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Integrated water resources management and flood risk management

Opportunities and challenges in developing countries

Rudresh Kumar Sugam, Md. Humayain Kabir, Sherin Shiny George and Mayuri Phukan

Introduction

Floods are natural events induced by a combination of climatic and edaphic conditions, river channel features, and anthropogenic influences (Akintola and Ikwuyatum, 2006). The number of documented flood incidents has been steadily increasing during the last two decades. The number of individuals killed or seriously harmed by flood disasters has increased dramatically around the world (United Nations-Water, 2011). Every year, floods affect an estimated 520 million people around the world, resulting in up to 25,000 deaths (Jha et al., 2012). Analysing high resolution global spatial flood event data (Global Flood Database), Tellman et al. (2021) found that between 2000 and 2015, there has been a 20%–24% increase in the proportion of the population exposed to floods (around 58–86 million more people at flood risk), which is nearly ten times higher than previous estimate (2.6%) between 1970 and 2010 (Jongman et al., 2012). Developing countries are the worst sufferers, as increased flood exposure was concentrated in Asia and sub-Saharan Africa, whereas developed countries are better prepared for flood risks (Figure 16.1).

As a flood is a hydrological extreme event, integrated water resources management (IWRM) can play a significant role in mitigating the risks and impacts. Many international institutions such as the Global Water Partnership (GWP), the World Water Council, the World Bank, and the United Nations, as well as national governments, have promoted IWRM as a key means of improving access to safe water supply and sanitation and, more broadly, alleviating poverty and improving people's lives in many developing countries. The GWP defines IWRM as 'a process that promotes the coordinated development and management of water, land, and related resources to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' (GWP, 2000). IWRM also advocates for collaboration across all sectors of water management, such as water availability, quality, flood

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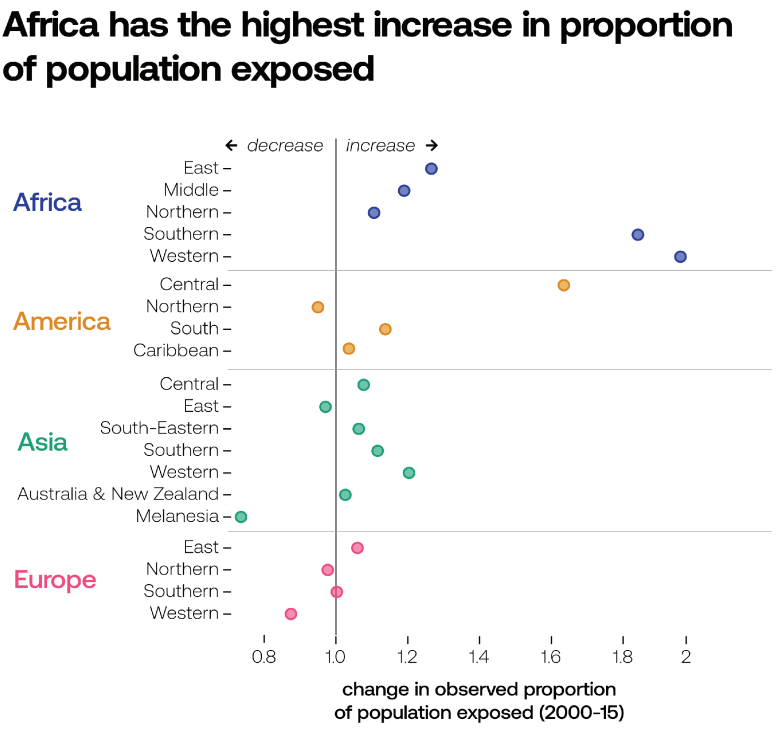

Figure 16.1 Increase in population exposed to floods between 2000 and 2015

Source: Global Flood database (a collaboration between Cloud to Street and the Flood Observatory [DFO]), accessed at Global Flood Database (cloudtostreet.ai) on 10 Nov 2021

risk, and ecosystem health. Integrated planning and management can enable a more comprehensive assessment of risks and uncertainties by considering river basin as a unit, as well as promoting learning and adaptation as new threats develop (Folke et al., 2005).

Generally, the flood risk management cycle encompasses a risk management plan (characterisation, risk perception and communication, risk assessment and mapping), flood mitigation (land use planning, flood zoning, regulations), flood protections (structural and non-structural measures), flood preparation (flood forecasting, early warning systems, information and warnings, flood emergency management plans), flood response (rescue, damage mitigation information), and flood recovery (short-term and long-term). Flood risk management involves the adoption of measures such as the construction of levees and embankments in order to reduce flood damage while also allowing for some flooding (Vis et al., 2003). Natural floods also bring several benefits to humans, especially in the agriculture sector; for example, they bring nutrients to agricultural fields and increase the agricultural output. The community needs to build adaptive capacity to minimise flood risks. Adaptive capacity is influenced by a variety of social, economic, technical, knowledge-related, institutional, and cultural mechanisms (Brouwer et al., 2007). IWRM as an approach talks about all these dimensions of water management. Floating homes and adapted interiors for houses (e.g., not putting electrical installations in the basement) are some examples of structural flood-resilient structures (McLeman and Smit, 2006).

Countries across the world such as the United States (US), the European Union (EU), India, Bangladesh, and several African countries have adopted IWRM concepts in managing

flood risks and holistic management of water resources. However, there are some challenges to the realistic application of IWRM. These include a mismatch between needs and conditions in developing countries, the complexity of the IWRM approach, lack of skills and financial resources, institutional capacity, lack of sensitivity to traditional practices, genuine stakeholder participation, equity, and accountability, and rushed implementation (Beveridge and Monsees, 2012).

Literature review

Fragmented traditional approaches to water management are being phased out with an increasing focus on multi-dimensional approaches. The globally accepted concept of IWRM has evolved over multiple decades. The Mar del Plata Conference of 1977 laid the foundations of the IWRM concept wherein the importance of integrated management of resources was highlighted. The Dublin Principles, 1992, further outlined the importance of multi-level stakeholder participation for holistic resource management. The recommendations of the Dublin principles were presented in Agenda 21, which was developed from the 1992 Earth Summit in Rio de Janeiro (Ibisch et al., 2016). It emphasised that elements of water systems are connected through larger social and ecological processes and must not be neglected when taking economic development actions (Serra-Llobet et al., 2016b). IWRM has been adopted globally as a dedicated Sustainable Development Goal (SDG) 6.5, which aims that all countries "By 2030, implement IWRM at all levels, including through trans boundary cooperation as appropriate". The target is monitored by two indicators: degree of IWRM implementation and proportion of trans-boundary basin area with water cooperation arrangements.

