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REVIEW ARTICLE

Review of assessing the impact of climate change on tank irrigation: Vulnerabilities and adaptation strategies

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Abstract

Tank irrigation systems, crucial for global food security, face significant threats from climate change, including rising temperatures, altered precipitation patterns, and increased extreme weather events that impact water availability, compromising ecosystem conservation and agricultural productivity. This review article examines key strategies to enhance resilience in tank irrigation systems to address these challenges, ensuring sustainable development. In addition to bringing climate change impacts to urban communities, this survey raises one–of–a–kind difficulties, looking like mountains in which extreme slopes and precipitation designs intensify soil disintegration and make it difficult for water to be watered down. Strategies that work include using contour bunds, terracing, and checking dams to reduce runoff and retain more water. Vegetative barriers and afforestation improve slope stability, percolation pits and infiltration trenches increase groundwater recharge. By integrating these techniques, soil quality can be maintained and water availability can be resilient in urban and mountainous zones. Despite these strategies, challenges persist, including insufficient funding, limited institutional capacity, and inadequate climate information. Water quality becomes affected, and climate change becomes a big bane, like when the pH goes down due to acid rain in tank irrigation systems, which impacts soil health and crop productivity. These hazards are countered by lime treatment for acidity neutralization, buffer zone strategies facilitated with vegetative barriers to act as pollutants filters, and afforestation to reduce sulfur and nitrogen emissions. Furthermore, developing climate-resilient infrastructure, encouraging water-saving technologies such as precision irrigation, and enhancing climate information services for farmers are also required to address knowledge gaps. Sustainable tank irrigation systems need stakeholders, policymakers, and researchers to collaborate to ensure food security and environmental resilience.

Keywords

adaptive agricultural practices; climate resilience; rainwater harvesting technique; soil and water conservation; tank irrigation systems; water management strategies

Introduction

Disrupting water resources and rainfall patterns, climate change creates a wide range of challenges that are changing hydrological systems around the globe. These will appear as more frequent extreme weather events, unpredictable precipitation, rising temperatures, greater water scarcity, and destabilizing ecosystems. These impacts are particularly severe in regions still relying on traditional water management practices, e.g., disruption of tank irrigation systems severely compounds challenges of soil erosion, declining water storage, and declining agricultural productivity. Tank irrigation systems have historically been critical in semiarid and rural regions for capturing and storing rainwater for agriculture, groundwater recharge and rural livelihoods. Though historically significant, these systems are emerging vulnerable under the changed climatic conditions, and urgent adaptation measures must be taken to sustain these systems. Siltation, governance issues and extreme weather events pose unique challenges and present opportunities for resilient tank irrigation through innovative water management and conservation strategies.

Through this study, we examine the resilience of tank irrigation systems to climate change in the context of an integrated rainwater harvesting, soil conservation, and water-efficient crop management package. This tank has numerous uses, such as aquaculture, flood control, groundwater recharge, fish farming, and provision of drinking water to millions of urban and rural populations, including their livestock (1). For a long time now, people in southern India have known about tanks, and evidence shows that monarchs, chiefs, and landlords used them to finance their construction (2). It is the most crucial source of minor irrigation. Small–scale farmers who rely on tank irrigation may find this helpful technology. Over the history of India, tanks have played a significant role in preserving ecological and social harmony in rural communities through rainwater harvesting and storage systems(3). However, irrigation as an ancient Indian practice can first be associated with Tamil Nadu state, which boasts the nation's oldest extant examples (4). Since independence, primary sources for tank irrigation have consistently decreased. This is evident from the decreased proportionate importance of tanks, among other forms of irrigation, indicating deterioration. At the same time, there is increasing concern that some of the country's poorest areas are likely to suffer more from drought in case these huge and priceless resources collapse.

However, rainfall pattern changes associated with climate change, increasingly frequent extreme storms and increasing global temperatures affect El Niño's timing, strength and frequency. The functionality of these tank irrigation systems may change to pose water scarcity, reduce crop yields and increase the rural communities' vulnerability to rely on the former. These challenges need urgent adaptation measures to boost the resilience of tank irrigation systems facing changing climate stresses. The strength of tank irrigation systems to climate impacts, the existing strategies, and their effectiveness are reviewed. Key adaptation approaches include infrastructural development to modernize storage and distribution, technological innovations of precision irrigation, adaptive management, which integrates climate forecasts or sustainable water practice, and watershed management (Fig. 1).

