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Indigenous Knowledge and Community-Based Climate Adaptation in the Thar Desert, India

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Abstract

Community-Based Organizations (CBOs) play a crucial role in promoting locally grounded climate change adaptation, particularly in ecologically vulnerable dryland ecosystems. This study examines the role of CBOs in advancing local knowledge systems to support and strengthen climate change adaptation and resilience in the Thar Desert ecosystem of India. To understand this, we employed a qualitative research design, conducting twelve in-depth interviews, eight focus group discussions, and ethnographic observations in four villages in Rajasthan. We analyzed these data using a grounded theory approach to identify key institutional mechanisms, adaptive practices, and constraints influencing community-led adaptation. The findings suggest that CBOs play complementary roles in revitalizing indigenous water-harvesting systems, strengthening food security, and facilitating intergenerational knowledge transfer. Despite issues such as the dwindling of traditional knowledge, the breakdown of knowledge-sharing mechanisms, uneven participation of women in decision-making, limited technical capacity, and inadequate funding support, these practices have the potential to build resilience and consolidate social relationships. The study highlights the need for locally-led adaptation and provides observations to facilitate replication in other contexts. Further, it highlights the need for policy frameworks that formally recognize and strengthen CBOs as key actors in climate adaptation.

1. Introduction

Climate change poses one of the most urgent and complex challenges to sustainable development, disproportionately affecting ecologically fragile and socially vulnerable ecosystems. Globally, studies have documented an increase in the intensity and number of extreme weather events such as tropical storms, floods, and prolonged droughts, disasters that exacerbate pre-existing structural inequalities that disproportionately impact the most marginalized (Ngcamu, 2023; Bunnell, 2019; Mehra et al., 2017; Carvajal, 2007). Patterns are similarly observable across the Global South, where CBOs play a crucial role in addressing climate risks through locally rooted adaptation practices (Khanal et al., 2017; Ashraf et al., 2018). In South Asia, and particularly in India, CBOs have historically contributed to community resilience by facilitating collective management of natural resources and knowledge systems (Mehra, 2018, 2017, 2012; Mehra et al., 2015). In specific regions such as Rajasthan and the Thar Desert, community-led initiatives, such as groundwater recharge, watershed management, and the revitalization of common property resources, have strengthened adaptive capacities in environments stressed by climate change (Chorran et al., 2021; Everard, 2015). These insights, from global to local contexts, highlight the vital role of CBOs in developing equitable and sustainable climate adaptation pathways. Climate adaptation has thus emerged as a vital and inevitable survival strategy, formally designed by the state alongside local and organic innovations.

Given that global temperatures are estimated to have increased by 1.1°C to 1.9°C from pre-industrial levels (WMO, 2024), the urgency for scalable and sustainable adaptation strategies has never been greater. Successful adaptation involves various measures, such as building resilience, maintaining sustainable resource management, encouraging climate-resilient practices, restoring habitats, alongside inclusive policies for underrepresented and marginalized groups (Schmidt-Thome, 2017). Researchers and policymakers now recognize the benefits of community-based adaptation methods, where participation is focused locally, using cultural knowledge and equity (Devi et al., 2022).

Despite our progress, significant gaps remain in our understanding, particularly concerning the specific mechanisms by which CBOs influence adaptation processes and the challenges they encounter. This study seeks to fill these gaps by exploring the role of CBOs in implementing climate change adaptation strategies in the Thar Desert.

CBOs are crucial in implementing locally grounded adaptation strategies (Hlophe, 2016). These are grassroots institutions that mobilize community members around shared goals, deeply rooted in ecocultural stewardship. Their strength lies in merging indigenous knowledge systems with contemporary challenges, fostering collective action and empowering marginalized groups. Numerous studies worldwide have affirmed the capacity of CBOs to yield effective climate adaptation outcomes, ranging from small-scale water harvesting in Kenya (Castelli et al., 2022) to watershed development in Ethiopia (Abelieneh, 2017) and community-based fisheries management in Brazil (Martins & Gasalla, 2020). In India, CBOs have played a crucial role in strengthening rural resilience (Choudhary & Subramanian, 2021).

However, despite the available global evidence, significant knowledge gaps persist, particularly in arid regions such as the Thar Desert. There is still little understanding of how CBOs implement adaptation practices in the face of extreme water scarcity, socio-economic vulnerability, and ecological degradation. Documentation on the processes through which CBOs mobilize local knowledge, navigate institutional barriers, and sustain adaptation initiatives over time is limited. Gaining insight into these mechanisms is crucial for assessing their effectiveness and identifying the context-specific challenges that influence adaptation outcomes in desert environments.

2. Method

2.1. Study area

The Thar Desert, located in western India, is recognized as the world's most densely populated hot desert, housing approximately 16 million people, resulting in a population density of 83 people/sq.km (Charan & Sharma, 2016). Covering roughly 10% of India's total land area, the Thar stretches across Rajasthan and into Gujarat, lying between latitudes 24°40' to 30°12' N and longitudes 69°3' to 76°0' E (Sharma & Mehra, 2009).