The IWRM concept implies that the maximum benefits will accrue across economic, social, and environmental dimensions when the degree of coordination is optimised. This is closely tied to concepts of the 'nexus approach' and 'adaptive capacity' (Ibisch et al., 2016). Underlying principles of IWRM include institutional integration, level of institutional interaction, economic valuation of resources, environmental protection, stakeholder participation, and equity and efficiency (Benson and Lorenzoni, 2017). IWRM seeks to bring coordination across distinct aspects of management such as water supply, water quality, flood risk, and ecosystem health.

Flood risk management (FRM) is a vital component of IWRM (Verweij et al., 2021). It aims to increase the productivity of floodplains and coastal zones, achieve efficient usage of river basin resources, decrease negative impacts on livelihoods, and decrease existing flood risk levels while also increasing the resilience of the system (Associated Programme on Flood Management, 2017). FRM includes the following elements: adopting a suitable combination of structural and non-structural measures, integration of land and water management in planning, and adopting integrated management of hazards such as landslides. The aim is to arrive at an optimal combination of measures that decrease flood risk to acceptable environmental, social, and economic costs. (Topalović and Marković, 2018). Based on cost-benefit analysis and the capability of an intervention (structural or non-structural) to lower the flood risks/damage, each proposed intervention is assigned a different priority level. (Serra-Llobet et al., 2016a). A complete understanding of the risk necessitates a systems-based approach since it covers diverse sources of flooding, flooding pathways, exposure of people to flood events, and potential consequences at a basin level. With integration, there may be options to merge projects under different sectors to maximise benefits, for example, combining FRM projects with urban sewerage and waste disposal projects or rail and road development projects. Equitable sharing is also necessary when developing FRM plans, and a balance must be determined between social and economic benefits (Asian Development Bank, 2018).

Performance measures of IWRM and FRM include the level of development of river board institutions, poverty reduction, adaptive management, and social learning, among others. Monitoring of IWRM and FRM typically involves evaluating multiple dimensions such as degree of integration, the scale of management, institutionalisation across actors and levels, stakeholder participation, gender equity, ecology, and the environment. (Gain et al., 2017). Indicators such as assessment tools, management scale, water use integration, stakeholder consultation, awareness, capacity building, funding, regulatory aspects, technical means, availability of joint plans, consistency of timelines for monitoring, coherence of goals, and interventions across project boundaries (maximised synergy, managed trade-offs, maximised time and cost efficiencies) are used to assess the strength of policies for the purpose of integration with respect to FRM as well as to evaluate the implementation of FRM as a whole (Cumiskey et al., 2019).

Several developed countries have adopted IWRM; however, it is not clear whether it is being implemented in its totality. Analysis of Swiss flood risk management policies since the mid-19th century reveals that flood policies have not been framed as economic or voluntary instruments but rather as coercive requirements. Most flood risk–related policies were developed as reactions to flooding events rather than as pre-emptive guidance (Metz and Glaus, 2019). Implementation of flood risk–related prevention measures is not always straightforward; for example, a study based in the UK found that urban development continues to be allowed in flood-prone areas, and in Paris, building activities continue in flood-prone areas since financial mechanisms are available for compensating flood losses (Dieperink et al., 2016). In the latest UNEP monitoring report of SDG 6.5, it was found that around 52 countries made moderate progress, and 22 countries made substantial progress in IWRM (see Figure 16.2). Although the concept of IWRM has been around for almost three decades, 47% of the countries (87) report "low" or "medium-low" levels of IWRM implementation. Local and regional governments tend to be lax when implementing non-structural mitigation measures since these tend to be non-binding and more informal.

Case studies on adoption of IWRM for FRM

Bangladesh

Bangladesh stands as the sixth most vulnerable country in the world for flooding (Rosaidul Mawla et al., 2020). Seasonal monsoon rainfall, discharge from the upstream region, and sea-level rise cause severe flooding. Climatic change–induced extreme events, unplanned economic development, rapid urbanisation, land-use changes and poor governance are also responsible for the increased flood risk in the country (Gain et al., 2015). Furthermore, the country confronts issues in managing climate change impacts, water demand, and safe drinking water supply, as well as deteriorating water quality, reversing fishery decline, and maintaining natural habitats such as coastal wetlands and marshes.

Policy reforms

The first master plan for water management for Bangladesh was prepared after the floods of 1954 and 1955 with the objective of increasing agricultural production through engineering solutions to flooding control and drainage improvement, followed by irrigation facilities. The recommendations of the International Bank for Reconstruction and Development (IBRD)

