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Modeling principles, criteria and indicators to assess water sector governance for climate compatibility and sustainability

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The United Nations SDGs Report 2020 revealed that climatic variability victimized masses across the globe in 2018 and the global average temperature would rise to 3.2°C during this century. The GHG emission reduction targets for 2030 were prioritized under the Paris Climate Agreement (PCA) of 2015 to keep the rise in global temperature below 1.5°C. Here, parallel action for climate adaptation is on top of it. However, targets for both adaptation and mitigation are lagging. Climatic variations will continue more likely with similar trends thus influencing the development needs vis-à-vis environmental security and sustainability of resources. It entails climate compatibility, particularly for the water security agenda for SDG-13 and Paris Climate Agreement (PCA), which requires an inclusive governance regime and ownership for national and sub-national scenarios. In this context, this paper aimed to assess existing water sector governance for climate compatible development (CCD) by taking the case of Pakistan which is among the top 10 countries vulnerable to climate change. Considering the limitations of available methodologies due to the involvement of various aspects and concepts of governance, an integrated multivariate mix-method model was formulated by combining rules and rights-oriented approaches. This MCDA-based model integrates six novel climate governance principles against six basic components of the basic institutional governance framework; Simple Multi-attribute Rating Technique (SMART) with a set of sectoral indicators of 09 criteria of climate compatible development (CCD). It proved well for this water sector case study with cross-sectional data from 340 key informant interviews (KIIs) and 17 focus group discussions (FGDs) in Pakistan, validated statistically. It can be used for periodic sectoral governance assessments for CCD.

KEYWORDS

SDG-13, climate compatible development, climate governance principles, CCD criteria, governance indices, MCDA

1 Introduction

Climate change phenomena are now widely realized as very severe outcomes of risk and present the biggest challenge for the current century (Eleftheriadis and Anagnostopoulou, 2017; Jiang et al., 2017), which require a serious approach toward impacts mitigation and coping strategies (Rahman and Salman, 2013; Iqbal and Khan, 2018). The global mean temperature is a big anomaly (IPCC, 2018). World Meteorological Organization (WMO) research indicates that the year 2018 saw a rise in global mean temperature of 0.99°C ± 0.13°C relative to the baseline for the pre-industrial period (1850–1900) along with the low-level La Niña effect was observed in the year 2018 (WMO, 2019). The year 2018 was also included in NOAA's ranking for the top 10 warmest periods in record of the past 109 years (Blunden and Arndt, 2019). The United Nations SDGs Report 2020revealed that climatic variability victimized masses across the globe in 2018 and the global average temperature would rise to 3.2°C during the current century. Climate change will certainly continue with similar trends, affecting development requirements for environmental security and resource sustainability by escalating the frequency and severity of natural catastrophes and other calamities. (United Nations, 2020).

The cascading effects of climatic variations on all sectoral economies have raised serious concerns about the relationship between nature and human beings. It would plague not only the social wellbeing but also the sustainability of the entire world due to a wide variety of dilemmas (Carvalho and Peterson, 2009). On one hand, the climate response strategies are 'context-dependent'; while on the other hand, options have interlocking of SDG-13 with other SDGs due to complex interdependence (Blanchard et al., 2017). It has a concern, particularly in the context of terrestrial versus marine ecosystems. The cascading effects of climate change on food security have a supply and demand interplay between marine fisheries and agriculture worldwide (Teh and Sumaila, 2013; Thiault et al., 2019), thus the agenda of the SDGs becomes very important. Consumption trends would observe a more likely shift, particularly in the 'context-dependent' scenario due to changes in dietary and lifestyle patterns. It would be a matter of concern for the targets set for SDG-12.

The key driver of GHG emissions is a very close nexus of water, energy, and food (agriculture) in the context of environmental security (Ali and Iqbal, 2017; Hassan et al., 2018). The climate, energy, land, agriculture, and water nexus has very strong connections with many SDGs (Sridharan et al., 2018) including SDG-13, SDG-12, SDG-7, SDG-6, and SDG-2. There may be a paradigm shift due to water and energy insecurity (Hassan et al., 2021) and its crises as a result of a supply and demand gap (Bilal et al., 2018). It can be better understood once a clear picture of the current state of governance for climate-compatible development, environmental security, and sustainability of the water sector in developing countries. It was considered at length that the situation can be rationalized further to have better planning for CCD response options through a case study of a developing country like Pakistan.

Pakistan is among the top 10 countries vulnerable to climate change. The frequency of extreme climatic events is high and variable, which includes frequent and devastating floods with large-scale impacts. There is a need to assess the adequacy of preparedness to cope with climatic changes, particularly for flood risk management and disaster risk reduction. In the business-as-usual case of Pakistan, the effects of climatic variations would likely be increased manifold due to implementation of the massive China-Pakistan Economic Corridor (CPEC) Plan, which is a collaborative part of the Belt & Road Initiative (BRI) of China (Iqbal and Haider, 2020; Waheed et al., 2021). Like other vulnerable developing countries, the overall climate change scenario entails having an inclusive climate response mechanism in Pakistan.

According to UN SDGs Report 2020, the ownership and action of the global community could not be observed as per the spirit of commitments for collective actions regarding obligations to cope with climate change. The business-as-usual scenario regarding the unsustainable use of natural resources continued as desired funds could not be mobilized to reverse the "climate crisis" by overcoming the major challenge of climate financing toward response strategies (United Nations, 2020). The 2030 targets for the reduction of GHG emissions were prioritized under PCA to keep the rise in temperature below 1.5°C. Here, parallel action for climate adaptation is on top of it. In this context, the response against targets set under various Sustainable Development Goals (SDGs) is critically important for the overall climate agenda. However, targets for both adaptation and mitigation are lagging. There is a need to create a synergy between PCA (UNFCCC, 2015) and SDGs, particularly the SDG-13 (UN, 2015) to have a coherent response to water, energy, and food (agriculture) nexus for environmental security and sustainability (Campbell et al., 2014). It entails climate compatibility (Mitchell and Maxwell, 2010), particularly for the water security agenda under PCA and SDG-13, which requires an inclusive governance regime and ownership, particularly for national and sub-national scenarios (Iqbal and Khan, 2018; Iqbal and Khan, 2021; Iqbal et al., 2021).

It is critical that developing countries are not only at the forefront of climate vulnerability but also have complex governance arrangements, funding constraints, and a lack of ownership. It raises concerns about the adequacy of the system to put in place an effective climate response mechanism. Unfortunately, the available information cannot be narrowed down further to have deep insight into the adequacy of the governance for climate compatibility and sustainability of the water sector vis-à-vis development needs. Hence, there is a need to examine it in national, sub-national, and local scenarios by employing a comprehensive and widely accepted analysis model which considers various governance approaches and multiple aspects. Although the available literature reflects various assessment frameworks (Douxchamps et al., 2017; FAO, 2017; Ha et al., 2018; Oliveira and Hersperger, 2018), there is the non-existence of a widely accepted and standardized analysis model to meet all requirements by covering all dimensions of governance for CCD (Pyone et al., 2017). The propagation of the governance assessment subject was found to a reasonably good extent in the existing literature, with abundant and diverse dimensions (Sanchez and Roberts, 2014; Thornton et al., 2018). The various dimensions of governance assessment show the application of principles (Chuku, 2010; Lockwood et al., 2010; Dasgupta and Roy, 2011; Aven and Renn, 2018), criteria (Wise et al., 2016; Wood et al., 2017), and indicators (Emenanjo et al., 2015; Dong and Hauschild, 2017). Whereas perspectives on methodological shortcomings also exist (Ritchie et al., 2010; Nakano et al., 2017).

The lack of wider acceptability in the methodological context is due to the cross-cutting nature and complexity to govern the climate change phenomenon, particularly for climate compatibility, environmental security, and sustainability of the water sector. The complexity is due to the involvement of multi-sectors, multi-actors, multi-approaches (i.e., the rules to rights-based approaches) (Pierre and Peters, 2020), and a variety of conceptual frameworks in terms of formal and informal ways of governance including the customary practices particularly for the rights on the natural resources (Follesdal et al., 2004; Stone, 2011; Kleine, 2014) including the water. It is also important to consider the originality of the terminology 'governance' in the modern world as the alternate arguments link it with *'the origin of human civilization* on planet Earth (Ysa et al., 2014). Whereas governance received significant attention during the 1980s, overall its concepts and approaches are still ambiguous (Anderson et al., 2014). On one hand, the 'command-and-control' mechanism with 'top-down' working has several weaknesses in the 'rules-based' system due to which stakeholders have critical views about its effectiveness and legitimacy. While on the other side, the rights-oriented governance approach creates attraction vis-à-vis importance given to rights, inclusion, participation, accountability and active engagement of all kinds of relevant actors and the political economy. It promotes constructive relationships through a negotiation structure and arrangements to shape interactions about a particular issue (Visseren-Hamakers and Glasbergen, 2007; Saunders and Reeve, 2010). It is pertinent that the CCD's conceptual framework vis-à-vis the agenda for water security and sustainability needs a comprehensive assessment model as it cannot be dealt with through such an *ad hoc* method that partially deals with its entire scope. Aforesaid in view, the paper aimed to assess water sector governance for CCD by taking the business-as-usual case of arrangements and response measures in Pakistan.

1.1 Aim and objectives

This paper stems from a broad research study aimed at developing a model for framework analysis and periodic assessment of the adequacy of governance for CCD and response mechanisms and options with their effective application in all sectoral economies (Iqbal, 2021). This paper revolves around three objectives: i) developing principles, criteria, and indicators (PCIs) for CCD in the water sector; ii) analyzing the existing framework of governance for CCD with a case study of water sector in Pakistan; and iii) provision of research-based discussion and recommendations to bring about improvements in governance arrangements for CCD at federal, provincial and district levels. Technically, the water sector requires adaptation and resilience strategies directly, while indirectly it interlocks with mitigation and low carbon development strategies in the context of its nexus and interplay with agriculture and energy sectors, thus being important for all four elements of climate-compatible development. The geographical limitations of this case study were set in the context of Pakistan.