This area boasts ecological diversity, influenced by elements from the Palearctic, Oriental, and Saharan zones. It is home to unique wildlife species, including the Chinkara (*Gazella bennettii*), Blackbuck (*Antilope cervicapra*), and Indian gerbils (Prakash, 1963). Over 80% of the Thar Desert's population depends on agriculture and livestock for subsistence (Dhir, 2018), with nearly 65% of the area's land cultivated despite recurring droughts, salinity issues, and the erosion of agro-biodiversity (Pankaj et al., 2020). Post-monsoon crop failures average around 33% annually, underscoring the vulnerability of local food systems and the consequent nutritional insecurity (Scanlon et al., 2010). However, the region is often affected by irregular rainfall, high temperatures, and strong winds

that reduce humidity and limit surface water availability. During the monsoon, water temporarily pools in depressions and playas before evaporating, leaving alkaline residues (Scanlon et al., 2010). Local communities heavily rely on it, particularly in the semi-arid eastern zones where variations in land use and population density influence water extraction rates.

Large-scale irrigation projects were initiated during the 20th century to mitigate aridity and enhance agricultural productivity. These included the Gang Canal (1927), which diverted 7.59 million acre-feet of water from the Ravi-Beas rivers to irrigate over 1 million hectares, and the Indira Gandhi Nahar Project (1961), which expanded irrigation infrastructure throughout Rajasthan via an extensive canal network (Rao, 2005; Roy, 1983). Despite the irrigation infrastructure, reports by the Indian Meteorological Department and recent studies highlight that climate change has exacerbated agrarian stress and disrupted already fragile ecosystems (Bhati & Chhangani, 2023).

With almost half of the past century experiencing drought, households have been forced to allocate large parts of their expenditure to obtaining water (Poonia & Rao, 2013). Groundwater is often found well below the surface and, in many cases, is saline, causing health problems such as fluorosis (Modasiya et al., 2014). The transition to mechanized alternative practices, such as tube wells, has added to the inequalities. Though these pre-existing technologies offer temporary ease, they are economically and environmentally unsustainable for most rural families. Women and marginalised ethnic and caste groups bear the heaviest brunt in this crisis, walking longer distances to collect water while navigating deep-seated social disparities that restrict their access to resources (Opare, 2007).

Historically, communities of the Thar Desert have developed a variety of innovative traditional practices and water-harvesting structures, such as *taanka* (subterranean reservoir for rainwater collection), *naadi* (pond used for harvesting rainwater), *khadin* (clay bund embankments utilized for rainwater collection in agricultural practices), and *berry* (percolation well used for harvesting rainwater), to adapt to their challenging environment (Singhal, 2024; Sharma, 2022; Goyal & Gaur, 2022). These systems highlight the profound interconnections between indigenous knowledge, ecological understanding, and cultural adaptation.

A classic example of this function can be observed in the initiatives of Gramin Vikas Vigyan Samiti (GRAVIS), a non-profit organization working toward sustainable development and healthcare services, education and environmental conservation, established in 1983. Through its field offices in Rajasthan, GRAVIS has established more than 4,000 CBOs, with a reach of almost 1.8 million people. These include Self-Help Groups (SHGs), Village Older People Associations (VOPAs), Intergenerational Learning Groups (ILGs), and Village Development Committees (VDCs), all of which serve different purposes, ranging from preserving traditional knowledge and facilitating intergenerational exchange to promoting gender equality and sustainable natural resource management.

The present study examines four villages across three districts within the Thar Desert (Rajasthan), based on the level of activity and the strength of existing networks facilitated by GRAVIS – Jodhpur Rural, Phalodi, and Jaisalmer (Fig. 1*)* for their active presence of CBOs. In Jodhpur Rural District, Gagari village (Tehsil Osian) was identified. It has an area of 1,594 hectares with a population of about 3,500. The region receives about 360 mm of rainfall annually and experiences a temperature range from 10° C to 49° C (IMD, 2023). It lacks perennial rivers, relying instead on rivers like the Luni and Mithri, as well as local wells, for its water supply. Most residents are engaged in farming and agricultural labour, with the village comprising 34.9% Scheduled Caste and 3.9% Scheduled Tribe populations (Population Census, 2011).

In the Phalodi district, we visited two villages – Bap and Kalran. The former spans 10,981 hectares and is home to 10,393 people, of whom 21.1% belong to the Scheduled Caste and 0.6% to the Scheduled Tribe communities. Bap village receives an average of 193 mm of rainfall annually, and most of its residents are cultivators or agricultural workers. Kalran village (Tehsil Phalodi) covers 1,097 hectares and has a population of 1,987, with 10.9% of the population classified as Scheduled Caste (Population Census, 2011). Most residents are farmers. It also faces a low literacy rate of 21.8%, rendering this community socio-economically vulnerable, and indicating comparatively lesser educational access and awareness within these communities than in other villages.

In the Jaisalmer district, Unda (Tehsil Fatehgarh) village was sampled. It covers an area of 4,557 hectares and has a small population of 790 inhabitants, comprising 35.3% Scheduled Castes and 1.5% Scheduled Tribes. The region receives about 293.5 mm of rainfall and experiences temperatures from 5° C to 50° C (IMD, 2023). Agriculture is the primary occupation across all the sampled villages, with only minor variations in demographic makeup and infrastructure development.

2.2. Study design, data collection and analysis

The study employed a qualitative case study design to examine the role of CBOs in climate change adaptation in the Thar Desert. Four villages across Jodhpur Rural, Phalodi, and Jaisalmer districts were purposively selected based on the presence and active functioning CBOs facilitated by GRAVIS. Participants were identified using a chain referral method based on their level of knowledge and extent of involvement with the CBOs. Initially, the GRAVIS team assisted in selecting participants and establishing contact with them. The interviews were subsequently conducted independently by the first author, following informed verbal consent due to socio-cultural sensitivities, as participants expressed hesitation to sign written documents, often associating them with land or property-related formalities. The data collection employed a mixed-methods approach, including in-depth interviews, focus group discussions (FGDs), and ethnographic observations, all of which were documented in field notes to capture informal conversations, rituals, water practices, and everyday adaptation strategies. The study was carried out only after appropriate clearances were obtained from the first author's Institutional Review Board (IRB/ACA-MSc/0001/HS/04/2024).

A semi-structured question guide (*Annexure B*) was developed collaboratively, allowing us to follow up on themes such as traditional ecological knowledge, resource governance, gender dynamics, and local innovations in water and land management. Conversations were recorded after obtaining explicit permission to do so. This was followed by transcription of audio recordings and translation from Marwari to English. Field notes and transcripts were reviewed to identify emerging themes related to the roles, adaptive practices, and issues confronting CBOs. Following a grounded theory approach (Stough &

Lee, 2021; Bytheway, 2019), insights were grouped into thematic clusters related to the research question, including institutional roles, adaptive practices, governance mechanisms, and perceived challenges. This approach ensured that interpretations remained grounded in participants' narratives and local contexts.

3. Results

3.1. Role of Community-Based Organizations in Adaptive Governance

The studied villages have benefited from the facilitation of local non-governmental organizations and illustrate the role and contribution of four key types of CBOs: Village Development Committees (VDCs), Self-Help Groups (SHGs), Village Older People Associations (VOPAs), and Intergenerational Learning Groups (ILGs) (Fig. 2*)*. These CBOs collectively function as governance platforms that enable planning, implementation, and social legitimacy of adaptation interventions.

The VDCs function as central planning bodies, ensuring equitable representation by including members from diverse social and caste backgrounds, with women comprising 50% of the membership. These are annually elected *Gram Sabha* (village assembly) committees, charged with addressing the community's most pressing needs, monitoring project works, and managing resources, such as the *Gram Kosh* (village development fund).

SHGs are collectives primarily composed of women who work together to achieve financial autonomy through joint savings and microcredit programs. Their capacity development activities extend beyond economic empowerment alone, encompassing civic rights education, reproductive health education, sustainable agricultural practices, and water management. This combination of activities builds individual agency and community resilience.

VOPAs, comprising older persons aged sixty and above, have become critical advisory bodies in climate change adaptation. Even though they do not directly launch projects, their experiential knowledge and indigenous knowledge contribute vital information in choosing the beneficiaries and maintaining cultural continuity in resource utilization. The gender-sensitive structure of VOPAs begins by forming separate groups for men and women, thereby promoting inclusive participation in traditional water management systems, including the maintenance of *taankas and naadis*.

ILGs involve older women, teenagers, and people with disabilities, and work to promote social cohesion. They also facilitate knowledge sharing regarding environmental protection, traditional healing, and agricultural practices. These programs tend to work in partnership with Panchayati Raj institutions (Locally elected government councils serving a group of villages) and community health workers.

Collectively, these CBOs operate adaptive governance by linking indigenous knowledge systems with contemporary institutional frameworks, enabling community-led responses to climate variability while negotiating social hierarchies and external dependencies within an integrated system: VDCs provide guidance and strategic leadership, whereas SHGs, VOPAs, and ILGs facilitate implementation, mobilization, local participation and inclusion. VDCs also employ a co-financing approach, in which beneficiaries pay some portion of the intervention cost, and the remaining amount is subsidized by GRAVIS or by government schemes like MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act), which helps in subsidizing the labour costs for water conservation or natural resource management-related interventions. This partnership builds a sense of ownership while promoting the financial sustainability of the said intervention. This harmony is particularly evident in water management, a field of vital importance in the Thar Desert.

3.2. Hybrid Water Management: Bridging Tradition and Innovation

Water security emerged as a central axis of climate adaptation across all study villages, with CBOs having restored and formalized indigenous rainwater harvesting systems like *taankas, naadis*, and *berrys*, to ensure the backbone of local water management, particularly in the absence of perennial surface water sources. *Taanka* is one of the most common and enduring solutions in the region. The tanks effectively harvest runoff from rooftops and graded slopes, conserving it for use during dry periods. With support from concrete under schemes such as MGNREGA, it was noted that *taankas* (Fig. 3) are now more durable and contribute to better water quality than their erstwhile earthen counterparts (GRAVIS, 2017). In contrast to smaller household cisterns, *taankas* are equipped with filtration inlets and outlets that boost efficiency, minimize contamination, and prolong water availability.

The *Naadi*, (Fig. 4*)*, a publicly shared pond found in natural depressions and supported by embankments and vegetated catchment areas (*aagore*), serves multiple purposes: it provides water for livestock, facilitates community gatherings, and helps mitigate local drought effects. Its maintenance is governed by community norms established by VDCs, which typically prohibit bathing, tree felling, and waste dumping in the vicinity to preserve water quality.

Berrys (Fig. 4) are compact drainage wells constructed within clay-lined sandy terrain or at the bottoms of *naadis* or *khadins*, allowing access to deeply percolated groundwater after surface water evaporates. Usually at depths of 2 to 10 meters, these structures are important in hyper-dry areas and are maintained through community labour, regular desilting, and infrastructural reinforcement. With these traditional systems, new techniques such as drinking water tube wells, Bio Sand Water Filter (BSWFS), and *Diggis* (line storage tanks) complement water protection efforts. Tube wells serve as vital sources of potable water for communities during extreme droughts (Sharma, 2023).

BSWFs (Fig. 5*)* help address salinity and fluoride contamination issues in Thar groundwater by providing household-level purification. *Diggis* (Fig. 5), built by local panchayats every 10 kilometres in areas like *Phalodi*, alleviate the burden of water collection, particularly for women, and support livestock through adjacent surface troughs. These innovations are not isolated interventions; they function within a comprehensive institutional framework where VDCs manage planning, resource mobilization, and maintenance. According to Local people, in areas where these systems have been implemented, they have improved livestock care, reduced seasonal migration, increased school attendance, especially among girls, and enhanced livelihood diversification. While these technologies provide short-term relief, they also introduce new dependencies and risks, particularly in relation to groundwater over-extraction. The

coexistence of traditional and modern systems thus represents a hybrid adaptation pathway, one that enhances resilience but requires careful institutional regulation to avoid maladaptive outcomes.

3.3. Enhancing Food Security and Ecological Resilience

Additionally, water security and agricultural resilience are other critical components of climate adaptation facilitated by CBOs. In response, CBOs have reintroduced Indigenous practices such as the *khadin* system (Fig. 6A*)*. This creates optimal conditions for sowing crops in the post-monsoon period, while also helping control soil erosion and increase biomass. Community involvement in constructing *khadins*, including the cofinancing of labor, is an important factor in influencing long-term sustainability. Agroforestry (Fig. 6B) initiatives play a critical role in restoring ecological balance by replenishing degraded communal lands, such as gochars (grazing commons) and Orans (sacred groves), with native grasses, including *dhaman* (*Cenchrus ciliaris*) and *sewan* (*Lasiurus scindicus*). These lands, managed by VDCs, are often placed under participatory and rotational grazing bans to facilitate ecological recovery. Additionally, the VDCs support the reintroduction of important tree species such as *khejri* (*Prosopis cineraria*), *neem* (*Azadirachta indica*), *babool* (*Acacia nilotica*), and *bordi* (*Ziziphus nummularia*) help stabilize the soil, increase the nutrient content, and provide vital resources like fodder, firewood, and fruit, thus reinforcing the socio-ecological integrity of the area.

Addressing food insecurity and malnutrition, especially among women and children, is also an important intervention under the leadership of local CBOs. Household kitchen gardens (Fig. 7*)*, typically featuring 15–20 plants, are cultivated near homes and irrigated with water from *taanka* systems. These gardens are protected by fencing and are primarily managed by women, thereby reducing their dependence on external food sources. Concurrently, GRAVIS and local CBOs have co-created community seed banks in partnership with the Central Arid Zone Research Institute (CAZRI). These local seed banks (Fig. 9) promote the use of locally adapted, native seeds selected for their drought tolerance and yield performance. After harvest, seeds are stored using traditional methods, such as in earthen pitchers alongside neem leaves and ash, and then redistributed to smallholder farmers who often lack access to formal seed markets. This cyclical model confirms the importance of genetic diversity and local sovereignty over agricultural inputs. These initiatives complement arid horticulture units (Fig. 8*)*, providing training and resources to cultivate drought-resistant fruits, such as lemons and pomegranates. Rainwater harvesting systems provide irrigation for these micro-orchards, increasing household nutrition and income.

Communities have also developed low-cost plant-care techniques in response to severe water shortages. For instance, placing covered earthen pots filled with water near plant roots helps reduce evaporation and maintain consistent moisture without requiring daily irrigation (Fig. 9*)*. Mulching, which involves using organic matter such as millet husks or grass clippings, helps conserve soil moisture, regulate soil temperature, and reduce weed growth, ultimately improving crop establishment during drought (Kader et al., 2019).

In wind-eroded landscapes like Tinwari (Jodhpur Rural), communities stabilize dunes by using brushwood barriers (Fig. 10*)*, followed by afforestation with native drought-resistant species such as *Acacia nilotica*, *Albizia lebbeck*, gum acacia, etc. Afforestation efforts not only combat desertification but also restore land for agricultural use. Communities support traditional ethnobotanical knowledge to meet their food and medicinal needs. Edible desert plants such as *khejri* (*Prosopis cineraria*), *ker* (*Capparis decidua*), *meethajal* (*Salvadora oleoides*), and *lassora* (*Cordia dichotoma*) provide essential nutrients during periods of scarcity, serving as both fodder and herbal remedies. A comprehensive number of edible species, preserved through oral tradition and community mapping, showcases the ecological wisdom embedded in local knowledge systems. By incorporating these species into their daily diets, communities enhance their resilience to food insecurity and promote biodiversity in one of the world's most challenging environments.

3.4. Gendered Challenges and Power Relations

While women make up nearly half of VDC membership and play vital roles within SHGs, field observations and focus group discussions indicate that decision-making authority is predominantly held by senior male members. Women's participation often appears to be symbolic, meeting institutional requirements without translating into meaningful influence over planning, beneficiary selection, or resource allocation. As one SHG member explained, "*We sit in the meetings and give our opinions, but the final decision is taken by the senior men.*" Similarly, during discussion in *Kalran*, women noted that, "*Our names are there in the committee, but planning works is mostly discussed by the men.*" Such accounts indicate that women's inclusion often meets representation requirements, yet their influence remains limited in practice.

Water-harvesting structures such as *taankas*, *naadis*, and *berrys* are situated within gendered property and governance frameworks, where men typically control decisions related to construction, financial flows, and maintenance oversight. In stark contrast, women engage with these systems daily.

Caste further exacerbates gendered inequalities in adaptation outcomes. Women from Scheduled Caste households reported increased difficulties in accessing shared water sources and participating in community deliberations, particularly in villages where customary hierarchies are deeply entrenched. In several villages, participants recalled that earlier water sources were segregated; as one elderly respondent noted, "*In old times, the berry (well) was only for one community. Others were stopped from taking water*." Women from lower-caste households also explained that limited access to formal water structures compelled them to create informal storage pits: "*We made small holes like a taanka by ourselves to collect rainwater. Whatever water we get, even if salty, we use it for everything*." Such accounts indicate that adaptation benefits are not distributed evenly; instead, caste status mediates both access to water infrastructure and voice within community governance structures.

SHGs have emerged as important, albeit limited, spaces for empowerment. Participation in savings and credit groups has enhanced women's financial autonomy, confidence, and collective identity, thereby enabling them to exert greater bargaining power within their households. However, translating this economic agency into ecological governance remains inconsistent. While SHGs facilitate discussions on water management and agriculture, their recommendations are rarely incorporated into VDC planning.

VOPAs and ILGs play a vital role in challenging existing hierarchies by legitimizing women's experiential knowledge, especially in areas such as traditional water practices, seed conservation, and ethnobotanical uses. Older women, in particular, act as custodians of ecological memory. However, their authority often remains informal and relies on social recognition rather than institutional backing.

3.5. Perceived challenges faced by CBOs

CBOs have the potential to facilitate climate adaptation and rural resilience within the Thar Desert. Their importance lies in reviving traditional practices and bridging external support systems to meet local needs. However, these grassroots institutions face complex challenges that threaten their operational effectiveness and long-term sustainability. One of the most pressing challenges identified is the erosion of institutional memory and traditional ecological knowledge. As community elders pass away without structured mechanisms to transfer their experiential learning, vital practices such as indigenous water harvesting, seed conservation, and traditional medicine are increasingly at risk of being lost. As one elderly VOPA member remarked, "*Earlier, we knew how to manage water with taanka and khadin without any outside help. Now the young generation does not learn these things*." The decline of oral traditions, the migration of the younger generation, and the influence of externally imposed development models have further exacerbated the intergenerational gap. A senior participant noted, "*Young people go outside for work. They are not interested in our old ways.*" While VOPAs and ILGs have tried to address this issue by institutionalizing intergenerational dialogue, they tend to have a limited reach and experience irregular engagement.

Financial variability poses an important challenge for CBOs. Many operate under chronic resource limitations, heavily relying on project-based funding or government schemes. This volatility in funding hinders long-term planning, restricts local infrastructure development, and limits the scope of training and capacity-building initiatives. Moreover, limited financial literacy among CBO members can aggravate the challenge, leading to suboptimal budgeting, weak accountability, and underutilization of available funds. VDC's leader in Phalodi also expressed frustration over the variability of financial support, noting that even well-designed climate adaptation projects are often placed on hold or stopped due to funding delays and administrative hurdles. As one VDC leader explained, "*When funds are delayed, work stops. Even if planning is complete, we cannot continue without money.*"

In addition, the financial constraint is a lack of technical capability. Although CBOs possess contextual knowledge and social connections, they often lack capabilities in key domains, such as climate science, sustainable agriculture, and water engineering. Many members have reported struggling to comprehend project documentation, comply with requirements, and work effectively with technical partners. One committee member shared, "*We understand our land and water, but when officials bring papers and technical terms, we cannot fully understand them.*" This skills gap undermines the quality and scale of interventions, leaving CBOs reliant on NGOs. Limited monitoring and evaluation mechanisms can also impact access to continued funding and institutional backing.

Additionally, gender and caste inequity are still significant barriers to inclusive adaptation. While women are officially represented in VDCs and SHGs, field observations suggest that women are often excluded from decision-making processes. For example, across multiple meetings in *Gagari*, *Bap*, and *Kalran*, women were physically present but seldom invited to speak, and key decisions, such as beneficiary selection or water management priorities, were often dominated by male elders. Patriarchal cultures with deep-seated biases affect women's ability to contribute to decisions around water management, even though their everyday lives are intricately and intimately connected with care and management of families, farms and livestock. One female SHG member described how her input was often ignored or dismissed at community meetings, even though women bear the heaviest burden of water scarcity-related challenges. She stated, "*We sit in the meetings, but final decisions are taken by the senior men.*" Such exclusion not only consolidates gender-based risks but also negatively affects the overall resilience of communities.

Other structural obstacles involve poor linkages to government agencies, irregular coordination with executing agencies, and weak health infrastructure. Most CBO representatives complained about the irregular or ineffective participation of local government officials, which has caused delays in project approvals and hindered access to welfare schemes. A VDC member commented, "*Officials come once, and then we do not see them again. Files remain pending for months.*" Additionally, high turnover rates of staff, poor training, and less than adequate time devoted to project activities weaken organizational stability and operating effectiveness. The lack of adequately equipped Primary Health Centres (PHCs) exacerbates communities' vulnerability, particularly in the context of climate-related health hazards such as heat stress, waterborne illness, and malnutrition. In the view of a member from Jodhpur's SHG, the unavailability of accessible health services significantly undermines the community's ability to recover from extreme climatic events and prolonged droughts. As one SHG member explained, "*When someone falls sick during heat or drought, we must travel far. There is no proper health centre here.*"

4. Discussion and Conclusion

This study finds that CBOs in the Thar Desert function as intermediaries linking indigenous ecological knowledge with formal climate adaptation frameworks. While they create institutional spaces for collective action and localized adaptation practices such as water harvesting and seed conservation, their effectiveness is shaped by entrenched gender hierarchies, caste dynamics, financial instability, and generational shifts in knowledge systems.

The results underscore the vital role that CBOs in the Thar Desert play as intermediaries between indigenous knowledge systems and formal adaptation frameworks (Mimura et al., 2014). By integrating climate responses into culturally legitimate institutions, CBOs facilitate socially acceptable, ecologically sound, and contextually resilient adaptation strategies. Unlike top-down interventions, these locally grounded approaches leverage the strengths of collective memory, customary governance, and the interdependence of community members (Abelieneh, 2017; Bonatti et al., 2013; Mehra, 2012; McClymont & Myers, 2012; Dumaru, 2010; Lasage et al., 2007; Dale, 2001; Weinberger & Jütting, 2001). In this sense, adaptation in the Thar Desert emerges not merely as infrastructural adjustment but as a negotiated social process mediated through community institutions.

The study reveals that the outcomes of CBO-led adaptation efforts are uneven and influenced by internal social dynamics. Persistent gender hierarchies continue to affect access to decision-making spaces. Although women are represented numerically in VDCs and SHGs, their participation often remains procedural rather than substantive. This situation mirrors Agarwal's (2001) distinction between nominal participation and effective participation, where mere

presence does not equate to genuine voice or authority. The gendered divide between experiential ecological knowledge and institutional authority aligns with Rocheleau et al.'s (1996) concept of a “gendered ecology of knowledge,” in which women’s environmental expertise is often undervalued within formal governance structures.

Similar trends have been documented globally. Meinzen-Dick et al. (2014) note that women's involvement in collective action yields positive outcomes only when institutional frameworks expressly support women’s leadership and decision-making power. In the Thar context, while CBOs enhance participatory spaces, adaptation processes remain entrenched in broader patriarchal and caste-based systems. From a feminist political ecology perspective, effective climate adaptation necessitates more than just numerical inclusion; it requires a redistribution of authority, recognition of gendered knowledge systems, and institutional mechanisms that address structural inequalities (Agarwal, 1997; 2010; Meinzen-Dick et al., 2014). Absent such transformations, community-based adaptation may inadvertently reinforce existing hierarchies, even as it seeks to tackle environmental stress.

Caste significantly influences the dynamics of adaptation. Access to shared water resources, platforms for deliberation, and institutional power continue to be shaped by customary hierarchies. This underscores that vulnerability to climate stress is not merely an ecological issue but is socially differentiated. Similar observations have been made in other South Asian contexts, where adaptation outcomes are influenced by existing power structures (Pandey et al., 2015). Therefore, understanding adaptation governance necessitates recognizing its operation within historically entrenched systems of stratification.

Another pressing challenge emerging from this study is the decline of traditional ecological knowledge and its intergenerational transmission. As elders pass away and younger generations migrate or shift their aspirations towards urban employment, the continuity of orally shared practices related to water management, seed preservation, and medicinal knowledge becomes increasingly fragile. This trend reflects broader changes linked to modernization and evolving cultural values (Inglehart & Baker, 2000; Pelling, 2010; Agrawal, 2020). Shifting aspirations and economic insecurity diminish the perceived value of collective stewardship and customary institutions, potentially undermining the social cohesion necessary for ongoing collective action. Similar tensions between modernization and community-based environmental governance have been recorded in African watershed initiatives (Abelieneh, 2017) and Latin American agro-ecological movements (Bonatti et al., 2013), where generational transitions affect the sustainability of local institutions.

Financial and technical limitations significantly influence the operational stability of CBOs. Their reliance on project-based funding hampers long-term planning and may restrict institutional autonomy once external support diminishes. Similar challenges have been observed in Kenyan sand dam projects (Lasage et al., 2007), where community-led initiatives are susceptible to changes in donor commitment. These cross-regional analyses indicate that, while community-based adaptation provides socially embedded pathways for resilience, its sustainability heavily relies on consistent institutional support and supportive governance frameworks.

Despite these challenges, the practices documented in the Thar Desert offer valuable insights for adaptation strategies in arid and semi-arid regions worldwide. Indigenous water harvesting techniques, such as *taankas* and *khadins*, seed conservation methods, and collective planning initiatives demonstrate how redundancy, ecological diversity, and culturally rooted norms can enhance adaptive capacity. Rather than supplanting traditional systems, effective adaptation frameworks might benefit from reinforcing locally legitimate institutions that already enjoy trust and participation.

Therefore, policy frameworks should go beyond viewing CBOs merely as implementing agencies for externally devised projects. They should be acknowledged as pivotal governance actors in adaptation planning and resource coordination. Strengthening CBOs requires enduring financial mechanisms, technical capacity-building, and institutional reforms that address gender and caste-based inequities. Legal recognition, enhanced connections with government departments, and mechanisms for the meaningful inclusion of marginalized groups are vital to ensure that community-based adaptation contributes not only to ecological resilience but also to social justice.

The experiences from the Thar Desert suggest that climate adaptation is most effective when anchored in place-based knowledge systems, collective institutions, and equitable governance structures. While community-based adaptation holds promise, it must be accompanied by structural transformations to guarantee that resilience-building efforts do not perpetuate existing inequalities, but instead promote inclusive and sustainable forms of environmental governance.

Declarations

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Author Contribution

Conceptualization: HS, SB, SPM, LC, PT: Formal analysis: HS and SB: Methodology: HS, SB, SPM, LC, PT; Writing draft: HS; Review and editing: HS, SB, SPM, and PT.

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Figures

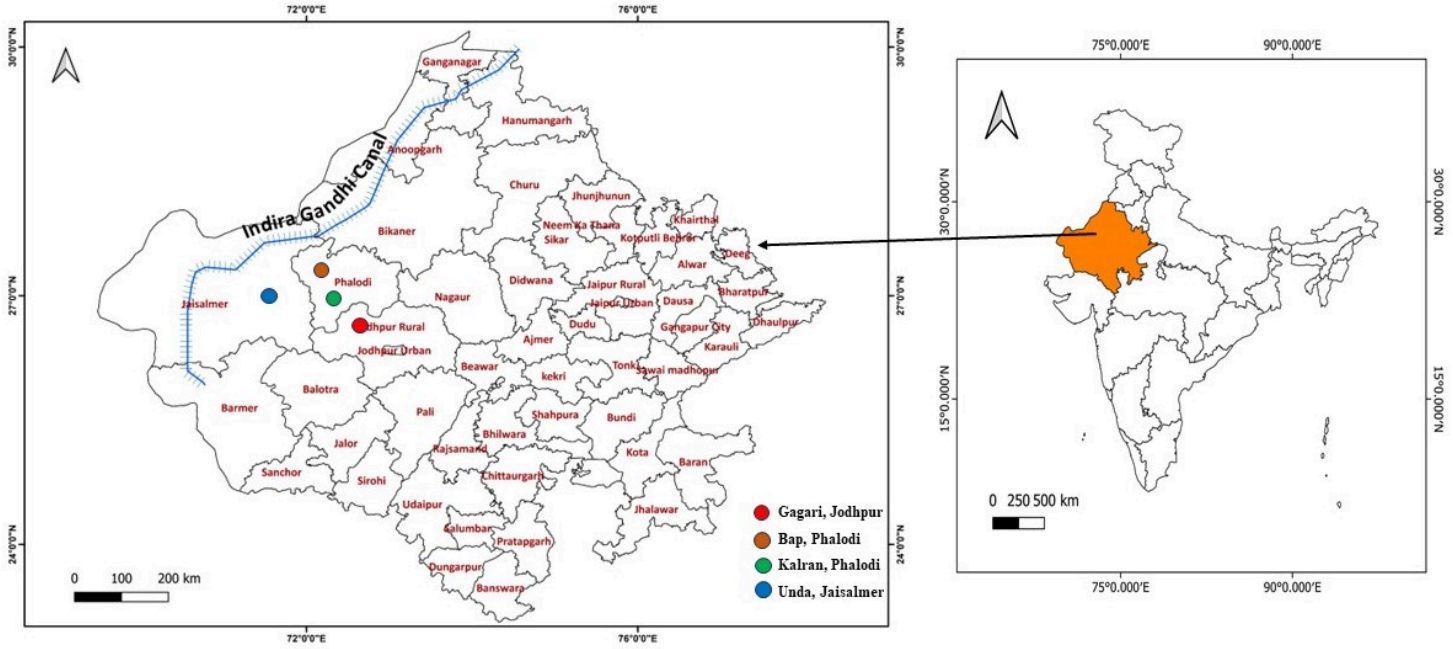


Figure 1

Location of targeted villages in the Thar Desert, Rajasthan, India.

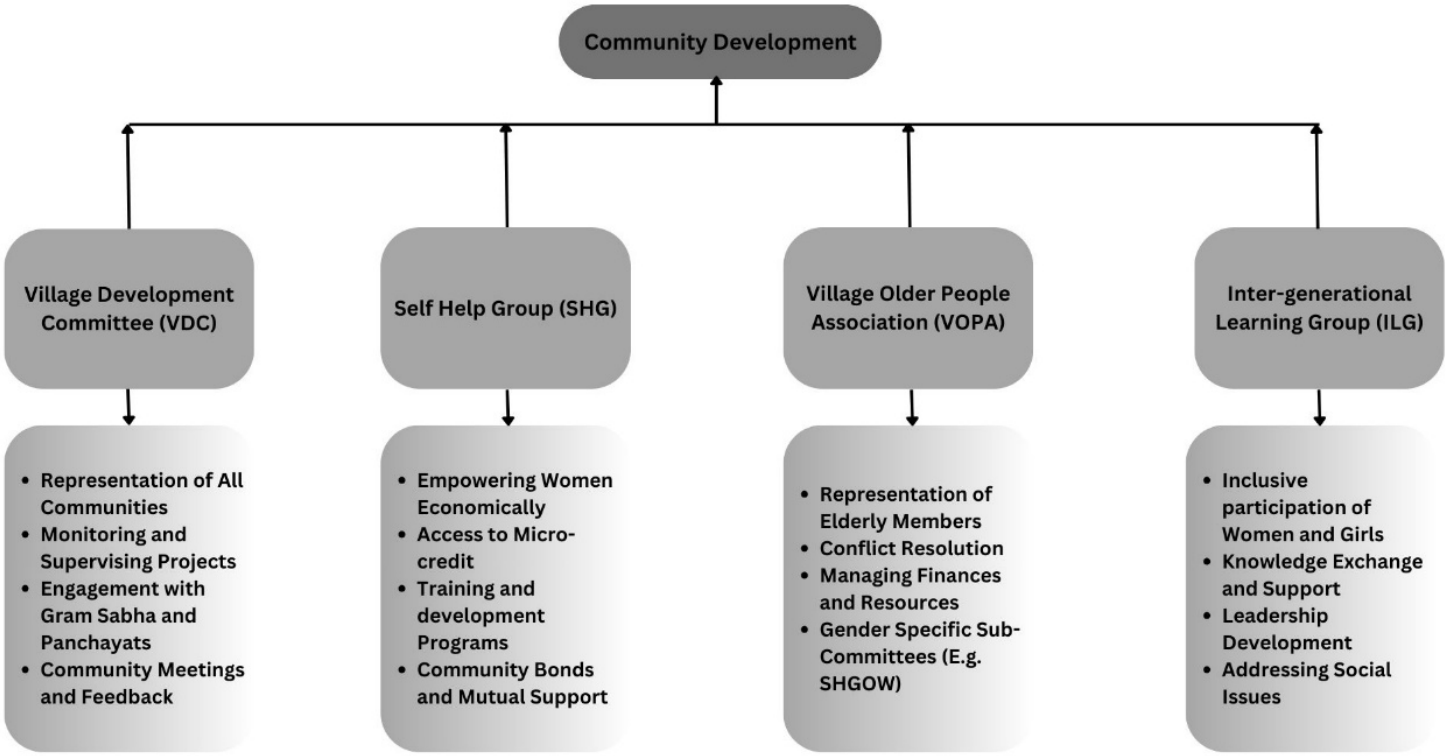


Figure 2

Role of CBOs in the community development for climate adaptation



Figure 3

-Taanka



Figure 4

A.*Naadi*&**B**. *Berry*



Figure 5

A. *Bio Sand Water Filter (BSWF)*; **B.***Diggi*



Figure 6

A. *Khadin;* B. *Agro-Forestry*



Figure 7

Kitchen Garden



Figure 8

Seed Collection by local peoples.



Figure 9

A. Arid Horticulture Unit; B. Utilizing small earthen pot for Plant Care.



Figure 10

Farming over Sand Dunes.

Supplementary Files

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