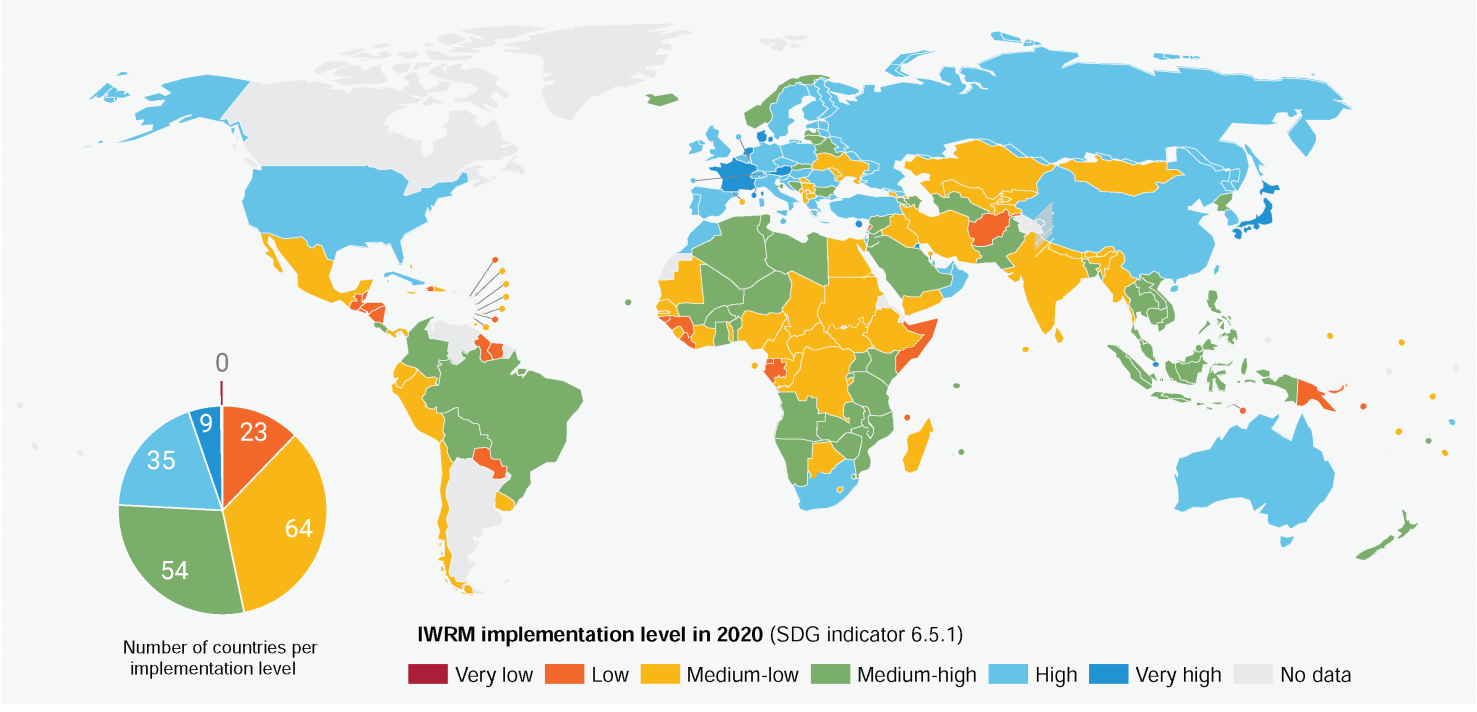

Figure 16.2 IWRM implementation level by country

Source: UNEP, 2021

report of 1972 shifted emphasis from flood control using purely structural engineering solutions to water management using a combination of structural and non-structural measures in Bangladesh. The "integrated management" approach of IWRM has been highly reflected in policy shifts. The adoption of the National Water Policy (NWPo) in 1999 served as a milestone towards the institutionalisation of IWRM in Bangladesh. It addressed the institutional, legal, and financial aspects with incentives, formulation of water rights, and water pricing for equitable water management. It also acknowledged transboundary cooperation among co-riparian countries.

The National Water Plan (NWP) Phase-I of 1986 assessed water availability from various sources and projected the future water demand by different sectors. After the consecutive floods of 1987 and 1988, the Flood Action Plan (FAP) was endorsed by the government of Bangladesh with the aim of stabilising food production in 1992. The Flood Plan Coordination Organisation published a set of guidelines that officially recognised community participation in flood management projects. The National Water Plan Phase-II of 1991 introduced catchment-scale planning and analytical tools for flood management by categorising the country into different hydrological regions. The National Water Management Plan (NWMP) of 2004 adopted a multi-sectoral approach to water management and emphasised non-structural (soft) approaches instead of only hard engineering approaches (Gain et al., 2017).

The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) integrates issues of climate change in planning and designing processes to support economic growth and poverty reduction. The National Adaptation Programme of Action (NAPA) provides guidelines on the implementation of adaptation initiatives through building synergies with other programmes. The NWMP and BCCSAP have considered intersectoral integration for economic development, poverty reduction, food security, and protection of the natural environment.

Key policy documents such as NWPo, NWMP, and NAPA have recognised the involvement of diverse groups of stakeholders in water management projects. Water is also recognised as an economic and social good through the formulation of water rights allocation and water pricing tools in NWPo and the Bangladesh Water Act.

Institutional reforms

Institutional transition in Bangladesh through the establishment and reorganisation of various key institutions reflects the "integrated management" approach of IWRM. The Water Resources Planning Organisation (WARPO) and National Water Resources Council (NWRC) coordinate with different ministries for integrated water management. WARPO has transitioned from overlooking agricultural water management to overseeing water resource management of the country through the authority provided by the recent enactment of the Bangladesh Water Act. The Institute of Water and Flood Management (IWFM) undertakes multi-disciplinary research and capacity development programs in flood management with a focus on IWRM.

The Bangladesh Haor and Wetlands Development Board (BHWDB) and Barind Multipurpose Development Authority (BMDA) have adopted catchment-scale planning for water management. The institutional setup of WARPO and BWDB recognises the impact of ecological and environmental issues on water resources. Also, the Local Government Engineering Department (LGED) facilitates people's participation in project formulation and implementation. Key institutions such as LGED and BMDA have also adopted economic principles of cost recovery, pricing, and tariffs in water projects. The Bangladesh Water Development Board, (BWDB) with the original mandate of providing infrastructures for flood control, drainage, and

irrigation, has undergone institutional reforms and has undertaken the partial implementation of cost recovery.

Transition in water development projects

Since the 1960s, there has been a gradual change in conceptualisation, design, operation, and management of water development projects (Gain et al., 2017). The Char Development and Settlement Project (CDSP) undertook sectoral integration at the project level through integrated management of land and water along with safe drinking water provision and sanitation, social forestry, livelihood enhancement, and disaster management. It prioritised social equity, human rights, and women's representation by working directly with the poor and marginalised communities. Projects such as the Coastal Embankment Rehabilitation Project (CERP) and Coastal Embankment Improvement Project (CEIP) took into consideration the hydrological environment during the project planning stage. The Southwest Area Integrated Water Resources Management Project (SWAIWRMP) and Integrated Planning for Sustainable Water Management (IPSWAM) added prominence to IWRM implementation in the country. Recent projects such as the Blue Gold programme have integrated participatory water management with the development of business and market linkages and consideration of potential impacts of climate change and upstream interventions.