1.2 Research question for application of framework model

The innovative multivariate mix-method analysis model was employed to assess water sector governance for CCD by taking the business-as-usual case of arrangements and response measures. It tested the key research question; whether a proactive and inclusive governance mechanism at national, sub-national, and local levels is in place for climate compatibility, environmental security, and sustainability of the water sector in Pakistan? For a comprehensive assessment of overall arrangements, the key research query was narrowed down further and indicators were developed accordingly to investigate the different components of the basic governance framework. The basis for the null hypothesis regarding the placement of inclusive and adequate climate response was that there is no such mechanism so far established or exists.

1.3 Significance of the study

Six (06) novel climate governance principles, nine (09) CCD response criteria and 281 water sector indicators were developed in a systematic way and successfully tested by undertaking the case study of Pakistan, which is a significant achievement considering the incorporation of multi-approaches, multi-sectors and multi-actors involved to govern multifacet challenge of climate change. A wide variety of variables vis-à-vis governance approaches and components, technical aspects vis-à-vis response measures and methodological aspects to quantify, deduce and present results in an integrated way. This model approach can be utilized in partial of full form for periodic assessment and reporting the state of governance for CCD in water sector.

2 Methodological framework

2.1 Study approach

Considering the limitations of available methodologies, an integrated approach was adopted for devising a multivariate mix-method model by combining rules and rights-oriented approaches of governance along with all other variables associated with the concept of CCD and methodological aspects regarding principles, criteria, and indicators. This model integrates six climate governance principles against six basic components of the basic institutional governance framework, principles of good governance outlined by the World Bank, and the Simple Multi-attribute Rating Technique (SMART) under the umbrella of the Multi-criteria Decision Analysis (MCDA) method (Daim et al., 2009; Amer and Daim, 2011; Costa et al., 2017; Ishtiaque et al., 2019; McIntosh and Becker, 2020) with a set of 281 composite indicators of 09 CCD response criteria.

2.2 Study design and variables for devising analysis model

Figure 1 and Figure 2 provide the breakdown and logical arrangement of different sets of variables. Figure 1 explicitly describes the overall study design and all the variables involved in logical arrangements for the integration of different governance approaches, components, constituencies, principles, criteria, indicators, tools and methods, types of data, and indices. Whereas Figure 2 provides specific detail of principles, criteria, and indicators of components of a basic governance framework.

Generally, governance analysis revolves around three variables of institutional design, capacity, and activities. However, the overlapping

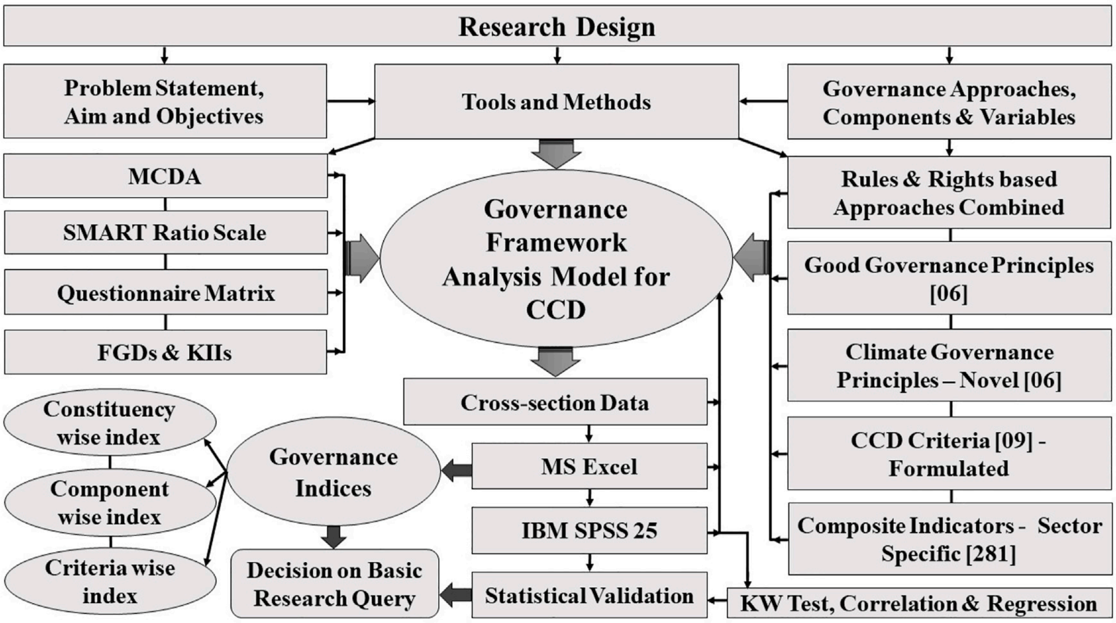

FIGURE 1
Major study design [source: (Iqbal, 2021)].

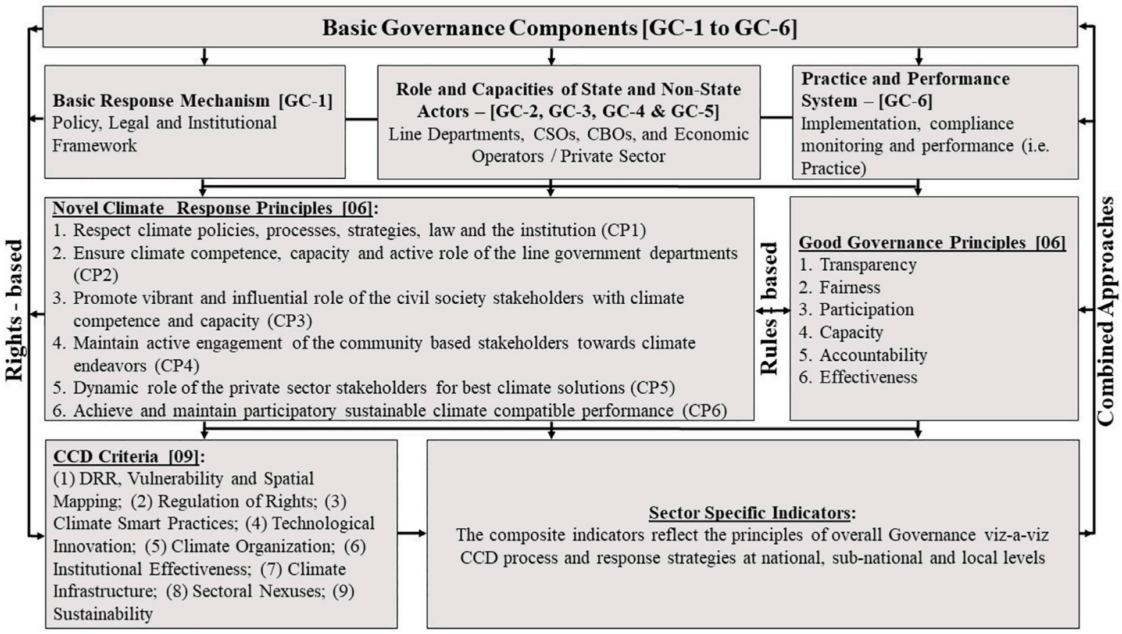

FIGURE 2
Principles, criteria and indicators for CCD assessment model source: (Iqbal, 2021):].

aspects of these three aspects are not expressed well in the available literature. For this study, the basic governance framework is primarily categorized into three major parts and further classified into six components to bring more clarity for which the institutional design, capacity, and activities are found cross-cutting to a large extent. Earlier, the six components were used in an Indonesian study for assessing REDD + governance against the principles of good governance (Kartodihardjo et al., 2013). Whereas this study is more advanced and innovative as it provides climate principles against six governance components and integrates various concepts and approaches. The first part deals with the basic response mechanism by covering policy, legal and institutional arrangements and it is termed governance component 1 (GC1). It is the main component, the adequacy of which is critically important for CCD response

TABLE 1 Direct and indirect linkages of criteria with conceptual parts of CCD [Source: (Iqbal, 2021)].

Conceptual parts of CCD	Applicability of CCD's response criteria for the water sector								
	WC[a]-1	WC-2	WC-3	WC-4	WC-5	WC-6	WC-7	WC-8	WC-9
Adaptation	√	√	√	√	√	√	√	√	√
Resilience	√	√	√	√	√	√	√	√	√
Mitigation	-	√	√	√	√	√	√	√	√
Low Carbon Development	-	√	√	√	√	√	√	√	√

[a]Water sector criterion for CCD, response strategies.

strategies and courses of action. The second part is associated with the capacity of all state and non-state actors, and it was narrowed down into four governance components (GCs) i.e., capacity of: government actors (GC2); academia and civil society organizations (GC3); local community organizations/associations (GC4); and private actors (GC5). The third part deals with performance-based execution i.e., practice system (GC6).

With the active participation of twelve (12) subject experts selected based on their field experience, three (03) consecutive FDGs sessions were organized for deliberation and conclude all variables by taking into account the existing concepts (informal to formal), approaches (rules and rights oriented) and components of governance, and existing methods of assessments concerning CCD scope and the response measures required for all sectors. The selected expert group was composed of professionals and academicians. The most relevant and available experts were approached from the big pool of professionals who are working at Islamabad in the areas of water, agriculture and energy vis-à-vis climate change response initiatives. For holding session at Islamabad, attendance of experts was targeted from ministry of water resources, Pakistan Council of Research in Water Resources (PCRWR), Indus River System Authority (IRSA), climate change related departments including Ministry of Climate Change, Global Change Impact Studies Center (GCISC) and National Disaster Management Authority (NDMA), and energy related departments including power generation as well as allied organizations like National Energy Efficiency and Conservation Authority (NEECA), Ministry of National Food Security & Research, Alternative Energy Development Board (AEDB), Pakistan Council for Renewable Energy Technology (PCRET), and faculty members from various universities. Flip charts and flash cards were used to keep the discussion interactive and focused. Before FDG sessions, an initial qualitative desk review was done by employing the content analysis technique through which CCD scope and response measures were identified and shared with experts for their detailed review and feedback based on well-established technique of situation or problem tree analysis for different climate scenarios for effective decision-making (Wellman, 1983; Hovland, 2005; Borgatti et al., 2009; Dey, 2012; Norris et al., 2012; Serrat, 2017; Iqbal et al., 2022). These are practiced widely for good planning and management cycles through cause and effect analysis which can be easily produced through FGDs (Hovland, 2005).