Methodology

The basis of this review article is secondary data collected from a systematic literature review. We used specific keywords and search strategies in academic databases like Scopus, Web of Science, Google Scholar, and SpringerLink and focused on gathering appropriate information. The primary keywords used were: "climate change," "tank irrigation systems," "rainwater harvesting," "climate resilience," "soil and water conservation," "adaptive strategies," and "water-efficient agriculture." For instance, search results were refined using Boolean operators (AND/OR) to ensure that all peer-reviewed articles, reports and case studies dated back to the last twenty years were covered. Selected literature was critically reviewed, and data were interpreted to identify key themes relating to the vulnerabilities caused by tank irrigation systems and the ways of adapting to various climate scenarios. Case studies in rural and semiarid regions were prioritized with solutions based on infrastructural, technological, and managerial methods. Data interpretation was a thematic analysis to synthesize these into coherent narratives.

Vulnerability of Tank Irrigation Systems to Climate Change

The agricultural sector's vulnerability to climate change depends on three constituents, i.e., the system's exposure, sensitivity, and adaptive capacity (5). Tank irrigation systems are becoming increasingly vulnerable even though they are beneficial. There are several reasons why this is possible. According to(6), climate change is making precipitation patterns more unpredictable and less reliable in the form of snow and rain. In this case, the rain becomes different. Thus, when should farmers water their crops without knowing if it will rain or not? This affects the tank pools, which fill up so that there will be no need for another time to fill them up with water. For example, there has been an increase in the intensity of droughts, floods, and hurricanes as a result of climate change over time which has led to significant damage. Tank catchment areas may have an even bigger water shortage because of changes in the way it rains and warmer weather on average(7). The battle for a scarce resource such as water is further fuelled by growing population numbers and businesses demanding more supplies. These factors make tank watering systems feel more under pressure than ever before. Soil erosion coupled with deposition leads to some reduction in storage capacity for tank reservoirs over time. This makes them unusable for holding water and providing irrigation water in return, after all, rather than posing more risks than before. However, due to such changes in rainfall patterns as a result of global warming, soil erosion could become worse and siltation rates for tanks could increase.

Many tank irrigation systems do not receive proper maintenance, and thus, structures collapse because of bad governance, inadequate funds, or lack of technical knowledge (8). More often than before, this can cause infrastructure damage through extreme weather events caused by climate change and also reduce water supplies. This requires a comprehensive plan that involves

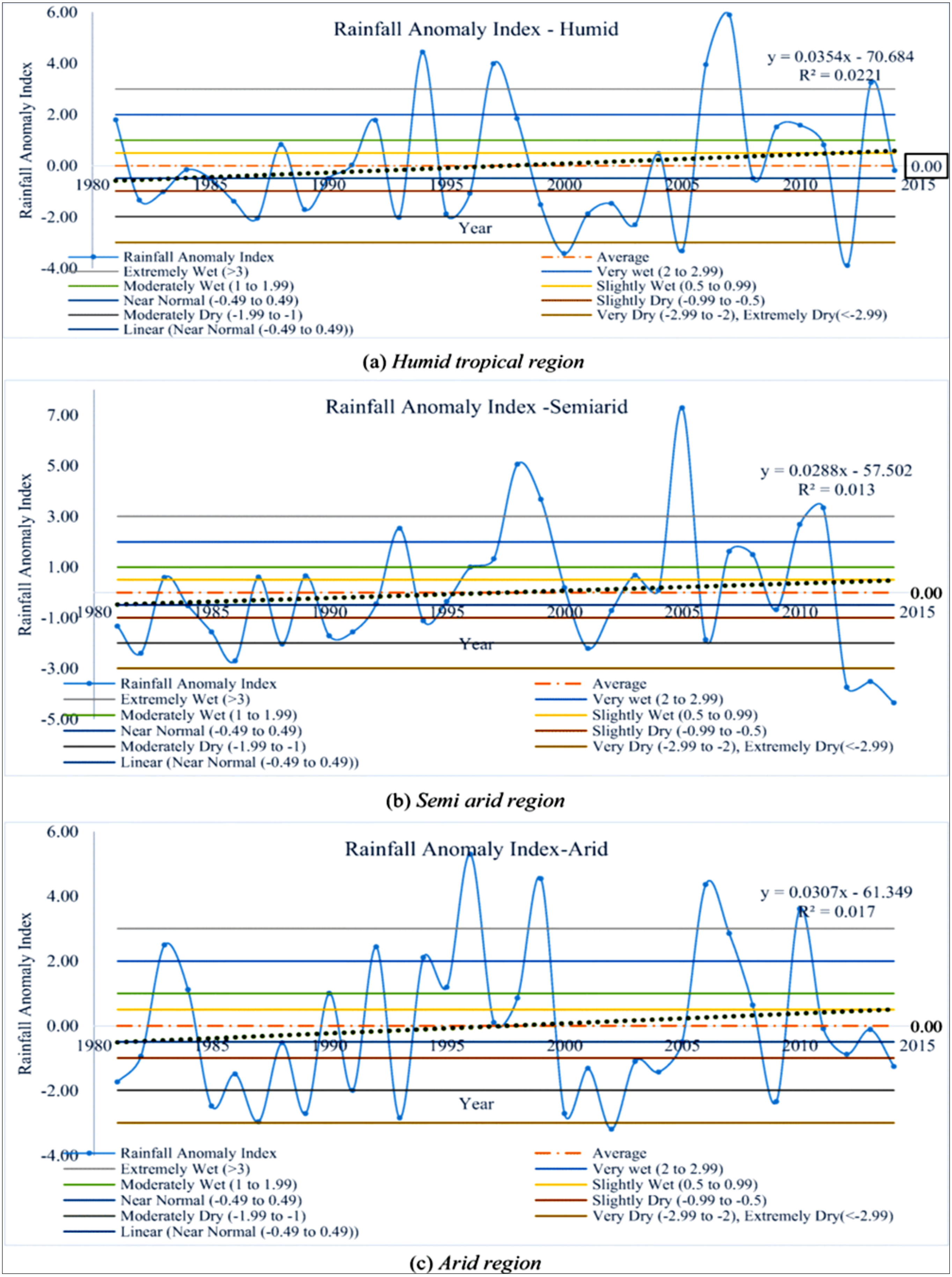

Fig.1. Graph showing historical temperature and rainfall trends in semiarid regions of India.

community participation programs working together with strengthening organizations planning for sustainable land use and employing water management techniques that will be able to withstand climate change impacts. So that these areas can continue to be sustainable with the changing climate, we must develop more muscular systems for tank irrigation. Fig. 2. demonstrates a comprehensive visual framework for understanding the vulnerabilities of tank

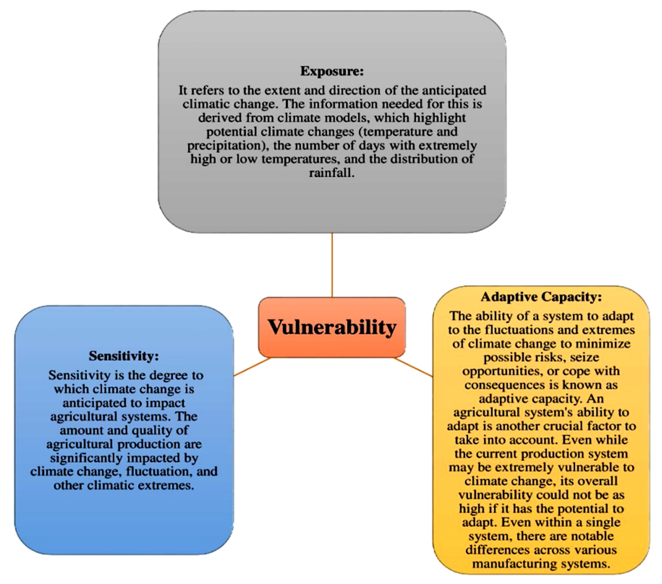

Fig. 2. Vulnerability of agricultural system to climate change and variability.

irrigation systems to climate change. It shows the interplay between exposure, sensitivity, and adaptive capacity, which must be considered in a complete analysis of agricultural systems' vulnerability. For example, events consistent with those depicted in the figure increase in unpredictability of precipitation patterns, or the frequency of extreme weather events correspond well with the challenges outlined above. The urgency of these adaptations-including upgrades to our infrastructure towards a more adaptive model and improvements to how we manage water-is emphasized by this visual.

Climate Change Impacts on Tank Irrigation Systems

Climate change's effects on established patterns are making precipitation less predictable. These systems of tank irrigation fill reservoirs, so adapting to changing rainfall patterns is essential (9). Long dry spells followed by heavy rain could prevent the filling of tank reservoirs and reduce irrigation water. Due to changes in the time and distribution of rainfall, irrigation schedules, planting patterns and agricultural productivity can be altered, affecting the farmers' livelihoods.

Increased frequency and intensity of extreme weather events

One of the most striking impacts of climate change on tank irrigation systems is an increase in the frequency and severity of extreme weather events. Infrastructure and water management practices are threatened by increasingly frequent storms, cyclones, floods, and drought (10). Flooding may ruin irrigation infrastructure such as reservoirs, canals, or other structures, causing runoff, siltation, and soil erosion. However, an extensive drying period causes a drop in the pool surface, making it difficult for plants to receive sufficient water.

Rising temperatures and its effects on water availability and evaporation

Temperatures will rise with climate change, which will considerably affect the amount of water available and how fast it evaporates in reservoir irrigation systems. Warmer temperatures hasten water vaporization from storage tanks and soil. Thus, more water is lost that cannot be replenished. Similarly, high temperatures could cause plants to need more water, changing how irrigation and crops must be grown. In response to these impacts of increasing temperatures, we may require water-saving technologies, better irrigation methods, and drought–tolerant crops that can sustain agriculture amidst a changing environment (11).

For instance, water resources within the region are at risk of climatic change and variability impacts on the hydrological cycle (12). With semiarid regions, local hydrological systems and water resources will be significantly influenced by the fast climate changes that come with global warming (13). This is highly important because these areas have high water and agricultural problems; therefore, addressing them requires a prior understanding of the consequences of climate change (14). Consequently, research on climate change's effects on water availability in these regions is essential. Besides, long–term planning for water resources is increasingly being required. In semi-arid zones, irrigation tanks are vital in managing water resources. This sustainability balances ecological conservation measures and irrigation, which depend upon it (15). Traditional tank systems are an essential seasonal irrigation source that enables. Due to its topography and soil conditions, most of these tanks are in India's semiarid Deccan Plateau region (16,17).

To do an impact assessment, one typically establishes a validated and calibrated hydrologic model of the watershed. Then, for various climate change scenarios, one estimates the future stream flow or input into the tank (18). This is difficult because most watersheds lack survey data measuring Zoning can accurately determine river flow in non–watersheds (19). Regionalization is the data movement from non–existent areas to non–existent areas with similar landscapes, vegetation, climate, and geography (20). One way to implement model parameter regionalization is to use calibrated values from gauged watersheds in the same region to create regionalized values for ungauged watersheds (21). Some methods for regionalizing parameters include physical similarity–based simple parameter transfer, spatial proximity, ratio, global averaging, regression, and interpolation methods like kriging and inverse distance weighting (IDW) (22).

Resilience Framework for Tank Irrigation Systems

In the framework of tank irrigation, resilience refers to how these systems can cope with and recover from various climate change–induced pressures, shocks, or disturbances while remaining functional and supporting sustainable agricultural production (23).

Framework for assessing resilience

Tank irrigation systems' adaptability to climate change depends on many elements. An all-encompassing resilience assessment framework may include building and systems tank infrastructure such as reservoirs, canals, embankments, and drainage systems, which are assessed for environmental and extreme weather resilience (24).

It considers structural integrity, maintenance, water, silt, and erosion resistance. Hydrological resilience focuses on tank systems' ability to efficiently manage water resources in response to variable precipitation, evaporation, and groundwater dynamics (25). This capability assesses water storage capacity, recharge systems, distribution efficiency, and resilience to water supply changes. Ecological resilience is the ability of tank ecosystems to withstand pollution, invasive species, or habitat loss while maintaining structure function and biodiversity. It includes species diversity, habitat connectivity, ecosystem services, and environmental resilience (26). Social-ecological resilience involves community, agriculture, and institutional adaptation to climate change (27).

Key components of a resilient tank irrigation system

Several strategies and components are used to improve a tank irrigation system and make it more adaptable and sustainable. For example, such a system may involve recycling wastewater, catching rainwater, storing flood water underground or in surface structures, and extracting groundwater as the primary water source, thus reducing dependence on one source (28). Climate–resilient tanks, canals, gates, and spillways that are well–built and adequately maintained form part of the infrastructure that ensures a reliable, safe water supply is available, minimizing the number of leaks affecting flood damage associated with bad weather occurrences(29). Effective water management practices such as demand-based scheduling of irrigations based on user preferences in line with climatic conditions, water-saving technologies like drip lines/ sprinklers, and precision irrigation practices, among others, while embracing conjunctive utilization of available water resources, can help increase the efficiency of its use thereby reducing wastage as shown in Fig. 2. This leads to habitat provision by advocating for the sustainability management of the tank's ecosystem which covers riparian habitats, wetlands as well as biodiversity corridors including nutrient cycling and flood regulation, as well as enhancing ecological resilience and water quality (30).

Local community and farmers' participation in decision–making processes, learning network development and knowledge exchange, training and awareness programs, and livelihood diversification initiatives are ways to enhance social resilience and collective action for sustainable water management (31). To improve institutional resilience and facilitate effective climate change adaptation, it is crucial to develop enabling policies, regulations, and institutional frameworks that support adaptive management, promote fair distribution of water, resolve conflicts, encourage climate-smart agriculture practices, and provide financing and technical support for building resilience (32). Rain gardens and bioswales transform tank irrigation systems. Shallow vegetated depressions rain gardens capture and filter runoff, prevent sedimentation and promote groundwater recharge. Vegetated channels that direct and infiltrate stormwater, mitigate erosion and improve water quality in tank systems constitute bioswales.

Adaptation Strategies for Enhancing Resilience in Tank Irrigation Systems

Water management techniques for improving resilience

Successful water management is essential to render water tanks more climate change resilient. Various ways can be used to handle water to optimize availability, minimize wastage, and improve the entire system. Rainwater harvesting is a good way to store water for future use (33). This method of harvesting rainwater reduces reliance on outside sources and helps them get more during seasons of scarcity. Many people have gutters and downspouts installed on their roofs to collect rainwater and store it in tanks or reservoirs. Other methods include contour bunds, check dams, or swales, which catch surface runoff during rainfall (34). Tank irrigation systems employed with rainwater harvesting capture and store rainwater for agricultural purposes. Contour bunds constructed along contour lines divide the field into small strips, slowing the runoff to recharge groundwater. Small barriers across streams or check dams, reduce runoff and allow for infiltration. Runoff is stored in percolation tanks (shallow reservoirs) that recharge aquifers and are used during dry spells. Farm ponds and gabion structures add further on tanks to prevent erosion and sedimentation. They decrease water availability and soil stability and increase water availability, promote sustainable agriculture, and maintain tank functionality in vulnerable areas without depending on erratically occurring rainfall.

Groundwater recharge techniques

Water is treated artificially and released into the aquifers using different groundwater recharge techniques to revive spent aquifers and stabilize water levels for agricultural purposes. Standard methods include Small pits or ponds built to trap rainwater that recharges aquifers (35). Recharge wells or boreholes inject treated wastewater or surface water into the aquifer to raise groundwater reserves (36). Basins for recharging, infiltration galleries, and trenches used as catchment areas can direct underground flows and store underground water. Such water conservation measures can help tank irrigation systems cope with climate change and water scarcity and maintain their capacity in commercial farming. For it to be effective and continue functioning you must plan for it, get the right people involved in it, and manage it closely.

Efficient water use practices

It is necessary to encourage adopting water-friendly practices to maximize crop yields, minimize losses, and optimize water use efficiency for agriculture. There are several ways to save water in farming: One way of enhancing soil moisture preservation, suppressing weed growth, and reducing transpiration is by applying organic or synthetic mulch materials on the soil surface (37). Soil Moisture Monitoring includes the installation of soil moisture sensors or tensiometers that monitor soil moisture levels and aid in developing irrigation schedules based on crop water demands, hence minimizing excess watering and avoiding wasting too much water. Soil and Water Conservation Techniques are essential to improve the resilience of tank irrigation systems. Mulching is defined as applying an organic or synthetic material on the soil to waterproof it, retain moisture, and prevent weeds. Terracing means creating step-like slope formations – minimizing runoff and soil erosion and maximizing water retention. Irrigation methods such as drip or sprinkler systems control water use, avoid water,e and optimize its use. These practices conserve soil fertility, increase water infiltration, provide sustainable water availability, and enable sustainable agricultural productivity despite climate variability.

Crop management strategies for building resilience

The infrastructure must be improved for tank irrigation systems to be climate resilient. Tanks and canals need periodic repairs and maintenance. The authors of this article (38) Suggest examining tanks' walls, embankments, spillways, and canals for structural weaknesses. If some are found, they should be repaired to strengthen those sections. Desiltation and dredging of tank reservoirs and canals will restore storage capacity, increase water flow, and prevent siltation (39). Vegetation buffer zones along canal banks and around tanks trap sediments and contaminants while stabilizing soil against erosion, enhancing water quality.

Infrastructure improvement necessitates the upgrading of irrigation systems. Modern technology and approaches can enable efficient water distribution networks with minimum losses. Wireless monitoring devices controlled by sensors reduce water wastage in farming (40). Using sprinkler heads under pressure or drip irrigation allows for more precise amounts of water during application compared to shallow furrows or flood techniques so that less evaporation occurs, leading to more effective utilization of the liquid element (41).

For tank irrigation systems, resilience requires crop management. This includes growing drought-tolerant crops that help minimize the effects of water scarcity and climatic variation. Breeding and selection can produce crops with high water use efficiency, heat stress resistance, and drought tolerance (42). Millets, sorghum, pigeon peas, and various legumes are all examples of water-efficient crops that enhance resilience. Even if there is a problem with water supply during dry seasons, productivity will not be affected. Consequently, crop rotation, intercropping, and agroforestry are necessary for soil health, biodiversity conservation, and income generation by farmers, promoting their ability to adapt to climate change (43). Lastly, farming communities using climate–resistant crop varieties survive against changing weather patterns. Climate-smart agriculture and participatory plant breeding have helped develop these cultivars (44). There should be an improvement in crop management approaches, given that tank irrigation systems would strengthen themselves further and not lose their agricultural production while helping farmers adapt to climate change. Sustainable tank irrigation systems heavily require water-efficient crops. For example, millet and sorghum can survive drought and bear high yields, while pigeon peas can. Genetically engineered rice and wheat with improved water use efficiency are a scientific innovation that helps fight water scarcity. Management strategies include crop rotation, intercropping and precision irrigation, optimizing resource use.

Policy and Institutional Interventions

Policy and institutional changes are needed to make tank irrigation systems more resilient and secure the continuation of water management practices under changing climatic conditions (45). Government policies and programs are critical for enhancing these systems' resilience by providing support services, such as guidance on what type of assistance should be given or provided by different stakeholders, including financial resources (46). Government policies and programs that encourage tank irrigation systems in place are essential as they provide the necessary guidelines, rewards system, and expertise needed to construct infrastructure, enhance management capabilities, as well as be adaptable (47). For example, governments could develop regulations that promote expenditure on the rehabilitation of broken water infrastructure and help farmers transition towards farming practices that can withstand future weather shocks such as droughts (48). This process occurs at the grassroots level, where entities such as water user clubs, cooperatives, and community–based organizations play a crucial role in managing and overseeing tank irrigation systems (49). Frequently working closely with these groups is vital since they deeply know their local environment, culture, and social dynamics. Thus, using context–specific adaptation strategies based on this, would allow for more involvement by people at the grassroots levels (50). Additionally, the engagement of communities may boost social interactions, thus promoting the formation of resilient networks in which farmers can exchange ideas (51).

Conversely, implementing policies and strengthening institutions on tank irrigation systems has advantages and disadvantages. These entail low budgetary allotments, poor infrastructure maintenance, dysfunctional government arrangements, and limited institutional capacity (52). Marked problems with poor governance, minor maintenance, and no funding for upgrading infrastructure plague tank irrigation systems. Issues like outdated design and inefficient water distribution make these problems worse. Droughts and extreme weather events are becoming more complicated by climate change. One must address regional variability, promote community participation, and equalize water distribution to scale up successful strategies. The resolution to these issues lies in the imperative need for and a deliberate effort by businesses, government agencies, and other civil society organizations to mobilize more resources, enhance technical capacity, and strengthen institutional coordination (53). However, there are possibilities for enhancing policy coherence, innovation, and teamwork towards increasing community resilience even with these challenges. Remote sensing, including geographic information systems (GIS) and decision support systems, can help control, forecast, and monitor water resources better (54). On a broader scale, learning becomes easier; change happens faster, and successful methods can be used when partnerships between different groups are built, or information is shared. To make tank irrigation systems more resilient while ensuring that water resources are utilized sustainably for agricultural purposes in the context of climate change, governments could take advantage of this opportunity by collaborating with local institutions and communities to address the key issues (55).