Challenges and opportunities

The principles of IWRM are well reflected in the policies, institutional setups, and water project planning in Bangladesh. However, improvements are required in terms of capacity building of key stakeholders, periodic monitoring and evaluation of project performance, and legal framework for the enforcement of law and policies. Catchment-scale planning has been suggested across major policies and project frameworks in the country; however, basin-scale planning for transboundary rivers is not smoothly happening with co-riparian countries.

Institutional transition in Bangladesh is driven by various physical and socio-political factors such as water hazards, arsenic contamination, saline intrusion, population pressure, poverty, and vulnerability. Coordination among different institutions started due to the observed effect of large-scale water projects on other sectors. Various multinational donors and international agencies played a key role in the adoption of IWRM in Bangladesh.

Emphasis has been put on the participation of the local community after unsuccessful attempts at earlier project implementation due to lack of community support. Stakeholder participation also ensures the financial viability and long-term sustainability of public projects. Recent projects have also included gender and equity dimensions of community participation. However, studies have observed that at the field level, project implementation needs to address underlying socio-economic inequalities among communities and gender groups. While donor agencies emphasise community participation, participation is limited to public consultation. Significant improvement is required in mobilising decision making with respect to project outcomes between different stakeholder groups (Dewan et al., 2014).

India

Flood is a recurring disaster in India, causing large-scale loss of life, properties, and livelihood. According to National Disaster Management Authority (NDMA), out of the total geographical area of 329 million hectares (mha) of the country, more than 40 mha is prone to floods.

Institutional and policy framework for flood management

Following 1954, India made significant investments in riverine flood control, including the development of different structural measures such as embankments, detention reservoirs, and drainage improvements in river basins (Mohanty et al., 2020).

In India, water is a state topic; hence the central government often serves as a financial and advisory agency for water management. The Ministry of Jal Shakti, which is part of the central government, oversees disaster management in the country. The Central Water Commission (CWC) is the nodal agency for water resource management, providing technical advice to various agencies and states as well as promoting flood control practices through infrastructure development and maintenance, the development of flood forecasting systems, and information dissemination. India's two major river basins are Ganga and Brahmaputra; the Ganga Flood Control Commission (GFCC) and the Brahmaputra Board prepare flood control master plans for Ganga and Brahmaputra basin regions, respectively. For all disaster-related initiatives, the National Disaster Management Authority is the central agency. It is well supported by central agencies such as the India Meteorological Department (IMD), National Remote Sensing Centre (NRSC), and National Institute of Disaster Management (NIDM) in getting information and building capacity on floods in India. At the state level, there are disaster management authorities and departments such as irrigation and public works which support flood risk management. Thus, India has a well-established network of institutions working at various levels. However, the quality of data and overall response time during floods still need vast improvement.

The National Water Policy, 2012, establishes a clear intent of adopting IWRM principles for FRM as well as integrating flood forecasting technology backed by hydrological data management. It suggested morphological studies of the major rivers and the preparation of frequency-based flood inundation maps for flood-prone regions.

Transboundary river management

India shares water with Pakistan, Bangladesh, China, Nepal, and Bhutan. To date, there are not many information-sharing and joint efforts happening for flood management amongst the countries due to geo-political tensions.

Reservoir management

The Dam Safety Organization (DSO) was set up in 1979 to develop a dam safety procedure to assist the state governments in undertaking remedial measures in the event of dam failure. The National Committee on Dam Safety (NCDS) formulated the guidelines for the development and implementation of Emergency Action Plans (EAP) in 2005. The Dam Rehabilitation and Improvement Project (DRIP) was launched in 2012 to provide technological advances, rehabilitation material, capacity building, and technical regulations to the dam operating authority.

Flood forecasting network

The Central Water Commission is the government institution in charge of flood predicting data collection and analysis. The 325-station Flood Forecasting Network is dispersed over 20 river systems in 25 states. Flood forecasting and advance warning for 197 low-lying areas/towns and 128 reservoirs assist user agencies in determining mitigation steps such as persons being evacuated and their movable property being moved to safer sites. During floods, in a year, CWC

regional offices across the country issue over 7000 flood forecasts and advance warnings to user agencies. The overall accuracy of CWC's forecasts over the last few years has been above 90% (Central Water Commission, GoI, 2021).

Opportunities for improving flood management through adoption of IWRM principles

It can be clearly observed that institutions and policies exist in the country for adopting IWRM for FRM. However, at the local level, participation of all stakeholders is still limited, and information dissemination in India usually follows a top-down approach. Capacity development of institutions at the local level and riparian communities is an essential step towards increasing adaptive capacity against flood risks. Also, the shift from reliance on structural measures to integrating non-structural measures such as flood forecasting, land-use planning, flood plain mapping, and increased coordination among government agencies in India needs a further push. The governance structure involved in flood management requires better coordination among the state and the centre to make up for the lack of efficient enforcement of projects and guidelines, with timely monitoring of project activities (MoWR, 2017). Empowering local communities to participate in flood management needs to be accelerated. While several policy recommendations on flood management taking an integrated approach towards water resource management have been developed, their implementation has been inadequate. The government should also explore micro-insurance and appropriate grants for post-disaster recovery. Further at the basin level, co-riparian countries will have to develop better relationships for achieving IWRM in a true sense.

European Union

The EU adopted the Water Framework Directive (WFD) in 2000 to ensure sustainable use of fresh water across Europe though conservation and restoration of water bodies. It tasked the EU Member States with preparing river basin management plans (RBMPs) to achieve the objective of "good ecological status" of the water bodies. WFD steered in the concept of IWRM in EU with its elements such as a basin-wide approach, public participation, and incorporation of precautionary principles for environmental protection (Global Water Partnership, 2015). The EU adopted the Floods Directive (FD) in 2007 after the devastating floods in Central Europe in 2002, which directed Member States to conduct assessment for flood risk and formulate catchment-based flood risk management plans. The FD refers to the WFD in its instruction to undertake coordinated application of the two directives, particularly in the formulation of RBMPs and FRMPs and active participation of relevant stakeholders in the planning process (European Commission, 2014; Hedelin, 2016).