After a successful consultation process, nine (09) generic CCD response criteria (i.e., Disaster Risk Reduction, Vulnerability & Spatial Mapping = WC-1; Regulation of Rights = WC-2; Climate-Smart Practices = WC-3; Technological Innovation = WC-4; Climate Organisation = WC-5; Institutional Effectiveness = WC-6; Nexus of water, energy, and agriculture = WC-8, and Sustainability = WC-9) were formulated against six (06) climate governance principles, which are based on the foundation of the overall institutional framework for response mechanism i.e., governance components 1 to 6 (GC1 - GC6) as shown in Figure 2.

The compatibility of all nine criteria was thoroughly analyzed for their application to all sectors of the economy against four parts of CCD's conceptual framework i.e., adaptation, resilience, mitigation, and low carbon development. It was done through an in-depth situation/problem tree analysis exercise in which all direct and indirect linkages were scrutinized, the outcome of which for the water sector is shown in Table 1. It reveals that the phenomenon of climate change is not only cross-cutting but also has cascading effects through direct and indirect linkages. Although the scientific community and the existing literature discuss such an effect and response options, the actual scope to determine comprehensive and adequate strategies for the governance of different sectoral economies is still neither understood nor reported well in the context of climate compatibility, environmental security, and sustainability.

It is anticipated that the derived six (06) climate governance principles (CGPs) will act as main vehicles and nine (09) criteria will be precursors for CCD to carry forward the agenda in all sectoral economies. Whereas sector-specific indicators will be the means of verification for that particular segment of sectoral economies *per se*, to assess the adequacy of the overall governance framework for climate compatibility, environmental security, and sustainability.

These criteria are unique in the sense that they all can be applied not only to the water sector but also to any other sector to assess the adequacy of the governance framework for climate response at any tier of the constituency in any country. The only sector-specific thing is the comprehensive set of indicators which varies on a case-to-case basis. Earlier to the publication of this study on the water sector, climate response principles and criteria were successfully applied to the agriculture and energy sector by having a sector-specific comprehensive set of composite indicators. A set of 281 composite indicators was determined for this water sector study; a breakdown summary of which is shown in Table 2 while the actual contents are provided in Supplementary Appendix SA1.

2.3 Tools for primary data collection

It was necessary to distinguish and utilize all variables (all components of the governance i.e., GC1 to GC6 and PCIs) easily and effectively. For this, multivariate coding was devised before shaping the structured questionnaire for primary data collection.

TABLE 2 Composite Indicators based on governance component and CCD criteria [Source: (Iqbal, 2021)].

Governance component (GC)	CCD's response criteria for water sector									Total indicators
	WC-1	WC-2	WC-3	WC-4	WC-5	WC-6	WC-7	WC-8	WC-9	
GC1	4	3	5	4	5	8	6	5	3	43
GC2	6	4	6	5	7	10	11	6	3	58
GC3	6	4	5	5	6	5	4	4	3	42
GC4	7	3	3	3	4	5	4	4	3	36
GC5	3	3	4	3	2	5	4	4	3	31
GC6	11	6	9	8	8	13	9	4	3	71
Total Indicators	37	23	32	28	32	46	38	27	18	281

The SMART compatible questionnaire matrix (Table 9 in Supplementary Appendix SA1) was developed for applicable set of water sector governance indicators, by adding columns on the right side of composite indicators' table and applying a ratio scale with a range of scoring from 0 to 10 by respondents i.e., no response/not applicable (0), very poor (0.01–1.99), poor (2.00–3.99), considerable response (4.00–4.99), fair response (5.00–5.99), good progress (6.00–7.49), very good performance (7.50–8.99), excellent achievement (9.00–10.0). MCDA's SMART is a very effective technique to produce quantitative indices for different issues including governance aspects to help in the decision-making process at all levels; that is why it is well recognized and practiced worldwide (Edwards, 1977; Leskinen and Kangas, 2005; Gärtner et al., 2008; Heinrich Blechinger and Shah, 2011). Although the exercise was time taking, it was effectively used for scoring through FGDs and KIIs. Quantitative output through FGD sessions was unique and interesting. It establishes that any feedback gathered through FGD can also be quantified and analyzed with other datasets acquired through KIIs, subject to harmonization and normalization of questions. The measuring tool in the form of a questionnaire for primary data was validated through a pre-test at Islamabad.

2.4 Sampling plan, locations, and sample size for case study

The sampling plan of this case study consisted of two important segments i.e., the sample size and the geographical scope to record primary data through FGDs and KIIs for the principle decision to cover the entire scope of the study by undertaking national (federal), sub-national (provincial) and local (district) level constituencies throughout Pakistan. Therefore, all seven capitals (i.e., federal and provincial) were included for geographical coverage at the national and sub-national levels under the scope of this water sector study. Whereas ten district-level constituencies were chosen following rigorous analysis and examination of existing and completed climate response-related projects by all stakeholders, including government-led initiatives. The local level geographical coverage includes Badin and Sanghar districts from Sindh province, Rajanpur and Bahawalpur districts from Punjab province, Mansehra and Swat districts from Khyber Pakhtunkhwa, Khuzdar and Jhal Magsi districts from Balochistan province, Muzaffarabad district from Azad Jammu Kashmir (AJK), and Ghizer district from Gilgit-Baltistan. It was decided to conduct twenty (20) KIIs and one FGD for each location thus 357 total observations were recorded for the water sector. Responses were collected from key informants working in water, agriculture and energy sectors related federal, provincial, and district government departments including representation from academic institutions, civil society organizations, private sector and local community.

2.5 Data handling and analysis

All raw data entries were done in 'MS Excel 2013'. Subsequently, data were cleaned, and governance indices were prepared. Separate sheets were prepared to run the dataset in 'IBM SPSS Statistics 25' for performing three different statistical validation tests including 'Kruskal-Wallis (KW) hypothesis test', Pearson correlation, and Multivariate Regression. A combination of these three statistical tests proved well to have an in-depth analysis of various dimensions of the sample. KW test helped in authenticating the normal distribution of the sample and assessing the dominating variables. It remained in practice in similar studies (Atif et al., 2018). Pearson correlation and Regression analyses helped in understanding the relationship between different criteria and governance components in constituencies. Earlier, these tests were applied and reported successfully on similar research topics of CCD in different sectors of the economy i.e., energy and agriculture (Iqbal et al., 2021; Iqbal and Khan, 2021; Iqbal et al., 2022).

3 Results

The water sector governance index for all three tiers of the constituency regarding components of the governance framework is shown in Table 3. The index with criteria and governance component-wise breakdown is given in Table 4. Whereas, for a quick overview of different dimensions, results are graphically presented by different types of graphs as shown in Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7. Overall results depict GC1 index scores of 6.54 (good), 4.19 (considerable), and 3.12 (poor) with an average score of 4.61 (considerable); GC2 index scores of 7.30 (good), 3.84 (poor), and 2.25 (poor) with an average score of 4.46

TABLE 3 Overall water sector index of governance for CCD.

Constituency level	Components of the governance framework						Average score	Ranking
	GC1	GC2	GC3	GC4	GC5	GC6		
National	6.54	7.30	5.87	2.78	1.86	3.96	4.72	Considerable
Sub-national (All Provinces)	4.19	3.84	2.93	1.86	1.40	3.02	2.87	Poor
Local level (All districts)	3.12	2.25	1.69	1.28	0.58	1.84	1.79	Very Poor
Average Score	4.61	4.46	3.50	1.97	1.28	2.94	3.13	Poor
Ranking	Considerable	Considerable	Poor	Very Poor	Very Poor	Poor	Poor	-

Source: (Iqbal, 2021):

TABLE 4 Water Sector Index based on Governance Components & CCD Criteria (Iqbal, 2021).

Governance component (GC)	CCD's response criteria for water sector									Average score	Ranking
	WC[a]-1	WC-2	WC-3	WC-4	WC-5	WC-6	WC-7	WC-8	WC-9		
GC1	5.25	3.30	4.99	4.94	4.94	4.94	5.04	4.76	3.37	4.61	Considerable
GC2	5.13	3.26	4.79	4.76	4.80	5.00	4.81	4.62	3.00	4.46	Considerable
GC3	4.04	2.47	3.80	3.82	3.83	3.88	3.83	3.52	2.27	3.50	Poor
GC4	2.18	1.69	2.13	2.12	2.10	2.09	2.09	2.11	1.23	1.97	Very poor
GC5	1.33	1.23	1.35	1.34	1.39	1.35	1.37	1.34	0.84	1.28	Very poor
GC6	3.49	2.58	3.14	3.03	3.04	3.30	3.03	2.80	2.06	2.94	Poor
Average Score	3.57	2.42	3.37	3.34	3.35	3.43	3.36	3.19	2.13	3.13	Poor
Ranking	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	-

[a]Water sector criterion for CCD, response strategies; Source: (Iqbal, 2021).

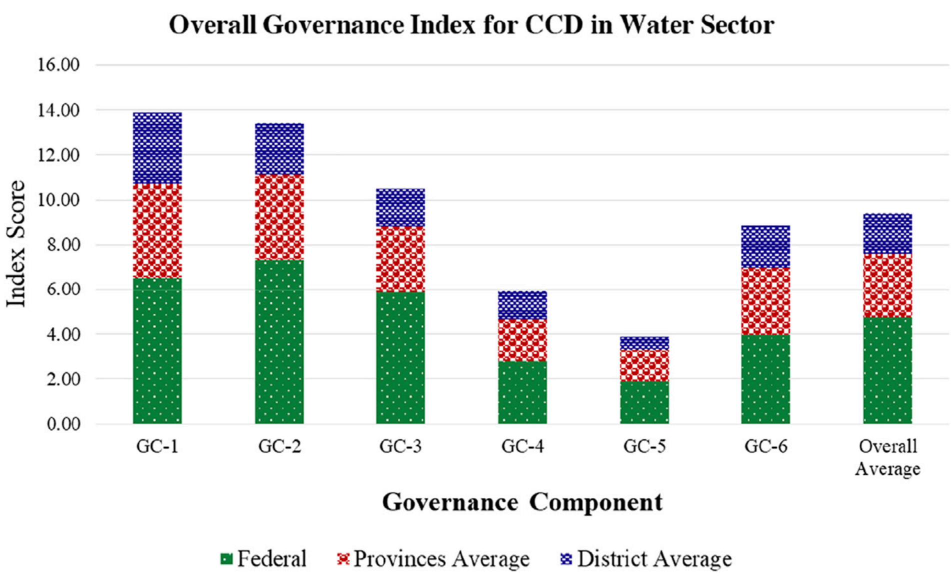

FIGURE 3
Index showing the overall state of water sector governance.