Technological Innovations for Enhancing Resilience in Tank Irrigation Systems

Solar–powered pumping systems

(56) Found that solar–powered irrigation pumps reduce emissions of greenhouse gases and eliminate the need for grid electricity or diesel generator use. Solar–powered pumps used in rural or off-grid settings can inexpensively and sustainably pump water from tanks or wells. Farmers will save on expenses, increase energy efficiency, and cope with fuel price fluctuations and power disruptions (57).

Sensor-based irrigation controllers

To optimize irrigation scheduling and water application, sensor-based irrigation controllers use soil moisture sensors, weather data, and evapotranspiration models, enabling efficient water use and maximization of crop yields (58). Sensor-based irrigation controllers continuously monitor soil moisture levels and weather conditions, enabling precision irrigation, which minimizes water wastage, reduces energy consumption, and lowers the chances of overwatering/underwatering (59).

Governance and Management Interventions

Remote sensing and GIS applications

Remote sensing and geographic information systems (GIS) are valuable technologies for observing, mapping, and managing agricultural landscapes and tank irrigation systems (60). The health of plants can be determined by remote sensing data collected from aircraft or satellites. Water–stressed areas can be identified, agricultural production can be monitored, and the effectiveness of water use can be assessed using remote sensing images sourced from aircraft or satellites. The most important things that GIS platforms do include spatial analysis, land use mapping, hydrological models, and decision support.

Decision support systems (DSS)

DSS platforms optimize water use, crop management, and irrigation scheduling by integrating actionable insights and recommendations derived from data, models, and algorithms. Real-time data availability, weather forecasts, and simulation models have enabled DSS platforms to serve both policymakers, farmers and water resource managers with up–to–date information, making it easier for them to make informed decisions relating to irrigation planning like crop selection or even water allocation (61). DSS tools are good at optimizing resource use, minimizing risks, and maximizing the economy by integrating user preferences with agronomic constraints and environmental considerations. They can also be resilient to climate variability and change. By adopting these new technologies, the tank irrigation system's resilience against the impacts of climate change, production levels, and effectiveness are heightened (62).

Cost-benefit analysis of resilience measures

CBAs may be used in assessing the financial viability and ROI of resilience–enhancing treatments for tank irrigation systems (63). Cost-benefit analysis should measure, value, and compare costs and benefits to determine net economic impacts. These are steps required in cost-benefit analysis. (64). This includes externalities like social and environmental harm and wasted opportunities (65). Resilience measures affect agricultural productivity positively and improve water savings, crop losses, water quality, and ecosystem services directly and indirectly (66). However, it can help enhance food security, poverty, and climate change adaptation/capacity–building programs under resilience frameworks (Fig. 3)(67).

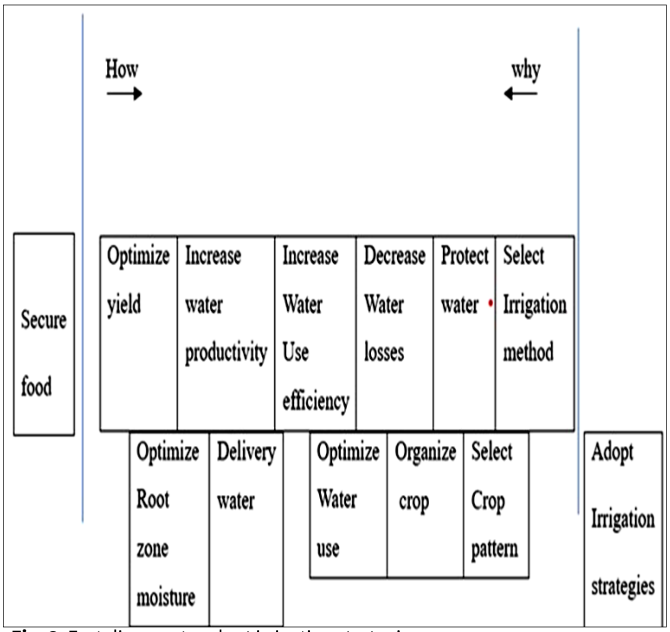

Fig. 3. Fast diagram to adopt irrigation strategies.

Market–based instruments for adapting adaptation strategies

Economic incentives for adaptation strategies

When it comes to making people adopt mitigation measures and modify their conduct, monetary rewards are very significant. Government financial help may go into subsidies, grants, or rebates to motivate investment in resilience–building actions such as infrastructure development, water–saving technologies, and weather–resistant crops. (68). Tax incentives and credits may lead businesses and farmers into environmentally friendly activities like using renewable energy systems or undertaking water conservation measures. Payments give landowners or agriculturalists cash for Ecosystem Services (PES) schemes that clean water supplies, filter carbon dioxide out of the atmosphere, and protect wildlife populations. According to (69), PES systems promote sustainability by offering people a reason for the protection and restoration of natural resources. Market–based tools such as tradable permits for greenhouse gas emissions trading scheme enterprises, including cap–and–trade for emissions cuts in industries, make it more profitable to use resources effectively, cut pollution, and maintain land quality. (70).

Financial mechanisms for supporting resilience–building efforts

Financial methods are paramount to tank irrigation systems since they assist in aggregating resources, making investments efficient, and paying for resilience–building projects. (71)Here are some examples of how money is handled:

Governments can utilize their national budgets, development grants, or foreign aid to pay for resilience projects, infrastructure improvements, and activities that enhance people's capacities. (72)Suggests that public finance can address market failures, make it easier for people to spend, and offer funding to projects that do good things for society and the environment. The private sector can support extra financing to improve infrastructure, adopt new technologies, and enhance community resilience through business loans, venture capital, and public-private partnerships (PPPs) (73).

Climate finance mechanisms such as green bonds, climate funds, and carbon markets are considered to help generate funds to fund various activities geared towards mitigating or adapting to climate change (74). It is intended to aid ecosystem and community adaptation. By enabling people access to savings accounts, insurance policies, and loans, microfinance assists local communities in making money, diversifying their livelihoods, and engaging in activities that make them more resilient. (75).

Opportunities for Scaling up Successful Adaptation Strategies

For peer–to–peer learning, knowledge sharing, and capacity–building initiatives, it is possible to develop ways of replicating, adapting, or scaling up successful adaptation strategies across different regions and contexts (76,77). Advocacy efforts, policy dialogues, and collaborative partnerships can promote policy innovation, mainstream resilience–building into development agendas, and mobilize political support and financial resources for adaptation efforts (78). Public-private partnership agreements with the private sector, technology transfer agreements, and market–based incentives may help unlock investments, leverage expertise, and accelerate the adoption of innovative solutions to enhance resilience (79).

Conclusion

The review highlights key strategies to enhance the resilience of tank irrigation systems, including infrastructure improvements, the development of innovative technologies, and the implementation of adaptive management practices to address climate-related challenges. However, financial, institutional capacity, and climate change risks should be addressed for tank irrigation to be successful. Conversely, creativity, cooperation, and adaptability can come from scaling up well–done adaptation initiatives. Tank irrigation systems have an impact on food security as well as agricultural livelihoods and ecosystem sustainability. People living under precarious conditions need support to build resilience towards water resources and sustainably promote development despite climate change. Researchers must work with practitioners and politicians to overcome the remaining challenges and maximize new opportunities. Policymakers must fund infrastructure renovation, modernization, and resilience–building to make tank irrigation more adaptable while promoting sustainable water management. Technological advances, socioeconomic evaluations, policy studies, and information gaps should be researched to improve tank irrigation systems. Practitioners should support collaborative partnerships, knowledge networks, and multi-stakeholder engagement platforms to enhance local, national, and worldwide resilience–building information exchange, skill development, and collective action. Everyone must work together, take responsibility, and stay committed to strengthening tank irrigation systems. If we work together, we can make water and agriculture more fair, resilient, and sustainable under climate change.

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Authors' contributions

SR designed the study framework and drafted the manuscript. AM conceived the overall research idea and provided guidance.MR, RP, RB and KP supervised the study and coordinated the manuscript preparation. All authors read and approved the final manuscript.

Compliance with ethical standards

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