This resulted in integration of flood risk management with the existing river basin management planning process by considering the impacts of flood control measures on river health, flow, and physico-chemical elements. In 2015, EU Member States presented river basin plans which incorporated flood risk management plans with a focus on flood prevention, protection, and preparedness. Various non-structural measures such as land-use management and river and floodplain restoration are promoted under the WFD. Flood hazard and risk maps were prepared after preliminary assessment of riverine and coastal regions prone to flooding. Funds for flood management activities were channelled through river basin authorities of state and regional and local governments, as well as local users. The EU also provides funds through various programs such as the LIFE programme, Special Accession Programme for Agricultural and Rural Development (SAPARD) or the EU Solidarity Funds; through structural and cohesion funds; or

through the Common Agricultural Policy. Following is a case study of the Catalan River Basin in Spain representing typical FRM processes in the EU.

Catalan River Basin District, Catalonia, Spain

The Catalan River Basin region in Spain comprises an area of 16,428 km^2, which includes several smaller river basins that drain to the Mediterranean Sea. It has a high population density of 420 inhabitants/km^2. The rivers in the basin have highly irregular and variable flows; high urban and industrial water demand add to the low flow conditions and water stress in the region (Munné et al., 2021).

Institutions

Spain's framework for water resource management has been traditionally led by regional governments through the formation of river basin management districts since the 1920s. The integration of the WFD into Spanish legislation in 2003 brought about changes extending the decision-making process to stakeholders beyond water users (Hernández-Mora and Ballester, 2011).

The Catalan Water Agency (ACA), which is a public entity under the regional government, is responsible for implementation of WFD in the region. The Ministry of the Environment and Rural and Marine Affair Affairs is the central government agency which reports to the European Commission on the status and progress of WFD implementation. There are specified nodal agencies to look after various aspects of flood risk management, including land use planning and flood zoning (Directorate General of Territorial and Urban Planning), flood mitigation planning for inland waters (Catalan Water Agency) and coastal areas (State Directorate General of Coast and Sea Sustainability), emergency response (Directorate General of Civil Protection and the Meteorological Service), and post-disaster recovery – (the Insurance Compensation Consortium and the State Entity of Agricultural Insurance) (Ortega and Hernández-Mora, 2010; Serra-Llobet et al., 2016b)

Stakeholders' participation covering various aspects of IWRM

The Catalan Water Agency divided the basin into 16 sub-basins to improve public engagement, and each sub-basin did a shared diagnosis of flood risk assessment. Eventually, numerous players participated in multi-stakeholder consultations and workshops, which culminated in the creation of proposed disaster management methods. Information about management strategies was also provided to stakeholders through a system of feedback meetings (Hernández-Mora and Ballester, 2011). This exercise, which involved about 5000 actors, led to the development of catchment-based flood risk analysis: Flood Directive and flood hazard maps were developed for high-, medium-, and low-probability flood scenarios. These maps are used by the civil and municipal departments to define flood risk zones. While the Flood Directive requires the development of maps showing future flood risk, these maps are yet to be completely developed due to inadequate information availability about future socio-economic and climate changes.

Financing of implementation activities for river basin and flood management

The regional government, water consumers, municipal governments, and state governments all contribute to the budget for activity execution. Only 10% of the money goes to flood

prevention and mitigation, with the rest going to water supply, water quality improvement, research innovation, and developmental activities. (Serra-Llobet et al., 2016b).

Thus, Europe has taken a top-down approach with a common obligatory flood-specific policy framework with the Floods Directive within the WFD. The requirements of the WFD led to integration of IWRM principles across flood risk management for Catalan and across the EU in general. The regional government of Catalan has attempted to integrate relevant national and regional laws, inter-institutional coordination, and encouraging stakeholder participation. Adoption of WFD has also improved the level of publicly available information as well as the relationship between different actors involved in water management.

Thus, the EU in a true sense has been able to implement IWRM for FRM by bringing co-riparian countries under one umbrella, developing institutional and financial mechanisms to support initiatives, and ensuring stakeholder participation at all levels.

United States

Various federal level initiatives such as the Water Resources Planning Act of 1965, Unified National Program (UNP) for Floodplain Management of 1994, and Flood Insurance Act of 1968 made attempts to bring concepts of IWRM for water resource management into the United States. However, policy implementation has been difficult due to the lack of coordination among agencies and disconnection with land-use decisions made at the local level. About 100,000 local agencies and 300 state-level agencies deal with distinct aspects of water management in the US. Following is a case study of the San Francisco Bay Area representing the adoption of IWRM for FRM in the US.

San Francisco Bay Area, California, US

The San Francisco Bay area in the US is an estuary covering a watershed of about 153,000 km^2 which receives runoff from the Sacramento-San Joaquin Rivers. It has a population of about 7 million. It is also a biodiversity hotspot, serving as a habitat for over 500 species of wildlife and a wintering and stopover area for migratory birds (McKee et al., 2013; Taylor and Kudela, 2021).

California created the Integrated Regional Water Management (IRWM) program in 2002 to encourage collaboration among local water agencies for the development of regional-level integrated water management plans. The nature of participation of regional agencies was voluntary to allow local governments to choose their jurisdictional boundaries and governance structure. However, this led to each of the 48 regions in the region developing individual IWRM plans with different approaches.

Institutions

The San Francisco Bay Area Integrated Regional Water Management Plan (IRWMP) was initiated in 2004 with regional and local governments, agencies and citizen groups signing a letter of mutual understanding to prepare a water management plan work by adopting IWRM framework. A coordinating committee consisting of representatives of agencies responsible for four different functional areas: water supply (the Bay Area Water Supply and Conservation Agency); wastewater management (the Bay Area Clean Water Agencies); water, flood, and storm water management (Bay Area Flood Protection Agencies Association); and catchment protection (public and non-profit agencies) served as the organising body for implementation

of the IRWMP. However, the representation of agencies responsible for flood management was limited to land use planning divisions and flood control agencies. Multiple groups of key stakeholders were identified by the committee through information collected from water management agencies, public meetings, and public forums. Various community workshops, surveys, and regional and sub-regional meetings were conducted to discuss water management needs and to prioritise regional requirements (CCWater, 2019).

