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Climate resilience in Tanzanian farming cooperatives: Adaptive strategies for food security

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Abstract

Smallholder irrigation schemes in Morogoro, Tanzania, underpin rice-based farming systems, which are further supported by maize, cassava, and small-scale trade. These households face recurrent flooding, waterlogging, and persistent pest infestations, which threaten crop yields and income stability. Using surveys (n = 192) and key informant interviews, the study examines how cooperative irrigation schemes foster climate resilience through governance, shared infrastructure, and training. Results show high exposure to hydrological hazards, moderate livelihood diversification alongside rice cultivation, and higher adoption of climate-smart practices among members who received cooperative training and access to pooled inputs. The study identifies three cooperative mechanisms, resource pooling (including shared inputs), learning systems (including training sessions), and financial intermediation (such as access to credit), that reduce adaptation costs and increase the uptake of drought- and flood-tolerant practices. The study argues that cooperative governance links individual, farm-level adaptations to create a cohesive, system-level resilience within the irrigation command area.

Keywords: climate-smart adoption, collective action, farmer organisation, hydrological risk, irrigation governance

1 Introduction

Climate change poses a significant threat to food security worldwide, but smallholder farmers in sub-Saharan Africa (SSA) face disproportionate risks due to institutional and resource constraints (Calvin *et al.*, 2023). Although national policies, such as Tanzania's National Adaptation Plan (UNDP, 2020), address broad mitigation, solutions based on collective action at the local level remain overlooked in sustainability science. Farmer cooperatives, a cornerstone of agrarian economies, can help bridge this gap by combining indigenous knowledge with institutional support. However, their potential as resilience multipliers has not been widely studied (Li *et al.*, 2024).

Tanzania's heavy reliance on rain-fed agriculture makes it particularly vulnerable to climate shocks, including erratic rainfall patterns, prolonged droughts, and severe flooding events (FAO, 2022). These climatic extremes are disrupting agricultural productivity and rural livelihoods across the nation (Anser *et al.*, 2023), with cascading effects on household food security and economic stability.

The Morogoro region exemplifies this vulnerability as one of Tanzania's most important agricultural zones. Recent studies have documented an increase in the frequency and intensity of climate disasters in the region, with floods accounting for 67 % of natural hazards (IMF, 2023). Severe floods have resulted in yield losses of up to 35 % (Kimambo *et al.*, 2019) and annual infrastructure damage of approximately \$1.5 million (FAO, 2022). At the same time, Tanzania has implemented various adaptation measures through its National Climate Change Strategy (URT, 2012) and the National Adaptation Plan (UNDP, 2020). However, smallholder farmers still face significant barriers, including limited access to technology, financial constraints, and inadequate institutional support. This study examines the UWAWAKUDA cooperative irrigation farming project.

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in Morogoro, Tanzania, investigating how cooperatives can institutionalise adaptive strategies in response to compound climate shocks. It also examines the governance mechanisms that enable the scalability of these strategies.

Although numerous studies have examined smallholder farmers' perceptions of and adaptive responses to climate change across SSA (e.g., Mkonda, 2015; Mulwa & Visser, 2020; Mentges *et al*., 2023), the emphasis has largely been on individual behaviours, technology adoption, or agroecological practices. Considerably less attention has been paid to farmer cooperatives as institutional platforms for adaptation. Furthermore, existing research is disproportionately concentrated in West Africa or presented through broad national-level analyses. In contrast, Tanzania, particularly cooperative irrigation systems within East African smallholder settings, remains underrepresented in empirical scholarship on climate adaptation. This gap constrains our understanding of how collective governance arrangements shape resilience and household food security in vulnerable farming systems.

This study addresses these shortcomings by examining the UWAWAKUDA cooperative irrigation scheme in Morogoro, Tanzania. It pursues three objectives: to identify key climate-related challenges across environmental, agricultural, and economic dimensions; to analyse the adaptive strategies adopted by cooperative members; and to assess the role of cooperative structures in strengthening climate resilience. In focusing on cooperatives as institutional mechanisms of adaptation, rather than on individual perceptions or generic strategies, the study contributes to a more nuanced understanding of collective resilience-building in SSA.