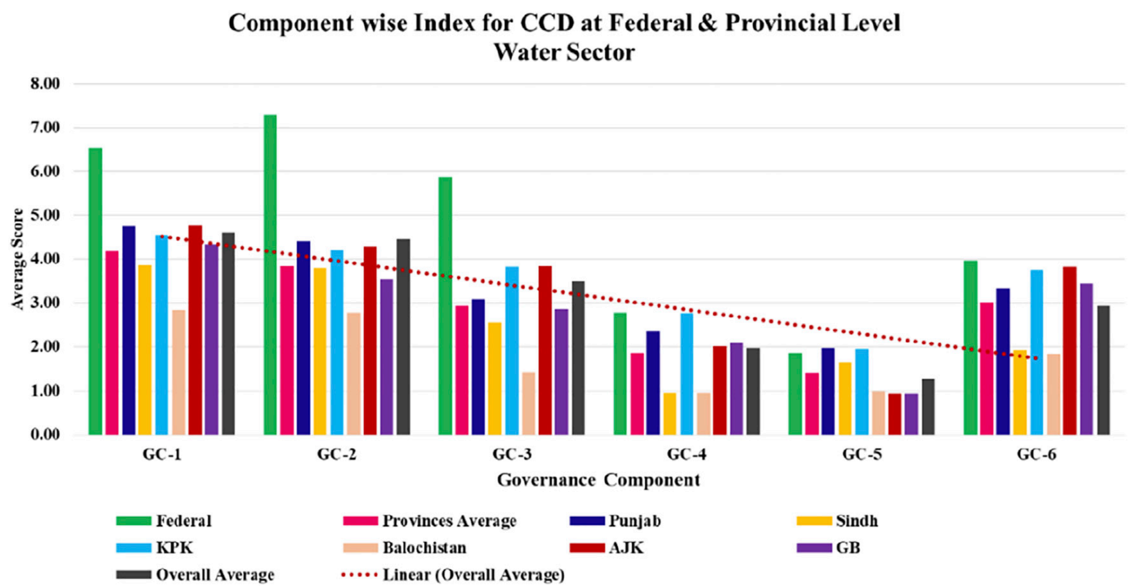

FIGURE 4
Index showing state of water sector governance at different constituencies.

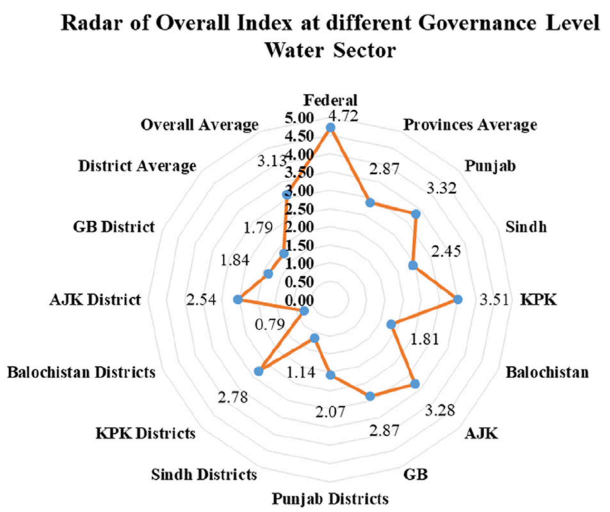

FIGURE 5
Radar showing the state of water sector governance in different constituencies.

(considerable); GC3 index scores of 5.87 (fair), 2.93 (poor) and 1.69 (very poor) with an average score of 3.50 (poor); GC4 index scores of 2.78 (poor), 1.86 (very poor) and 1.28 (very poor) with an average score of 1.97 (very poor); GC5 index scores of 1.86 (very poor), 1.40 (very poor) and 0.58 (very poor) with an average score of 1.28 (very poor); GC6 index scores of 3.96 (poor), 3.02 (poor) and 1.84 (very poor) with an average score of 2.94 (poor); and constituency-related average scores of 4.72 (considerable), 2.87 (poor) and 1.79 (very poor) at national, sub-national and local levels, respectively. However, a 3.13 (poor) score is the overall average CCD index for water sector governance in Pakistan. The governance indices for CCD in the water sector are not appealing particularly for results attained at provincial and district level constituencies vis-a-vis governance components and the CCD response criteria involved.

The gender-based and constituency-based outputs of the KW H-Test validate the normal distribution in the dataset as the null hypothesis for all the cases, about the distribution of recorded respondents' observations in the overall sample for the water sector, is rejected (*N* = 357; asymptotic significance 0.05). A strong positive relationship is observed among all interlocking governance components, except a slightly low-level value for GC5 i.e., 0.68 (1-tailed Pearson correlation; *N* = 357; *p-value* = 0.01), as shown graphically in Figure 8. The dependent variable for Regression analysis was governance component 6 (GC6) which is related to practice and performance. The R-value is 0.907 and the value of R^2 is 0.822. The *t*-test coefficients depict a significant and strong relationship between the dependent variable with all other independent variables except for the variable of GC1. All independent variables (i.e., GC1, GC2, GC3, GC4 & GC5) have good zero-order in their relationship with the dependent variable (i.e., GC6). Whereas the values of VIF and tolerance factors of collinearity do not support the relationship of the dependent variable with GC2. The VIF value of 19.207 is more than 10 and the tolerance value of 0.052 is less than 0.10 for GC2. The Regression output against the standardized residual for the overall sample depicts a good result The normal P-P plot and Scatter plot of the standardized residual is shown in Figures 9, 10. Within the boundary area of ±3, six patches in the Scatter plot correspond to and authenticate the KW H-test regarding the normality of the observations recorded at all tiers of the constituencies involved under the scope of the study. From the overall results, it is very much visible that all variables are impacting each other. However, the desired level of statistical significance is not achieved to an extent upon which the null hypothesis of the basic research query can be rejected. Detailed

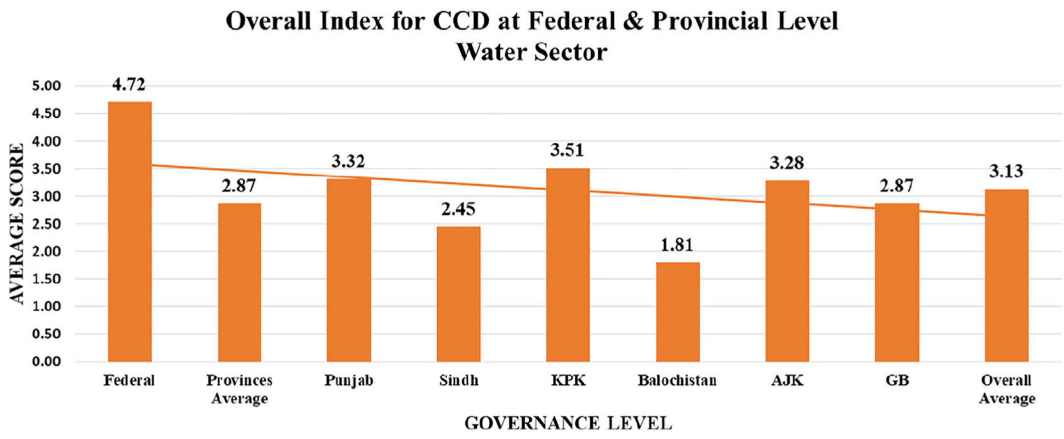

FIGURE 6
National and subnational state of water sector governance.

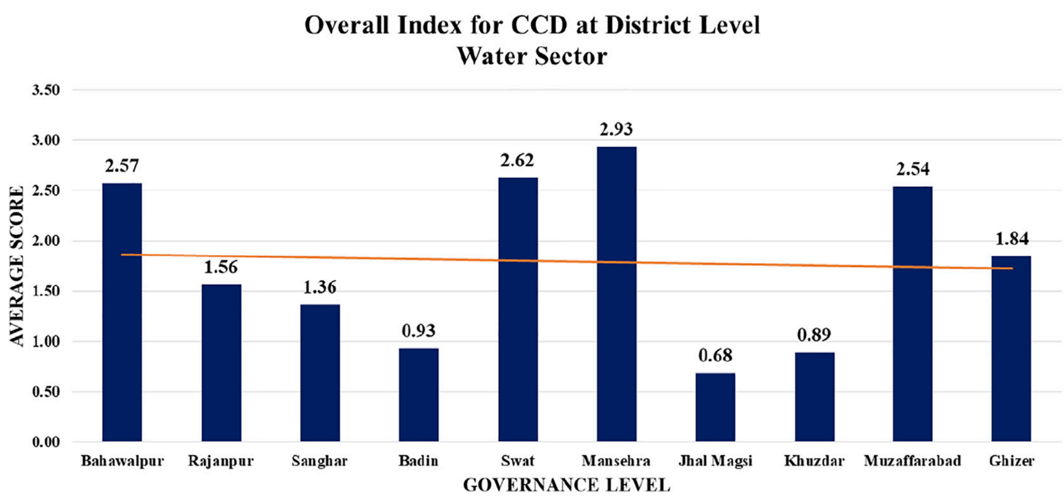

FIGURE 7
State of water sector governance in a local context.

SPSS outputs for KW H-Test, correlations (Pearson), and Regression tests are placed in Supplementary Appendix SA2.

4 Discussion

One of the most important externalities of the twenty-first century is the rise of changing climate as a non-traditional security issue. The phenomenon is quite worrying and reveals a significant risk to the environmental stewardship of natural assets, notably the water sector. Every sector of the economy and human wellbeing is now being affected by climate change. According to Pakistan Economic Survey (PES) 2019–20, Pakistan is currently experiencing severe hydrological disruptions, which increases the likelihood that the trend will continue to escalate. Flash floods might become more prevalent and regular in the streams of Pakistan's northern mountainous regions. This is true, especially for the sharpest peak and the "snow melt-fed basin" of the Kabul River. The Gilgit River Basin is yet another instance of a similar type, where the climate change consequences would presumably be more apparent due to higher water flows spurred on by the occurrence of rapid glacier melting. The Karakoram Anomaly, or stationary or shifting glaciers, is another intriguing phenomenon in Pakistan's northern Karakoram region. Even though the tipping point is unknown, rapid behavior is observed in the Shisper and Khurdopin glaciers which are at a higher risk of outburst. The Chitaboo Glacier in Chitral, where the tipping point has already been achieved owing to consequences of global warming, is also experiencing a rapid retreat at the same time. Future changes in precipitation will increase, and the volume of snow left will decline, resulting in greater river flow unpredictability and a decline in stream flow. Therefore, it would eventually affect the availability and reliability of groundwater. The year 2005 was among the hard-hit

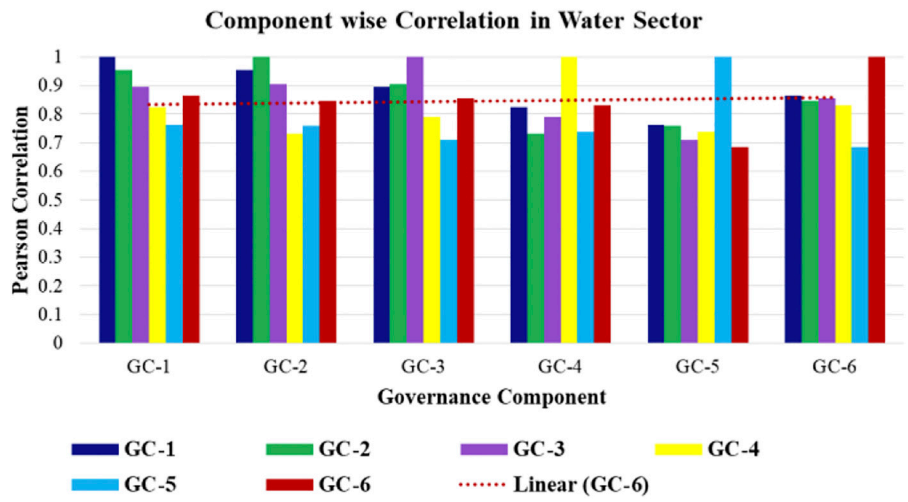

FIGURE 8
Correlations among governance components in the water sector.

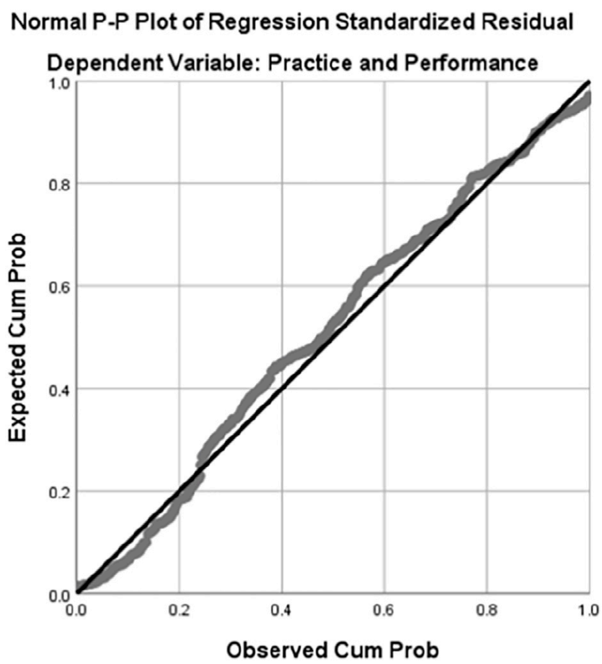

FIGURE 9
Regression's P-P plot for water sector governance index.

years for the economic growth of Pakistan due to changes in climatic conditions, especially in the Indus Basin System (GoP, 2020).

In Pakistan, policies, strategies, and institutional arrangements for dealing with climate change are at the advanced stage at the federal level. However, the provincial cases are still trailing. The stock survey and empirical data of national records, legislative documents, and plans for responding to climate change show many concurrent developments and substantive overlap in and across the records, which result in distortions, conflict, and ambiguity. For instance, the 'priority actions work plan document 2014' for adapting to, and mitigating climatic changes in Pakistan and the 'Framework for Implementation of Climate Change Policy of Pakistan 2014–2030' (FICCP) (GoP, 2013) documents by the Pakistani government have substantial commonalities concerning strategies and definite actions; as a result, the use of resource base as well as the duplicate efforts by different stakeholders can be seen as irrational. Likewise, Developments in disaster risk reduction remain quite complex and display redundancies in an uncoordinated manner. Sectorial ownership has also been a major impediment to Pakistan's governance system for so many years.

Considering the adaptation needs of the country, the major focus of Pakistan's FICCP (GoP, 2013) is on the agriculture sector so far (Iqbal and Khan, 2018). Since the water sector is now mostly a provincial issue, the governance structures at the provincial and district levels have a very close relationship to the FICCP's success. Like the agricultural sector in Pakistan, the water sector shares transversal synergies for both policies, strategies, and legal and institutional frameworks. These are required to regulate the appraisal of vulnerability, spatial mapping, and planning, Local Adaptation Plans of Actions (LAPAs), early-warning systems, advancement in technology, ecosystem-based solutions, climate institutions, and water and farming rights in dry rivers for better-informed adaptation of local communities. Additionally, these are also important in the context of climate change's rippling effects on groundwater water shortages vis-a-vis coastal and marine ecosystems at all governance levels i.e., global to local. Its significance arises from a complex connection between numerous components of terrestrial and aquatic ecosystems. This interaction is especially important in farming, maritime, and energy sectors, in particular when responding to climate-induced natural disasters and guaranteeing sustainable development. This agenda for the aforementioned sectors have strong ties as a result of their complicated interconnection, notably in the case of Pakistan.

Against the backdrop of the SDGs, a National Sustainable Development Strategy 2017(NSDS) has been developed by the Government of Pakistan in response to SDGs (GoP, 2017). It was also incorporated into the creation of the 2025 vision of Pakistan. The

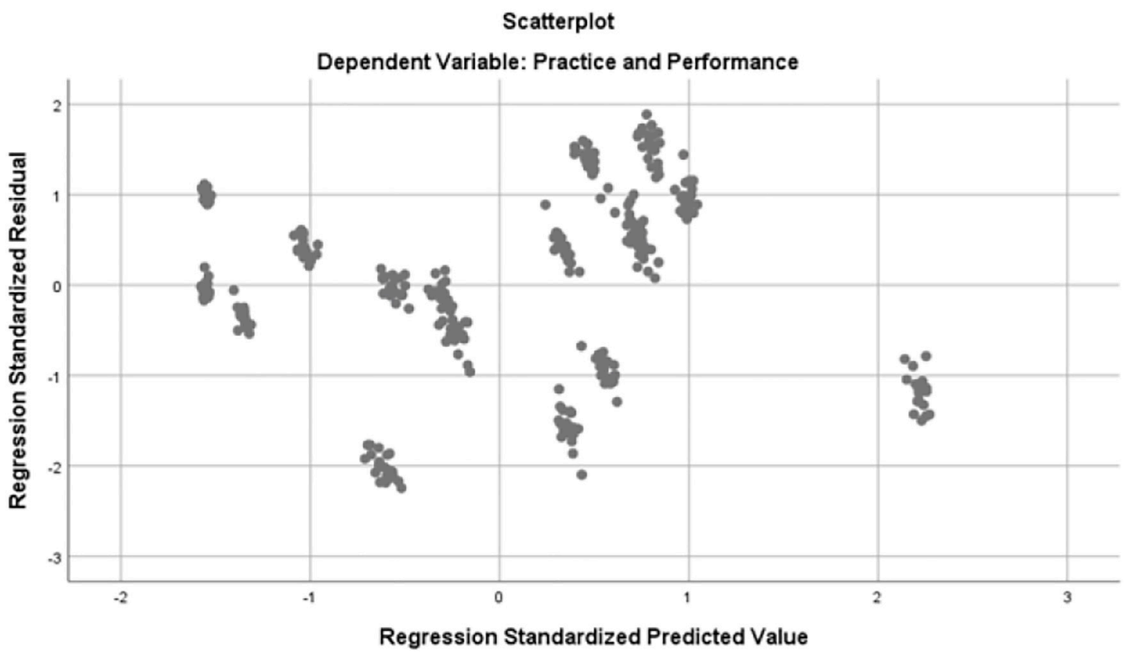

FIGURE 10
Regression's scatter plot water sector governance index.

country's national policy for climate change (NCCP) 2021 and its implementation structure, i.e., FICCP, is supported by the National Climate Change Strategy 2017(NSDS), a very thorough document that is based on a participatory approach. Grouping the SDGs into a set of five (05) technical clusters, which take into account the incredibly complex interconnectedness between the environmental sustainability of the natural ecological system, the economic reformation, and the wellbeing of people, put a greater emphasis on climate response across all SDGs. The will of all key actors is necessary for the 17 SDGs, together with systems of economic, financial, and political governance. The will of all major stakeholders is necessary for the 17 SDGs, together with systems of political, financial, and economic governance. According to the UN's SDGs Report from 2020, the current governance trends continue, the development is uneven and a fair role has not yet been attained at the scale of international actors to achieve the ambitious 2030 targets for the SDGs.

While utilizing statistical procedures for answering the main research question of this study, the governance indices for CCD in the water sector are not appealing particularly for results obtained at provincial and district level constituencies about governance components and the CCD response criteria involved. Earlier, similar trends were identified and reported for energy and agriculture sectors in Pakistan by the lead author and pool of his co-researchers/co-authors (Iqbal et al., 2021; Iqbal and Khan, 2021). This outcome corresponds to global trends in developing countries as highlighted by the United Nations in its status report of 2020 regarding SDGs. The outcome of this study reflects gaps and challenges for governance at national, sub-national, and local level constituencies due to which results depict low response with less preparedness towards CCD agenda in the water sector. These gaps are indicative of missing links, particularly for execution mechanisms against the planning due to the disconnect between the two. As usual for developing countries, the case of Pakistan also shows a relatively higher degree of response at the national level. It is evident that reliance for climate response is mostly linked with national system. Although FICCP (GoP, 2013) is a very good action-oriented document and national policy for climate change is updated in year 2022, the CCD agenda for water sector cannot move ahead in the absence of: legal cover, clarity of mandate for each tier of the constituency involved, provincial response strategies, LAPAs, riparian's water rights mechanism and early warning system. The overall state of climate response reflects the governance arrangements at basic level, which can be marked within the readiness boundaries. From the overall statistical results, it is very much visible that all variables are impacting each other. It is deciphered that the desired level of statistical significance is not achieved to an extent upon which the null hypothesis of the basic research query can be rejected.

Similar to the response for the agriculture sector, the developments at the national level for the CCD response under GC1 are remarkable for the water sector. Provinces have responded significantly in the interim, but district-level outcomes for the local context across Pakistan are uninspiring. The necessary information for CCD in the water sector is contained in federal policies and strategies. The components of Pakistan's Water Policy 2018 (GoP, 2018b) are currently prevalent and coordinated to address all aspects of development considered climate-friendly by adhering to the FICCP plan of 2014. The needs for adaptation in the water sector are determined to be fairly committed.

Climatic changes are to blame for the complex "transboundary water" problems that are affecting both the Kabul River system and the Indus Basin System. Given the high degree of climate vulnerability in South Asia, there are also significant riparian issues in the context of transboundary water, which is crucial for supporting a reduction of catastrophe risk and benefit sharing for a healthy agricultural economy. The Indus Water Commission (IWC) handles water-sharing entitlements with India on the eastern side. But because of all the disagreements between India and Pakistan, its performance is still debatable. The Kabul River would be another issue that would certainly cause severe riparian concerns in the western area of Pakistan, following the eastern riparian troubles. Nine major and minor rivers run through Pakistan and Afghanistan. But the Kabul River and its tributaries flow into Pakistan's Indus River. The four provincial constituencies of Pakistan use the water from the Kabul River. In Pakistan and Afghanistan, water is becoming increasingly scarcer and of lower quality due to rapid population expansion, urbanization, and climate change. Both nations are experiencing severe water shortages. In recent years, the annual flow of the Kabul River through Pakistan has also decreased. Dams along the river are being planned for construction in Afghanistan. The upgrading of the infrastructure would likely have a detrimental impact on Pakistan's irrigation system as well as the revenues and standard of living in each region. Both Pakistan and Afghanistan lack benefit-sharing mechanisms due to the absence of mutual agreement, as is the case between India and Pakistan on the eastern side. Due to the long-standing rivalry between India and Pakistan, the geopolitical situation in the region is constantly volatile. This is significantly crucial for solving water disputes on both eastern and western borders regarding the shared basin, taking into account Indian investments in Afghanistan's water sector projects along the Kabul River.

Groundwater provides 50% of the domestic, 40% of the industrial, and 20% of the agricultural use, especially irrigation. Therefore, it is one of the essential for human water supply needs. Its demand will rise under the projected future climatic conditions. Determining groundwater vulnerability owing to climatic changes and catastrophic events is crucial. Even though Section 3.3 of the water sector of the FICCP included a strategy for groundwater recharge adaptation, no suitable provincial system for groundwater mapping has yet to be created. Pakistan has more than 1,000 kilometers of coastline, and its marine ecosystem supports a substantial number of species in the ocean and estuaries, as well as in coastal settlements. The FICCP has addressed measures for the marine ecosystem not only in its section on water adaptation, but also in its sub-section on maritime and coastal ecosystems, section 10.3, and section 10 on other vulnerable ecosystems. The same section 10.3 of FICCP's strategy 1.4 calls for steps to maintain optimal river flows, which are crucial in estuary and delta regions for preserving a healthy marine ecology and supporting the spawning grounds of numerous marine fish species. Maritime climate change is a neglected segment at the moment.

The perpetually ignored marine ecosystem, coastal management, and seawater have indeed been given greater emphasis in the National Water Policy 2018 (GoP, 2018a), which has found synergy with the FICCP strategies and actions for adaptation in the water sector. According to this arrangement, a suitable framework for a marine management strategy can be further developed to manage Pakistan's marine water ecosystem effectively. Water conservation is stated in the provincial agricultural plans as well, but the extension department's function and capabilities present a significant obstacle. Due to regional political, institutional, and cultural differences, the adaptation approaches are also found to be difficult in many nations. Pakistan has experienced unstable conditions for overall political governance since the separation. In the framework of Pakistan's federal and provincial governments, it has been noted that there is a lack of an institutionalization strategy with distinct functions and legal recourse. The issue has been exacerbated since Pakistan's Constitution underwent its 18th amendment. The success of the water industry depends on cross-sector input for adapting to climate change, where the level of response is poor. Punjab Province promulgated its climate change policy in the year 2017 and the provincial water policy in December 2018 (Government of Punjab, 2017; Government of Punjab, 2018). The significant area of risks related to climatic disasters is included in section 1.3 of Punjab's "Water Policy 2018," which offers a concise summary of several approaches or antecedents for an efficient provincial water plan. Overall the policy addresses improving the availability of water through efficient management of groundwater, floods, droughts, water logging, salinity, demand and supply, and climatic vagaries in relation to usage and allocation of water; improving water quality and the aesthetic value of the environment; offering drinking water and hygiene; and attaining stable income source through the establishment of appropriate water pricing mechanisms; the IWRM (Integrated Water Resource Management) approach; addressing riparian and transboundary concerns, technology related to water, legislation and licensing, institutional reform, bolstering, and enhancing capacity, and information dissemination through public engagements. It has taken into account the significance of riparian and transboundary matters with relevance to provincial stability regarding the allocation of water. In Section 10, it has been disclosed that the Indus Water Treaty (IWT) between India and Pakistan is the 'Environmental fluxes' missing piece in the decades-old document. The Punjab Water Act was subsequently promulgated in 2019 (Government of Punjab, 2019) to carry on the policy commitments. The crucial next stage, however, would be a clear set of strategies and their course of action including immediate actions both short and long term. The Sindh province declared its clean water policy in 2017, and it was reported from documents that the province of Sindh is also planning to promulgate a provincial water policy. The other provinces, on the other hand, are much behind the current state of comprehensive policy and plans connected to water.

At the moment, federal initiatives are the main source of the climate response. It would not be possible for Pakistan's water sector adaptation strategy as proposed by the FICCP to be successful without the existence of provincial climate programs with clear roles and legal protection for inter-sectoral linking. At the federal and provincial levels, there needs to be a very serious, narrow and specific, and action-oriented agenda for riparian issues. According to the study findings for the water sector, policies, approaches, and institutional configuration are at an advanced stage at the federal level, which is consistent with the original issues identified that was based on an extensive review of relevant literature. However, the vast bulk of cases is far behind at the provincial level. The statistical evaluation gathered survey data from federal level documentation, legal recourses, and plans for responding to climate change, however, shows that there are multiple concurrent developments and content overlap among the papers, which leads to distortion, misunderstanding, and conflict. Sectoral ownership has also continued to be a significant obstacle to Pakistan's governance structure over many years. The National Wetland Management Plan is included in the 2018 National Water Policy, and the FICCP also covers it, but there are issues with departmental jurisdiction as a result of a lack of legal recourse, departmental clarity, and coordination for the proper management of this extremely important water resource. With the right positioning of wetlands, clear roles and responsibilities require legal protection. Above all, the line department's capability is a clear and essential component of the entire governance structure. The study's findings indicate that while line department capacity (GC2) is robust at the national scale, it is lacking at the provincial and district levels. At the national level, the civil society stakeholders' (GC3) capacity is fair, but there is still more work to be done in Pakistan at the provincial and district levels. In two crucial areas, namely Local Adaptation Plans of Actions (LAPAs) and a system for early warning, missing links regarding the capabilities of the line departments were discovered. The same is true in Pakistan's agriculture sector. As the index scores relate from poor to very difficult circumstances from the federal to the district settings, the capacities of the actors under GC4 and GC5 have demonstrated a significant gap from the progressive governance tendency. In the case of Baluchistan, the entire picture is rather depressing. The federal institutions and community-based stakeholders are observed to have a significant disconnection, which is a highly important and constricting aspect of CCD response methods and must be cautiously addressed to actively involve all related actors. This unit's prime objective is to mainstream the local actors because the water sector is a provincial component and the agriculture extension department has the necessary authority. The provincial governments must improve coordination between the institutional mechanisms at the federal, provincial, and district levels and reinforce this crucial aspect of local governance.

The federal and provincial governments must undertake capacity mapping exercises to better plan for future needs of adapting to climate change. For this reason, a need assessment of various aspects of CCD may utilize the governance indicators generated as part of this study. This would be essential for boosting performance under GC6 through better practices. The major challenges of sustainability and the policing of rights in all constituencies throughout Pakistan are shown in the results under GC6. At all levels, there is a significant gap between planning and execution. At the federal and provincial levels, there are several useful documents that can particularly help the broader climate goals along with supporting CCD, however, there are still major issues in their implementation. Similar circumstances exist in Pakistan's agricultural industry. Financial resources are a concern, but they are also constrained by a lack of political will and the desired degree of capabilities. All of the FGDs' participants agreed that this situation quickly deteriorated after Pakistan's national constitution's 18th amendment, which was accompanied by seriously poor coordination between provincial and federal institutions. As a result, the effectiveness of those institutions remains low, as evidenced by the governance index debated during all group discussions. During the FGDs, it was suggested that a serious political interest, capacity building, and allocation of sufficient financial resources may result in a satisfactory performance at all governance levels. This would be crucial in boosting GC6's performance, which is now poor at the province and district levels yet fair to good across the board for other areas of the governance indicators. For the water sector in Pakistan, it is necessary to develop and carry out prefectural prosecutable climate response strategies with clearly defined roles and responsibilities to address this significant subtle difference under the practice and efficiency aspect under the sixth governance component (GC6), particularly in the provincial and local level context. Priority should be given to assigning sufficient financial resources, however, there is now a shortfall, particularly for the adaptation segment, necessitating that both federal and provincial governments address this issue in their process of planning and administering budgets. The sustainability of the CCD requirements across all components of the governance system would be ensured by a strong commitment to the innovative climate indicators disseminated through this research.

5 Conclusion

The adoption of an integrated approach for the formulation of a multivariate mix-method model proved well for the water sector case study. It combined rules and rights-oriented approaches of governance along with all other variables associated with the concept of CCD and methodological aspects of principles, criteria, and indicators, and produced results successfully. A combination of three statistical tests proved well to have an in-depth analysis of various dimensions of the sample. It can be used for periodic sectoral climate governance assessments for CCD, by using a modified set of indicators. In the context of governance for CCD, this will help in overcoming the limitations of available methodologies. The findings on methodological aspects reveal that the phenomenon of climate change is not only cross-cutting but also shad cascading effects through direct and indirect linkages. Although the scientific community and the existing literature discuss such an effect and response options, the actual scope to determine comprehensive and adequate strategies for the governance of different sectoral economies is still neither understood nor reported well in the context of climate compatibility, environmental security, and sustainability. It is anticipated that the derived six (06) climate governance principles (CPs) will act as the main vehicles and nine (09) criteria will be the precursors for CCD to carry forward the agenda in all sectoral economies. These criteria are new and unique in sense that they all can be applied not only to water sector but also to any sector to assess the adequacy of a governance framework for climate response at any tier of the constituency in any country. As far as the findings of the study are concerned, the governance indices for CCD in the water sector are not appealing particularly for results attained at provincial and district level constituencies of governance components and the CCD response criteria involved. This outcome corresponds to global trends in developing countries highlighted by the United Nations in its status report of 2020 regarding SDGs. The outcome of the study reflects gaps and challenges of governance at national, sub-national, and local level constituencies due to which results depict low response with less preparedness towards CCD agenda in the water sector. These gaps are indicative of missing links, particularly for the execution mechanism against the planning due to a disconnect between the two. As usual for developing countries, the case of Pakistan also shows a relatively higher degree of response at the national level. It is evident that reliance on climate response is mostly linked to the national system. Although FICCP is a very good action-oriented document and national policy for climate change is updated in the year 2022, the CCD agenda for the water sector cannot move ahead in the absence of legal cover, clarity of mandate for each tier of the constituency involved, provincial response strategies, LAPAs, riparian's water rights mechanism, and early warning system. The overall state of climate response reflects the governance arrangements at a basic level, which can be marked within the readiness boundaries. From the overall statistical results, it is very much visible that all variables are impacting each other. It is deduced that all nine criteria impact each other, however, the basis for the null hypothesis regarding the placement of inclusive and adequate climate response is that there is no such mechanism so far established or exists that cannot be rejected for the overall case of water sector governance. It is construed that a coherent and inclusive response mechanism to address climate change impacts for CCD in the water sector of Pakistan is absent.

Data availability statement

The data that support the finding of this study are available from the first and corresponding authors on request.

Ethics statement

Ethics review and approval/written informed consent was not required as per local legislation and institutional requirements.

Author contributions

All authors contributed substantially to the manuscript. All authors have read and agreed to the published version of the manuscript. KMJI extracted and shaped the basic idea, methodology, results, discussion, and conclusion. MIK supervised the overall work and helped in drafting the introduction, discussion, and abstract parts. AAS and MAURT complemented in the discussion, logical conclusion, and facilitation in submission to a journal. AM, VY, and WLF reviewed and edited the overall paper technically and scholarly. Whereas WU assisted in referencing, formatting and proofreading.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2023.989930/full#supplementary-material

References

Ali, I., and Iqbal, K. M. J. (2017). Joint efficiency analysis of thermoelectric power plants: Energy sector prospects for climate mitigation in Pakistan. *Abasyn J. Soc. Sci.* 10, 232–245. Available at: https://www.academia.edu/37466160/Disaster_Risk_Management_and_Climate_Change_for_Business_Continuity_and_Sustainable_Development_i_Guest_Editorial.

Amer, M., and Daim, T. U. (2011). Selection of renewable energy technologies for a developing county: A case of Pakistan. *Energy sustain. Dev.* 15, 420–435. doi:10.1016/j.esd.2011.09.001

Anderson, P., Bühringer, G., and Colom, J. (2014). *Reframing addictions: Policies, processes and pressures*.

Atif, S. B., Saqib, Z., Ali, A., and Zaman, M. H. (2018). The impacts of socio-economic factors on the perception of residents about urban vegetation: A comparative study of planned versus semi-planned cities of Islamabad and rawalpindi, Pakistan. *Appl. Ecol. Environ. Res.* 16, 4265–4287. doi:10.15666/aeer/1604_42654287

Aven, T., and Renn, O. (2018). Improving government policy on risk: Eight key principles. *Reliab. Eng. Syst. Saf.* 176, 230–241. doi:10.1016/j.ress.2018.04.018

Bilal, H., Khan, M. I., and Siwar, C. (2018). Inconsistencies in the power sector of Pakistan identified through strategic environmental assessment. *Sci. Technol. Dev.* 37, 19–27. doi:10.3923/std.2018.19.27

Blanchard, J. L., Watson, R. A., Fulton, E. A., Cottrell, R. S., Nash, K. L., Bryndum-Buchholz, A., et al. (2017). Linked sustainability challenges and trade-offs among fisheries, aquaculture and agriculture. *Nat. Ecol. Evol.* 1, 1240–1249. doi:10.1038/s41559-017-0258-8

Blunden, J., and Arndt, D. S. (2019). State of the climate in 2018. *Bull. Am. Meteorol. Soc.* 100, 326–S306. doi:10.1175/2019bamsstateoftheclimate.1

Borgatti, S. P., Mehra, A., Brass, D. J., and Labianca, G. (2009). Network analysis in the social sciences. *Science* 323, 892–895. doi:10.1126/science.1165821

Campbell, B. M., Thornton, P., Zougmoré, R., van Asten, P., and Lipper, L. (2014). Sustainable intensification: What is its role in climate smart agriculture? *Curr. Opin. Environ. Sustain.* 8, 39–43. doi:10.1016/j.cosust.2014.07.002

Carvalho, A., and Peterson, T. R. (2009). Discursive constructions of climate change: Practices of encoding and decoding. *Environ. Commun.* 3, 131–133. doi:10.1080/17524030902935434

Chuku, C. A. (2010). Pursuing an integrated development and climate policy framework in africa: Options for mainstreaming. *Mitig. Adapt. Strateg. Glob. Chang.* 15, 41–52. doi:10.1007/s11027-009-9203-8

Costa, H. G., Gomes, C. F. S., and de Barros, A. P. (2017). Sensibility analysis of MCDA using prospective in Brazilian energy sector. *J. Model. Manag.* 12, 475–497. doi:10.1108/JM2-01-2016-0005

Daim, T., Yates, D., Peng, Y., and Jimenez, B. (2009). Technology assessment for clean energy technologies: The case of the Pacific Northwest. *Technol. Soc.* 31, 232–243. doi:10.1016/j.techsoc.2009.03.009

Dasgupta, S., and Roy, I. (2011). *Good agricultural governance: A resource guide focused on smallholder crop production*. Bangkok, Thailand: Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific. Available at: https://www.fao.org/3/ba0113e/ba0113e00.pdf (Accessed February 8, 2023).

Dey, P. K. (2012). Project risk management using multiple criteria decision-making technique and decision tree analysis: A case study of Indian oil refinery. *Prod. Plan. \& Control* 23, 903–921. doi:10.1080/09537287.2011.586379

Dong, Y., and Hauschild, M. Z. (2017). "Indicators for environmental sustainability," in *Procedia CIRP* (Elsevier B.V.), 697–702. doi:10.1016/j.procir.2016.11.173

Douxchamps, S., Debevec, L., Giordano, M., and Barron, J. (2017). Monitoring and evaluation of climate resilience for agricultural development – a review of currently available tools. *World Dev. Perspect.* 5, 10–23. doi:10.1016/j.wdp.2017.02.001

Edwards, W. (1977). How to use multiattribute utility measurement for social decisionmaking. *IEEE Trans. Syst. Man. Cybern.* 7, 326–340. doi:10.1109/TSMC.1977.4309720

Eleftheriadis, I., and Anagnostopoulou, E. (2017). Measuring the level of corporate commitment regarding climate change strategies. *Int. J. Clim. Chang. Strateg. Manag.* 9, 626–644. doi:10.1108/IJCCSM-09-2016-0145

Emenanjo, I., Braimoh, A., Heumesser, C., Rawlins, M., and Zhao, Y. (2015). *Developing indicators for climate-smart agriculture (CSA)*.

FAO (2017). *Tracking adaptation in agricultural sectors - climate change adaptation indicators*. Rome: Food and Agriculture Organization of the United Nations. doi:10.18356/87fe25de-en

Follesdal, A., Christiansen, T., and Piattoni, S. (2004). "Informal governance in the European Union: An introduction," in *Informal governance in the European Union*, 1–21. doi:10.2139/ssrn.1752191

Gärtner, S., Reynolds, K. M., Hessburg, P. F., Hummel, S., and Twery, M. (2008). Decision support for evaluating landscape departure and prioritizing forest management activities in a changing environment. *For. Ecol. Manage.* 256, 1666–1676. doi:10.1016/j.foreco.2008.05.053

GoP (2013). *Framework for implementation of climate change policy*.

GoP (2017). *National sustainable development strategy of Pakistan*.

GoP (2018a). *National water policy*. Available at: http://mowr.gov.pk/wp-content/uploads/2018/06/National-Water-policy-2018-2.pdf.

GoP (2020). *Pakistan economic survey 2019-20*. Available at: http://www.finance.gov.pk/survey/chapter_20/PES_2019_20.pdf.

GoP (2018b). *Pakistan water policy*.

Government of Punjab (2017). *Punjab climate change policy*.

Government of Punjab (2019). *The Punjab water act*.

Government of Punjab (2018). *The Punjab water policy*.

Ha, T. P., Dieperink, C., Dang Tri, V. P., Otter, H. S., and Hoekstra, P. (2018). Governance conditions for adaptive freshwater management in the Vietnamese Mekong Delta. *J. Hydrol.* 557, 116–127. doi:10.1016/j.jhydrol.2017.12.024

Hassan, M., Afridi, M. K., and Khan, M. I. (2018). An overview of alternative and renewable energy governance, barriers, and opportunities in Pakistan. *Energy Environ.* 29, 184–203. doi:10.1177/0958305X17743036

Hassan, M., Khan, M. I., Mumtaz, M. W., and Mukhtar, H. (2021). "Energy and environmental security nexus in Pakistan," in *Energy and environmental security in developing countries*. Editor M. Asif (Cham: Springer International Publishing), 147–172. doi:10.1007/978-3-030-63654-8_6

Heinrich Blechinger, P. F., and Shah, K. U. (2011). A multi-criteria evaluation of policy instruments for climate change mitigation in the power generation sector of Trinidad and Tobago. *Energy Policy* 39, 6331–6343. doi:10.1016/j.enpol.2011.07.034

Hovland, I. (2005). *Successful communication A toolkit for researchers and civil society Organisations.pdf*. London, United Kingdom: Overseas Development Institute. Available at: https://haiweb.org/wp-content/uploads/2015/07/Successful-Communication.pdf.

IPCC (2018). *Global warming of 1.5° C*.

Iqbal, K. M. J., Barykin, S. Y., Kharlamov, A. V., Kharlamova, T. L., and Khan, M. I. (2021). Innovative multivariate energy governance model for climate compatible development: The case of Pakistan. *Acad. Strateg. Manag. J.* 20, 1–22.

Iqbal, K. M. J., Akhtar, N., Khan, M. O., and Khan, M. I. (2022). Mix-method modelling of actors' capacity for environmental sustainability and climate compatible development in energy sector. *Environ. Sci. Pollut. Res.* 29, 50632–50646. doi:10.1007/s11356-022-19399-1

Iqbal, K. M. J. (2021). *Governance analysis for climate compatible development in Pakistan*. Available at: http://prr.hec.gov.pk/jspui/handle/123456789/20751.

Iqbal, K. M. J., and Haider, B. B. (2020). Geo-political and geo-economic dynamics of the region in developing the sea-based economy of the IOR countries. *Polaris– J. Marit. Res.* 3, 21–42. doi:10.53963/pjmr.2020.002.2

Iqbal, K. M. J., and Khan, M. I. (2018). Climate governance: Implementing water sector adaptation strategies in Pakistan. *Policy Perspect.* 15, 139–155. doi:10.13169/polipers.15.3.0139

Iqbal, K. M. J., and Khan, M. I. (2021). Mix-method analysis for assessing the adequacy of the state of governance for climate compatible development in agriculture sector. *Int. J. Mod. Agric.* 10 (1), 1120–1141.

Ishtiaque, A., Eakin, H., Chhetri, N., Myint, S. W., Dewan, A., and Kamruzzaman, M. (2019). Examination of coastal vulnerability framings at multiple levels of governance using spatial MCDA approach. *Ocean. Coast. Manag.* 171, 66–79. doi:10.1016/j.ocecoaman.2019.01.020

Jiang, J., Wang, W., Wang, C., and Liu, Y. (2017). Combating climate change calls for a global technological cooperation system built on the concept of ecological civilization. *Chin. J. Popul. Resour. Environ.* 15, 21–31. doi:10.1080/10042857.2017.1286145

Kartodihardjo, H., Khatarina, J., Santosa, M. A., Safitri, M., Soeprihanto, P., Effendi, S., et al. (2013). *Participatory governance assessment: The 2012 Indonesia forest, land, and REDD+ governance index*. Jakarta, Indonesia: UNDP Indonesia.

Kleine, M. (2014). Informal governance in the European union. *J. Eur. Public Policy* 21, 303–314. doi:10.1080/13501763.2013.870023

Leskinen, P., and Kangas, J. (2005). Rank reversals in multi-criteria decision analysis with statistical modelling of ratio-scale pairwise comparisons. *J. Oper. Res. Soc.* 56, 855–861. doi:10.1057/palgrave.jors.2601925

Lockwood, M., Davidson, J., Curtis, A., Stratford, E., and Griffith, R. (2010). Governance principles for natural resource management. *Soc. \& Nat. Resour.* 23, 986–1001. doi:10.1080/08941920802178214

McIntosh, R. D., and Becker, A. (2020). Applying MCDA to weight indicators of seaport vulnerability to climate and extreme weather impacts for U.S. North Atlantic ports. *Environ. Syst. Decis.* 40, 356–370. doi:10.1007/s10669-020-09767-y

Mitchell, T., and Maxwell, S. (2010). *Defining climate compatible development*. London: CDKN - a project funded by the UK Department for International Development (DFID). Available at: https://cdkn.org/sites/default/files/files/CDKN-CCD-Planning_english.pdf (Accessed February 8, 2023).

Nakano, R., Zusman, E., Nugroho, S. B., Jaeger, A., Janardhanan, N., Muchtar, M., et al. (2017). "Low carbon governance in Indonesia and India: A comparative analysis with recommendations," in *Procedia engineering* (Elsevier), 570–588. doi:10.1016/j.proeng.2017.07.112

Norris, R. H., Webb, J. A., Nichols, S. J., Stewardson, M. J., and Harrison, E. T. (2012). Analyzing cause and effect in environmental assessments: Using weighted evidence from the literature. *Freshw. Sci.* 31, 5–21. doi:10.1899/11-027.1

Oliveira, E., and Hersperger, A. M. (2018). Governance arrangements, funding mechanisms and power configurations in current practices of strategic spatial plan implementation. *Land use policy* 76, 623–633. doi:10.1016/j.landusepol.2018.02.042

Pierre, J., and Peters, B. G. (2020). *Governance, politics and the state. 2nd ed*. New York, NY: Red Globe Press, Bloomsbury Publishing Inc.

Pyone, T., Smith, H., and van den Broek, N. (2017). Frameworks to assess health systems governance: A systematic review. *Health Policy Plan.* 32, 710–722. doi:10.1093/heapol/czx007

Rahman, A., and Salman, A. (2013). A district level climate change vulnerability index of Pakistan. CEECC Work. Pap. 5, 18. Available at: https://www.pide.org.pk/~pideorgp/pdf/WorkingPaper/CEECC WorkingPaper-5.pdf.

Ritchie, B., Ruhanen, L., Scott, N., and Tkaczynski, A. (2010). Governance: A review and synthesis of the literature. *Tour. Rev.* 65, 4–16. doi:10.1108/16605371011093836

J. Roberts and J. C. Sanchez (Editors) (2014). *Transboundary water governance: Adaptation to climate change*.

Saunders, J., and Reeve, R. (2010). "Monitoring governance safeguards in REDD+," in *Background paper one* (London, United Kingdom: Expert Workshop). 24th–25th May.

Serrat, O. (2017). "The five whys technique," in *Knowledge solutions: Tools, methods, and approaches to drive organizational performance* (Singapore: Springer Singapore), 307–310. doi:10.1007/978-981-10-0983-9_32

Sridharan, V., Howells, M., Ramos, E. P., Sundin, C., Almulla, Y., and Fuso-Nerini, F. (2018). "The climate-land-energy and water nexus: Implications for agricultural research," in *CGIAR Science Forum*, 1–7. Available at: https://iaes.cgiar.org//sites/default/files/images/SF18_PPT_Fuso%20Nerini.pdf (Accessed February 8, 2023).

Stone, R. W. (2011). *Controlling institutions: International organizations and the global economy*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Teh, L. C. L., and Sumaila, U. R. (2013). Contribution of marine fisheries to worldwide employment. *Fish. Fish.* 14, 77–88. doi:10.1111/j.1467-2979.2011.00450.x

Thiault, L., Mora, C., Cinner, J. E., Cheung, W. W. L., Graham, N. A. J., Januchowski-Hartley, F. A., et al. (2019). Escaping the perfect storm of simultaneous climate change impacts on agriculture and marine fisheries. *Sci. Adv.* 5, eaaw9976. doi:10.1126/sciadv.aaw9976

Thornton, P. K., Whitbread, A., Baedeker, T., Cairns, J., Claessens, L., Baethgen, W., et al. (2018). A framework for priority-setting in climate smart agriculture research. *Agric. Syst.* 167, 161–175. doi:10.1016/j.agsy.2018.09.009

UN (2015). *Sustainable development goals*. Available at: https://sdgs.un.org/goals.

UNFCCC (2015). *Paris agreement*.

United Nations (2020). *The sustainable development goals report 2020*, 68. Available at: https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf.

Visseren-Hamakers, I. J., and Glasbergen, P. (2007). Partnerships in forest governance. *Glob. Environ. Chang.* 17, 408–419. doi:10.1016/j.gloenvcha.2006.11.003

Waheed, A., Fischer, T. B., and Khan, M. I. (2021). Climate change policy coherence across policies, plans, and strategies in Pakistan — implications for the China – Pakistan economic corridor plan. *Environ. Manage.* 18, 793–810. doi:10.1007/s00267-021-01449-y

Wellman, B. (1983). "Network analysis: Some basic principles," in *Sociological theory* (Wiley), 155–200. doi:10.2307/202050

Wise, R. M., Butler, J. R. A., Suadnya, W., Puspadi, K., Suharto, I., and Skewes, T. D. (2016). How climate compatible are livelihood adaptation strategies and development programs in rural Indonesia? *Clim. Risk Manag.* 12, 100–114. doi:10.1016/j.crm.2015.11.001

WMO (2019). *WMO statement on the state of the global climate in 2018.*

Wood, B. T., Quinn, C. H., Stringer, L. C., and Dougill, A. J. (2017). Investigating climate compatible development outcomes and their implications for distributive justice: Evidence from Malawi. *Environ. Manage.* 60, 436–453. doi:10.1007/s00267-017-0890-8

Ysa, T., Albareda, A., and Forberger, S. (2014). "What is governance," in *Reframing addictions: Policies, processes and pressures.*