One of the five goals of the San Francisco Bay Area IRWMP was regional flood improvement, and it identified various strategies for effective flood risk management, including integrated land and water management, leveraging natural watersheds, and using a mix of structural and non-structural measures. It was not, however, integrated with the Bay Area Plan, which encourages the construction of transit hubs, many of which are in floodplains, or with local development plans. As a result, the San Francisco Bay Area IRWMP's land-use management contradicts the ideas in the Bay Area Plan (Serra-Llobet et al., 2016b).

Zimbabwe

Floods cause loss of livestock and human lives, crops, and infrastructure and lead to the outbreak of diseases such as malaria and cholera in flood-affected areas of Zimbabwe. For instance, the Mzarabani and Guruve districts located within the Zambezi basin in the northern part of Zimbabwe are affected by seasonal floods due to rainfall, occurring in January or February, and cyclone-induced floods. The districts are located between the Kariba and the Cabora Basa dams and at the confluence of two main tributaries of Kariba and Zambezi rivers. The release of water from the Kariba dam and rising water levels at Cabora Basa dam cause severe flooding in the region. The region covers an area of about 8,000 km^2 with a population of about 300,000 (Madamombe, 2004). The main economic activities in the region are commercial and subsistence agriculture, livestock rearing, and wildlife management.

Flood management practices

Zimbabwe adopts structural and non-structural measures for flood mitigation. Structural measures include dams and weirs which are put in place to improve water security through water storage and for flood mitigation. However, storage availability in these structures is inadequate and hence the flood control potential is limited. Water release from the dams also causes floods in the catchment area.

The non-structural flood mitigation measures include flood forecasting, clearly defined areas for settlement, and rescue operations. Based on meteorological forecasts, river flows are assessed for the probability of flooding. The information is disseminated by responsible agencies, and evacuation arrangements are made. However, there is a time lag between the flood forecast and the flood event, which reduces the time for flood preparation, and the accuracy of forecasts is also limited. In recent years, there has been an improvement in data collection of rainfall, information dissemination, and awareness generation. Multi-sectoral meetings on flood management are also coordinated by the civil protection agencies, which see attendance and involvement by relevant stakeholders.

Policy and institutional setup

The flood management process in Zimbabwe involves several agencies. Disaster preparedness is initiated by the central government, while local administration is responsible for its implementation (Gwimbi, 2004).

The Water Act (1998) played a key role in promoting IWRM in Zimbabwe, which has been adopted as a basis for water resources management. The country has been divided into seven catchments, each of which is managed by a Catchment Council with elected representatives from the different water users. The Zambezi Action Program (ZACPRO) brings the basin countries together for integrated management of the basin. However, at present, the member countries have different policies for the management of their portion of the Zambezi.

The Civil Protection Act presents the legal instruments and the powers vested in different agencies for disaster management. The Civil Protection Organization of Zimbabwe is responsible for the management of flood emergencies, which has a working party of representatives from the health, foreign affairs, water, mining, state security, and information departments of the government.

The National Policy for Disaster Management suggests the involvement of every citizen for efficient flood management. While the central government initiates hazard reduction measures through various sectorial ministries, the local administration is responsible for implementing and maintaining the activities. Existing government, private, and non-governmental organisations are adopted structurally, materially, and technically within the program, so that they can be involved in undertaking protective, relief, and rehabilitation measures during a disaster. The mandate for stakeholder involvement was adopted after cyclone-induced floods, and this change in policy reflects a major shift towards an integrated flood management approach.

Financial resources allocated annually by the government for flood management are extremely low, and in the case of larger resource requirements post-major disasters, the government allocates funds and assistance from the international community and the private sector.

Opportunities

The major issues observed in flood management framework of Zimbabwe are a fragmented approach to flood management, centralised decision making, inadequate training for rescue and relief, and lack of involvement of local community in the process of managing disasters (Gwimbi, 2004). In recent times, using a combination of hard engineering solutions and soft solutions and the involvement of different governmental agencies and stakeholder groups have improved flood management in Zimbabwe. Further improvements are required in the lead time and accuracy in forecasting for better flood preparedness. There is also a need to manage floods by considering the Zambesi basin as one unit in a coordinated manner by involving all eight basin countries.

Discussion

From the various case studies analysed, it can be clearly seen that IWRM principles have been accepted and adopted by countries across the globe for FRM. However, due to diverse levels of financial capability, technical skillsets, governance structure, cross-sectoral engagements, and stakeholder participation, the countries are at diverse levels of IWRM adoption. For example, in the EU countries where governance of all the river basins is done by WFD, it allows all the co-riparian countries to work together. Moreover, the EU has the requisite financial and technical skills to develop cross-sectoral aligned institutional structure and robust hydrological information system. In addition, since the stakeholders are contributing to flood management financially as well, they have a clear incentive in participating in any event on FRM.

In a financially restricted country such as Zimbabwe, there are several challenges when it comes to the implementation of the IWRM concept, as financial resources are limited. It is

likely that the development of hydrological databases and institutional structures will be challenging and assistance from other countries or the private sector will be necessary to develop FRM plans. Also, in such cases, economic activity will be prioritised over ecological preservation (Tariq et al., 2020).

Countries like India and Bangladesh are well placed somewhere in between the EU, US, and Zimbabwe. While they have the policies and institutions in place at the central and state levels, at the ground level, there is a lack of long-term vision, financial independence, skilled workforce, and participation from stakeholders. In such cases, even when the funding is available, the projects are not implemented properly. Several capacity-building initiatives are required to build the adaptive capacity of the riparian communities and the departments associated with flood-related emergency measures in these countries. If we look at the case of the US, it is disintegrated due to its enormous size and lack of binding principle at the country level, though the country has been able to develop flood resilience due to the availability of a prominent level of technical skillsets, dedicated institutions, and finances. However, in terms of the adoption of IWRM for FRM, it lags far behind many countries.

IWRM is not an easy concept to understand and implement and to realise its full potential on the ground. The key challenges identified according to the UNEP report (2021) included lack of coordination and institutional collaboration, low policy coherence, low financing, weak institutional capacity, and lack of data on monitoring of IWRM. At a regional level, efforts were lagging in Southern and Central Asia, Caribbean, sub-Saharan Africa, and Oceania. The EU is seen as the region where IWRM has been achieved in true sense; however, there is no single country that has accomplished all four dimensions of IWRM (i.e., an enabling environment, institutional structure, multisectoral stakeholder participation and suitable management instruments, and sufficient financing). In the survey carried out by UNEP, it was found that financing for infrastructure and IWRM management is the dimension that performed the worst and remains a barrier to successful IWRM implementation. Around 135 countries mentioned financing as a major challenge. Basin-level management arrangements have also been found to be lagging. Around 70% of countries reported that the budget requirements for undertaking IWRM activities at the basin level are grossly insufficient. Considering finance options such as increasing revenue from water services, increasing central government investment, and improving implementation efficiency can improve the financial situation. Developing countries are dependent on international financing that forms a substantial portion of the finance for IWRM. In terms of disaster management, including that of flooding, about 50% of the countries reported that disaster management is mostly implemented on an ad hoc basis, and there are limited long-term programs (UNEP, 2021).

To execute policy to action, strategies on formation and mobilisation of organisations (civil societies, public and private sectors) across scales is often overlooked, although they play a vital role in catalysing change (World Water Council, 2014). Challenges also occur when integrating across sectors, since there may be competing sector demands and conflicts. Furthermore, developing balanced solutions and agreeing to risk sharing and trade-offs is not easy (Howarth, 2017). Participation of local people is important to make projects successful since it would bring in the social and equity contexts while also helping determine the context for adaptive capacity (Gain et al., 2017), thus setting the correct stage for IWRM adoption in the long term.

Conclusion

There is no doubt that IWRM is a long-term and sustainable method of FRM and increasing the adaptive capacity of institutions and communities. However, achieving all four elements of IWRM should be envisaged as a long-term process and not an easily achievable target. There

are several things to learn from countries which have been successfully able to make progress in this direction. Specifically, for developing and under-developed countries, the transition from traditional structural measure–based FRM to IWRM would be a challenging task. They would require financial as well as technical support from other countries and the private sector. Last but not least, the role of information, communication, and education activities across various departments, educational institutes, and the local community level would be the main step towards the adoption of IWRM for FRM.

References

Akintola, F. O. and Ikwuyatum, G. O. (2006) 'Sustainability issues in flood management in Nigeria', in Ivbijaro, F. A. and Akintola, F. O. (eds.). *Sustainable environmental management in Nigeria*. Book Builders, pp. 197–207.

Asian Development Bank (2018) *Integrating flood and environmental risk management: Principles and practices*. ADB East Asia Working Paper Series 15. ADB. doi: http://dx.doi.org/10.22617/WPS189607-2

Associated Programme on Flood Management (2017) *Selecting measures and designing strategies for integrated flood management*. Policy and Tools Document Series 1. www.floodmanagement.info/publications/guidance%20-%20selecting%20measures%20and%20designing%20strategies_e_web.pdf

Benson, D. and Lorenzoni, I. (2017) 'Climate change adaptation, flood risks and policy coherence in integrated water resources management in England', *Regional Environmental Change*, 17, pp. 1921–1932. doi: https://doi.org/10.1007/s10113-016-0959-6

Beveridge, R. and Monsees, J. (2012) 'Bridging parallel discourses of integrated water resources management (IWRM): Institutional and political challenges in developing and developed countries', *Water International*, 37(7), pp. 727–743. doi: https://doi.org/10.1080/02508060.2012.742713

Brouwer, R. et al. (2007) 'Socioeconomic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh', *Risk Analysis*, 27(2), pp. 313–326. doi: https://doi.org/10.1111/j.1539-6924.2007.00884

CCWater (2019) *San Francisco Bay Area integrated regional water management plan*. Contra Costa Water District. www.ccwater.com/DocumentCenter/View/8741/Bay-Area-IRWM-Plan-2019-Update-PDF

Cumiskey, L. et al. (2019) 'A framework to assess integration in flood risk management: Implications for governance, policy, and practice', *Ecology and Society*, 24(4), p. 17. doi: https://doi.org/10.5751/ES-11298-240417

Dewan, C., Buisson, M. C. and Mukherji, A. (2014) 'The imposition of participation? The case of participatory water management in coastal Bangladesh', *Water Alternatives*, 7(2), pp. 342–366.

Dieperink, C. et al. (2016) 'Recurrent governance challenges in the implementation and alignment of flood risk management strategies: A review', *Water Resources Management*, 30, pp. 4467–4481. doi: https://doi.org/10.1007/s11269-016-1491-7

European Commission (2014) *Links between the floods directive (FD 2007/60/EC) and water framework directive (WFD 2000/60/EC)*. European Commission.

Flood Forecasting/Hydrological Observation | Central Water Commission, Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, GoI (2021). www.cwc.gov.in

Folke, C., Hahn, T., Olsson, P. and Norberg, J. (2005) 'Adaptive governance of social-ecological systems', *The Annual Review of Environment and Resources*, 30, pp. 441–473. doi: https://doi.org/10.1146/annurev.energy.30.050504.144511

Gain, A. K., Mondal, M. S. and Rahman, R. (2017) 'From flood control to water management: A journey of Bangladesh towards integrated water resources management', *Water*, 9(1), pp. 1–16, 55. doi: https://doi.org/10.3390/w9010055

Gain, A. K. et al. (2015) 'An integrated approach of flood risk assessment in the eastern part of Dhaka City', *Natural Hazards*, 79(3), pp. 1499–1530. doi: https://doi.org/10.1007/s11069-015-1911-7

Global Water Partnership (GWP) (2000) *Integrated water resources management*. TAC Background Paper No. 4. Global Water Partnership. www.gwpcacena.net/en/pdf/tec04.pdf

Global Water Partnership (GWP) (2015) *Integrated water resources management in Central and Eastern Europe: IWRM vs EU water framework directive*. Global Water Partnership.

Gwimbi, P. (2004) 'The effectiveness of early warning systems for the reduction of flood disasters: Some experiences from cyclone induced floods in Zimbabwe', *Journal of Sustainable Development in Africa*, 9(4).

Hernández-Mora, N. and Ballester, A. (2011) *Public participation and the role of social networks in the implementation of the water framework directive in Spain*. Ambientalia SPI. Retrieved 29 March 2022.

Hedelin, B. (2016) 'The EU floods directive trickling down: Tracing the ideas of integrated and participatory flood risk management in Sweden', *Water Policy*, 19(2), pp. 286–303. doi: https://doi.org/10.2166/wp.2016.092

Howarth, W. (2017) 'Integrated water resources management and reform of flood risk management in England', *Journal of Environmental Law*, 29(2), pp. 1–11. doi: https://doi.org/10.1093/jel/eqx015

Ibisch, R. B., Bogardi, J. J. and Borchardt, D. (2016) *Integrated water resources management: Concept, research and implementation*. Springer International Publishing, pp. 3–32. doi: https://doi.org/10.1007/978-3-319-25071-7

Jha, A. K., Bloch, R. and Lamond, J. (2012) *Cities and flooding: A guide to integrated flood risk management for the 21st century and a summary for policy makers*. The World Bank.

Jongman, B., Ward, P. J. and Aerts, J. C. J. H. (2012) 'Global exposure to river and coastal flooding: Long term trends and changes', *Global Environmental Change*, 22, pp. 823–835. doi: https://doi.org/10.1016/j.gloenvcha.2012.07.004

Madamombe, E. (2004) *Zimbabwe: Flood management practices – selected flood prone areas Zambezi basin*. WMO/GWP. www.floodmanagement.info/publications/casestudies/cs_zimbabwe_full.pdf

McKee, L., Lewicki, M., Schoellhamer, D. and Ganju, N. (2013) 'Comparison of sediment supply to San Francisco Bay from watersheds draining the Bay Area and the Central Valley of California', *Marine Geology*, 345, pp. 47–62. https://doi.org/10.1016/j.margeo.2013.03.003

McLeman, R. and Smit, B. (2006) 'Migration as an adaptation to climate change', *Climatic Change*, 76, pp. 31–53. doi: https://doi.org/10.1007/s10584-005-9000-7

Metz, F. and Glaus, A. (2019) 'Integrated water resources management and policy integration: Lessons from 169 years of flood policies in Switzerland', *Water*, 11(1173), pp. 1–27. doi: https://doi.org/10.3390/w11061173

Mohanty, M., Mudgil, S. and Karmakar, S. (2020) 'Flood management in India: A focussed review on the current status and future challenges', *International Journal of Disaster Risk Reduction*, 49, p. 101660. doi: https://doi.org/10.1016/j.ijdrr.2020.101660

MoWR (2017) *Report of the comptroller and auditor general of India on schemes for flood control and flood forecasting*. Ministry of Water Resources. https://cag.gov.in/webroot/uploads/download_audit_report/2017/Report_No.10_of_2017

Munné, A. et al. (2021) 'A proposal to classify and assess ecological status in Mediterranean temporary rivers: Research insights to solve management needs', *Water*, 13(6), p. 767. https://doi.org/10.3390/w13060767

Ortega, C. and Hernández-Mora, N. (2010) 'Institutions and institutional reform in the Spanish water sector: A historical perspective', in *Water policy in Spain*. CRC Press.

Rosaidul Mawla, M., Sultana, N. and Shiblee, M. (2020) 'Myths, safety and awareness of lightning protection in Bangladesh', *International Journal of Electrical Components and Energy Conversion*, 6(2), p. 7. https://doi.org/10.11648/j.ijecec.20200602.11

Serra-Llobet, A., Conrad, E. and Schaefer, K. (2016a) 'Governing for integrated water and flood risk management: Comparing top-down and bottom-up approaches in Spain and California', *Water*, 8(1), pp. 1–22, 445. doi: https://doi.org/10.3390/w8100445

Serra-Llobet, A., Conrad, E. and Schaefer, K. (2016b) 'Integrated water resource and flood risk management: Comparing the US and the EU', *3rd European Conference on Flood Risk Management*, 7, pp. 1–12. doi: https://doi.org/10.1051/e3sconf/20160720006

Tariq, M. A. U. R., Farooq, R. and van de Giesen, N. (2020) 'A critical review of flood risk management and the selection of suitable measures', *Applied Sciences*, 10(23), 8752, pp. 1–18. doi: https://doi.org/10.3390/app10238752

Taylor, N. and Kudela, R. (2021) 'Spatial variability of suspended sediments in San Francisco Bay, California', *Remote Sensing*, 13(22), p. 4625. https://doi.org/10.3390/rs13224625

Tellman, B. et al. (2021) 'Satellite imaging reveals increased proportion of population exposed to floods', *Nature*, 596, pp. 80–86. doi: https://doi.org/10.1038/s41586-021-03695-w

Topalović, Ž. and Marković, D. (2018) 'Integrated approach to flood management', in Anguillari, E. and Dimitrijević, B. (eds.). *Integrated urban planning: Directions, resources and territories*. TU Delft Open, pp. 143–169.

UNEP (2021) *Progress on integrated water resources management*. Tracking SDG 6 Series, Global Indicator 6.5.1 Updates and Acceleration Needs. www.unwater.org/publications/progress-on-integrated-water-resources-management-651-2021-update/

United Nations-Water (2011) *Cities coping with water uncertainties*. Media Brief, UN-Water Decade Programme on Advocacy and Communication. www.un.org/waterforlifedecade/swm_cities_zaragoza_2010/pdf/02_water_uncertainties.pdf

Verweij, S., Busscher, T. and van den Brink, M. (2021) 'Effective policy instrument mixes for implementing integrated flood risk management: An analysis of the "Room for the River" program', *Environmental Science and Policy*, 116, pp. 204–212. doi: https://doi.org/10.1016/j.envsci.2020.12.003

Vis, M. et al. (2003) 'Resilience strategies for flood risk management in the Netherlands', *International Journal of River Basin Management*, 1(1), pp. 33–40. doi: https://doi.org/10.1080/15715124.2003.9635190

World Water Council (2014) *Integrated water resource management: A new way forward*. A Discussion Paper of the World Water Council Task Force on IWRM. www.worldwatercouncil.org/sites/default/files/Initiatives/IWRM/Integrated_Water_Resource_Management-A_new_way_forward%20.pdf