The study is framed by the theory of resilience and adaptive capacity (Folke *et al*., 2004), which provides a lens for understanding how farming systems withstand and recover from climate disturbances. The framework distinguishes between structural responses, such as infrastructure improvements, and adaptive responses, such as flexible farming practices; both are crucial for sustainable adaptation (Adger *et al*., 2005). By applying this theory to the cooperative context, the research offers novel insights into how collective action can strengthen smallholder resilience. Our work advances a social-ecological system perspective, which is critical for achieving Sustainable Development Goals (SDGs) 2 and 13, and fills a key gap: understanding how collective action transforms local adaptation into sustainable policy.

2 Materials and methods

This study employed a sequential mixed-methods approach (Creswell & Creswell, 2018) to comprehensively examine the impacts of climate change and adaptation strategies among UWAWAKUDA cooperative farmers in Morogoro, Tanzania. The design integrated quantitative surveys with qualitative interviews to provide both breadth and depth of understanding.

2.1 Sampling strategy

Purposive sampling was employed for three main reasons: (1) to capture information-rich cases of farmers with direct experience of climate change adaptation (Patton, 2015); (2) to ensure representation across gender, landholding size, and farming experience within the cooperative; and (3) due to logistical challenges in reaching randomly selected farmers across dispersed zones. A total of 192 respondents were surveyed, a sample size consistent with both the cooperative's membership and benchmarks from comparable adaptation studies (Mulwa & Visser, 2020). Pilot testing also confirmed that qualitative responses reached saturation.

2.2 Data collection

Primary data collection employed a triangulated approach combining quantitative surveys, qualitative interviews, and secondary data analysis. The quantitative component involved administering structured questionnaires face-to-face to all 192 participants. Three types of instruments were used: Likert-scale items measuring perceived climate impact severity (1–5); multiple-choice questions documenting adaptation strategy adoption; and open-ended questions capturing qualitative insights. The qualitative component involved conducting semi-structured interviews with four purposively selected key informants representing different stakeholder perspectives: a district cooperative officer (policy), a regional agricultural officer (technical), a cooperative farm manager (operations), and a lead irrigation specialist (adaptation techniques). Secondary data supplementation included meteorological records (2015–2022) from the Tanzania Meteorological Authority, annual cooperative production reports, and national climate adaptation policy documents. This enabled a temporal and contextual analysis of the observed climate patterns and policy implementation gaps.

2.3 Data analysis and ethical considerations

The study employed comprehensive analytical approaches for both quantitative and qualitative data. The quantitative analysis utilised descriptive statistics (frequencies/percentages) to profile demographic characteristics and climate impact patterns, while inferential statistics, including chi-square tests, examined relationships between adaptation strategies and farm characteristics. Logistic regression modelling identified socioeconomic predictors of successful adaptation. Qualitative analysis was conducted using MAXQDA (2022) software. This implemented Fereday & Muir-Cochrane's (2006) hybrid thematic approach, combining deductive coding aligned with resilience theory with inductive coding for emergent themes. Rigorous code validation was achieved through intercoder reliability checks of the analysis of key informant interviews.

The research received an ethical approval letter (Ref: MA.84/261/02/"A"/68/16) from the University of Dodoma (UDOM), with all participants providing written informed consent after receiving detailed explanations of study objectives, voluntary participation rights, confidentiality protections through anonymous data coding, and secure data storage protocols. This rigorous mixed-methods design facilitated both the statistical generalisation of climate adaptation patterns and a nuanced understanding of behavioural dynamics, while the strategic sampling approach ensured the representation of diverse farmer experiences within the cooperative's climate change challenges.

2.4 Rationale for method choices

This mixed-methods design was created to leverage the strengths of different approaches. Quantitative data revealed the rates at which farmers adopted adaptations and the statistically significant relationships among variables, while qualitative insights provided in-depth explanations of the underlying motivations and contextual factors influencing farmers' behaviour. This triangulation of methods enhanced the validity of the findings by cross-verifying results from different data sources. By integrating numerical patterns with narrative explanations, the approach enabled the identification of common trends across the cooperative and the understanding of localised adaptation dynamics. The methodology was meticulously crafted to balance scientific rigour with practical relevance, ensuring the generation of actionable policy insights while rigorously adhering to ethical research standards and respecting participant rights throughout the investigative process.

3 Results

This section presents the study's empirical findings, organised around household demographics, farm characteristics, income distribution, livelihood activities, climate hazards, adaptation strategies, and the cooperative's institutional role. The results draw on survey data (n = 192), key informant interviews (KIIs), and field observations. Emphasis is placed on how cooperative mechanisms shape the adoption of climate-smart practices and strengthen members' resilience.

3.1 Study context: The cooperative and irrigation system

The study was conducted at the UWAWAKUDA Irrigation Cooperative in Mvomero District, Morogoro, Tanzania. The scheme operates a single rice-growing season (March–July) and relies on gravity-fed irrigation from the Wami River. Most members cultivate 0.4 to 2 ha under irrigation and rely on limited household labour.

The cooperative provides collective services, including bulk input procurement, farmer training, and the operation and maintenance (O&M) of canals. It has 287 members (53.7 % male; 46.3 % female) and is governed by an elected Board of Directors, an Annual General Meeting (AGM), and professional staff (Manager, Farm Manager, Accountant, Business & Marketing Officer, and Internal Auditor). Rice is the dominant crop (100 % of households), whereas maize (16 %) and cassava (5 %) are supplementary crops. Some households engage in bodaboda transport (15 %), fishing (5 %), and food vending (2 %) for additional income. The irrigation command area comprises 250 ha of demonstration plots and approximately 2,500 ha of surrounding farmland, supported by TARI Dakawa.

Governance is anchored in an Annual General Meeting (AGM) and an elected Board of Directors, supported by professional staff (Manager, Farm Manager, Accountant, and Business and Marketing Manager) and an Internal Auditor (Table 1). Key farming activities follow a fixed calendar: land preparation (March), transplanting (April), and harvesting (July).

A cooperative leader explained:
"Our system depends on collective effort. Members contribute labour and fees for canal cleaning and water allocation. Without this, floods and blockages would make rice farming impossible". (Board Chair, KII)

3.2 Household and farm characteristics

Household demographics influence adaptive capacity through labour availability, education, and gendered participation in cooperative activities. The surveyed households represent a subset of the broader UWAWAKUDA membership. While the cooperative's registry shows near gender parity (see Section 3.1), the survey sample contained a slightly higher share of male respondents, reflecting men's predominance in land ownership and decision-making roles.

Table 1: *Study context and system background.*

Domain	*Indicator*	*Value / Description*
Farms	Mean household size (persons)	1–3 members (63.5 %), 4–6 members (26.5 %), >7 members (10 %)
	Median cultivated area (ha)	1–5 ha (majority). Equitable access for men and women
	Share under irrigation (%)	Rice is the main irrigated crop; one irrigated season (March–July); Wami River water
Cooperative	Total members (M/F, %)	154 males (53.7 %), 133 females (46.3 %)
	Services	Seed/fertiliser; training; operational and maintenance of irrigation; marketing facilitation
Irrigation	Command area (ha)	250 ha demonstration plots; 2,500 ha research land base (TARI Dakawa) supported by TARI Dakawa
	Canal structures	Intake + drainage; maintained under O&M protocols
Crops	Main irrigated crop(s)	Rice (dominant, 100 % of households)
	Secondary crops & activities	Maize, cassava; fishing (5 %); bodaboda transport (15 %); food vending (2 %)
Calendar	Key operations	Land preparation in March; transplanting in April; harvest in July

Survey results indicate that most member households are small and have limited formal education, which constrains labour supply during peak agricultural periods and affects the acquisition and adoption of new practices (Table 2). Marital status patterns suggest that household responsibilities and access to resources vary across groups, with implications for participation in training and collective work. As noted by one irrigation officer:
"Low education limits how quickly farmers grasp and adopt improved methods, so field demonstrations are essential for learning." (Irrigation Officer, KII)

Table 2: *Demographic characteristics of respondents (N = 192).*

Variable	*Category*	*Percentage (%)*
Sex	Male	64.6
	Female	35.4
Education	Primary	90.1
	Secondary+	9.9
Marital status	Single	10.4
	Married	50.0
	Divorced	25.0
	Widowed/Widower	14.6

3.3 Household income

Monthly household income varied widely (Table 3). Most respondents fell within the mid-income range (approximately TZS 301,000 – 400,000), indicating moderate but uneven capacity to invest in adaptive measures.
"Floods destroy our crops, and those with savings can replant, but poorer households just wait for the next season." (Farmer, FGD)

Table 3: *Monthly household income (N = 192).*

Monthly income (TZS)	*Equivalent (USD)*	*Percentage (%)*
100k–200k	43–87 $	13.0
201k–300k	88–130 $	28.0
301k–400k	131–174 $	47.0
401k–500k	175–217 $	12.0

3.4 Livelihood activities

Livelihoods were primarily anchored in irrigated rice production, reported by all members. Rice production was widespread, and 7.8 % of households engaged in off-farm trading. Secondary activities included maize production (16.1 %), cassava (5.2 %), fishing (5.2 %), motorcycle (bodaboda) transport (15.1 %), and food vending (2.1 %). Other small-scale trades and casual labour accounted for 4.2 %. Table 4 provides a breakdown of livelihood activities. These patterns reveal modest diversification, with farming remaining the backbone of livelihoods, underscoring the limited diversification that constrains adaptive flexibility. As one respondent explained:
"When rice fails, some members ride bodaboda or sell fish, but these activities are small. Rice is everything here." (Farmer, KII)

Table 4: *Livelihood activities of cooperative members.*

Livelihood activity	*Percentage (%)*
Rice production (on-farm)	100
Rice trading/marketing (off-farm)	7.8
Maize production	16.1
Bodaboda services	15.1
Fishing	5.2
Cassava production	5.2
Food vending	2.1
Other (petty trade, casual labour, etc.)	4.2

3.5 Climate challenges

All respondents experienced flooding and crop damage (Table 5). Flooding was universal and often caused crop damage, delayed planting, and infrastructure loss. Secondary effects included waterlogging, erosion, and pest or disease outbreaks. During the January–April 2025 floods, about 15 % of the irrigated command area was damaged.
"This year the floods covered more than 280 ha. Even if you had seed, you could not plant. We had to wait until the water drained." (Farm Manager, KII)

Table 5: *Climate hazards reported by cooperative members.*

Domain	*Hazard*	*Percentage (%)*
Environmental	Flooding	100
	Waterlogging	37.5
	Soil erosion	25.0
Agricultural	Crop damage	100
	Delayed planting	100
	Pest/disease outbreaks	56.8
Economic	Infrastructure damage	100
	Increased costs	100

3.6 Adaptation strategies

Farmers employed multiple environmental and agricultural strategies to reduce climate risks (Table 6). Drainage maintenance was the most common environmental measure, while use of tolerant seed varieties and adjusted planting calendars were key agricultural responses.

Economic diversification into maize, cassava, fish farming, and small enterprises provided partial buffers, though these activities remained secondary. Institutional support was critical: over half of the members had received adaptation training, and collective canal maintenance involved the vast majority.

Table 6: *Adoption strategies of UWAWAKUDA cooperative members.*

Domain	*Strategy / indicator*	*Adoption / participation (%)*
Environmental	Drainage maintenance	83.0
	Water harvesting	39.0
	Conservation agriculture	22.0
Agricultural	Tolerant seed varieties (drought/flood resistant)	56.0
	Adjusted planting calendar	48.0
	Crop rotation	32.0
	Integrated Pest Management (IPM)	29.0
Economic	Diversification of crops and non-farm activities	16.0
Institutional	Received climate adaptation training	57.6
	Training effectiveness	64.0
	Financial literacy & governance training	*
	Participation in joint canal maintenance	92.0
Cooperative effect	Training: adopters of ≥1 practice (trained vs. not trained)	72 vs. 38
	Input access: adopters of ≥1 practice (access vs. no access)	69 vs. 41
	Tenure: adopters of ≥1 practice (≥3 yrs vs. <3 yrs)	66 vs. 43

Adoption of at least one climate-smart practice was strongly linked to cooperative support. Members with training, input access, or longer tenure showed markedly higher adoption rates than others. As one member explained:
"If the cooperative did not organise canal cleaning, each farmer would suffer alone. Together we keep the water moving." (Member, KII)

3.7 Cooperative role in building climate resilience

The UWAWAKUDA cooperative functioned as the central institution aligning household coping strategies with broader climate-adaptation efforts. Its contribution was strongest in four areas: knowledge and training, access to resources, collective action, and governance.

Knowledge and training

Survey data show that 57.6 % of members received climate-adaptation training, with 64.7 % rating it very effective, 33.5 % moderately effective, and 1.8 % ineffective. Additional training covered good agricultural practices, financial literacy, and cooperative governance. