, further threatening agricultural productivity and coastal ecosystems with rising sea levels.

Climate projections indicate increasing rainfall variability in Sri Lanka. The wet zone is experiencing more intense rainfall events, while the dry and intermediate zones are projected to become drier with prolonged dry spells (Punyawardena et al. 2013; Marambe et al. 2014). The dry zone, which covers three-quarters of the country and depends largely on the northeast monsoon rainfall, produces a major share of Sri Lanka's food, making it highly vulnerable to the impacts of extended dry periods. The wet zone, receiving rainfall from both monsoons, is prone to floods and landslides. Rising temperatures and short-term droughts further stress agriculture across the island (Premalal and Punyawardena 2013). Coastal areas are also increasingly at risk from storms and rising sea levels, threatening both ecosystems and livelihoods.

Sri Lanka has two main agricultural seasons: Maha (October–March) and Yala (April–September). Increased

rainfall variability during the first inter-monsoon (March–April) and southwest monsoon (May–September) disrupts Yala agriculture. Similarly, variability during the second inter-monsoon (October–November) and northeast monsoon (December–February) affects Maha, which produces 75% of the national paddy output (DCS 2024), mostly from dry-zone river basins. Any shift in rainfall timing, intensity, or duration directly disrupts planting schedules, reduces yields, and heightens vulnerability for smallholder farmers who depend on predictable weather patterns.

Sri Lanka has 103 river basins, with 12 accounting for 70% of the annual runoff of about 52 billion cubic meters (Bm³) (Amarasinghe et al. 1999). The Mahaweli River, the largest, contributes 19% of national water resources, originating in the wet zone and flowing 335 km to the Eastern Province. Other major rivers in the wet zone (Kalu, Kelani, Nilwala, and Walawe) account for 33% of resources. In contrast, key dry-zone rivers—Malwathu Oya, Yan Oya, Kala Oya, and Mi Oya—account for only 2.7% of the water resources. Many dry-zone rivers become “closed basins” during dry periods, with no flow to the sea for weeks or months (Amarasinghe et al. 1999). As most rainfall in these basins falls between November and February, water storage is critical to secure supplies for agriculture and domestic use throughout the year. Total storage capacity is about 8.5 Bm³, with 3.8 Bm³ in the Mahaweli Basin alone, making it the most significant storage region.

Small village tanks, dating back 300–400 years with early Indo-Aryan settlements (Brohier 1934), were initially built to provide water for drinking, bathing, and agriculture. Stone inscriptions show that the first tanks emerged in the upper watersheds of the Mi Oya, Kala Oya, and Daduru Oya, later expanding to Anuradhapura and other areas along the Malwathu Aru, Mahaweli, Amban Ganga, Madura Oya, Walawe Ganga, and Kirindi Oya river basins. Between AD 400 and 700, anicuts (small weirs) were added to divert streams for village needs. Today, Sri Lanka has over 16,400 small tanks, many integrated into about 1,660 tank cascade systems (GoSL 2025). These hydrologically interconnected tanks capture and pass water downstream, maximizing storage and reuse. Minor irrigation systems—including small tanks, cascades, and anicuts—supply water to 29% of paddy-irrigated land (1.1 million hectares) (DCS 2024). Beyond agriculture, they

support domestic use, livestock, and other livelihoods (Dharmasena 2010).

Major irrigation systems with large tanks and reservoirs supply 52% of Sri Lanka's paddy lands, making them crucial for food security and rural livelihoods. Another 19% of paddy lands rely entirely on rainfall. Rainfed conditions also determine the cultivation of other seasonal and annual crops. Groundwater plays a vital role in supplementing rainfed agriculture, especially in the dry zone, where agro-wells and tube wells provide irrigation during dry spells (Amarasinghe et al. 2020). This supplemental irrigation is increasingly important as rainfall becomes less reliable.

Given this high dependency on climate-sensitive water sources, Sri Lanka is extremely vulnerable to floods and droughts (Amarnath et al. 2017; Amarasinghe et al. 2020). Adaptation interventions have therefore focused on the most vulnerable dry-zone basins. Notable projects include the Green Climate Fund-supported Climate Resilient Integrated Water Management Project (CRIWMP) and the World Bank-funded Climate Smart Irrigated Agriculture Project (CSIAP), together representing over USD 120 million in investments to strengthen climate resilience in communities reliant on tank cascades (GCF 2016; World Bank 2019). Another significant initiative, the World Bank-funded River Basin Plan Development Program (USD 120 million), also called the CRIP project (World Bank 2014), aimed to incorporate climate adaptation into long-term river basin planning, moving beyond traditional water supply-demand approaches to more climate-resilient strategies.

Most previous small tank rehabilitation projects have primarily focused on physical improvements (Aheeyar 2013). In contrast, CRIWMP and CSIAP incorporate strong institutional improvement components, particularly the development of cascade management committees (CMCs). These are designed to enhance water and land management at the cascade system level while strengthening intra- and inter-tank cooperation among farmer organizations (FOs) and other water user organizations such as fisheries groups, women's agriculture groups, etc. At present, only the FOs play a major role in water management, and that also is limited to their own tank command areas. The CMCs embody multiscale polycentric governance (MPG), a concept Ostrom (2010) described as relevant institutions at various scales and sectors operating as independent entities with decision-making powers. Although they function autonomously, they also collaborate and compete toward achieving a common goal.

Among other interventions, CRIWMP and CSIAP also implemented crop diversification with climate-smart practices. Similarly, river basin planning with a particular emphasis on climate change was implemented at the same time, representing a shift away from traditional planning approaches that focus simply on water supply and demand.

The three interventions—1) forming cascade management committees, 2) promoting crop diversification with climate-smart practices, and 3) developing river basin plans with an emphasis on climate change—have many transformative qualities. According to Fedele et al. (2019), six defining characteristics of transformative adaptation interventions (TAIs) are as follows:

- **Restructuring:** TAIs involve significant shifts in a system's fundamental properties, functions, or interactions.
- **Path-shifting:** TAIs lead to changes in the system's current trajectory.
- **Innovative:** They introduce knowledge, policies, or technologies that transition the system to a new state.
- **Multi-scale:** The impacts of TAIs extend across various scales, including spatial, jurisdictional, or sectoral levels.
- **System-wide:** They effect systemic changes across entire regions, ecosystems, landscapes, or communities.
- **Persistent:** These changes result in long-term shifts that may not necessarily be irreversible.

CMCs are relevant as they promote a holistic water resource management model that integrates all tanks from upstream to downstream, ensuring effective water governance in tank cascade systems. They are coherent because they involve all water users, from farmers, fishers, women, livestock, etc., and facilitate cross-scale knowledge exchange and coordination. They also restructure water management to include knowledge of water availability and return flows of different tanks to promote sustainable management of resources. They shift fragmented water management to structured approaches guided by traditional water masters ("*wel vidane*"). CMCs further support operations of cascade-level organizations, strengthening inter-tank water management strategies through legal and policy frameworks. They improve governance across various spatial scales, from individual tanks to cascade and sub-watershed levels. They support system-wide sustainable soil, land, and water management practices, mitigating impacts on ecosystems. CMCs also encourage ecological practices and water conservation, enhancing drought resilience and contributing to long-term environmental sustainability.

Crop diversification with climate-smart agricultural practices introduces precision farming and drought- and heat-tolerant crops, optimizing resource use against climate stressors; it contributes to stable farmer income and ecosystem sustainability by buffering against climate- and pest-related risks; it transitions land use from low-value monocrop, particularly paddy, to high-value

production systems, thereby enhancing profitability and resource efficiency; it shifts production from low-value crops to high-value integrated crop-livestock production systems; it promotes a shift from surface irrigation to advanced technologies such as drip, sprinkler, and underground irrigation to improve water use efficiency; it addresses water scarcity through improved irrigation systems, supporting food security and sustainable livelihoods, diversifying income sources and enhancing resilience to climate shocks.

Basin management plans that incorporate climate change risks strengthen resilience to climate-induced hazards—such as floods and droughts—by integrating climate risk into investment planning at the basin level; they align actions, investments, and strategies within specific geographic contexts to manage climate risks; they restructure large-scale infrastructure development, including levees and embankments, to mitigate flood risks and improve overall basin management; they shift trajectories by upgrading critical infrastructure (dams, reservoirs, water supply systems) to adapt to projected climate scenarios and ensure long-term resilience; they promote nature-based solutions, the adoption of new technologies, and the revision of traditional investment planning frameworks to incorporate climate resilience; they impact a multiscale spectrum of stakeholders from local communities to regional authorities, aligning basin-wide environmental and socioeconomic objectives; they facilitate job creation, income generation, and improved living conditions while ensuring sustainable

water management across entire basins; and they secure long-term adaptation through investment in resilient infrastructure, preparing regions to cope with future climate variability and extremes.

The new transformative adaptation options have the potential to induce system-level sustainable changes in agricultural production and livelihoods in tank cascade systems. However, it remains uncertain whether implementing these TAOs sufficiently addresses the growing complexities of governance under climate change (Amarasinghe and Seo 2022). Notably, the country currently has over 40 institutional arrangements for water management (Samad et al. 2017; Chandrasekara et al. 2021), underscoring the complex nature of water management.

This paper examines ex-ante the impacts of these interventions and multiscale polycentric governance elements on enhancing climate resilience. The lessons learned from the analysis would assist in modifications to the ongoing implementation and future planning so that proper governance elements are combined to enhance the impacts of interventions.

The section that follows describes the analytical framework for assessing the impacts of three TAOs with a multiscale polycentric governance mechanism via an impacts pathways approach. Section 3 discusses the results, while Section 4 offers policy-relevant findings from the analysis.

Methodology and Data

Conceptual Framework for Impact Assessment

For the impact assessment, the study adapts the conceptual and analytical frameworks developed by Saleth et al. (2023) to evaluate the role of governance in enhancing climate resilience through transformative adaptation options (TAOs). Saleth et al. (2023) empirically tested this framework in a similar study under the research activities of the CGIAR Initiative on Climate Resilience (ClimBeR) in Morocco, where the Government of Morocco implemented innovative programs to address ongoing climate uncertainties. Although the agroecological and geographical settings of the two countries are different, the

two frameworks are a valid approach to analyze governance roles in enhancing climate resilience.

Climate-related disasters disproportionately affect water, land, and ecosystems, triggering cascading disruptions in agriculture and food systems (Figure 1). These impacts compromise food, water, and income security, which are essential components of climate resilience. Many adaptation responses remain short-term, such as cash aid during droughts or evacuations during floods. Though helpful, these reactive coping mechanisms must be repeatedly deployed. More enduring measures—such as improved seeds or desilting tanks—offer incremental improvements but often fail to yield resilient outcomes when used in isolation or without institutional support.

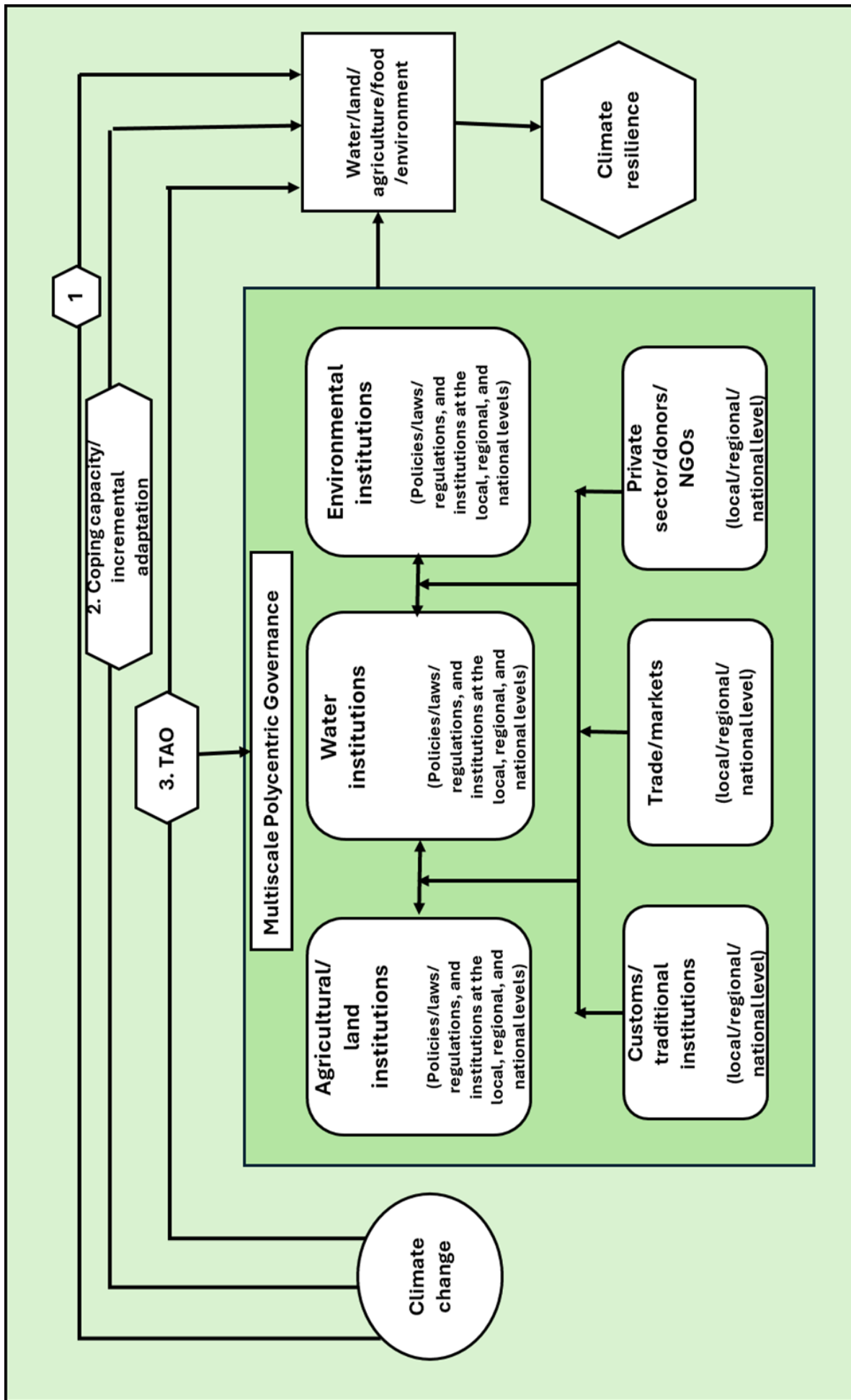


Figure 1. A conceptual framework for analyzing the impacts of governance on climate resilience.

Notes: TAO - Transformative adaptation option; NGO - Nongovernmental organization.

Source: Adapted from Saleth et al. 2023.

When planning and implementing adaptation interventions—or any intervention—governance elements such as institutions, policies, rules, and regulations are often taken for granted or receive the least attention. This oversight occurs mainly because their contributions are difficult to quantify. However, a proper understanding of the connections between governance across different sectors and scales is crucial to assessing impacts. It is hypothesized that a multiscale polycentric governance framework is essential for supporting TAOs and achieving sustainable outcomes that lead to climate resilience.

Analytical Framework

The analytical framework employs an impact pathways approach (Figure 2), where impact transmission factors (ITFs) serve as channels through which MPGs contribute to TAOs to achieve intermediate policy goals (IPGs) related to food, water, and income security. These, in turn, support the final policy goal (FPG) of climate resilience. The framework's key elements—TAOs, ITFs, and IPGs—define its impact domains. Both TAOs and MPGs serve as entry

points for policy interventions across all impact domains. Certain ITFs also serve as policy instruments, influencing the outcomes of other ITFs further downstream in the impact pathway. For instance, changes in cropping patterns and intensity can affect several ITFs, including land and water productivity, labor productivity, crop yields, feed supply, and livestock production.

The analytical framework for this study considers 3 TAOs, 22 MPGs, 21 ITFs, 5 intermediate policy goals (IPGs), and 2 final policy goals (FPGs). Along with climate change (CC), the framework considers 52 other variables. The three TAOs considered for the analysis are:

TAO1 – Development of river basin plans focusing on climate change impacts

TAO2 – Cascade Management Committees with improved farmer organizations

TAO3 – Crop diversification to high-value crops with climate-smart practices

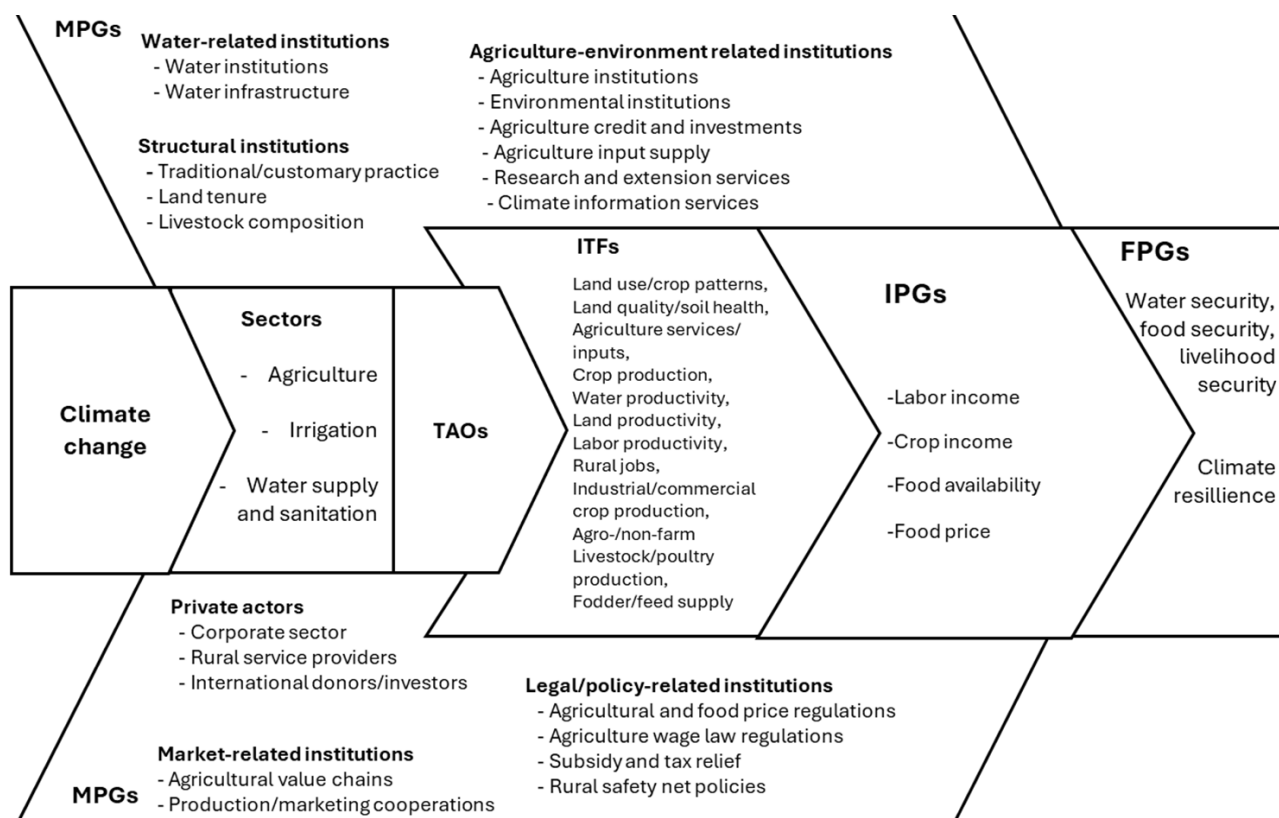


Figure 2. Elements of the impact pathways approach to governance impacts analysis.

Notes: MPG - Multiscale polycentric governance; TAO - Transformative adaptation option; ITF - Impact transmission factor; IPG- Intermediate policy goal; FPG - Final policy goal.

Multiscale Polycentric Governance (MPG) Elements

The 22 governance elements considered in this framework primarily fall into six MPG categories, based on their operational and logistical arrangements (Table 1). Besides the climate change impacts variable (X₁), all MPG variables are exogenous.

The categorization in Table 1 facilitates the design of coherent policy interventions with increased collaboration

by focusing on similar MPG variables. For example, water-related institution domains comprise water institutions and water infrastructure. Innovative water infrastructure improvements will not be practical without enhanced institutional capacity development for water management. Agriculture-related institutions also have interdependent institutions. Improvements in agriculture, science, and technology, as well as research, extension systems, and decision-support systems, will not function effectively without the enhanced capacity of, and collaboration with, agricultural institutions.

Table 1. Categories and elements of multiscale polycentric governance (MPG).

MPG domains		MPG Variables
MPG_D1	Water-related institutions	X ₂ Water institutions X ₃ Water infrastructure
MPG_D2	Agriculture- and environment-related institutions	X ₄ Agricultural institutions X ₅ Environmental institutions X ₆ Agricultural credit and investment institutions X ₇ Agricultural input supply X ₈ Agricultural science, technology, research, and extension systems X ₉ Climate information and decision-support systems
MPG_D3	Market-related institutions	X ₁₀ Agricultural value chains X ₁₁ Agriculture production/Marketing corporations X ₁₂ Agricultural market regime X ₁₃ Agriculture market price X ₁₄ Agricultural crop and employment insurance
MPG_D4	Legal and policy-related institutions	X ₁₅ Agricultural and food price regulation policies X ₁₆ Agricultural wage laws and regulations X ₁₇ Subsidy and tax relief policies X ₁₈ Rural social safety net policies
MPG_D5	Private actors	X ₁₉ Rural service providers X ₂₀ International donors and investors X ₂₁ Corporate sector agencies/Players
MPG_D6	Structural institutions	X ₂₂ Customary institutions X ₂₃ Land tenure (farm size, land leasing, etc.)

Many MPG variables are broad and encompass multiple institutions. For example, water-related institutions encompass not only water management bodies such as the Irrigation Department (national and provincial) and the Department of Agrarian Development (DAD), but also water user associations, as well as water rights, policies, and regulations. Agricultural institutions comprise entities such as the Department of Agriculture, provincial agricultural departments, the DAD, and agrarian service centers under the DAD. In the context of tank cascades,

environmental institutions include the Forest Department and wildlife conservation authorities.

Land tenure systems encompass factors such as land size, ownership, and leasing arrangements, while agricultural input supply covers seeds, fertilizers, weedicides, and other related inputs. Customary and traditional institutions also play a role, such as Bethma cultivation during droughts, where available tank water is allocated to irrigate 50% of the total command area among all

farmers, ensuring some cultivation for all farmers by sharing the limited water supply.

Impact Transmission Factors

The 21 impact transmission factors (ITFs) define 7 impact domains (ITF_D) (Table 2) that contribute to achieving 5 intermediate policy goals (IPGs). Each ITF may also include various sub-transmission factors that are not explicitly addressed in the analysis. For instance, water availability for the agricultural sector could include rainfall, small and large tanks, reservoirs, and irrigation allocations. Water supply comprises the domestic, livestock, and industrial sectors. Land and soil quality may refer to areas affected by waterlogging,

salinity, soil degradation, or lands with access to irrigation.

Farm and labor income IPGs are key determinants of livelihood security, while food availability and food prices contribute to food security. The analysis treats livestock size and composition as endogenous variables because feed supply, in the context of Sri Lanka, is a key factor influencing them, particularly as an element of climate adaptation. Physical water productivity, defined as production per unit of water used, depends on both land productivity and the amount of water used. Economic water productivity, which measures the value generated per unit of water, is determined by production levels, prices, and the quantity of water used.

Table 2. Impact transmission domains.

Impact transmission and policy domain		Impact transmission and policy factors		
TAOs	TAOs	TAO1 TAO2 TAO3	Y ₂ Y ₃ Y ₄	River basin planning focusing on climate change Forming cascade management committees Diversification to high-value crops
ITF_D1	Water availability and supply	ITF_1 ITF_2 ITF_3	Y ₁ Y ₅ Y ₆	Climate investments in water-related work Water availability (Sectoral variable: Irrigation) Water supply (Sectoral variable: Water for people, animals, and industries)
ITF_D2	Area, land quality, and cropping pattern	ITF_4 ITF_5	Y ₈ Y ₉	Land quality and soil health Cultivated or cropped area
ITF_D3	Productivity	ITF_6 ITF_7 ITF_8 ITF_9	Y ₁₀ Y ₁₁ Y ₁₂ Y ₁₃	Cropping pattern Land productivity Water productivity Labor productivity
ITF_D4	Production	ITF_10 ITF_11 ITF_12 ITF_13 ITF_14	Y ₁₄ Y ₁₅ Y ₁₆ Y ₁₇ Y ₁₈	Crop production Industrial and commercial crop production Feed supply Livestock size and composition Livestock production
ITF_D5	Sectoral performance	ITF_15 ITF_16	Y ₇ Y ₁₉	Agriculture sector performance Agro-industries and non-farm sector performance
ITF_D6	Cost, prices and income	ITF_17 ITF_18 ITF_19	Y ₂₀ Y ₂₁ Y ₂₂	Cultivation cost Market prices Crop income
ITF_D7	Rural jobs and wages	ITF_20 ITF_21	Y ₂₃ Y ₂₄	Rural jobs Rural wages
IPG_D1	Policy goals	IPG_1 IPG_2 IPG_3 IPG_4 IPG_5	Y ₂₅ Y ₂₆ Y ₂₇ Y ₂₈ Y ₂₉	Farm income Labor income Food availability Food price Water security

System of Mathematical Equations

The interactions between climate change, multiscale polycentric governance (MPG), transformative adaptation options (TAOs), impact transmission factors (ITFs), and policy goals are complex (Annex A, Figure A.1). For instance, water availability is influenced by climate investments, the three TAOs, and four MPG components: water institutions, water infrastructure, agriculture/food policies, climate information, and decision-support systems, as well as climate change impacts (these

relationships are represented by various arrows in Annex A, Figure A.1).

To better understand and quantify the magnitude of these interactions, they are modeled using a system of mathematical equations (Table 3). The equation system treats the MPG domain variables and climate change impacts (CLCIMPACT) as exogenous, while TAOs and ITFs are treated as endogenous. The system consists of 30 sequentially related equations, where each endogenous dependent variable relies on some endogenous variables from previous equations as well as exogenous factors.

Table 3. Equation system for assessing TAO-MPG-ITF-IPG interactions in Sri Lanka.

Number	Dependent variable	Equation form
1	Y_1 Climate investments	$= f_1(X_2, X_4, X_5, X_{20}, X_{21})$
2	Y_2 River basin planning	$= f_2(Y_1, X_2, X_3, X_4, X_{16}, X_{19}, X_{21}, X_{23})$
3	Y_3 Forming cascade management committees	$= f_3(Y_2, Y_1, X_2, X_3, X_4, X_5, X_6, X_{16}, X_{18}, X_{21}, X_{22})$
4	Y_4 Diversification to high-value crops	$= f_4(Y_2, Y_1, X_1, X_2, X_3, X_4, X_5, X_6, X_9, X_{16}, X_{19}, X_{21}, X_{23})$
5	Y_5 Water availability (irrigation)	$= f_5(Y_4, Y_3, Y_2, Y_1, X_1, X_2, X_3, X_9, X_{15})$
6	Y_6 Water supply	$= f_6(Y_5, Y_2, X_1, X_2, X_3)$
7	Y_7 Agriculture sector performance	$= f_7(Y_5, Y_4, Y_3, Y_1, X_3, X_7, X_8, X_9, X_{10}, X_{15})$
8	Y_8 Land quality and soil health	$= f_8(Y_5, X_1, X_{23})$
9	Y_9 Cultivated area	$= f_9(Y_8, Y_5, Y_2, X_3, X_4, X_5, X_{22}, X_{23})$
10	Y_{10} Cropping patterns	$= f_{10}(Y_9, Y_8, Y_5, Y_4, Y_3, Y_2, Y_1, X_{12}, X_{15}, X_{19}, X_{23})$
11	Y_{11} Land productivity	$= f_{11}(Y_{10}, Y_9, Y_8, Y_7, Y_5, Y_4, X_2, X_3, X_5, X_7, X_{23})$
12	Y_{12} Water productivity	$= f_{12}(Y_{11}, Y_{10}, Y_5, Y_4, Y_3, X_2, X_9)$
13	Y_{13} Labor productivity	$= f_{13}(Y_{11}, Y_{10}, Y_5, X_7, X_{23})$
14	Y_{14} Crop production	$= f_{14}(Y_{12}, Y_{11}, Y_9, Y_{10}, Y_4, X_1, X_4, X_6, X_{11}, X_{19})$
15	Y_{15} Industrial/Commercial crop production	$= f_{15}(Y_{12}, Y_{11}, Y_4, X_1, X_4, X_5, X_6, X_{10}, X_{17}, X_{19}, X_{21})$
16	Y_{16} Feed supply	$= f_{16}(Y_{14}, Y_{11}, Y_{10}, Y_9, X_{22})$
17	Y_{17} Livestock composition	$= f_{17}(Y_{16}, Y_9, X_1, X_4, X_5, X_6, X_{11}, X_{19})$
18	Y_{18} Livestock production	$= f_{18}(Y_{17}, Y_{16}, Y_{10}, X_1, X_6, X_{11}, X_{19}, X_{21})$
19	Y_{19} Agro-industries/Non-farm sector production	$= f_{19}(Y_{18}, Y_{15}, Y_{14}, X_6, X_{10}, X_{18}, X_{21})$
20	Y_{20} Rural wages	$= f_{20}(Y_{19}, Y_{18}, Y_{15}, Y_{14}, Y_{13}, X_{16})$
21	Y_{21} Rural jobs	$= f_{21}(Y_{20}, Y_{19}, Y_{18}, Y_{13}, Y_{11}, X_6, X_{14}, X_{16})$
20	Y_{22} Cultivation cost	$= f_{22}(Y_{20}, Y_4, X_7, X_{14}, X_{18}, X_{23})$
21	Y_{23} Market price	$= f_{23}(Y_{18}, Y_{15}, Y_{14}, X_{12}, X_{15})$
22	Y_{24} Crop income	$= f_{24}(Y_{22}, Y_{23}, Y_{14}, Y_{11}, Y_4, X_{10}, X_{14})$
25	Y_{25} Farm income	$= f_{25}(Y_{24}, Y_{18}, Y_{15}, X_{11}, X_{18})$
26	Y_{26} Labor income	$= f_{26}(Y_{21}, Y_{20}, Y_{18}, X_{11}, X_{18})$
27	Y_{27} Food availability	$= f_{27}(Y_{23}, Y_{18}, Y_{14}, X_{12}, X_{17}, X_{11})$
28	Y_{28} Food price	$= f_{28}(Y_{23}, Y_{14}, X_{12}, X_1)$
29	Y_{29} Water security	$= f_{29}(Y_6, Y_5, X_2, X_{22}, X_3, X_1)$

Notes: TAO - Transformative adaptation options; MPG - Multiscale polycentric governance; ITF - Impact transmission factor; IPG - Intermediate policy goal.

Empirical Estimation

For empirical estimation of the equation system, the study considered a sample of 178 stakeholders from the Yan Oya, Malwathu Oya, Kala Oya, and Mi Oya river basins. The four basins were selected due to the proximity in

their implementation timelines. The first phase of river basin planning was completed in 2020, and the CMCs and crop diversification in tank cascades are currently being implemented. The Malwathu Oya, Yan Oya, Kala Oya, and Mi Oya (Figure 3) lie within the dry zone of Sri Lanka and are highly vulnerable to droughts.

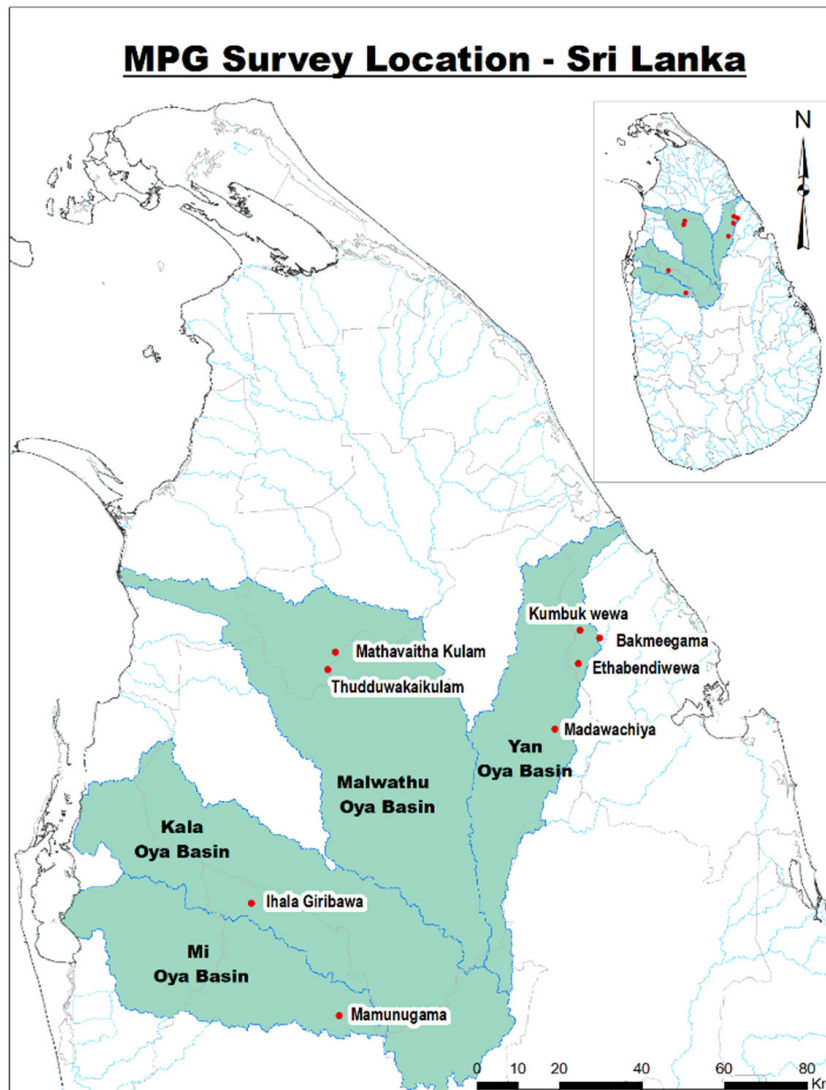


Figure 3. Cascades selected from the Malwathu Oya, Kala Oya, Mi Oya, and Yan Oya river basins for empirical study.

These basins were selected based on climate variability, risk to agriculture, and adaptation projects already implemented. The Malwathu Oya Basin, called Aruvi Aru in the lower reaches, is the second longest river with a length of 162 km. Anuradhapura, Vavuniya, and Mannar districts cover the Malwathu Oya area. The Yan Oya, the country's fifth-longest river, flows for 142 km, originating in the hilly terrain of Dambulla and Sigiriya, and flows northeast and drains into the sea at Pulmoddai in the Trincomalee district. Anuradhapura, Trincomalee, Matale, and Polonnaruwa are the riparian districts of Yan Oya. Mi Oya also originates in the hilly regions of Dambulla, within the boundaries of the Matale, Kurunegala, and Anuradhapura districts in the North Western Province. It spans approximately 118 km in length.

The intra-annual variability of surface runoff is a major constraint in the selected basins. Although the annual per capita surface runoff in the Malwathu Oya, Yan Oya, Kala Oya, and Mi Oya basins exceeds the 1,700 m³/person/

year water scarcity threshold suggested by Falkenmark et al. (1989), more than 85% of this runoff occurs during the four-month period from November to February. Both intra- and inter-annual rainfall variability significantly limits productive agriculture in these basins. Eleven large tanks and over 3,800 small tanks are spread across the four basins. Unlike in other river basins, a significant portion of agriculture here is rainfed, relying heavily on rainfall stored in small tanks or tank cascade systems.

This study empirically estimated a system of equations based on perception data from a sample of 198 stakeholders. Given that many institutions within and outside the river basins were involved in the planning and implementation of TAOs, the sample also included officials from relevant external organizations based outside the river basins. The stakeholders surveyed were from eight cascades: four in the Yan Oya basin, two in the Malwathu Oya basin, and one each in the Kala Oya and Mi Oya basins. Table A.1 in Annex A provides the sample composition,

which includes 78 (39%) farmers from tank cascades where CMCs are being implemented. Additionally, the sample included 68 (34%) stakeholders from various institutions within the river basins across three provinces, and 52 officials and other stakeholders from outside the provinces, representing sectors such as agriculture, irrigation, research/extension, and the private sector.

The equation system has 52 variables. The perception data for these variables include several sub-questions to capture the interactions among different TAOs, MPGs, and impact domains (see Annex B for the questionnaire). For example, seven sub-questions assess the perception of linkages between water availability and other exogenous or endogenous variables, including the effectiveness of:

- water infrastructure in minimizing the impacts of climate change on water availability;
- water institutions minimizing climate change impacts on water availability;
- CMCs and strengthening FOs on water savings;

- diversification to high-value crops and climate-smart agriculture/water management practices for water savings;
- river basin investment plans for climate resilience on water availability;
- current agriculture/water /land laws/regulations affect water availability; and
- the negative impacts of climate change on water availability.

In total, there are 235 sub-questions on 52 variables to assess the interactions of climate change, MPG, TAO, ITF, and policy goals.

The perception score for each sub-question is based on a scale of 1 (lowest) to 10 (highest), with zero indicating no idea. The average perception score of the sub-questions is the score of the main question. Using a scale of 1–10 helps to assess the relative magnitude of the interactions between different variables. The descriptive statistics of the variables are presented in Annex A, Table A.2.I.

Results – Estimates of the System of Equations

After estimating various types of models (linear and log transformation, with and without constant) and conducting diagnostic analysis for consistency and performance, the study selected the linear equation system with no constant to present the impact analysis. The diagnostic analysis subjected the equation system to heteroscedasticity, autocorrelation, normality tests, and rank and order determination (Annex A, Table A.2). The diagnostics show that all 29 equations have high R² values, indicating high predictive ability (Table 4).

Of the 29 equations, 11 still have high first-order autocorrelation, 20 have heteroscedastic errors, and 18 have non-normal error structures (Annex A, Table A.2). Given the complexity of equation systems and multicollinearity, many equations likely violate standard assumptions in econometric estimations. These are some of the limitations of our analysis, and these can affect the direction and magnitude of some of the significant coefficients in the equations in Table 5.

Table 4. Overall estimates of the equation system.

Number	Equation	Number of observations	Parameters	RMSE	R-Square	Chi-Square statistic	P
1	Y_1	198	6	1.12	0.96	5409	0.000
2	Y_2	198	10	1.21	0.97	7418	0.000
3	Y_3	198	12	1.32	0.96	6610	0.000
4	Y_4	198	9	0.97	0.98	12078	0.000
5	Y_5	198	9	1.18	0.97	10367	0.000
6	Y_6	198	5	1.29	0.97	6380	0.000
7	Y_7	198	12	1.58	0.96	6404	0.000
8	Y_8	198	5	1.42	0.96	5513	0.000
9	Y_9	198	10	1.26	0.97	9145	0.000
10	Y_{10}	198	10	1.25	0.97	8777	0.000
11	Y_{11}	198	12	1.27	0.97	10508	0.000
12	Y_{12}	198	9	0.88	0.99	17696	0.000
13	Y_{13}	198	5	1.25	0.97	8088	0.000
14	Y_{14}	198	12	1.14	0.97	10213	0.000
15	Y_{15}	198	11	1.05	0.97	7576	0.000
16	Y_{16}	198	5	1.15	0.97	8846	0.000
17	Y_{17}	198	8	1.37	0.96	4982	0.000
18	Y_{18}	198	8	0.85	0.98	11663	0.000
19	Y_{19}	198	7	1.88	0.88	2023	0.000
20	Y_{20}	198	6	1.31	0.96	4835	0.000
21	Y_{21}	198	6	1.66	0.94	3546	0.000
22	Y_{22}	198	7	0.99	0.98	10044	0.000
23	Y_{23}	198	10	1.23	0.97	7145	0.000
24	Y_{24}	198	8	1.10	0.98	9081	0.000
25	Y_{25}	198	5	1.01	0.98	9385	0.000
26	Y_{26}	198	6	1.31	0.96	5448	0.000
27	Y_{27}	198	6	0.95	0.98	10753	0.000
28	Y_{28}	198	5	1.02	0.98	10151	0.000
29	Y_{29}	198	6	1.64	0.94	4004	0.000

Source: Authors' estimation

Table 5. Coefficients of the equation system.

Dependent variable	Independent variables	Coefficient estimate	Standard error	Z-value	P> z	95% interval	Confidence
1 Y_1 - Climate investments	X_1	0.204	0.035	5.890	0.000	0.136	0.271
	X_2	0.164	0.068	2.410	0.016	0.031	0.297
	X_5	0.170	0.059	2.880	0.004	0.054	0.285
	X_6	0.118	0.058	2.030	0.043	0.004	0.232
	X_{10}	0.060	0.036	1.660	0.097	-0.011	0.132
	X_{21}	0.163	0.054	3.030	0.002	0.058	0.268
2 Y_2 - River basin planning	Y_1	0.248	0.095	2.610	0.009	0.062	0.434
	X_2	-0.080	0.062	-1.280	0.201	-0.202	0.043
	X_3	0.290	0.046	6.280	0.000	0.199	0.380
	X_4	0.067	0.059	1.140	0.256	-0.049	0.182
	X_5	-0.134	0.054	-2.490	0.013	-0.240	-0.029
	X_{19}	0.197	0.056	3.510	0.000	0.087	0.307
	X_{21}	0.045	0.055	0.820	0.410	-0.062	0.153
	X_6	0.056	0.045	1.240	0.213	-0.032	0.144
	X_{23}	0.312	0.042	7.450	0.000	0.230	0.395
	X_{16}	0.043	0.036	1.170	0.240	-0.029	0.114

Continued...

Dependent variable	Independent variables	Coefficient estimate	Standard error	Z-value	P> z	95% interval	Confidence
3 Y ₃ - Forming cascade management committees	Y ₁	0.506	0.107	4.750	0.000	0.297	0.715
	Y ₂	1.013	0.131	7.710	0.000	0.755	1.270
	X ₂	-0.158	0.070	-2.250	0.024	-0.295	-0.020
	X ₃	-0.172	0.057	-3.010	0.003	-0.285	-0.060
	X ₄	0.073	0.065	1.120	0.261	-0.054	0.201
	X ₅	0.105	0.062	1.690	0.092	-0.017	0.226
	X ₆	0.084	0.055	1.530	0.126	-0.024	0.191
	X ₈	0.227	0.082	2.790	0.005	0.067	0.387
	X ₁₆	-0.177	0.042	-4.250	0.000	-0.258	-0.095
	X ₁₉	-0.056	0.063	-0.890	0.373	-0.179	0.067
	X ₂₁	-0.173	0.061	-2.810	0.005	-0.293	-0.052
X ₂₂	0.107	0.052	2.050	0.040	0.005	0.209	
X ₂₃	-0.084	0.060	-1.410	0.160	-0.201	0.033	
4 Y ₄ - Crop diversification with climate- smart practices	Y ₃	0.957	0.063	15.280	0.000	0.834	1.079
	X ₂	-0.151	0.056	-2.690	0.007	-0.261	-0.041
	X ₃	-0.020	0.041	-0.490	0.621	-0.101	0.060
	X ₄	-0.122	0.048	-2.560	0.010	-0.216	-0.029
	X ₅	0.007	0.045	0.150	0.880	-0.082	0.096
	X ₆	-0.061	0.041	-1.480	0.139	-0.142	0.020
	X ₁₂	0.111	0.042	2.660	0.008	0.029	0.193
	X ₁₉	0.215	0.046	4.640	0.000	0.124	0.306
X ₂₁	0.074	0.044	1.690	0.091	-0.012	0.161	
5 Y ₅ - Water availability	Y ₁	0.307	0.092	3.320	0.001	0.126	0.488
	Y ₂	0.237	0.113	2.100	0.035	0.016	0.458
	Y ₃	-0.736	0.115	-6.420	0.000	-0.961	-0.512
	Y ₄	0.639	0.117	5.440	0.000	0.409	0.869
	X ₁	0.252	0.040	6.320	0.000	0.174	0.330
	X ₂	0.134	0.057	2.330	0.020	0.021	0.246
	X ₃	0.073	0.052	1.410	0.159	-0.028	0.174
	X ₉	0.016	0.056	0.290	0.772	-0.094	0.127
	X ₁₅	0.093	0.033	2.870	0.004	0.030	0.157
6 Y ₆ - Water supply	Y ₂	0.502	0.103	4.850	0.000	0.299	0.704
	Y ₅	0.608	0.157	3.880	0.000	0.301	0.916
	X ₂	0.046	0.070	0.660	0.511	-0.092	0.184
	X ₃	-0.111	0.065	-1.710	0.087	-0.239	0.016
	X ₁	-0.014	0.069	-0.200	0.843	-0.149	0.122
7 Y ₇ - Agriculture sector performance	Y ₁	0.495	0.243	2.040	0.042	0.018	0.972
	Y ₃	-0.905	0.171	-5.290	0.000	-1.241	-0.570
	Y ₄	0.622	0.181	3.440	0.001	0.267	0.976
	Y ₅	-0.349	0.225	-1.550	0.121	-0.790	0.092
	Y ₆	0.394	0.168	2.340	0.019	0.064	0.724
	X ₁	0.364	0.081	4.490	0.000	0.205	0.522
	X ₃	0.102	0.067	1.520	0.129	-0.030	0.234
	X ₇	-0.189	0.121	-1.570	0.117	-0.426	0.047
	X ₈	0.192	0.081	2.370	0.018	0.033	0.351
	X ₉	0.108	0.101	1.070	0.286	-0.090	0.307
	X ₁₀	-0.087	0.094	-0.930	0.352	-0.272	0.097
	X ₁₅	0.241	0.051	4.740	0.000	0.141	0.341
8 Y ₈ - Land quality and soil health	Y ₅	0.707	0.128	5.500	0.000	0.455	0.959
	X ₄	-0.061	0.063	-0.970	0.330	-0.184	0.062
	X ₁	0.107	0.074	1.440	0.149	-0.038	0.252
	X ₂₃	-0.003	0.053	-0.060	0.952	-0.106	0.100

Continued...

Dependent variable	Independent variables	Coefficient estimate	Standard error	Z-value	P> z	95% interval	Confidence
9 Y ₉ - Cropping patterns	Y ₃	-0.665	0.117	-5.680	0.000	-0.894	-0.435
	Y ₄	0.397	0.129	3.080	0.002	0.144	0.651
	Y ₂	0.841	0.121	6.940	0.000	0.603	1.078
	Y ₅	0.439	0.094	4.690	0.000	0.255	0.622
	Y ₈	0.338	0.091	3.700	0.000	0.159	0.518
	X ₉	-0.030	0.057	-0.520	0.604	-0.142	0.082
	X ₁₂	-0.026	0.051	-0.520	0.602	-0.126	0.073
	X ₁₅	0.089	0.035	2.540	0.011	0.020	0.158
	X ₁₉	-0.188	0.054	-3.450	0.001	-0.294	-0.081
X ₂₃	-0.209	0.053	-3.940	0.000	-0.313	-0.105	
10 Y ₁₀ - Cultivated area	Y ₂	0.755	0.186	4.050	0.000	0.390	1.120
	Y ₅	-0.127	0.152	-0.830	0.404	-0.426	0.171
	Y ₈	-0.069	0.127	-0.540	0.588	-0.318	0.180
	Y ₁₀	0.834	0.210	3.970	0.000	0.422	1.247
	X ₃	-0.094	0.067	-1.400	0.162	-0.226	0.038
	X ₄	-0.071	0.057	-1.250	0.212	-0.182	0.040
	X ₅	-0.029	0.061	-0.470	0.640	-0.148	0.091
	X ₁₉	-0.069	0.054	-1.290	0.198	-0.175	0.036
	X ₂₂	-0.054	0.057	-0.940	0.346	-0.165	0.058
X ₂₃	-0.106	0.061	-1.720	0.085	-0.226	0.015	
11 Y ₁₁ - Land productivity	Y ₄	-0.181	0.079	-2.270	0.023	-0.336	-0.025
	Y ₅	-0.167	0.124	-1.350	0.176	-0.409	0.075
	Y ₈	0.061	0.114	0.530	0.594	-0.163	0.285
	Y ₉	1.781	0.255	6.990	0.000	1.282	2.280
	Y ₁₀	-0.484	0.179	-2.700	0.007	-0.834	-0.133
	X ₂	0.034	0.045	0.750	0.452	-0.054	0.122
	X ₃	-0.142	0.054	-2.630	0.009	-0.248	-0.036
	X ₄	0.047	0.046	1.010	0.315	-0.044	0.137
	X ₅	0.053	0.046	1.150	0.251	-0.037	0.142
	X ₇	0.005	0.048	0.110	0.912	-0.088	0.099
	X ₈	-0.001	0.050	-0.020	0.982	-0.100	0.097
	X ₂₃	0.005	0.041	0.120	0.907	-0.075	0.085
12 Y ₁₂ - Water productivity	Y ₂	0.045	0.118	0.380	0.702	-0.186	0.276
	Y ₃	-0.303	0.106	-2.860	0.004	-0.511	-0.096
	Y ₄	0.272	0.103	2.640	0.008	0.070	0.475
	Y ₅	0.371	0.122	3.040	0.002	0.132	0.610
	Y ₉	-0.085	0.206	-0.410	0.682	-0.488	0.319
	Y ₁₁	0.673	0.159	4.230	0.000	0.361	0.985
	X ₂	0.074	0.056	1.340	0.180	-0.034	0.183
	X ₉	0.027	0.044	0.610	0.540	-0.060	0.114
	X ₁₀	-0.078	0.043	-1.820	0.069	-0.162	0.006
13 Y ₁₃ - Labor productivity	Y ₅	-0.314	0.140	-2.240	0.025	-0.589	-0.040
	Y ₉	-0.037	0.211	-0.180	0.860	-0.451	0.377
	Y ₁₂	1.146	0.196	5.840	0.000	0.762	1.531
	X ₇	0.048	0.061	0.790	0.430	-0.072	0.168
	X ₂₃	0.147	0.047	3.090	0.002	0.054	0.240

Continued...

Dependent variable	Independent variables	Coefficient estimate	Standard error	Z-value	P> z	95% interval	Confidence
14 Y ₁₄ Food production	Y ₃	0.444	0.113	3.910	0.000	0.222	0.666
	Y ₄	0.223	0.106	2.110	0.035	0.016	0.431
	Y ₉	0.055	0.287	0.190	0.849	-0.508	0.618
	Y ₁₀	-0.513	0.186	-2.760	0.006	-0.878	-0.149
	Y ₁₂	0.881	0.185	4.760	0.000	0.519	1.244
	X ₁	0.035	0.044	0.790	0.429	-0.051	0.121
	X ₂	-0.026	0.048	-0.540	0.589	-0.120	0.068
	X ₃	-0.026	0.044	-0.590	0.553	-0.113	0.060
	X ₆	-0.077	0.037	-2.100	0.036	-0.150	-0.005
	X ₁₀	-0.147	0.054	-2.720	0.007	-0.252	-0.041
	X ₁₁	0.033	0.049	0.680	0.498	-0.063	0.129
	X ₁₉	0.051	0.054	0.960	0.339	-0.054	0.156
15 Y ₁₅ - Industrial and commercial crop production	Y ₃	0.291	0.095	3.070	0.002	0.105	0.477
	Y ₁₂	0.102	0.244	0.420	0.674	-0.375	0.580
	X ₁	0.026	0.054	0.490	0.627	-0.080	0.133
	X ₂	0.171	0.056	3.040	0.002	0.061	0.282
	X ₃	-0.036	0.053	-0.690	0.493	-0.139	0.067
	X ₆	-0.104	0.061	-1.710	0.088	-0.223	0.015
	X ₁₀	0.005	0.068	0.070	0.947	-0.128	0.137
	X ₁₃	0.256	0.249	1.030	0.304	-0.232	0.743
	X ₁₇	0.109	0.065	1.670	0.095	-0.019	0.238
	X ₁₉	0.064	0.062	1.030	0.302	-0.057	0.185
	X ₂₁	0.039	0.062	0.620	0.534	-0.083	0.161
16 Y ₁₆ - Feed supply	Y ₉	0.573	0.194	2.950	0.003	0.192	0.953
	Y ₁₀	0.326	0.241	1.350	0.176	-0.146	0.798
	Y ₁₄	-0.298	0.152	-1.960	0.050	-0.596	-0.001
	Y ₁₅	0.412	0.130	3.160	0.002	0.156	0.668
	X ₂₂	-0.009	0.042	-0.200	0.838	-0.092	0.074
17 Y ₁₇ - Livestock size and composition	Y ₁₀	0.286	0.189	1.510	0.131	-0.085	0.657
	Y ₁₆	0.457	0.195	2.340	0.019	0.074	0.840
	X ₁	0.146	0.060	2.430	0.015	0.028	0.264
	X ₄	0.182	0.070	2.590	0.010	0.045	0.320
	X ₆	0.220	0.067	3.290	0.001	0.089	0.350
	X ₅	-0.064	0.069	-0.920	0.357	-0.199	0.072
	X ₁₁	-0.176	0.076	-2.330	0.020	-0.325	-0.028
	X ₁₉	-0.117	0.081	-1.450	0.148	-0.276	0.042
18 Y ₁₈ - Livestock production	Y ₉	0.108	0.104	1.040	0.299	-0.096	0.313
	Y ₁₆	0.275	0.112	2.450	0.014	0.055	0.495
	Y ₁₇	0.483	0.084	5.750	0.000	0.318	0.648
	X ₁	-0.039	0.038	-1.030	0.301	-0.114	0.035
	X ₆	0.079	0.042	1.860	0.062	-0.004	0.161
	X ₁₁	-0.011	0.039	-0.270	0.789	-0.088	0.067
	X ₁₉	0.050	0.044	1.140	0.253	-0.036	0.137
	X ₂₁	0.023	0.041	0.560	0.578	-0.057	0.102
19 Y ₁₉ - Agro-based industries and non-farm sector production	Y ₁₈	-0.486	0.213	-2.280	0.023	-0.904	-0.068
	Y ₁₅	1.601	0.260	6.160	0.000	1.091	2.111
	Y ₁₄	-0.488	0.193	-2.530	0.011	-0.866	-0.111
	X ₆	0.340	0.090	3.760	0.000	0.163	0.517
	X ₁₀	0.017	0.090	0.190	0.851	-0.159	0.193
	X ₁₉	-0.151	0.093	-1.630	0.102	-0.333	0.030
	X ₂₁	0.079	0.088	0.910	0.365	-0.092	0.251

Continued...

Dependent variable	Independent variables	Coefficient estimate	Standard error	Z-value	P> z	95% interval	Confidence
20 Y ₂₀ - Agriculture market price	Y ₁₄	0.483	0.148	3.260	0.001	0.192	0.773
	Y ₁₅	-0.293	0.181	-1.620	0.105	-0.648	0.061
	Y ₁₈	0.759	0.140	5.420	0.000	0.485	1.033
	X ₁₂	0.017	0.067	0.250	0.799	-0.114	0.148
	X ₁₅	0.005	0.044	0.120	0.905	-0.080	0.090
	X ₁₇	-0.051	0.065	-0.780	0.436	-0.179	0.077
21 Y ₂₁ - Rural wage	Y ₁₃	0.038	0.191	0.200	0.841	-0.336	0.413
	Y ₁₄	-0.108	0.199	-0.550	0.586	-0.498	0.281
	Y ₁₅	0.495	0.266	1.860	0.063	-0.027	1.016
	Y ₁₈	0.740	0.220	3.360	0.001	0.308	1.171
	Y ₁₉	-0.444	0.128	-3.480	0.000	-0.694	-0.194
	X ₁₆	0.204	0.064	3.200	0.001	0.079	0.330
22 Y ₂₂ - Rural jobs	Y ₁₁	0.168	0.137	1.230	0.219	-0.100	0.436
	Y ₁₃	0.099	0.167	0.590	0.553	-0.228	0.426
	Y ₁₈	0.012	0.168	0.070	0.944	-0.318	0.342
	Y ₁₉	0.186	0.072	2.570	0.010	0.044	0.327
	Y ₂₁	0.587	0.116	5.050	0.000	0.359	0.815
	X ₁₄	0.078	0.049	1.610	0.107	-0.017	0.174
	X ₁₆	-0.121	0.045	-2.700	0.007	-0.209	-0.033
23 Y ₂₃ - Cultivation cost	Y ₃	0.123	0.134	0.920	0.356	-0.139	0.385
	Y ₁₀	-0.456	0.254	-1.800	0.072	-0.953	0.041
	Y ₁₁	1.279	0.252	5.080	0.000	0.785	1.772
	Y ₂₁	0.011	0.111	0.100	0.920	-0.206	0.228
	X ₇	0.119	0.063	1.910	0.056	-0.003	0.242
	X ₁₀	-0.127	0.071	-1.800	0.072	-0.265	0.011
	X ₁₉	-0.046	0.057	-0.800	0.422	-0.157	0.066
	X ₁₄	0.015	0.059	0.260	0.792	-0.099	0.130
	X ₂₃	0.021	0.054	0.390	0.697	-0.085	0.127
X ₁₈	-0.016	0.044	-0.360	0.721	-0.102	0.070	
24 Y ₂₄ - Crop income	Y ₄	0.106	0.100	1.060	0.287	-0.089	0.301
	Y ₉	1.231	0.341	3.610	0.000	0.563	1.898
	Y ₁₁	-0.125	0.202	-0.620	0.537	-0.520	0.271
	Y ₂₃	-0.111	0.188	-0.590	0.556	-0.480	0.258
	X ₁₀	-0.209	0.216	-0.970	0.334	-0.632	0.214
	X ₁₃	0.352	0.128	2.760	0.006	0.102	0.602
	X ₁₀	-0.182	0.067	-2.720	0.007	-0.313	-0.051
	X ₁₄	-0.027	0.058	-0.470	0.635	-0.141	0.086
25 Y ₂₅ - Farm income	Y ₁₅	-0.073	0.112	-0.650	0.514	-0.293	0.147
	Y ₁₈	0.287	0.154	1.870	0.062	-0.015	0.588
	Y ₂₄	0.906	0.084	10.780	0.000	0.741	1.070
	X ₁	-0.104	0.046	-2.280	0.023	-0.193	-0.015
	X ₁₈	-0.050	0.044	-1.130	0.258	-0.136	0.036
26 Y ₂₆ - Labor income	Y ₁₈	0.758	0.189	4.020	0.000	0.388	1.128
	Y ₁₉	-0.235	0.084	-2.790	0.005	-0.401	-0.070
	Y ₂₁	-0.255	0.133	-1.910	0.056	-0.516	0.007
	Y ₂₂	0.698	0.158	4.430	0.000	0.389	1.006
	X ₁	0.013	0.051	0.250	0.805	-0.088	0.113
	X ₁₈	-0.004	0.046	-0.100	0.923	-0.095	0.086

Continued...

Dependent variable	Independent variables	Coefficient estimate	Standard error	Z-value	P> z	95% interval	Confidence
27 Y ₂₇ - Food availability	Y ₁₄	0.649	0.116	5.610	0.000	0.422	0.876
	Y ₁₈	0.041	0.101	0.400	0.688	-0.158	0.239
	X ₁	0.069	0.047	1.480	0.140	-0.023	0.161
	X ₁₂	0.222	0.052	4.230	0.000	0.119	0.324
	X ₁₃	0.010	0.100	0.100	0.923	-0.187	0.206
28 Y ₂₈ - Food price	X ₁₇	0.007	0.048	0.140	0.885	-0.087	0.101
	Y ₁₄	0.032	0.167	0.190	0.851	-0.297	0.360
	Y ₂₇	1.011	0.202	5.000	0.000	0.614	1.407
	X ₁	-0.004	0.053	-0.080	0.933	-0.109	0.100
29 Y ₂₉ - Water security	X ₁₂	-0.084	0.074	-1.150	0.251	-0.228	0.060
	X ₁₃	0.079	0.103	0.770	0.444	-0.123	0.280
	Y ₅	0.985	0.185	5.310	0.000	0.622	1.349
	Y ₆	0.033	0.126	0.260	0.792	-0.214	0.281
	X ₁	-0.234	0.079	-2.970	0.003	-0.389	-0.080
	X ₂	0.037	0.079	0.470	0.641	-0.118	0.192
	X ₃	0.077	0.071	1.080	0.279	-0.062	0.215
	X ₂₂	0.093	0.063	1.490	0.137	-0.030	0.216

Source: Authors' estimation

The major highlights of the equation system estimates (in Table 5) are as follows:

Equation 1 shows that **climate change** can significantly impact **climate-related investments**. Multi-sectoral participation of water, agricultural, and environmental institutions, donors, investors, and the private sector plays a key role in driving these investments.

Equations 2 and 3 highlight that **climate investments** notably influence the preparation of **river basin plans and the formation of cascade management committees (CMCs)**. In these equations,

- Water infrastructure, rather than water institutions, significantly impacts the development of both river basin plans and CMCs. This could stem from most stakeholders' perception that investing in the infrastructure needs of small tanks is more important than investing in the institutions that manage them. Water management in small tanks is predominantly farmer-led, with farmer organizations or water user associations playing a limited role in the development of river basin plans.
- The negative coefficient for environmental institutions suggests that stakeholders perceive these entities to play a minimal role in river basin planning and CMC formation. Many stakeholders also report a lack of cooperation between environmental, water, and agricultural institutions in establishing CMCs.
- The negative coefficient for water infrastructure in Equation 3 suggests that the current state of the infrastructure may hinder the **formation of effective CMCs**. However, stakeholders believe that well-

structured river basin plans could positively influence CMC development. Since tank cascades are seen as integral components of a river basin, basin-level planning is expected to have a significant impact on water management within its sub-watersheds.

- Climate investments significantly influence the preparation of river basin plans and the formation of CMCs. Among the MPG elements, water infrastructure, rather than water institutions, plays a decisive role in the development of CMCs.
- The negative significant coefficient of environmental institutions indicates that most stakeholders perceive environmental institutions as playing a minor role in river basin planning and forming CMCs. Field observations also suggest that there is little cooperation among environmental, water, and agricultural institutions in forming CMCs.
- The negative sign for water infrastructure in Equation 3 may indicate that the existing conditions of the infrastructure do not support the formation of well-functioning CMCs. Stakeholders perceive that river basin plans can positively influence the formation of CMCs. Stakeholders believe that tank cascades are part of a river basin, and basin-level planning will influence the water management of its sub-watersheds.
- Among other factors, land tenure plays a significant role in river basin plans but not in the formation of CMCs. This could be due to the considerable variation in land tenure across river basins compared to the smaller variation within a cascade system. Agricultural wage laws have a negative impact on the formation of CMCs, whereas customary institutions exert a positive influence.

- Interestingly, although the corporate sector does not play a significant role in river basin plan development, its influence is channeled through climate investments, as indicated in Equation 1. Similarly, while agricultural institutions have a significant impact on climate investments, they do not directly affect river basin plan development. In the next section, we explore these marginal effects in more detail, using reduced-form equations to evaluate the influence of X variables on Y, as well as Y variables on other Y variables.

Equation 4 focuses on **diversification into high-value crops** with climate-smart practices. In this context,

- Water institutions have a significant negative influence, while CMCs exert a significant positive influence. This may be because most water institutions, besides farmer organizations (FOs), have limited involvement in managing water allocations in small tanks. In contrast, CMCs, through their coordination with FOs, could play a much larger role in determining water allocations for paddy and other crops.
- As expected, rural service providers and agricultural market structures significantly impact decisions regarding crop diversification. While agricultural credit institutions do not directly affect diversification into high-value crops, their influence is indirectly transmitted through CMCs, where the effect is positive and significant.

Equations 5 and 6 are on the **water availability for irrigation and water supply to the domestic and industrial sectors**. They show that, besides climate change impacts, river basin planning and crop diversification TAOs and MPG variables—water institutions, agriculture, and food-related policies—significantly influence water availability. However, CMCs have a significant negative influence on water availability. This may be due to the perception that these committees may impose restrictions on water allocation at individual tanks, which is at the discretion of individual farmer organizations. The significant positive influence of climate change impacts could be due to stakeholders' perspectives of the positive influence of climate investments, rather than the impacts of climate change themselves, on water resources and infrastructure. Equation 6 shows the significant positive influence of river basin planning and water availability on domestic and industrial water supply.

Equations 8 and 9 are on the ITFs of **land quality and soil health, and cropping patterns**. Stakeholders perceive,

- Water availability is a significant factor affecting land quality and soil health. Crop diversification and river basin planning TAOs have a significant positive relationship with cropping patterns ITF, while CMCs have a significant negative relationship. The latter may

be due to perceived water allocation changes after forming CMCs, which may affect crop diversification decisions. Water availability, and land quality and soil health ITFs have a significant positive influence on cropping pattern decisions. Land quality and soil health ITFs are positively related to cropping patterns.

- Of the MPGs, research and extension systems influence land quality and soil health. Agriculture and food policy MPG has a significant positive effect, while rural service providers and land tenure negatively influence crop diversification. It is clear that crop diversification choices are constrained by land tenure, especially where landholdings are small or leased, and that the current level of rural service delivery may not be sufficient to change cropping pattern decisions.

Equation 10 on the **cultivated area** shows that it has a positive influence on river basin planning and cropping patterns. The negative influence of land tenure, as on cropping patterns, may be due to small land size and/or leased land. Although water availability significantly influences cropping pattern decisions, it does not affect cultivated areas. Except in extreme drought conditions, most farmers cultivate small lands completely.

Equations 11 to 13 address **productivity-related** ITFs. Equation 11 shows that the cropping pattern is the only variable with a significantly positive relationship with land productivity, while crop diversification and water infrastructure have a negative relationship. Land productivity, water availability, and high-value crops have a significant positive relationship with water productivity. Land productivity and land tenure significantly influence labor productivity. Land tenure, perhaps in terms of land ownership or large land sizes, positively contributes to higher labor productivity.

Equations 14 to 18 are on **production-related** ITFs (food crop production, industrial and commercial crop production, feed supply, and livestock production).

- Stakeholders perceive that water productivity significantly influences crop production more than land productivity does. This may be due to stakeholders' strong perception of recurrent water scarcity, which affects land productivity and, in turn, crop production, as well as the possibility that water use is already factored into water productivity.
- Changes in cropping patterns, underdeveloped value chains, and inadequate agricultural credit institutions have negatively affected food production.
- CMCs, agricultural institutions, and state tax policies significantly influence industrial and commercial crop production.
- Land productivity, cultivated area, and customary institutions significantly influence feed supply.
- Feed supply is a significant factor affecting livestock size, composition, and production. Agricultural institutions play a significant positive role in livestock composition and size.

- In contrast, agricultural marketing and production corporations have a reverse effect on livestock composition and size. The latter shows that enhanced agricultural production and marketing corporations could encourage agricultural diversification toward livestock production, which stakeholders perceive as a likely outcome of climate change.

Equations 7 and 19 are on **sectoral performance** (agricultural, agro-based, and non-farm sectors).

- Agriculture sector performance is related to the MPG elements of research and extension systems and policies on agriculture and food production.
- Diversification to high-value crops also influences the performance of the agriculture sector.
- Industrial and commercial crop production significantly influences agro-based industries and non-farm sector performance, while crop and livestock production have a significant negative influence. This may indicate stakeholder awareness and the difficulty in starting or expanding agro-based industries, particularly in food and livestock production.
- The stakeholders perceive that agricultural credit institutions positively influence the expansion of agro-based and non-farm sector industries.

Equations 20, 23, and 24 are on **market prices, production costs, and crop income**, respectively.

Stakeholders perceive that food and livestock production influence market prices. The lack of a significant relationship between domestic agricultural market regimes and prices may indicate that stakeholders perceive these regimes as having little influence on the prices they receive for their products. Market access is a major constraint for people living in the selected cascades in extremely rural areas. Agricultural inputs, rural wages, and crop areas significantly influence cultivation costs. High-value crops and market prices determine crop income. Among the MPG elements, agricultural value chains—identified as a weak element—are perceived to negatively influence production costs and crop income.

Equations 25 to 29 assess the policy goals of **farm and labor income, food availability and prices, and water security**. Crop income significantly influences farm income; however, the extent of industrial and commercial crops is too small to have a positive impact on farm income. Livestock production has a positive, though insignificant, influence on farm income. This shows that there is scope for agricultural diversification of crops and livestock to influence farm income in these cascades. However, livestock production and rural jobs exert a significant positive influence, whereas rural wages and agro-based industries are perceived to negatively affect labor income. This shows an opportunity for developing agro-based and non-farm sector industries to increase farm income and rural employment.

Policy Interventions

MPGs, and some TAOs and ITFs are policy instruments designed to improve the performance of the TAOs, downstream ITFs, and the broader policy goals of food, water, and livelihood security. The stakeholder survey examined perceptions of the strengths and weaknesses of MPG elements, their contributions, and their interactions with TAOs and ITFs. As survey responses were based on a scale of one to ten, they reflect stakeholders' perceptions of the relative contributions of different MPGs within and across ITFs. For instance, a low score (e.g., one) does not necessarily indicate irrelevance but rather reflects stakeholders' views on the operational significance or current effectiveness of a particular MPG. These relative scores help prioritize the interventions needed to strengthen MPG elements and ITFs to better achieve policy goals.

Some interventions focus solely on enhancing MPG elements related to institutions, policies, laws, and regulations, which act as exogenous factors in the equation system. Other interventions combine MPG elements with TAOs and ITFs that are endogenous to the system. These interventions can bolster multiple ITFs or target a specific ITF within the framework.

MPG as Policy Instruments

The relative influences of MPG domains across and within TAO, ITFs, and IPGs are shown in Table 6, and the contributions for individual ITFs are shown in Annex A, Table A.3. The impacts across ITFs (row-wise, columns 2–6) show how an MPG domain can influence one or more ITFs. The effect within the ITF (columns 7–12) shows how

MPG domains influence an individual ITF. Table 6 and Annex A, Table A.3 represent the impacts of MPG domains and, where applicable, of individual MPGs across and within ITF domains. These impacts are estimated using the reduced form equations in Annex C.

MPG impacts across ITF domains

- The most considerable positive impact of **water-related institutions (MPG_D1: water institutions and water infrastructure)** is on water availability and supply (ITF_D1), productivity (ITF_D3), and production (ITF_D4). The next highest impacts are on intermediate policy goals (IPGs) and the prices-income-cost MPG domain (ITF_D7). Within MPG_D1, water institutions MPG plays a significant role in the effects of ITF_D1 and, to a lesser extent, ITF_D3. The role of water infrastructure MPG is prominent in other ITFs.
- The lowest impact of water-related institutions is on the TAO domain. However, water infrastructure significantly influences TAOs. This is understandable, given that water institutions, aside from farmer organizations, play a minor role in managing water in village tanks. This limited role of water institutions influenced stakeholders' perceptions of the current state of water institutions, which resulted in a lower perception of TAOs and, for that matter, of ITF_D2, including cropped area, cropping pattern, and land quality. The findings indicate the important role of infrastructure in the successful implementation and operation of TAOs, such as river basin plans, CMCs, and crop diversification in the cascade command areas. Substantial importance is also given to the role of water-related institutions, particularly water infrastructure, in achieving water security policy goals (IPG_6).
- The largest impact of the **agriculture- and environment-related institutional domain (MPG_D2)** is on the TAOs, followed closely by the production domain (ITF_D4). ITF_D2 (cropped area, cropping patterns, and land quality) and ITF_D3 (land, water, and labor productivity) have the lowest impact. This contrasting perception shows the positive influence of agricultural institutions, such as the Department of Agrarian Development, on crop and livestock production, while pointing to the perceived negative influence of environmental departments—such as those responsible for forests and wildlife—inadequate effort for minimizing the crop damage from wild animals and constraining access to pasture lands for livestock rearing in tank cascades catchments, etc. These are major issues highlighted by the stakeholders, especially farmers, during field visits and survey discussions. These findings show that enhanced cooperation between water and environmental institutions can boost productivity and cropping patterns in tank cascades.
- The **market-related institutional domain (MPG_D3)** significantly influences policy goals, particularly through market regimes and prices, which greatly affect farm income and access to food. However, weak agricultural value chains and underperforming production/marketing corporations have a lower impact on improving productivity (ITF_D3) and production (ITF_D4). These are also stakeholders' observations of the key constraints of productivity and production growth.
- The **legal and policy-related MPG domain (MPG_D4)** has the largest influence on productivity (ITF_D3) and production (ITF_D4), followed closely by policy goals. However, the relatively lower influence than the other MPG domains suggests that removing policies and legal constraints can boost investments for increased productivity and production growth.

Table 6. Impacts of MPG policy domains as policy variables.

Impact transmission variable domain	MPG impacts across impact transmission domains						MPG impacts within impact transmission domains						Total
	MPG_D1	MPG_D2	MPG_D3	MPG_D4	MPG_D5	MPG_D6	MPG_D1	MPG_D2	MPG_D3	MPG_D4	MPG_D5	MPG_D6	
TAOs	-7.0	34.7	6.9	-5.1	12.3	46.6	-7	42	4	-9	36	34	100
ITF_D1	23.6	18.4	7.6	4.9	7.8	29.6	23	21	5	8	22	21	100
ITF_D2	-3.7	-6.4	9.5	12.1	11.6	18.3	-6	-12	10	34	53	21	100
ITF_D3	23.1	-10.2	12.3	20.5	10.4	-10.3	30	-16	10	46	39	-10	100
ITF_D4	21.8	29.4	7.1	19.3	17.8	8.1	14	23	5	23	32	4	100
ITF_D5	0.2	14.1	7.2	8.8	4.5	0.5	0	33	9	31	26	1	100
ITF_D6	15.4	6.3	6.1	11.5	10.8	1.7	24	12	6	32	24	2	100
ITF_D7	11.3	2.1	-0.2	12.2	6.8	-0.7	21	5	0	40	36	-1	100
IPGs	15.2	11.5	43.4	15.9	17.9	6.2	6	10	21	21	39	3	100
Total	100	100	100	100	100	100							100

Source: Authors' estimates

Notes: Impact transmission factor domains (ITF_D):

- ITF_D1 - Transformational adaptation options (TAOs) domain
- ITF_D2 - Water availability and supply domains
- ITF_D3 - Cropped area, cropping patterns, and land quality
- ITF_D4 - Productivity domain
- ITF_D5 - Production domain
- ITF_D6 - Sectoral performance domain
- ITF_D7 - Cost, prices, and incomes
- IPGs - Intermediate policy goals

Multiscale polycentric governance domains (MPG_D):

- MPG_D1 - Water-related institutions
- MPG_D2 - Agriculture- and environment-related institutions
- MPG_D3 - Market-related institutions
- MPG_D4 - Legal and policy-related institutions
- MPG_D5 - Private actors
- MPG_D6 - Structural institutions

- The **private actors MPG domain (MPG_D5)** has the largest impact on production (ITF_D4) and policy goals, followed by TAO and productivity. A detailed breakdown of the components of private actors—particularly rural service providers and corporate agencies—indicates that they can increasingly enhance the performance of TAO3 (crop diversification), productivity, and production within the ITF domains.
 - The **structural institutions domain (MPG_D6)** has the largest impact on TAOs and water availability and supply (ITF_D1), followed by land quality, cropping patterns, and crop area (ITF_D2) domains. The detailed breakdown of factors shows that by strengthening the role (or removing the constraints) of land tenure, MPG_D6 has the greatest potential for enhancing the performance of crop diversification, land quality and soil health, and water availability and supply.
2. **Reforming agricultural and food policies:** It is crucial to revise agricultural wage laws, land tenure, and food policies. These revisions should accommodate the transformative changes required for modernizing agriculture in the context of climate change.
 3. **Strengthening value chains:** It is essential to strengthen value chains and create space for rural service providers and corporate sector participation to support these changes and ensure sustainable development.
 4. **Strengthening water-related institutions:** Strengthening water infrastructure and enhancing collaboration between water institutions should go hand in hand to achieve higher impacts in terms of water availability and supply, productivity and production, and water security policy goals.

MPG impact within ITF domains

The MPG impacts within the impact transmission domains show that,

- **Private actors (MPG_D5)** could play a significantly larger role in most ITF domains, and TAOs. Stakeholders perceive that, among the private actors, rural service providers and the corporate sector can play a major role in enhancing the performance of most ITFs.
- The influence of **legal and policy-related MPG (MPG_D4)** spreads within seven ITF domains, except for TAOs and water availability and supply. Individually, agricultural and food price regulation policies (MPG_13) and agricultural wage laws and regulations (MPG_14) have the greatest influence. Understandably, some policies, laws, and regulations must be reviewed and amended to handle the modern complexities of operating CMCs and diversifying high-value crops.
- The **agriculture- and environment-related institutions (MPG_D2)**, particularly the agricultural and environmental institutions (MPG_3, MPG_4), can have a substantial influence on the TAO domain (ITF_D1).
- MPG_D1, MPG_D2, MPG_D5, and MPG_D6, particularly land tenure, are perceived to influence the water availability and supply domain (ITF_D1).

The key policy-relevant findings in the MPG impact analysis highlight the following strategies:

1. **Empowering individual institutions and strengthening collaboration between institutions:** Empowering individual institutions to foster collaboration across institutions can significantly influence various impact transmission factors, leading to broader systemic changes.

TAOs as Policy Instruments

This section analyzes the extent of TAOs' influence both within and across TAOs and ITFs along the identified impact pathways (see Table 7). The influence of individual ITFs is detailed in Annex A, Table A.4.

The river basin planning (TAO1) significantly influences the other two TAOs: CMC and crop diversification. River basin planning is exogenous to the CMC and crop diversification equations in the analytical and recursive equation setups. It could be argued that CMCs could also influence river basin planning if many CMCs are formed before river basin planning starts. However, this scenario is not considered since the formation of CMCs is only beginning now, and river basin planning has already started. Similarly, CMCs can substantially influence the crop diversification TAO. These findings suggest that the optimal implementation sequence is to first execute river basin plans, followed by the formation of CMCs and the introduction of crop diversification. This approach ensures the integration of climate and hydrological data with information on the water supply and demand in the tank cascade systems within the river basin. As the implementation of comprehensive river basin plans is a long-term goal, the establishment of CMCs is a practical initial step to facilitate crop diversification in tank cascade systems. Effective CMC management relies on knowledge of water availability in individual tanks, which can be gained through River Basin Plans or other sources, including rainfall and return flows.

The greatest cumulative impacts of CMCs and crop diversification across ITFs are observed in ITF_D2 to ITF_D4 and the policy goals (IPGs) categories, which address variables such as area, cropping patterns, productivity, production, costs, and crop income. Within ITFs, CMCs and crop diversification generally have a more pronounced influence.

Table 7. Impact of TAOs across and within impact transmission factors.

Impact transmission variables	TAO impact across impact domains			TAO impact within impact domains			
	TAO1	TAO2	TAO3	TAO1	TAO2	TAO3	Total
TAOs	18	7	0	68	32	0	100
ITF_D1	6	-1	8	41	-13	72	100
ITF_D2	17	18	19	27	35	38	100
ITF_D3	6	14	16	14	39	47	100
ITF_D4	25	27	20	30	40	31	100
ITF_D5	1	-1	5	12	-19	107	100
ITF_D6	10	15	11	23	42	34	100
ITF_D7	5	7	6	25	40	36	100
IPGs	12	15	15	24	37	39	100
Total	100	100	100				

Source: Authors' estimates

Notes: IPG - Intermediate policy goal

TAOs are:

- TAO1 - River basin planning with climate change in focus
- TAO2 - Cascade management committee formation
- TAO3 - Crop diversification to high-value crops with climate-smart practices

Impact transmission factor domains (ITF_D):

- ITF_D1 - Water availability and supply domains
- ITF_D2 - Cropped area, cropping patterns, and land quality
- ITF_D3 - Productivity domain
- ITF_D4 - Production domain
- ITF_D5 - Sectoral performance domain
- ITF_D6 - Cost, prices, and incomes
- ITF_D7 - Rural jobs and wages

The key policy-relevant findings of the TAO policy instrument analysis are:

- Simultaneously implementing CMCs and crop diversification can have a larger impact on production-related ITFs and policy objectives, regardless of the progress in river basin plan development.
- The impacts of CMCs and crop diversification are likely to be greater in basins with detailed river basin plans.

ITFs as Policy Instruments

In addition to MPGs and TAOs, some ITFs can also be policy entry points for enhancing downstream ITFs in impact pathways. Table 8 and Annex A, Table A.5 show the ITFs' impacts across and within the downstream ITFs and IPGs. Across ITFs,

1. ITF_D1 (climate investments, water availability, and supply) mainly influences ITF_D2 to ITF_D4.

2. The highest impact of ITF_D2 (area, cropping patterns, and land quality and soil health) is on ITF_D3 (productivity) and ITF_D4 (production), followed by ITF_D6 (rural jobs and wages).
3. The highest impacts of ITF_D3 are on ITF_D3 itself (land productivity enhances water productivity), and ITF_D4 (production).
4. ITF_D4 (production) influences ITF_D5 (especially, prices and crop income) and ITF_D6 (rural jobs and wages).
5. All ITFs significantly influence the intermediate policy goals of farm and labor income, food supply and prices, and water security.

Within ITFs, ITF_D2 has a substantial influence on five impact domains. ITF_D1 has the greatest impact on ITF_D2, followed by intra-component influence. ITF_D4 has the highest influence on ITF_D5.

Table 8. Impacts of ITFs across and within TAOs, ITFs, and IPGs.

A). ITF impact across impact domains								
	ITF_D1	ITF_D2	ITF_D3	ITF_D4	ITF_D5	ITF_D6	ITF_D7	IPG
ITF_D1	11	0	0	0	0	0	0	0
ITF_D2	17	10	0	0	0	0	0	0
ITF_D3	12	27	29	0	0	0	0	0
ITF_D4	16	22	22	8	0	0	0	0
ITF_D5	8	1	7	26	0	0	0	0
ITF_D6	8	16	6	20	0	-12	0	0
ITF_D7	4	8	10	5	51	0	29	0
IPGs	23	16	26	41	49	112	71	100
Total	100	100	100	100	100	100	100	100

B). ITF impact within the impact domains									
	ITF_D1	ITF_D2	ITF_D3	ITF_D4	ITF_D5	ITF_D6	ITF_D7	IPG	Total
ITF_D1	100	0	0	0	0	0	0	0	100
ITF_D2	58	42	0	0	0	0	0	0	100
ITF_D3	19	56	25	0	0	0	0	0	100
ITF_D4	26	47	19	7	0	0	0	0	100
ITF_D5	29	5	14	53	0	0	0	0	100
ITF_D6	19	49	8	27	0	-2	0	0	100
ITF_D7	12	36	18	11	6	0	17	0	100
IPGs	20	18	12	21	1	9	11	7	100

Source: Authors' estimation

Notes: IPG - Intermediate policy goal

Impact transmission factor domains (ITF_D):

- ITF_D1 - Water availability and supply domains
- ITF_D2 - Cropped area, cropping patterns, and land quality
- ITF_D3 - Productivity domain
- ITF_D4 - Production domain
- ITF_D5 - Sectoral performance domain
- ITF_D6 - Cost, prices, and incomes
- ITF_D7 - Rural jobs and wages

Conclusions and Policy Recommendations

This study illustrates how recently implemented transformative adaptation options (TAOs) influence climate resilience in village tank cascade systems in Sri Lanka. In this study, climate resilience focuses only on enhancing communities' food, livelihood, and water security. This does not cover environmental security, another key component of climate resilience. The analytical framework only considered three TAOs: planning river basin management with a climate change focus, establishing cascade management committees, and diversifying to high-value crops. All were implemented in the tank cascades considered in this study within a similar time frame. The establishment of CMCs and crop diversification are adaptation options that are implemented within a cascade. River basin planning, implemented independently from the other two, has a broader geographical focus, considering the entire river basin.

The findings from the analysis of data collected from the highly climate-vulnerable Northern, North Western, and Eastern provinces show clear interactions between TAOs, governance, impact transmission factors, and climate resilience. The analysis used stakeholders' perception data, measured on a 1–10 scale, including farmers, local community leaders, private sector actors, and government officials. Stakeholders perceive river basin planning as a prerequisite for successfully implementing cascade management committees and crop diversification within a tank cascade system. If river basin plans are absent, establishing cascade management committees cannot ensure the operationalization of crop diversification in the cascade command areas.

Multiscale polycentric governance plays an important role in enhancing climate resilience. The analysis considered 22 governance components (institutions, policies, laws, and regulations) in six major categories: water-related, agriculture- and environment-related, market-related, legal and policy-related institutions, private actors, and structural institutions. The results show that MPG elements can play a major role in one or more impact transmission factors. For example, the role of water infrastructure, legal and policy-related institutions, rural service providers, and the private sector can greatly influence many impact transmission factors, including water availability and supply, area and cropping patterns, productivity, and production, contributing to food, livelihood, and water security, and enhancing climate resilience.

The interactions of TAOs show that the optimal implementation sequence of TAOs is to first execute river basin plans, followed by the formation of CMCs and crop diversification. This approach ensures the integration of climate and hydrological data with information on water supply and demand in tank cascade systems within the river basin. As implementing comprehensive river basin plans is a long-term goal, establishing CMCs is a practical initial step

to facilitate crop diversification in tank cascade systems. However, effective CMC management relies on knowledge of water availability in individual tanks. Hence, CMC implementation should be supported by comprehensive land use of the cascade and water availability plans under different rainfall and return flow scenarios.

The greatest cumulative impacts of CMCs and crop diversification are across the impact transmission domains of cropped area/cropping patterns, production, and policy goals categories. Within ITFs, CMCs and crop diversification generally have a more pronounced influence.

As policy instruments, ITFs show that interventions in many ITFs can impact multiple other ITFs downstream of impact pathways and contribute to achieving intermediate policy goals related to food, water, and livelihood security.

The analysis of this paper suggests the following policy strategies.

- Encouraging collaboration across institutions can significantly affect various impact transmission factors, thereby magnifying the contribution to water, food, and livelihood security.
- Reforming existing agricultural wage structures, land tenure, and food policies, which influence impact transmission factors, is crucial for enabling the transformative changes necessary to modernize agriculture in the face of climate change.
- Strengthening value chains, empowering rural service providers, and creating space for corporate sector participation in value chains can strengthen several impact transmission factors.
- Enhancing water infrastructure and fostering better collaboration among water institutions should be pursued simultaneously to maximize the impacts on ITFs such as water availability and supply, productivity, production, and overall water security policy goals.
- Diversification into high-value crops should be implemented as a top priority. However, the impact of diversification can be enhanced with detailed river basin plans that consider climate variability alongside the effective functioning of cascade management committees. Comprehensive land use and water availability plans for tank cascades are critical for CMCs' success and for maximizing the benefits of crop diversification.
- Further interventions targeting individual impact transmission factors can amplify the effects of both MPGs and TAOs and the overall impacts along downstream transmission pathways. Key impact transmission factors for interventions include climate investments and water availability; cropped area, cropping patterns, and land quality and soil health; land, water, and labor productivity; crop and high-value crop production; livestock composition and production; and rural employment and wages.

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Annexes

Annex A. Analytical framework and statistical summaries

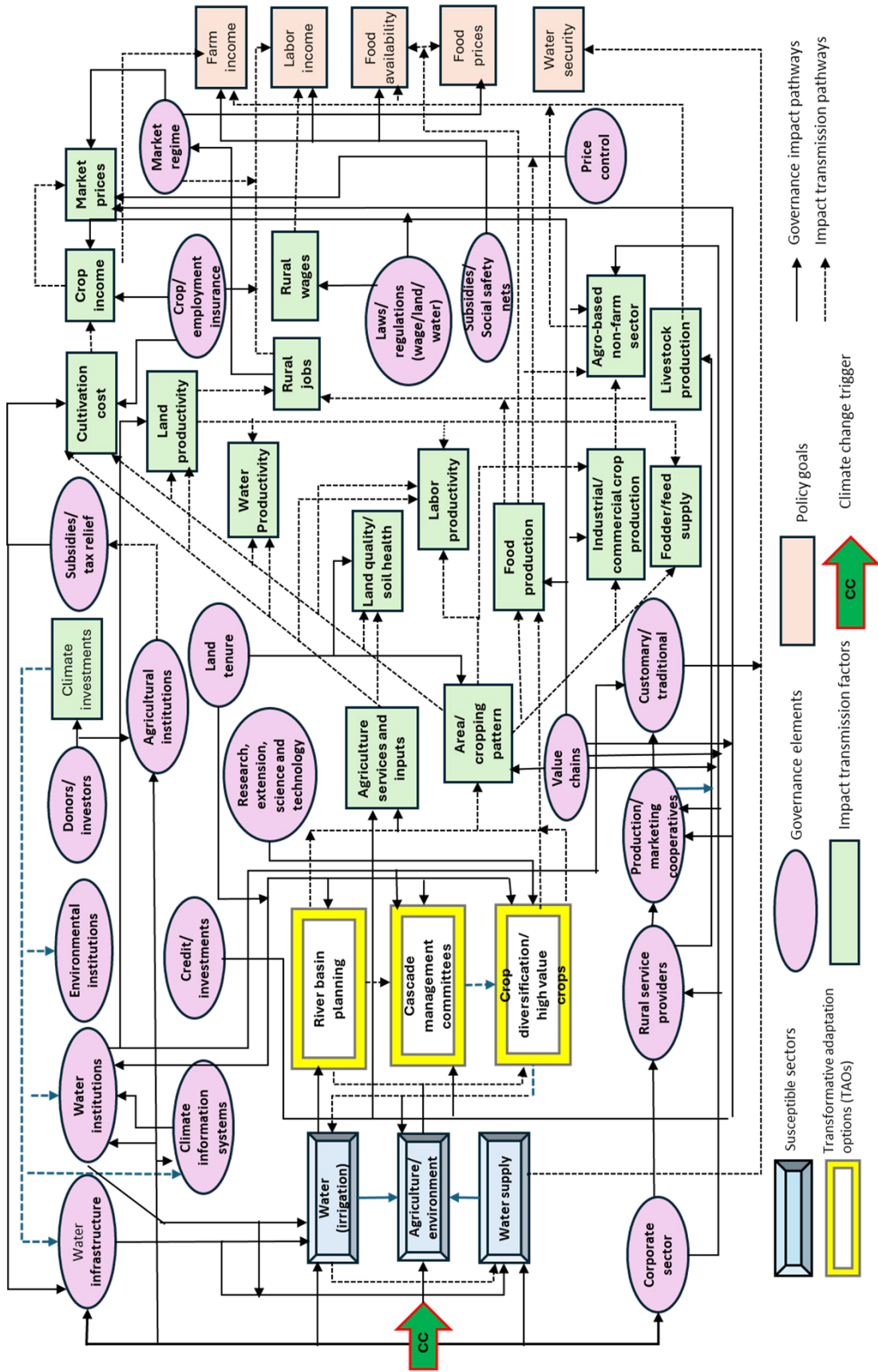


Figure A.1. Analytical framework for Climate Change, TAOs, MPGs, ITFs, and Policy Goals interactions analysis.

Table A.1. Composition of the stakeholder's sample.**Table A.1.I.** Gender composition

Gender	Frequency	Percentage
Male	158	80
Female	40	20

Table A.1.II. Location of the respondent

Location	Frequency	Percentage
Inside the basin	146	74
Outside the basin	52	26

Table A.1.III. Education

Education level	Frequency	Percentage
No education	1	1
Primary	50	25
Secondary	45	23
Graduate	35	18
Postgraduate	46	23
Technical	15	8
Others	3	2

Table A.1.IV. Sector

Agriculture	Frequency	Percentage
Agriculture	122	62
Water	35	18
Environment	9	5
Agro-business	2	1
Dairy/Livestock	0	0
Services	9	5
Academics/NGOs	6	3
Others	8	4

Table A.1.V. Profession

Education level	Frequency	Percentage
Government officials	78	39
Researchers/Experts	15	8
Political/Community leaders	1	1
Trade/Business	2	1
Credit/Insurance	2	1
Farming/Dairy/Meat Technicians/Service providers	75	38
Others	14	7
	7	4

Table A.1.VI. Discipline

Agriculture	Frequency	Percentage
Agriculture	122	62
Water	35	18
Environment	9	5
Agro-business	2	1
Dairy/Livestock	0	0
Services	9	5
Academics/NGOs	6	3
Others	8	4

Table A.1.VII. Experience

Number of years	Frequency	Percentage
<=5	25	13
6-10	30	15
11-15	32	16
16-20	21	11
21-25	14	7
26-30	26	13
31-35	9	5
>35	34	17

Source: Authors' estimation based on the stakeholder survey.

Table A.2. Summary statistics of variables and the diagnostics statistics of the equation system.**Table A.2.I.** Summary statistics

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
Climate change impacts	198	8.44	1.54	3.50	10.0
Water availability	198	7.08	1.26	2.14	9.8
Agriculture sector performance	198	7.34	1.44	1.25	10.0
Water supply/sanitation	198	7.13	1.44	1.75	10.0
Cascade management committees	198	6.72	1.63	1.00	9.7
Diversification to high-value crops	198	6.97	1.43	1.00	10.0
Land tenure	198	6.80	1.71	1.00	9.8
Customary and traditional institutions	198	5.86	1.60	1.33	9.17
Water institutions	198	5.86	1.56	1.00	10.0
Environmental institutions	198	5.34	1.70	1.00	9.6
Water infrastructure	198	7.16	1.56	2.00	10.0
Agricultural institutions	198	5.69	1.75	1.00	9.6
Domestic and international investors	198	7.11	1.93	1.00	10.0
Climate information and decision support systems	198	6.79	1.51	1.00	10.0
Agricultural credit and investment institutions	198	5.57	1.70	1.00	9.0
Agricultural science and technology, research and, extension system	198	6.36	1.36	1.57	9.5
Corporate sector agencies/Players	198	5.95	1.51	1.00	9.8
Rural service provider	198	6.22	1.59	1.00	9.6
Agriculture production/marketing corporations	198	5.88	1.65	1.00	10.0
Agricultural value chains	198	5.78	1.51	1.00	10.0
Subsidy and tax relief policies	198	6.63	1.49	1.00	11.6
Agricultural wage laws and regulations	198	6.26	1.80	1.00	10.0
Rural social safety net policies	198	7.20	1.98	1.00	10.0
Crop and employment insurance	198	7.05	1.47	1.20	10.0
Agricultural market regime	198	6.84	1.47	1.40	10.0
Agricultural and food price regulation policies	198	7.10	2.16	1.00	10.0
Cultivated area	198	7.17	1.42	2.67	10.0
Cropping pattern	198	7.25	1.15	3.75	9.7
Climate investments	198	5.68	1.50	1.50	9.2
Agricultural input supply	198	5.50	1.41	1.00	9.0
Land and soil quality	198	7.02	1.37	2.40	10.0
Land productivity	198	7.22	1.15	3.78	10.0
Water productivity	198	7.12	1.13	3.75	9.6
Labor productivity	198	7.02	1.31	1.00	9.3
Food production	198	6.85	1.04	3.00	9.7
Industrial/commercial crop production	198	6.31	1.39	1.00	11.6
Feed supply	198	6.99	1.30	1.00	10.0
Livestock size and composition	198	6.64	1.73	1.00	9.5
Livestock production	198	6.40	1.48	1.00	9.4
AGNFSECTR	198	5.17	1.94	1.00	9.4
Rural wages	198	6.36	1.71	1.00	10.0
Rural jobs	198	6.49	1.36	2.25	9.9
Cultivation cost	198	6.71	1.25	1.00	9.7
Agricultural market price	198	6.14	1.34	1.00	9.0
Crop income	198	7.44	1.34	2.33	10.0
Farm income	198	6.86	1.45	1.00	10.0
Labor income	198	6.62	1.42	1.00	10.0
Food availability	198	6.92	1.20	1.67	10.0
Food price	198	7.07	1.29	1.80	10.0
Water security	198	6.57	1.45	2.25	10

Table A.2.II. Rank and order statistics

Equation number	Parameters							Rank condition		Order condition	
	K	M	G	E	K-M	G-1	(K-M)-(G-1)	(K-M) > (G-1)	Status	(E-1)* (K-M)	Non-Zero Det
1	48	5	29	29	43	28	15	Yes	Overidentified	1204	Yes
2	48	8	29	29	40	28	12	Yes	Overidentified	1120	Yes
3	48	12	29	29	36	28	8	Yes	Overidentified	1008	Yes
4	48	12	29	29	36	28	8	Yes	Overidentified	1008	Yes
5	48	9	29	29	39	28	11	Yes	Overidentified	1092	Yes
6	48	5	29	29	43	28	15	Yes	Overidentified	1204	Yes
7	48	12	29	29	36	28	8	Yes	Overidentified	1008	Yes
8	48	4	29	29	44	28	16	Yes	Overidentified	1232	Yes
9	48	9	29	29	39	28	11	Yes	Overidentified	1092	Yes
10	48	9	29	29	39	28	11	Yes	Overidentified	1092	Yes
11	48	11	29	29	37	28	9	Yes	Overidentified	1036	Yes
12	48	7	29	29	41	28	13	Yes	Overidentified	1148	Yes
13	48	5	29	29	43	28	15	Yes	Overidentified	1204	Yes
14	48	10	29	29	38	28	10	Yes	Overidentified	1064	Yes
15	48	11	29	29	37	28	9	Yes	Overidentified	1036	Yes
16	48	5	29	29	43	28	15	Yes	Overidentified	1204	Yes
17	48	8	29	29	40	28	12	Yes	Overidentified	1120	Yes
18	48	8	29	29	40	28	12	Yes	Overidentified	1120	Yes
19	48	7	29	29	41	28	13	Yes	Overidentified	1148	Yes
20	48	5	29	29	43	28	15	Yes	Overidentified	1204	Yes
21	48	6	29	29	42	28	14	Yes	Overidentified	1176	Yes
22	48	7	29	29	41	28	13	Yes	Overidentified	1148	Yes
23	48	6	29	29	42	28	14	Yes	Overidentified	1176	Yes
24	48	7	29	29	41	28	13	Yes	Overidentified	1148	Yes
25	48	5	29	29	43	28	15	Yes	Overidentified	1204	Yes
26	48	5	29	29	43	28	15	Yes	Overidentified	1204	Yes
27	48	6	29	29	42	28	14	Yes	Overidentified	1176	Yes
28	48	4	29	29	44	28	16	Yes	Overidentified	1232	Yes
29	48	6	29	29	42	28	14	Yes	Overidentified	1176	Yes

Table A.2.III. P-values of normality, autocorrelation, and heteroscedasticity tests for individual and the whole system of equations.

Equation number	Ho: Normal	Ho: no Autocorrelation	Ho: No homoscedasticity	
	Jarque-Bera LM Test	Harvey LM test	Durbin-Watson statistics	Hall-Pagan LM test
1	0.39	0.05	1.72	0.78
2	0.00	0.13	1.78	0.26
3	0.02	0.17	1.79	0.02
4	0.00	0.01	1.64	0.02
5	0.25	0.91	1.97	0.75
6	0.00	0.00	1.48	0.68
7	0.76	0.01	1.61	0.23
8	0.53	0.11	1.76	0.03
9	0.33	0.00	1.43	0.00
10	0.00	0.44	1.87	0.00
11	0.59	0.56	1.91	0.07
12	0.00	0.97	1.99	0.03
13	0.00	0.30	1.85	0.07
14	0.89	0.68	1.94	0.91
15	0.00	0.33	1.86	0.14
16	0.00	0.39	1.87	0.00
17	0.00	0.25	1.83	0.21
18	0.00	0.49	1.90	0.01
19	0.00	0.16	1.80	0.01
20	0.01	0.01	1.61	0.18
21	0.00	0.14	1.78	0.05
22	0.00	0.01	1.63	0.00
23	0.97	0.02	1.66	0.37
24	0.01	0.23	1.82	0.56
25	0.00	0.54	1.89	0.06
26	0.01	0.03	1.69	0.01
27	0.39	0.01	1.61	0.03
28	0.00	0.15	1.78	0.00
29	0.35	0.02	1.64	0.02
Whole system				.000

Source: Authors' estimation

Table A.3. The relative contribution of MPG elements across impact transmission factors.

Impact transmission domains (ITF_Ds)	Impact transmission factors (ITFs)	Water-related institutions		Agriculture and environment-related institutions						Market-related institutions				
		MPG ₁	MPG ₂	MPG ₃	MPG ₄	MPG ₅	MPG ₆	MPG ₇	MPG ₈	MPG ₉	MPG ₁₀	MPG ₁₁	MPG ₁₂	MPG ₁₃
ITF_D1: TAOs	TAO1	-2.6	9.8	1.6	1.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TAO2	-7.0	3.8	6.3	6.2	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TAO3	-13.5	2.6	5.8	5.7	1.8	0.0	0.0	0.0	0.0	0.0	6.9	0.0	0.0
	Total	-23.1	16.2	13.6	12.9	8.2	0.0	0.0	0.0	0.0	0.0	6.9	0.0	0.0
ITF_D2: Water-availability and supply	ITF_1	8.5	0.0	0.0	7.1	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	ITF_2	11.5	0.4	3.4	1.7	0.8	-1.7	0.0	0.0	0.1	0.0	0.0	16.0	0.0
	ITF_3	0.2	3.0	1.9	1.0	-0.2	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0
	Total	20.2	3.3	5.3	9.8	5.1	-1.7	0.0	0.0	0.1	0.0	3.0	4.6	0.0
ITF_D3: Area, land quality, cropping	ITF_4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0
	ITF_5	-2.4	-10.1	-0.7	-0.7	-2.1	0.0	0.6	0.0	0.0	0.0	3.8	0.0	0.0
	ITF_6	-4.0	12.5	-1.1	-2.7	0.1	0.0	0.2	0.0	0.0	0.0	2.3	0.0	0.0
	Total	-6.1	2.4	-1.8	-3.4	-2.0	0.0	0.7	0.1	0.0	0.0	9.5	0.0	0.0
ITF_D4: Productivity	ITF_7	1.6	6.5	-0.4	-0.2	-3.8	0.0	1.6	0.0	0.0	0.0	3.8	0.0	0.0
	ITF_8	2.2	5.2	0.0	-0.2	-3.8	-0.2	1.1	-1.9	0.0	0.0	5.8	0.0	0.0
	ITF_9	1.5	6.1	-1.0	-0.6	-3.7	1.2	1.8	0.0	0.0	0.0	2.8	0.0	0.0
	Total	5.4	17.8	-1.4	-1.1	-11.3	1.0	4.5	-1.9	0.0	0.0	12.3	0.0	0.0
ITF_D5: Production	ITF_10	-3.0	2.2	3.9	3.9	-3.6	0.0	8.7	0.0	8.5	1.9	3.9	0.0	0.0
	ITF_11	-1.3	3.0	7.1	0.5	-3.1	0.0	0.6	-0.6	-0.1	0.0	1.9	0.0	0.0
	ITF_12	-2.7	11.1	0.9	-2.8	-0.8	0.0	0.1	-0.2	2.6	-0.6	2.2	0.0	0.0
	ITF_13	-2.3	8.5	6.3	-3.0	5.7	0.0	0.1	-0.1	1.3	-12.0	1.6	0.0	0.0
	ITF_14	-2.1	8.3	3.2	-2.3	4.8	0.0	0.1	-0.1	1.4	-7.2	1.8	0.0	0.0
	Total	-11.3	33.1	21.5	-3.6	2.9	0.0	9.6	-1.0	13.7	-17.9	11.4	0.0	0.0
ITF_D6: Sectoral performance	ITF_14	-2.2	2.2	1.3	0.1	-2.5	-5.4	5.5	2.7	-2.9	0.0	4.1	0.0	0.0
	ITF_16	0.3	-0.1	7.8	0.0	5.2	0.0	0.2	-0.8	3.4	2.4	0.3	0.0	0.0
	Total	-1.9	2.1	9.1	0.1	2.7	-5.4	5.7	1.9	0.5	2.4	4.3	0.0	0.0
ITF_D6: Prices, cost, and income	ITF_17	-2.6	6.4	2.5	0.0	2.6	0.0	0.6	0.1	-2.8	-4.5	3.6	0.0	0.0
	ITF_18	-2.8	7.7	0.2	0.8	-2.4	3.7	0.7	0.0	-6.8	0.0	4.6	0.0	0.0
	ITF_19	-1.8	8.5	-0.3	-0.1	-2.4	-0.4	0.7	0.0	-8.6	0.2	3.8	15.8	0.9
	Total	-7.3	22.6	2.4	0.7	-2.2	3.3	2.0	0.1	-18.2	-4.3	12.0	15.8	0.9
ITF_D7: Rural jobs and wages	ITF_20	-0.6	6.2	2.2	-1.2	0.0	0.2	0.7	-0.1	0.8	-3.3	2.0	0.0	4.9
	ITF_21	-2.0	7.7	1.7	-1.9	0.1	0.1	0.2	0.0	0.2	-6.7	1.9	0.0	0.0
	Total	-2.6	13.9	3.9	-3.0	0.2	0.2	0.9	-0.1	1.0	-10.0	3.9	0.0	4.9
ITF_D8: Policy goals (food, livelihood, and water security)	ITF_22	-2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.6	3.7	1.4	-1.3
	ITF_23	-1.4	8.1	1.7	-1.9	2.2	0.1	0.5	0.0	0.8	-6.1	2.1	0.0	3.5
	ITF_24	1.9	1.7	2.6	2.4	-2.1	0.0	0.9	0.0	-5.3	0.9	15.2	1.8	0.0
	ITF_25	-2.2	1.8	2.9	2.7	-2.4	0.0	1.0	0.0	5.9	1.1	10.9	5.0	0.0
	ITF_26	1.9	5.4	2.0	0.9	-1.9	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0
	Total	-1.8	17.0	9.2	4.1	-4.2	0.1	2.3	0.0	1.4	-5.7	37.2	8.2	2.3

Notes: MPG₁ - Water institutions; MPG₂ - Water infrastructure; MPG₃ - Agricultural institutions; MPG₄ - Environment-related institutions; MPG₅ - Agricultural credit institutions; MPG₆ - Agricultural input supply; MPG₇ - Agricultural research and extension; MPG₈ - Climate information and decision support systems; MPG₉ - Agricultural value chain; MPG₁₀ - Agricultural production cooperation and marketing institutions; MPG₁₁ - Agricultural market regimes; MPG₁₂ - Agricultural market prices; MPG₁₃ - Credit and insurance. MPG - Multiscale polycentric governance; TAO - Transformative adaptation option.

Table A.3 continued.

Impact transmission domains (ITF_Ds)	Impact transmission factors (ITFs)	Legal and policy-related institutions				Private actors			Structural institutions	
		MPG _14	MPG _15	MPG _16	MPG _17	MPG _18	MPG _19	MPG _20	MPG _21	MPG _22
ITF_D1: TAOs	TAO1	0.0	0.0	0.0	0.0	2.6	0.2	1.1	0.0	14.9
	TAO2	0.0	-2.6	0.0	0.0	1.8	0.7	0.1	5.5	11.0
	TAO3	0.0	-2.4	0.0	0.0	4.6	0.6	0.6	5.0	10.1
	Total	0.0	-5.1	0.0	0.0	9.0	1.5	1.8	10.6	36.1
ITF_D2: Climate investments, water availability and supply	ITF_1	0.0	0.0	0.0	0.0	0.0	0.0	1.0	9.6	0.0
	ITF_2	0.0	2.2	0.5	0.0	0.0	2.2	0.3	5.3	6.6
	ITF_3	1.4	0.8	0.0	0.0	2.7	0.3	1.4	-0.4	8.5
	Total	1.4	3.0	0.5	0.0	2.7	2.5	2.6	14.5	15.1
ITF_D3: Area, land quality, cropping	ITF_4	1.6	0.4	0.0	0.0	1.6	0.2	1.0	-0.5	15.8
	ITF_5	3.3	2.2	0.0	0.0	1.9	0.1	2.2	0.0	0.5
	ITF_6	2.2	2.4	0.0	0.0	2.2	0.2	2.3	-4.6	7.0
	Total	7.1	5.0	0.0	0.0	5.6	0.6	5.4	-5.0	23.3
ITF_D4: Productivity	ITF_7	4.3	3.1	0.0	0.0	1.1	0.0	2.4	-2.9	-3.5
	ITF_8	3.4	2.3	0.0	0.0	2.3	0.0	2.1	-2.4	-1.5
	ITF_9	4.1	3.2	0.0	0.0	0.5	-0.1	2.2	-3.1	3.1
	Total	11.9	8.6	0.0	0.0	3.9	-0.1	6.7	-8.3	-2.0
ITF_D5: Production	ITF_10	2.9	-0.1	0.0	0.0	2.5	0.3	1.2	3.2	0.6
	ITF_11	1.3	0.1	2.5	0.0	2.0	0.2	1.3	0.7	2.6
	ITF_12	2.0	2.2	1.0	0.0	1.9	0.2	2.2	-4.8	5.0
	ITF_13	1.5	1.7	0.5	0.0	0.3	0.1	1.7	-3.5	4.2
	ITF_14	1.6	1.6	0.5	0.0	1.7	0.2	1.9	-3.3	3.5
	Total	9.3	5.5	4.5	0.0	8.4	1.1	8.3	-7.7	15.8
ITF_D6: Sectoral performance	ITF_14	5.0	1.0	0.0	0.0	1.5	0.2	1.5	-1.7	-1.1
	ITF_16	-0.1	-0.6	3.5	0.0	-0.6	0.1	1.7	1.2	2.1
	Total	4.9	0.4	3.5	0.0	0.9	0.3	3.3	-0.6	1.0
ITF_D6: Prices, cost, and income	ITF_17	2.3	1.1	-1.5	0.0	1.9	0.2	1.7	-1.2	2.2
	ITF_18	3.1	1.5	0.0	-0.3	1.3	0.1	1.8	-0.6	0.2
	ITF_19	3.2	1.9	0.0	0.0	1.8	0.1	1.9	1.7	-0.6
	Total	8.7	4.6	-1.5	-0.3	5.0	0.4	5.4	-0.1	1.8
ITF_D7: Rural jobs and wages	ITF_20	2.2	1.7	0.6	0.0	1.4	0.1	1.7	-2.4	1.9
	ITF_21	1.8	5.9	-0.1	0.0	2.3	0.1	1.3	-3.1	3.0
	Total	4.0	7.7	0.6	0.0	3.7	0.2	3.0	-5.5	4.8
ITF_D8: Policy goals (food, livelihood, and water security)	ITF_22	3.2	2.1	0.1	-0.6	2.0	0.1	2.2	-2.3	0.0
	ITF_23	2.3	0.9	0.1	0.4	1.7	0.1	1.9	-3.4	2.6
	ITF_24	1.8	0.0	0.2	0.0	1.6	0.2	0.8	1.9	0.5
	ITF_25	2.1	0.0	0.2	0.0	1.8	0.2	0.9	2.1	0.6
	ITF_26	2.5	0.6	0.0	0.0	2.6	0.3	1.5	2.2	2.1
	Total	11.8	3.6	0.7	-0.2	9.7	0.9	7.3	0.5	5.7

Notes: MPG_14 - Agricultural and food price regulation policies; MPG_15 - Agricultural wage laws and regulations; MPG_16 - Subsidy and tax relief policies; MPG_17 - Rural social safety nets; MPG_18 - Rural service providers; MPG_19 - International donors and investors; MPG_20 - Corporate sector agencies/players; MPG_21 - Customary and traditional institutions; MPG_22 - Land tenure.

MPG - Multiscale polycentric governance; TAO - Transformative adaptation option.

Table A.4. The relative contribution of MPG elements within impact transmission factors.

Impact transmission domains (ITF_Ds)	Impact transmission factors (ITFs)	Water-related institutions		Agriculture and environment-related institutions						Market-related institutions				
		MPG	MPG	MPG	MPG	MPG	MPG	MPG	MPG	MPG	MPG	MPG	MPG	MPG
		-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13
ITF_D1: TAOs	TAO1	-7.7	28.6	5.4	3.4	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TAO2	-22.1	12.0	23.5	23.2	16.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TAO3	-41.6	8.1	20.9	20.5	6.7	0.0	0.0	0.0	0.0	0.0	13.4	0.0	0.0
	Total	-23.6	16.5	16.3	15.4	9.8	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0
ITF_D2: Water-availability and supply	ITF_1	26.9	0.0	0.0	26.1	16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	ITF_2	28.7	0.9	9.9	5.0	2.4	-5.0	0.0	0.0	0.1	0.0	0.0	7.2	0.0
	ITF_3	0.6	9.7	7.3	4.0	-0.8	0.0	0.0	0.1	0.0	0.0	6.2	0.0	0.0
	Total	19.8	3.3	6.1	11.2	5.8	-2.0	0.0	0.0	0.0	0.0	1.9	2.8	0.0
ITF_D3: Area, land quality, cropping	ITF_4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	8.6	0.0	0.0
	ITF_5	-28.6	-121.6	-10.1	-10.1	-29.1	0.0	8.4	0.4	0.0	0.0	29.1	0.0	0.0
	ITF_6	-13.6	43.0	-4.5	-10.8	0.3	0.0	0.6	0.1	0.0	0.0	5.0	0.0	0.0
	Total	-9.8	3.8	-3.5	-6.4	-3.8	0.0	1.4	0.2	0.0	0.0	9.7	0.0	0.0
ITF_D4: Productivity	ITF_7	6.4	25.6	-2.0	-1.2	-17.8	-0.1	7.6	0.1	0.0	0.0	9.5	0.0	0.0
	ITF_8	9.0	21.0	0.1	-1.2	-18.0	-0.7	5.0	-9.2	0.0	0.0	14.8	0.0	0.0
	ITF_9	5.5	22.5	-4.5	-2.4	-15.8	5.3	7.8	-0.1	0.0	0.0	6.5	0.0	0.0
	Total	6.9	23.0	-2.2	-1.6	-17.2	1.6	6.8	-2.9	0.0	0.0	10.1	0.0	0.0
ITF_D5: Production	ITF_10	-7.0	5.3	10.9	10.9	-10.1	-0.1	24.3	0.1	12.7	2.8	5.8	0.0	0.0
	ITF_11	-4.7	11.0	30.6	2.0	-13.4	0.0	2.5	-2.4	-0.1	0.0	4.4	0.0	0.0
	ITF_12	-9.1	37.7	3.6	-11.1	-3.4	0.0	0.4	-0.9	5.6	-1.2	4.7	0.0	0.0
	ITF_13	-9.4	35.4	30.8	-14.4	27.8	0.0	0.5	-0.5	3.3	-31.6	4.3	0.0	0.0
	ITF_14	-7.4	29.4	13.2	-9.5	20.0	0.0	0.5	-0.5	3.1	-16.2	4.0	0.0	0.0
	Total	-7.5	21.9	16.7	-2.8	2.3	0.0	7.5	-0.8	5.7	-7.5	4.8	0.0	0.0
ITF_D6: Sectoral performance	ITF_14	-10.6	10.6	7.4	0.7	-14.1	-30.7	31.0	15.5	-8.8	0.0	12.3	0.0	0.0
	ITF_16	1.1	-0.4	31.2	-0.1	20.9	0.0	0.9	-3.3	7.4	5.1	0.6	0.0	0.0
	Total	-3.7	4.2	21.3	0.2	6.4	-12.7	13.4	4.5	0.7	3.0	5.5	0.0	0.0
ITF_D6: Prices, cost, and income	ITF_17	-11.2	27.5	12.5	0.0	13.1	0.0	3.0	0.3	-7.8	-12.3	10.0	0.0	0.0
	ITF_18	-12.0	32.8	1.1	4.2	-12.0	18.4	3.6	0.1	-18.2	0.0	12.3	0.0	0.0
	ITF_19	-5.7	26.6	-1.0	-0.5	-8.8	-1.5	2.5	0.1	-16.9	0.3	7.4	31.2	1.7
	Total	-9.2	28.7	3.6	1.1	-3.3	4.9	3.0	0.2	-14.6	-3.5	9.6	12.7	0.7
ITF_D7: Rural jobs and wages	ITF_20	-2.2	22.7	9.6	-5.0	0.1	0.8	2.8	-0.5	1.8	-7.7	4.7	0.0	11.4
	ITF_21	-7.3	28.7	7.5	-8.2	0.5	0.3	1.0	0.1	0.5	-15.6	4.4	0.0	0.0
	Total	-4.7	25.7	8.5	-6.6	0.3	0.5	1.9	-0.2	1.2	-11.7	4.5	0.0	5.7
ITF_D8: Policy goals (food, livelihood, and water security)	ITF_22	-11.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-5.7	13.0	4.9	-4.5
	ITF_23	-5.3	30.7	7.8	-8.5	9.7	0.6	2.1	-0.1	1.8	-14.6	5.1	0.0	8.5
	ITF_24	6.7	5.8	10.4	9.6	-8.5	-0.1	3.6	0.0	-11.5	2.0	33.4	3.9	0.0
	ITF_25	-6.5	5.5	10.1	9.6	-8.5	-0.1	3.4	0.0	11.2	2.1	20.8	9.5	0.0
	ITF_26	5.8	16.4	7.1	3.3	-6.8	0.0	0.0	0.1	0.0	0.0	10.0	0.0	0.0
	Total	-1.3	12.2	7.7	3.5	-3.5	0.1	1.9	0.0	0.6	-2.6	16.9	3.7	1.0

Notes: MPG_1 - Water institutions; MPG_2 - Water infrastructure; MPG_3 - Agricultural institutions; MPG_4 - Environment-related institutions; MPG_5 - Agricultural credit institutions; MPG_6 - Agricultural input supply; MPG_7 - Agricultural research and extension; MPG_8 - Climate information and decision support systems; MPG_9 - Agricultural value chain; MPG_10 - Agricultural production cooperation and marketing institutions; MPG_11 - Agricultural market regimes; MPG_12 - Agricultural market prices; MPG_13 - Credit and insurance.
MPG - Multiscale polycentric governance; TAO - Transformative adaptation option.

Table A.4. continued.

Impact transmission domains (ITF_Ds)	Impact transmission factors (ITFs)	Legal and policy-related institutions				Private actors			Structural institutions		Total
		MPG _14	MPG _15	MPG _16	MPG _17	MPG _18	MPG _19	MPG _20	MPG _21	MPG _22	
ITF_D1: TAOs	TAO1	0.0	0.0	0.0	0.0	21.8	1.7	8.9	0.0	31.5	100
	TAO2	0.0	-14.7	0.0	0.0	16.8	6.3	0.5	12.6	25.1	100
	TAO3	0.0	-13.1	0.0	0.0	40.5	5.5	5.6	11.2	22.3	100
	Total	0.0	-9.0	0.0	0.0	26.4	4.4	5.1	7.7	26.4	100
ITF_D2: Climate investments, water availability and supply	ITF_1	0.0	0.0	0.0	0.0	0.0	0.0	8.7	21.7	0.0	100
	ITF_2	0.0	9.4	2.2	0.0	0.0	15.9	1.8	9.5	11.9	100
	ITF_3	8.0	4.7	0.0	0.0	25.7	2.5	13.1	-1.0	19.9	100
	Total	2.4	5.1	0.9	0.0	7.7	7.0	7.3	10.2	10.6	100
ITF_D3: Area, land quality, cropping	ITF_4	11.1	2.7	0.0	0.0	18.7	2.2	11.2	-1.3	45.7	100
	ITF_5	68.3	46.3	0.0	0.0	64.3	4.4	74.0	0.0	4.4	100
	ITF_6	13.4	14.5	0.0	0.0	21.2	2.3	22.7	-11.3	17.3	100
	Total	19.8	14.0	0.0	0.0	26.0	2.5	25.0	-5.8	26.9	100
ITF_D4: Productivity	ITF_7	30.1	21.3	0.0	0.0	12.2	-0.3	26.8	-8.2	-10.0	100
	ITF_8	23.8	16.1	0.0	0.0	26.0	0.3	24.4	-6.9	-4.4	100
	ITF_9	26.7	20.8	0.0	0.0	5.5	-1.1	23.3	-8.1	8.1	100
	Total	26.9	19.4	0.0	0.0	14.3	-0.4	24.8	-7.8	-1.9	100
ITF_D5: Production	ITF_10	11.8	-0.5	0.0	0.0	16.8	2.2	7.8	5.4	1.0	100
	ITF_11	8.0	0.5	15.7	0.0	21.1	2.1	13.9	1.9	6.7	100
	ITF_12	11.9	13.0	6.1	0.0	18.8	1.6	21.7	-11.7	12.2	100
	ITF_13	11.1	12.2	3.6	0.0	3.5	1.7	19.8	-10.5	12.5	100
	ITF_14	10.1	10.2	3.4	0.0	17.2	2.5	19.6	-8.4	8.9	100
	Total	10.7	6.3	5.2	0.0	15.9	2.0	15.7	-3.7	7.5	100
ITF_D6: Sectoral performance	ITF_14	42.0	8.5	0.0	0.0	21.3	3.2	21.3	-6.0	-3.7	100
	ITF_16	-0.8	-3.4	21.0	0.0	-6.3	1.1	16.8	2.9	5.1	100
	Total	17.0	1.5	12.3	0.0	5.2	2.0	18.7	-0.8	1.5	100
ITF_D6: Prices, cost, and income	ITF_17	17.6	8.5	-11.1	0.0	23.7	2.3	20.4	-3.6	7.0	100
	ITF_18	23.2	11.1	0.0	-2.0	15.4	1.7	21.8	-1.9	0.5	100
	ITF_19	17.4	10.5	0.0	0.0	15.9	1.0	17.3	3.8	-1.4	100
	Total	19.2	10.1	-3.3	-0.6	18.1	1.6	19.6	-0.1	1.6	100
ITF_D7: Rural jobs and wages	ITF_20	14.2	11.2	4.1	0.0	14.7	0.7	18.0	-6.4	5.0	100
	ITF_21	11.6	38.5	-0.4	0.0	24.1	1.1	13.7	-8.3	7.9	100
	Total	12.9	24.8	1.8	0.0	19.4	0.9	15.9	-7.3	6.4	100
ITF_D8: Policy goals (food, livelihood, and water security)	ITF_22	30.8	20.1	1.0	-6.1	31.0	2.0	34.0	-9.1	0.1	100
	ITF_23	15.0	6.1	1.0	2.8	18.5	0.8	20.4	-9.3	6.9	100
	ITF_24	11.2	-0.1	1.4	0.0	16.0	2.0	8.1	4.7	1.3	100
	ITF_25	10.9	-0.2	1.1	0.0	15.5	2.0	7.8	4.6	1.2	100
	ITF_26	13.0	3.2	0.0	0.0	22.5	2.6	13.4	4.8	4.6	100
	Total	14.8	4.4	0.9	-0.3	19.8	1.9	15.0	0.3	3.0	100

Notes: MPG_14 - Agricultural and food price regulation policies; MPG_15 - Agricultural wage laws and regulations; MPG_16 - Subsidy and tax relief policies; MPG_17 - Rural social safety nets; MPG_18 - Rural service providers; MPG_19 - International donors and investors; MPG_20 - Corporate sector agencies/players; MPG_21 - Customary and traditional institutions; MPG_22 - Land tenure.

MPG - Multiscale polycentric governance; TAO - Transformative adaptation option.

Table A.5. The relative contribution of TAOs across and within impact transmission factors.

Impact transmission domains (ITF_Ds)	Impact transmission factors (ITFs)	Across ITFs			Within ITFs			Total
		TAO1	TAO2	TAO3	TAO1	TAO2	TAO3	
ITF_D1: TAOs	TAO1	0	0	0	0	0	0	0
	TAO2	9	0	0	100	0	0	100
	TAO3	9	7	0	51	49	0	100
	Total	18	7	0	68	32	0	100
ITF_D2: Water -related institutions	ITF_1	0	0	0	0	0	0	0
	ITF_2	1	-1	5	12	-19	107	100
	ITF_3	5	-1	3	60	-9	48	100
	Total	6	-1	8	41	-13	72	100
ITF_D3: Area, land quality, cropping	ITF_4	1	-1	3	12	-19	107	100
	ITF_5	11	12	9	30	38	33	100
	ITF_6	5	7	6	25	40	36	100
	Total	17	18	19	27	35	38	100
ITF_D4: Productivity	ITF_7	2	6	4	15	48	37	100
	ITF_8	1	2	6	11	24	65	100
	ITF_9	3	6	6	16	41	43	100
	Total	6	14	16	14	39	47	100
ITF_D5: Production	ITF_10	3	4	1	30	58	12	100
	ITF_11	3	3	2	33	40	26	100
	ITF_12	9	9	8	29	37	34	100
	ITF_13	7	7	6	29	37	34	100
	ITF_14	3	3	3	28	37	35	100
	Total	25	27	20	30	40	31	100
ITF_D6: Sectoral performance	ITF_15	-2	-2	4	-158	-301	560	100
	ITF_16	2	1	1	41	29	30	100
	Total	1	-1	5	12	-19	107	100
ITF_D6: Prices, cost, and income	ITF_17	3	5	4	21	41	38	100
	ITF_18	3	4	2	28	45	27	100
	ITF_19	4	6	5	23	42	35	100
	Total	10	15	11	23	42	34	100
ITF_D7: Rural jobs and wages	ITF_20	3	3	3	26	39	35	100
	ITF_21	3	4	3	23	40	36	100
	Total	5	7	6	25	40	36	100
ITF_D8: Policy goals (food, livelihood, and water security)	ITF_22	4	6	5	24	41	35	100
	ITF_23	3	4	3	24	40	36	100
	ITF_24	2	3	1	30	57	13	100
	ITF_25	2	3	1	30	57	13	100
	ITF_26	1	-1	5	14	-19	105	100
	Total	12	15	15	24	37	39	100
Total ITF_Ds		100	100	100				

Notes: MPG - Multiscale polycentric governance; TAO - Transformative adaptation option.

Annex B. Survey questionnaire

(1) Respondent's Details:

(a) Name

(b) Age (Years)

(c) Gender (Male or Female)

(d) Education / Qualification

[No education = 1, Primary education = 2,
High-school education = 3, Graduate degree = 4,
Post-graduate degree = 5, Technical/special education = 6,
Others, if any (specify) = 7]

(e) Years of Experience (in years)

(f) Scale/Level

[International Level = 1, National level = 2,
Regional level = 3, Provincial level = 4, Local level = 5
Others, if any (specify) = 6]

(g) Sector

[Agriculture = 1, Water = 2, Environment = 3,
Agro-industries = 4, Dairy/meat/other non-farm enterprises = 5
Services = 6 , Academics/NGOs = 7, Others, if any (specify) = 8]

(h) Profession

[Government officials = 1, Researchers/experts = 2,
Political/community leaders = 3, Trade/business = 4
Credit/insurance/finance = 5, Farming/dairy/meat = 6,
technicians/ service providers = 7, Others, if any (specify) = 8]

(i) Discipline

[Agronomy/soil science etc. = 1, Hydrology/water etc. = 2,
Engineering = 3, Economics = 4, Other social sciences = 5,
Finance/management = 6, Others, if any (specify) = 7]

(j) Contact Details

(At least, place and phone number and email
needed for Verification)

Phone

Email.....

(2) Interview Details:

(a) Interviewer's Name

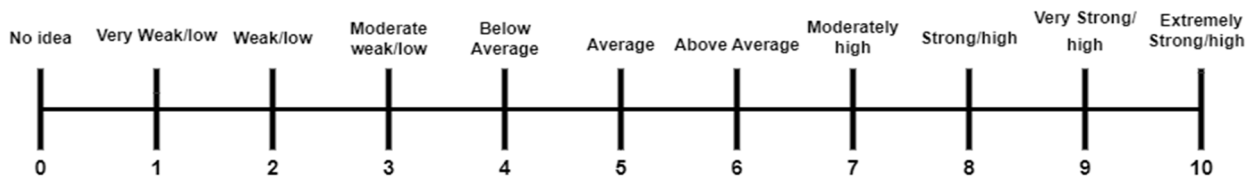
(b) Place and Date

(3) Verification Details:

(a) Verifier's Name

(b) Place and Date

Rate the perception on a scale of 0 -10



[I] THREAT/TRIGGER VARIABLE (1)

[1] Climate Change Impact (CLCIMPACT) (On Sectors)

- (a) How strong is your belief that Climate Change Impacts are real?
- (b) In your view, how severe are the Climate Change Impacts on Water and Agriculture?.....

[II] SECTORAL IMPACTS VARIABLES (3)

[2] Overall Impact on Water Resources Availability (WATRAVAIL)

- (a) To what extent do Climate Change Impacts negatively affect overall water resource availability?
- (b) How effective are Water Infrastructures in minimizing climate change impacts on water availability?.....
- (c) How effective are Water Institutions in minimizing climate change impacts on water availability?.....
- (d) How far can forming Cascade Management Committees and strengthening FOs (CMCs and FOs) lead to water savings?.....
- (e) How far can diversification to high-value crops and climate-smart agriculture/water management practices (DHVC and CSAP) lead to water savings?.....
- (f) How far can River Basin Investment Plans for climate resilience lead to water availability? ..
- (g) How far the current Agriculture/Water /Land laws/regulations affect water availability?.....

[3] Overall Impact on Agricultural Sector Performance (AGPERFORM)

- (a) To what extent do Climate Change Impacts affect agriculture sector performance?.....
- (b) How far does a change in Water Resource Availability affect agricultural sector performance?
- (c) How far does a higher priority for water allocation to urban/rural Water Supply affect agricultural sector performance (via reduced water resources for available for agricultural uses)?
- (d) To what extent do Agriculture/Wage/Land laws and regulations affect agriculture sector performance?.....

[4] Overall Impact on Urban/Rural Water Supply (for Domestic Use) (WATRSUPLY)

- (a) To what extent do Climate Change Impacts affect the levels of urban/rural water supply?.....
- (b) How far do changes in Water Resources Availability affect the levels of urban/rural water supply?
- (c) How effective are Water Infrastructures in securing the levels of urban/rural water supply?
- (d) How effective are Water Institutions in securing the levels of urban/rural water supply?.....

[III] TAO VARIABLES (3)

[5] Cascade Management Committees and Farm Organizations (CMC and FOs)

- (a) How far does Agricultural Sector Performance depend on the performance of CMCs and FOs?....
- (b) How critical is the Land Tenure system for the performance of Cas Mang Comm/FOs?.....
- (c) How critical are Water Infrastructures for the performance of CMC and FOs?.....
- (d) How critical are Water Institutions for the performance of CMC and FOs?.....
- (e) How critical are Credit and Investment Institutions for the performance of CMC and FOs?.....
- (f) How critical are Rural Service Providers for the performance of CMC and FOs?..
- (g) How critical are Corporate Sector Agencies/Players for the performance of CMC and FOs?
- (h) How will agriculture/land laws/regulations affect the promotion of CMC and FOs?

[6] Diversification to high-value crops and climate-smart agriculture practices (DHVC and CSAP) in tank rehabilitation (HVCCSAP)

- (a) How far does Agricultural Sector Performance depend on the extent of DHVC and CSAP?.....
- (b) How far can CMC and FOs promote DHVC and CSAP ?
- (c) How critical are the Water Infrastructures in promoting DHVC and CSAP ?
- (d) How critical are the Water Institutions in promoting DHVC and CSAP ?
- (e) How critical are the Credit and Investment Institutions in promoting DHVC and CSAP ?.
- (f) How critical are the Rural Service Providers in promoting DHVC and CSAP
- (g). How critical are the Corporate Sector Agencies/Players in promoting DHVC and CSAP ?
- (h). How critical are the Basin investment plans in promoting DHVC and CSAP?
- (g). How will Agriculture/land laws/regulations affect promoting DHVC and CSAP

[7] River Basin Investment Plan for Climate Resilience (RBIPCR)

- (a) How far does Agricultural Sector Performance depend on the River Basin Investment Plan?
- (b) How far are CMC and FOs supported by the River Basin Investment Plan
- (c) How far have water infrastructures been improved by the River Basin Investment Plan?
- (d) How far do water institutions benefit from /are included in the river basin investment plan?
- (e) How far can Credit and Investment Institutions support the River Basin Investment Plan?
- (f) How far can Rural Service Providers support the River Basin Investment Plan?.....
- (g) How far can Corporate Sector Agencies/Players support the River Basin Investment Plan?
- (h) How far are CMC and FOs facilitated by the River Basin Investment Plan?.
- (g) How will Agriculture/ Land laws/regulations affect the implementation of the River Basin Investment Plan?

[IV] INSTITUTIONAL (MPG ELEMENT) VARIABLES (20)

[8] Land Tenure (LANDTENUR)

- (a) How important are farm size and tenorial pattern for the decision to participate CMCs and FOs ?
- (b) How important are farm size and tenorial pattern for adopting improved farm and water technologies and practices?.....
- (c) How important are farm size and tenorial pattern for promoting DHVC and CSAP?
- (d) How important are farm size and tenorial pattern in promoting efficient water allocation and management?
- (e) How will long-term leasing of public lands affect the promotion of CMC and FOs ?
- (f) How will long-term leasing of jointly owned lands affect the promotion of CMC and FOs ?

[9] Customary and Traditional Institutions (CUSTINSTN)

- (a) How strong is the influence of customs/traditions on farmers' crop choice (especially, food/feed crops)?
- (b) How important are the roles of customary/traditional institutions in livestock/pasture development?
- (c) How important are the roles of customary/traditional institutions in groundwater sharing/management?
- (d) How far do customary/traditional institutions facilitate traditional management practices and incorporate modern technologies for Drinking water supply?
- (e) How far do customary/traditional institutions support government land/water management initiatives?
- (f) How far do customary/traditional institutions lead to farm divisions and land fragmentations, Bethma etc.?.....

[10] Water Institutions (WATRINSTN)

- (a) How adequate/ready are current Water Institutions to face the challenges of Climate Change?
- (b) How strong are the linkages between Water Institutions and Ag. Institutions?
- (c) How strong are the linkages between Water & Env. Institutions and Research/S&T/Extension System?.....
- (d) How far does Land Tenure (farm size/sub-division) affect the effectiveness of Water Institutions?
- (e) How far do Customary Institutions affect the effectiveness of Water. Institutions?.....
- (f) How far does Climate Information & Decision System improve the effectiveness of Water. Institutions?.
- (g) How far do Climate Investments improve the effectiveness of Water Institutions?

[11]. Environmental institutions (Forest/wildlife departments) (ENVINST)

- (a) How ready are environmental institutions to address the challenges of climate change?
- (b) How strong are the linkages/collaboration of Env. Institutions with water Institutions?
- (c) How strong are the linkages/collaboration of Env. Institutions with agri. Institutions?
- (d) How far do customary institutions affect the Env. Institutions?
- (e) How critical are the climate investments in strengthening the Env. Institutions?

[12] Water Infrastructures (WATRINFRA)

- (a) How adequate are Water Infrastructures to face the challenges of Climate Change?
- (b) How urgent is the need for additional Water Infrastructures?
- (c) How far can Climate Info & Decision Support System improve the performance of Water Infrastructures?
- (d) How far can Climate Investments enhance the extent and performance of Water Infrastructures?
- (e) How far can Subsidy/Tax Relief Policy improve the extent and performance of Water Infrastructures?.....

[13] Agricultural Institutions (AGENINSTN)

- (a) How adequate/ready are Ag. Institutions to face the challenges of Climate Change?
- (b) How strongly do International Donor/Technical Agencies/Investors support Ag. Institutions?.....
- (c) How strong are the linkages between Ag. Institutions and Water Institutions?
- (d) How strong are the linkages between Ag. Institutions and Env. Institutions?
- (e) How strong are the linkages between Ag. Institutions and Ag. Research/S&T/Extension System?
- (f) How adequate is the Climate Information/Decision Support System with the Ag. Institutions?.....

[14] International Donors, Development Agencies, and Investors (DONINVSTR)

- (a) How strong is the response of Donors/Development Agencies/Investors to climate change impacts?.....
- (b) How strong is the support of Donors/Development Agencies for water/agriculture/climate investment?.....
- (c) How strong is the support of Private International Investors for water/agriculture/climate investment?

[15] Climate Information and Decision-Support System (CLIMINSYS)

- (a) How adequate is Climate Info/Decision Support System to face the challenges of Climate Change?.....
- (b) How far can Ag. Institutions help to build/strengthen Climate Info/Decision Support System?
- (c) How far can Climate Investments help to build/strengthen Climate Info/Decision Support System?
- (d) How far can universities/international bodies support Climate Info/Decision Support System?.....

[16] Agricultural Credit and Investment Institutions (AGCRINSTN)

- (a) How critical are Ag. Institutions for the performance of Ag. Credit/Investment Institutions?.....
- (b) How far do international donors/development bodies contribute to Ag. Credit/Investment Institutions?
- (c) How far do private international investors contribute to support Ag. Credit/Investment Institutions?
- (d) In terms of overall performance, how adequate and efficient are the Ag Credit/Investment Institutions?
- (e) In terms of accessibility, how adequate and efficient is the Ag. Credit/Investment Institutions?

[17] Agricultural Research, Science & Technology, and Extension System (ARESEXSYS)

- (a) How strong is Ag. Research/S&T/Extension System to face the challenges of climate change?
- (b) How far is the Ag. Research/S&T/Extension System is accessible and affordable?
- (c) How far can Ag. Institutions contribute to Ag. Research/S&T/Extension System?
- (d) How far can Env. Institutions contribute to Ag. Research/S&T/Extension System?
- (e) How far can Climate Investments strengthen the Ag. Research/S&T/Extension System?
- (f) How far can Climate Info/Decision Support System help the Ag. Research/S&T/Extension System?
- (g) How far can CMCs and FOs contribute to Ag. Research/S&T/Extension System?

[18] Corporate Sector Agencies/Players in Agriculture and Rural Sectors (CORPSECTR)

- (a) How strong are the Impacts of Climate Change on Corporate Sector performance?
- (b) How strong is the involvement of the Corporate Sector in national Climate Adaptation Initiatives?
- (c) How extensive is the Corporate Sector involved in Water/Agricultural Sectors?
- (d) How far can Climate Investments promote the Corporate Sector's role in Water/Agricultural Sectors?
- (e) How far can Subsidy promote the Corporate Sector's role in Water/Agricultural Sectors?
- (f) How far can Ag. Credit & Investment Institutions promote Corporate Sector role in Water/Agriculture? ...

[19] Rural Service Providers (RSPROVIDR)

- (a) How critical are the Rural Service Providers for the Performance of Agricultural/Water/Rural Sectors?
- (b) How strong and accessible are the Rural Service Providers in the Agricultural/Water/Rural Sectors?.....
- (c) How far do Climate Investments promote the development of Rural Service Providers?
- (d) How far does Subsidy & Tax Relief Policy promote the development of Rural Service Providers?
- (e) How far do Ag. Credit & Investment Institutions promote the development of Rural Service Providers?
- (f) How far does Corporate Sector promote the development of Rural Service Providers?

[20] Agricultural Production and/or Marketing Cooperatives (APMKTCOOP)

- (a) How critical are the Ag. Prod/Mktg Coops for the Performance of Agricultural/Livestock Sectors?
- (b) How strong and accessible are the Ag. Prod/Mktg Coops in the Agricultural/Livestock Sectors?.....
- (c) How far do Rural Service Providers contribute to the development of Ag. Prod/Mktg Coops?
- (d) How far do Ag. Credit & Investment Institutions support the development of Ag. Prod/Mktg Coops?.....
- (e) How far does the Corporate Sector support the development of Ag. Prod/Mktg Coops?.....

[21] Agricultural Value Chain Networks (AVALCHAIN)

- (a) How critical are the Ag. Value Chains for the Performance of Agricultural/Livestock Sectors?
- (b) How strong and accessible are the Ag. Value Chains in the Agricultural/Livestock Sectors?.....
- (c) How far do Ag. Prod/Mktg Coops contribute to the growth/performance of Ag. Value Chains?
- (d) How far do Rural Service Providers contribute to the growth/performance of Ag. Value Chains?
- (e) How far do Ag. Credit and Investment Institutions support the growth/performance of Ag. Value Chains?..
- (f) How far does the Corporate Sector contribute to the growth/performance of Ag. Value Chains?.....

[22] Subsidy Policies (STAXPOLCY)

- (a) How far can Subsidy Policies reduce cultivation/production costs?
- (b) How far can Subsidy Policies promote the use of irrigation/farm technologies/equipment?
- (c) How easy for farmers and other players to access the Subsidy Policies benefits?
- (d) How far can Ag. Institutions enhance the effectiveness of Subsidy Policies?.....
- (e) How far can Climate Investments contribute to the effectiveness of Subsidy Policies?.....

[23] Agricultural/Wage/Land Laws and Regulations (AGWAGELAW)

- (a) How strong are local customs and social pressures in influencing rural wage rates?
- (b) How effective are the minimum wage legislation in guiding rural wage rates?
- (c) How effective are the special legal provisions (e.g., female workers, child labor; working hours) in terms of their effect on rural labor supply and employment?

[24] Rural Social SafetyNet Policies (“Samurdhi” and Farmer’s Pension) (SNETPOLCY)

- (a) How important are the proposed retirement benefits for farmers under new adaptation options?
- (b) How important are the “Samurdhi” benefits for poor rural groups under new adaptation options?
- (c) How effective is the proposed Social Agriculture Program in improving safety net roles in agriculture and livestock sectors in poor, fragile, and mountainous regions?

[25] Crop and Employment Insurance Program (CREMINSUR)

- (a) How important is crop insurance for protecting farmers from production uncertainties?
- (b) How far is crop insurance accessible and affordable to average farmers?
- (c) How important is employment insurance for protecting rural workers from employment uncertainties? ...
- (d) How effective are government support and regulations in ensuring employment insurance?
- (e) How effective are crop and employment insurance as coping mechanisms for climate risks in agriculture?..

[26] Agricultural Market Regime (AMKTREGIM)

- (a) To what extent do Agricultural Imports/Exports affect the Agricultural Market Regime?.....
- (b) How effective are the agricultural markets in providing the Right Prices for farmers?
- (c) How important are the Roles of Traders and Middlemen in marketing farm outputs?
- (d) How effective are Government Policies in Regulating Agricultural and Food Prices?
- (e) How serious can the Impacts of Droughts/Disasters be on the Agricultural Trade Regime?

[27] Agricultural Trade Regime (ATRDREGIM)

- (a) To what extent do the levels of domestic production affect the Agricultural Trade Regime?.....
- (b) To what extent do domestic market regulations affect Agricultural Trade Regime?.....
- (c) How important are the impacts of international trade agreements on the Agricultural Trade Regime?
- (d) How important are the corporate sector (as importers/exporters) in the Agricultural Trade Regime?.....
- (e) How serious can the impacts of droughts/disasters be on the Agricultural Trade Regime?

[28] Agricultural and Food Price Regulation Policy (AFPRPOLCY)

- (a) How effective are price regulations in controlling the food prices for consumers?....
- (b) Do price regulations distort agricultural markets and producers’ prices? If so, how serious is this effect?

[V] IMPACT TRANSMISSION VARIABLES (24)

[29] Cultivated or Cropped Area (CULTIAREA)

- (a) How far can Crop Pattern changes increase cultivated area (via water savings and expanded irrigation)?.....
- (b) How far can leasing of state and common tribal lands under CMCs and FOs increase the area under cultivation?...
- (c) How far can Basin Investment Plan increase the area under cultivation (via water savings)?.....
- (d) How far can Ag. Value Chains encourage more cultivated areas (via better price and marketing options)? ...
- (e) How far can Farm Technologies (e.g., **Zero tillage**, AWD, Parachute, Farm mechanization, etc.) increase cultivated area?.....
- (f) How far can Env (Forest/wildlife) institutions contribute to increasing cultivated area?

[30] Crop Pattern (CROPATERN)

- (a) How strong are the roles of farm size and land fragmentation in crop choice?.....
- (b) How far can CMCs and FO alter crop patterns towards industrial and commercial crops?.....
- (c) How far can Basin investment plans affect the area under food and fodder crops?
- (d) How far can CRIWMP (Upgrade climate-proof village irrigation systems, Rainwater Harvesting tank) increase the area under cultivation (via water savings)?
- (e) How far can changes in Crop patterns improve land productivity and farm income?
- (f) How far can changes in Crop Patterns improve land and soil health (via crop rotation)?
- (g) How far can Crop Pattern change help Agro-industries/Rural Non-farm Sector (via raw materials supply)?
- (h) How far can these Crop Pattern changes affect the Livestock Sector (via fodder/feed supply)?.....

[31] Climate Investments (CLIMINVEST)

- (a) How strong is the commitment of the government to making/promoting Climate Investments?.....
- (b) How adequate are the contributions of Agriculture Institutions to Climate Investments?
- (c) How adequate are the contributions of Env. Institutions to Climate Investments?.....
- (d) To what extent do International Donors/Devt. Agencies/Investors contribute to Climate Investments?.....
- (e) How adequate and effective are Climate Investments in meeting the challenges of Climate Change?
- (f) How effectively are Climate Investments used to build Climate-smart infrastructure?

[32] Agricultural Service and Input Supply (AGINSUPPLY)

- (a) How well does the Research/S&T/Extension System deliver these Agricultural Services and Inputs?
- (b) How far can Env. Institutions strengthen the Agricultural Services and Inputs?.....
- (c) How well do the Ag. Credit & Investment Institutions deliver these Agricultural Services and Inputs?.....
- (d) How well do the Rural Service Providers deliver these Agricultural Services and Inputs?.....
- (e) To what extent does the Corporate Sector contribute to Agricultural Services and Inputs?.....
- (f) How adequate and effective is the supply of Agricultural Services and Inputs?
- (g) How accessible and affordable are Agricultural Services and Inputs to farmers?

[33] Land Quality and Soil Health (LANDSQLTY)

- (a) To what extent do Small and Fragmented Farms reduce land and soil quality (via intense land use)?.....
- (b) To what extent does Crop Pattern (e.g., repeatedly cultivating same crop) reduce land and soil quality?.....
- (c) To what extent do Soil Erosion and Soil Salinity reduce land and soil quality (via intense land use)?.....
- (d) How effective is the Zero-tillage Technology in improving the productivity of poor lands in rainfed zones?.....
- (e) How important are livestock manures and farm bio-wastes in improving soil fertility and land quality?.....

[34] Land Productivity (LANPDRODY)

- (a) To what extent does Farm Size affect Land Productivity (via scale economies and land use intensity)?..
- (b) To what extent does Crop Pattern affect Land Productivity (e.g., high-value crops vs. food crops)?.....
- (c) To what extent do Ag. Services & Inputs contribute to Land Productivity (via input complementarities)?.....
- (d) To what extent does Irrigation Availability contribute to Land Productivity?
- (e) How far do Water Institutions contribute to Land Productivity (via water use efficiency/water productivity)?
- (f) How far do Env. Institutions contribute to Land Productivity (Via human-wildlife conflict
- (g) How effective is the Zero-tillage Technology in improving Land Productivity in rainfed zones?.....
- (h) How important are livestock manures and farm bio-wastes in improving soil fertility and land quality?.....
- (i) How effective are the AWD and micro irrigation Technology (drip and sprinkler) in improving the land productivity in irrigated lands?.....

[35] Water Productivity (WATRPRODY)

- (a) To what extent does Farm Size affect Water Productivity (via scale economies & land use intensity)?.....
- (b) To what extent does Crop Pattern affect Water Productivity (e.g., high-value crops vs. food crops)?.....
- (c) To what extent do Ag. Services & Inputs affect Water Productivity (via input complementarities)?.....
- (d) How far do Water Institutions contribute to Water Productivity (via water use efficiency)?.....
- (e) How far can Basin Investment Plans enhance Water Productivity (via water use efficiency)?.....
- (f) How far does Land Productivity contribute to Water Productivity (via soil fertility and land quality)?.....
- (g) How effective are the Zero tillage, AWD, and micro-irrigation Technologies (drip and sprinkler) in improving water productivity?
- (h) How far do Env. Institutions contribute to Water Productivity (Via human-wildlife conflict.....

[36] Labor Productivity (LABRPRODY)

- (a) To what extent does Farm Size affect Labor Productivity (via scale economies & labor use intensity)?.....
- (b) To what extent does Crop Pattern affect Labor Productivity (e.g., high-value crops vs. food crops)?.....
- (c) How far does Farm technologies contribute to Labor Productivity (via input complementarities)?.....
- (d) How far does Irrigation Availability contribute to Labor Productivity (via land productivity and labor use)?.....
- (e) How far does Land Productivity contribute to Labor Productivity (via soil fertility and land quality)?.....
- (f) How strong (or weak) is the association between Labor Productivity and Rural Wage Rates?.....
- (g) How effective are the zero tillage, AWD and micro irrigation Technologies (drip and sprinkler) in improving labor productivity.....

[37] Food Production (FOODPRODN)

- (a) How sensitive are the levels of Food Production to Climate Change (e.g., droughts & rainfall deficits)?.....
- (b) How far do Cas. Manag. Comm. and FOs and CSAP and crop diversification affect Food Production?.....
- (c) How far does a change in Area under Food Crops affect Food Production Levels?
- (d) How far can improved Land/Water Productivities compensate for change in Area under Food Crops?.....
- (e) How far do the Agricultural Value Chains support/contribute to Food Production?
- (f) How far do the Ag. Production & Marketing Coops support/contribute to Food Production?.....
- (g) How far do the Rural Service Providers support/contribute to Food Production?.....
- (h) How far do the Ag. Credit & Investment Institutions support/contribute to Food Production?.....
- (i) How far do the Trade and Domestic Market and Conditions affect Food Production?
- (j) How far do Env. Institutions Contribute to Food Production (Via human-wildlife conflict).....

[38] Industrial and Commercial Crop Production (INDCPRDN)

- (a) How sensitive is Ind & Commercial Crop Production to Climate Change (e.g., droughts & rainfall deficits)?...
- (b) How far do Cas. Manag. Comm. and FOs and CSAP promote Ind & Com Crop Production?.....
- (c) How strong are the Productivity & Income effects of Ind & Com Crop Production?.....
- (d) How important are the Trade and Domestic Market contributions of Ind & Com Crop Production?
- (e) How strong are the links between Ind & Com Crop Production and Agro-Inds & Rural Non-farm Sector?.....
- (f) How far do the Agricultural Value Chains support/contribute to Ind & Com Crop Production?
- (g) How far do the Rural Service Providers support/contribute to Ind & Com Crop Production?
- (h) How far can the Env. Institutions support Ind & Com Crop Production (via reducing human-wildlife conflicts)?.....
- (i) How far do the Ag. Credit & Investment Institutions support/contribute to Ind & Com Crop Production?.....
- (k) How far does the Corporate Sector support/contribute to Ind & Com Crop Production?.....

[39] Fodder and Feed Supply (FEEDSUPPLY)

- (a) How important are the Rainfed Areas for Fodder/Feed Production?
- (b) How sensitive is Fodder/Feed Supply to Climate Change (e.g., droughts & rainfall deficits)?.....
- (c) How strong are the links between Food Crop Production and Fodder/Feed Production?.....
- (d) How far do Crop Pattern Changes (to Industrial & Commercial Crops) affect fodder/feed supply?
- (e) How important are the roles of Common Pastures & Grazing Lands as fodder/feed supply sources.....
- (f) To what extent can Zero-tillage Technology can enhance the production of Fodder/Feed Crops?.....
- (g) How extensive is the use of Commercially Produced Fodder/Feed Productions?.....

[40] Livestock and Poultry Population Size and Composition (LIVSIZCOM)

- (a) How strong are the linkages between Farm Size and Livestock Population?
- (b) How strong are the linkages between Fodder/Feed Supply and Livestock Population?
- (c) How dominant is the Share of Commercial Enterprises (dairy + meat) in the total Livestock Population? ...
- (d) How dominant is the Share of Dairy Animals (relative to Meat Animals) in Total Livestock Population?.....

[41] Livestock and Poultry Production (LIVSPRODN)

- (a) How important are the Rainfed Areas for Livestock Production?
- (b) How sensitive is Livestock Production to Climate Change (e.g., droughts & rainfall deficits)?
- (c) How strong are the links between Food Crop Production and Livestock Production?.....
- (d) How far do Crop Pattern Changes (to Industrial & Commercial Crops) affect Livestock Production?
- (e) How sensitive are Livestock Production to changes in Trade and Market Conditions?
- (f) How far do the Agricultural Value Chains support/contribute to Livestock Production?
- (g) How far do the Production & Marketing Cooperatives support Livestock Production?.....
- (h) How far do the Rural Service Providers support/contribute to Livestock Production?
- (i) How far do the Ag. Credit & Investment Institutions support/contribute to Livestock Production?.....
- (j) How far does the Corporate Sector support/contribute to Livestock Production?
- (k) How Agriculture/ Land Laws/ Regulations affect Livestock and Poultry Production?.....

[42] Agro-Industries and Rural Non-farm Sector (AGNFSECTR)

- (a) How strongly are the Agro-Inds/Rural Non-Farm Sector linked with Food Crop Production?.....
- (b) How strongly are the Agro-Inds/Rural Non-Farm Sector linked with Ind & Com Crop Production?.....
- (c) How strongly are the Agro-Inds/Rural Non-Farm Sector linked with Livestock Production?
- (d) How far do the Agricultural Value Chains support Agro-Inds/Rural Non-Farm Sector?
- (e) How far do the Rural Service Providers support Agro-Inds/Rural Non-Farm Sector?.....
- (f) How far do the Ag. Credit & Investment Institutions support Agro-Inds/Rural Non-Farm Sector?.....
- (g) How far does the Corporate Sector support Agro-Inds/Rural Non-Farm Sector?.....

[43] Rural Jobs or Employment (RURALJOBS)

- (a) How far does Labor Productivity contribute to the level of Rural Employment?.....
- (b) How far does Land Productivity contribute to the level of Rural Employment?.....
- (c) How far does Livestock & Poultry Sector contribute to the level of Rural Employment?.....
- (d) How far do Agro-Inds & Rural Non-Farm Sector contribute to the level of Rural Employment?.....
- (e) How far do Rural Wage Rates determine the level of Rural Employment?.....
- (f) How far do Agriculture/Wage/ Laws and Regulations affect determine the level of Rural Employment?.....
- (g) How far can the requirement of Employment Insurance affect the level of Rural Employment?.....
- (h) How dominant is the Share of Women in total Rural Employment?.....

[44] Rural Wage Rates (RURALWAGE)

- (a) How strong is the association between Labor Productivity and Rural Wage Rates?.....
- (b) How strong is the association between Labor Demand (from all rural sectors) and Rural Wage Rates?
- (c) How strong are the effects of Minimum Wage Regulations on Rural Wage Rates?
- (d) How serious is the Gender-based Discrimination in Rural Wage Rates?.....

[45] Cultivation Costs in Crop Production (CULTICOST)

(Covers costs of land preparation, irrigation, fertilizer, other inputs, operational/maintenance costs of farm equipment, crop insurance premium, etc.)

- (a) How far does the Scale of Operation (Farm Size) reduce Cultivation Costs?.....
- (b) How far does Crop diversification to high-value crops increase Cultivation Costs?.....
- (c) How far do Labor Costs (Wage Rates) contribute to Cultivation Costs?
- (d) How costly is Ag. Services & Inputs and how far such costly services/inputs raise Cultivation Costs?.....
- (e) How far do the Subsidy Policies reduce Cultivations Costs?
- (f) How far can Crop Insurance increase Cultivations Costs?

[46] Market Prices for Farm Products (AMKTPRICE)

- (a) How effective and efficient are Market Prices in Conveying Real Incentives to farmers?
- (b) How far do Market Prices remain Stable (i.e., free of manipulations & seasonal/regional variations)?
- (c) How far do Market Prices get affected by Changes in Production Conditions?.....
- (d) How far do Market Prices get influenced by Trade Policy Changes (i.e., imports and exports)?.....

[47] Income from Crop Sector (CROPINCOM)

- (a) How far do Crop diversification to HV crops raise the level of Crop Sector Income?.....
- (b) How critical are Crop Productivity levels for determining the level of Crop Sector Income?.....
- (c) How critical are Predictable Market Prices for determining the level of Crop Sector Income?
- (d) How far does rising Cultivation Costs affect the level of Crop Sector Income?.....

- (e) How important are the Contributions of Ag. Value Chains to the level of Crop Sector Income?.....
- (f) How far does the effectiveness of Crop Insurance contribute to the stability of Crop Sector Income?.....

[48] Farm Income (FARMINCOM)

- (a) How dominant is the role of the Income from the Crop Sector in the total income of farmers?
- (b) How critical are Livestock and Rural Non-Farm Sectors as additional income sources for farmers?.....
- (c) How far do Social Safety nets (e.g., retirement benefits, stipends, etc.) contribute to farmers' Income?.....
- (d) How adequate is the income of farmers to meet their household food, income, and water security?.....
- (e) How serious are the effects of Climate Change on the level and fluctuations of farmers' Income?.....

[49] Labor Income (LABRINCOM)

- (a) How dominant is the role of the Wage Income in the total income of laborers?
- (b) How critical are Livestock and Rural Non-Farm Sectors as additional income sources for farmers?.....
- (c) How far do Social Safety nets (e.g., retirement, stipend, etc.) contribute to laborers' income?.....
- (d) How adequate is the Income of Laborers to meet their Household Food, Income, and Water Security?.....
- (e) How serious are the effects of Climate Change on the level and fluctuations of laborers' Income?.....

[50] Food Availability (FOODAVAIL)

- (a) How far does Food Availability depend on domestic Food Production?
- (b) To what extent does Food Availability depend on the production performance of Rainfed Regions?.....
- (c) How effective are the roles of the domestic Market Regime in ensuring adequate Food Availability?.....
- (d) How critical are the roles of Food Imports in ensuring adequate Food Availability?.....
- (e) How important are the roles of price and supply regulations in ensuring adequate Food Availability?.....
- (f) How serious are the effects of Climate Change on the level of Food Availability?.....

[51] Food Prices (FOODPRICE)

- (a) How far do Food Prices depend on domestic Food Production?
- (b) How strong are the roles of domestic Market Regime in ensuring stable Food Prices?.....
- (c) How critical are the roles of Food Imports in stabilizing Food Prices?.....
- (d) How important are the roles of price and supply regulations in ensuring stable Food Prices?.....
- (e) How serious are the effects of Climate Change on the level and variations of Food Prices?.....

[52] Water Security (WATRSECUR)

- (a) How adequate/efficient are Water Infrastructures (e.g., dams/storage) in ensuring Water Security?.....
- (b) How adequate/efficient are Water Institutions (e.g., basin agencies) in ensuring Water security?.....
- (c) How strong are the roles of Customary/Traditional Institutions in Water Security at local levels?.....
- (d) How sensitive is Water Security to the vagaries of Climate Change?

[VI] DEVELOPMENT GOAL VARIABLE (1)

[53] Rural Welfare (RURWELFAR)

- (a) How strong is the Food and Income Security status of rural groups in rainfed regions?.....
- (b) How strong is the linkage of Food and Income Security status of rural groups to River Basin investment planning?
- (c) How strong is the linkage of Food and Income Security status of rural groups to forming Cascade management committees & strengthening FO?
- (d) How strong is the linkage of Food and Income Security status of rural groups to Crop diversification and CSAP?.....
- (e) How strong is the Food and Income Security status of rural groups in food crop-based agriculture?.....
- (f) How strong is the Water Security status of rural groups in rainfed regions?
- (g) How strong are the contributions of Social and Safety net Programs to Rural Welfare?.....
- (h) How serious are the effects of Climate Change on the overall Welfare Status of all rural groups?.....

Annex C. Reduced form equations of endogenous variables (Y) on exogenous variables (X)

$$Y_1 = .233X_1 + .226X_4 + .143X_5 + .075X_{17} + .188X_{18}$$

$$Y_2 = 0.052 X_1 - 0.071 X_2 + 0.266 X_3 + 0.050 X_4 + 0.032 X_5 + 0.059 X_6 + 0.046 X_{13} + 0.203 X_{16} + 0.0167 X_{17} + 0.083 X_{18} + 0.293 X_{20}$$

$$Y_3 = 0.168 X_1 - 0.190 X_2 + 0.103 X_3 + 0.202 X_4 + 0.199 X_5 + 0.145 X_6 - 0.126 X_{13} + 0.144 X_{16} + 0.054 X_{17} + 0.004 X_{18} + 0.108 X_{19} + 0.216 X_{20}$$

$$Y_4 = 0.154 X_1 - 0.369 X_2 + 0.072 X_3 + 0.185 X_4 + 0.182 X_5 + 0.059 X_6 + 0.119 X_{11} - 0.116 X_{13} + 0.359 X_{16} + 0.049 X_{17} + 0.050 X_{18} + 0.099 X_{19} + 0.198 X_{20}$$

$$Y_5 = 0.314 X_1 + 0.010 X_2 + 0.108 X_3 + 0.055 X_4 + 0.026 X_5 - 0.055 X_6 + 0.079 X_{11} + 0.103 X_{12} + 0.024 X_{13} + 0.174 X_{16} + 0.0199 X_{17} + 0.1045 X_{18} - 0.0130 X_{19} + 0.033 X_{20} + 0.001 X_{21}$$

$$Y_6 = 0.210 X_1 - 0.005 X_2 + 0.081 X_3 + 0.061 X_4 + 0.033 X_5 - 0.007 X_6 + 0.052 X_{11} + 0.067 X_{12} + 0.039 X_{13} + 0.214 X_{16} + 0.021 X_{17} + 0.109 X_{18} - 0.008 X_{19} + 0.166 X_{20} + 0.001 X_{21}$$

$$Y_7 = 0.381 X_1 - 0.060 X_2 + 0.088 X_{21} + 0.060 X_3 + 0.042 X_4 + 0.004 X_5 - 0.080 X_6 - 0.174 X_7 + 0.176 X_8 - 0.05 X_9 + 0.070 X_{11} + 0.238 X_{12} + 0.048 X_{13} + 0.121 X_{16} + 0.018 X_{17} + 0.121 X_{18} - 0.034 X_{19} - 0.021 X_{20}$$

$$Y_8 = 0.334 X_1 + 0.007 X_2 + 0.058 X_{11} + 0.075 X_{12} + 0.018 X_{13} + 0.127 X_{16} + 0.0145 X_{17} + 0.076 X_{18} - 0.009 X_{19} + 0.031 X_{20} + 0.001 X_{21}$$

$$Y_9 = 0.252 X_1 - 0.065 X_2 - 0.276 X_3 - 0.023 X_4 - 0.023 X_5 - 0.066 X_6 + 0.019 X_8 + 0.048 X_{19} + 0.066 X_{11} + 0.1545 X_{12} + 0.105 X_{13} + 0.146 X_{16} + 0.010 X_{17} + 0.168 X_{18} + 0.010 X_{20} + 0.001 X_{21}$$

$$Y_{10} = 0.184 X_1 - 0.108 X_2 + 0.341 X_3 - 0.036 X_4 - 0.086 X_5 + 0.002 X_6 + 0.005 X_8 + 0.040 X_{11} + 0.106 X_{12} + 0.115 X_{13} + 0.168 X_{16} + 0.0180 X_{17} + 0.180 X_{18} - 0.090 X_{19} + 0.137 X_{20} + 0.001 X_{21}$$

$$Y_{11} = 0.295 X_1 + 0.044 X_2 + 0.176 X_3 - 0.014 X_4 - 0.008 X_5 - 0.122 X_6 - 0.001 X_7 + 0.052 X_8 + 0.065 X_{11} + 0.207 X_{12} + 0.146 X_{13} + 0.084 X_{16} - 0.002 X_{17} + 0.184 X_{18} - 0.056 X_{19} - 0.069 X_{20} + 0.001 X_{21}$$

$$Y_{12} = 0.282 X_1 + 0.142 X_3 + 0.001 X_4 - 0.008 X_5 - 0.122 X_6 - 0.005 X_7 + 0.054 X_8 + 0.100 X_{11} + 0.161 X_{12} + 0.109 X_{13} + 0.176 X_{16} + 0.002 X_{17} + 0.165 X_{18} - 0.047 X_{19} + 0.061 X_{20} - 0.030 X_{21}$$

$$Y_{13} = 0.229 X_1 + 0.041 X_2 + 0.166 X_3 - 0.033 X_4 - 0.018 X_5 - 0.117 X_6 + 0.039 X_7 + 0.058 X_8 + 0.048 X_{11} + 0.197 X_{12} + 0.154 X_{13} + 0.041 X_{16} - 0.008 X_{17} + 0.172 X_{18} - 0.060 X_{19} + 0.060 X_{20} + 0.001 X_{21}$$

$$Y_{14} = 0.318 X_1 - 0.081 X_2 + 0.061 X_3 + 0.126 X_4 + 0.126 X_5 - 0.116 X_6 - 0.001 X_7 + 0.280 X_9 + 0.032 X_{10} + 0.067 X_{11} + 0.136 X_{12} - 0.006 X_{13} + 0.194 X_{16} + 0.025 X_{17} + 0.09 X_{18} + 0.062 X_{19} + 0.012 X_{20} + 0.001 X_{21}$$

$$Y_{15} = 0.177 X_1 - 0.035 X_2 + 0.082 X_3 + 0.229 X_4 + 0.015 X_5 - 0.100 X_6 - 0.0002 X_7 + 0.019 X_8 - 0.001 X_9 + 0.033 X_{11} + 0.060 X_{12} + 0.004 X_{13} + 0.117 X_{14} + 0.158 X_{16} + 0.016 X_{17} + 0.104 X_{18} + 0.014 X_{19} + 0.050 X_{20} - 0.018 X_{21}$$

$$Y_{16} = 0.166 X_1 - 0.073 X_2 + 0.302 X_3 + 0.029 X_4 - 0.089 X_5 - 0.027 X_6 + 0.0001 X_7 + 0.003 X_8 + 0.045 X_9 - 0.010 X_{10} + 0.038 X_{11} + 0.095 X_{12} + 0.104 X_{13} + 0.049 X_{14} + 0.151 X_{16} + 0.013 X_{17} + 0.174 X_{18} - 0.094 X_{19} + 0.098 X_{20} - 0.007 X_{21}$$

$$Y_{17} = 0.263 X_1 - 0.062 X_2 + 0.233 X_3 + 0.203 X_4 - 0.095 X_5 + 0.183 X_6 + 0.00008 X_7 + 0.003 X_8 + 0.022 X_9 - 0.208 X_{10} + 0.028 X_{11} + 0.073 X_{12} + 0.080 X_{13} + 0.024 X_{14} + 0.023 X_{16} + 0.011 X_{17} + 0.130 X_{18} - 0.069 X_{19} + 0.082 X_{20} - 0.003 X_{21}$$

$$Y_{18} = 0.161 X_1 - 0.057 X_2 + 0.225 X_3 + 0.101 X_4 - 0.073 X_5 + 0.153 X_6 + 0.00008 X_7 + 0.004 X_8 + 0.024 X_9 - 0.124 X_{10} + 0.031 X_{11} + 0.077 X_{12} + 0.078 X_{13} + 0.026 X_{14} + 0.132 X_{16} + 0.019 X_{17} + 0.150 X_{18} - 0.064 X_{19} + 0.068 X_{20} - 0.004 X_{21}$$

$$Y_{19} = 0.053 X_1 + 0.009 X_2 - 0.003 X_3 + 0.249 X_4 - 0.001 X_5 + 0.167 X_6 - 0.00001 X_7 + 0.007 X_8 + 0.059 X_9 + 0.041 X_{10} + 0.005 X_{11} - 0.006 X_{12} - 0.027 X_{13} + 0.168 X_{14} - 0.050 X_{16} + 0.009 X_{17} + 0.134 X_{18} + 0.023 X_{19} + 0.041 X_{20} - 0.026 X_{21}$$

$$Y_{20} = 0.223 X_1 - 0.071 X_2 + 0.174 X_3 + 0.079 X_4 - 0.00001 X_5 + 0.083 X_6 - 0.0002 X_7 + 0.019 X_8 - 0.049 X_9 - 0.077 X_{10} + 0.063 X_{11} + 0.111 X_{12} + 0.054 X_{13} - 0.070 X_{14} + 0.150 X_{16} + 0.0148 X_{17} + 0.129 X_{18} - 0.023 X_{19} + 0.044 X_{20} + 0.002 X_{21}$$

Y21= 0.160 X1-0.054 X2+0.211 X3+0.055 X4-0.060 X5+0.004 X6+0.002 X7 +0.007 X8+0.004X9 -0.115 X10+0.032X11+0.085 X12+0.283 X13-0.003 X14+0.177 X16+0.008 X17 +0.101 X18-0.061 X19+0.058 X20+0.001X21

Y22= 0.176 X1 -0.016 X2+0.168 X3+0.071X4-0.037 X5-0.001 X6 +0.006 X7+0.021 X8+0.013X9 -0.057 X10 +0.035 X11+0.105 X12+0.083 X13+0.030 X14+0.109 X16+0.005 X17 +0.133 X18 -0.047 X19+0.037 X20-0.004 X21+0.084 X22

Y23= 0.254 X1 -0.077 X2 +0.211X3+0.007 X4+0.027 X5-0.077 X6+0.118X7+0.023 X8-0.117 X9 -0.0002 X10+0.079 X11+0.149 X12+0.071 X13-6.00508*↑6 X14-0.013 X15 +0.099 X16 +0.011 X17+0.140 X18-0.012 X19+0.003 X20+0.0007 X21+0.015 X22

Y24 = 0.251 X1-0.050 X2 +0.232 X3-0.009 X4-0.004 X5-0.077 X6-0.013 X7+0.022 X8-0.148 X9 +0.003 X10+0.065 X11+0.152 X12+0.092 X13+6.726↑7 X14+0.001 X15+0.139 X16 +0.009 X17+0.151 X18-0.033 X19-0.012 X20+0.0007 X21-0.025 X22+0.273 X23

Y25 = 0.149 X1+0.005 X20-0.028 X10+0.064 X11+0.152 X12+0.099 X13+0.005 X14-0.030 X15+0.153 X16 +0.010 X17+0.168X18-0.045 X19-0.057 X2-0.00005 X21-0.022 X22+0.240 X23

Y26= 0.194 X1-0.038 X2 +0.221X3+0.056 X4-0.061X5+0.070 X6+0.004X7+0.015 X8+0.013 X9 -0.105 X10+0.037X11+0.107946 X12+0.044 X13+0.007 X14+0.020 X15+0.133 X16 +0.006 X17+0.147 X18-0.067 X19+0.050 X20-0.0005X21+0.061X22

Y27 = 0.280X1-0.053 X2+ 0.0465 X3+0.082X4 +0.076 X5-0.0672 X6-0.0005 X7+0.028 X8-0.091 X9 +0.016 X10+0.263 X11+0.088X12-0.0008 X13+0.011 X14+0.126 X16+0.016 X17+0.064 X18+0.037 X19+0.010 X20+0.0003 X21+0.031 X23

Y28 = 0.2867 X1 -0.059 X2 +0.050 X3+0.092 X4+0.087 X5-0.077 X6-0.0006 X7+0.031 X8-0.102 X9 +0.0188 X10+0.189 X11+0.099 X12-0.002 X13+0.010 X14+0.141 X16+0.018 X17 +0.071 X18 +0.042 X19 +0.011 X20+0.0004 X21+0.086 X23

Y29 = 0.079X1 +0.052 X2 +0.147 X3+0.064 X4+0.030X5-0.061 X6 +0.090 X11+0.117 X12+0.029 X13+0.202X16+0.023 X17+0.120 X18+0.043 X19 +0.042 X20+0.001 X21

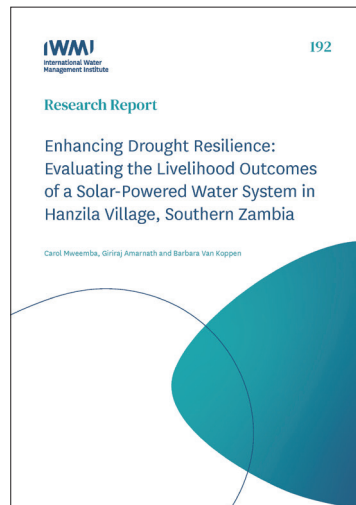
Where,

Endogenous variable name	Exogenous variable name
Y1 Climate investments in water-related work	X1 Climate change impacts
Y2 River basin planning focusing on climate change	X2 Water institutions
Y3 Forming cascade management committees	X3 Water infrastructure
Y4 Diversification to high value crops	X4 Agricultural institutions
Y5 Water availability (for irrigation)	X5 Environmental institutions
Y6 Water supply (for people, livestock, industries)	X6 Agricultural credit and investment institutions
Y7 Agriculture sector performance	X7 Agricultural input supply
Y8 Land quality and soil health	X8 Agricultural science and technology, research and development
Y9 Cropping pattern	X9 Agricultural value chains
Y10 Cultivated/Cropped area	X10 Agriculture production/marketing corporations
Y11 Land productivity	X11 Agricultural market regime
Y12 Water productivity	X12 Agricultural and food price regulation policies
Y13 Labor productivity	X13 Agricultural wage laws and regulations
Y14 Crop production	X14 Subsidy and tax relief policies
Y15 Industrial and commercial crop production	X15 Rural social safety net policies
Y16 Feed supply	X16 Rural service providers
Y17 Livestock size and composition	X17 International donors and investors
Y18 Livestock production	X18 Corporate sector agencies/players
Y19 Agro-industries and non-farm sector performance	X19 Customary institutions
Y20 Market prices	X20 Land tenure
Y21 Rural wages	X21 Climate Information Services and DSS
Y22 Rural jobs	X22 Agricultural crop and employment insurance
Y23 Cultivation cost	X23 Agriculture market price
Y24 Crop income	
Y25 Farm income	
Y26 Labor income	
Y27 Food availability	
Y28 Food price	
Y29 Water security	

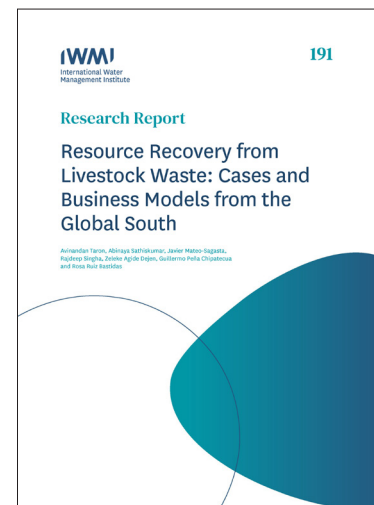
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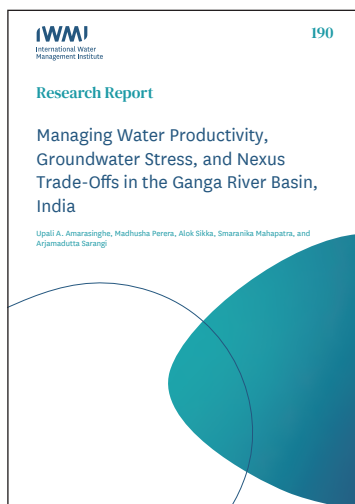
193 Combined Impacts of Transformative Adaptation and Multiscale Polycentric Governance for Enhancing Climate Resilience: A Case Study from Sri Lanka
<https://doi.org/10.5337/2025.237>



192 Enhancing Drought Resilience: Evaluating the Livelihood Outcomes of a Solar-Powered Water System in Hanzila Village, Southern Zambia
<https://doi.org/10.5337/2025.213>



191 Resource Recovery from Livestock Waste: Cases and Business Models from the Global South
<https://doi.org/10.5337/2025.215>



190 Managing Water Productivity, Groundwater Stress, and Nexus Trade-Offs in the Ganga River Basin, India
<https://doi.org/10.5337/2025.225>



189 Creating an Enabling Environment for Agricultural Innovations in Emerging Markets
<https://doi.org/10.5337/2025.209>



188 Afghanistan Drought Early Warning Decision Support (AF-DEWS) Tool
<https://doi.org/10.5337/2023.223>

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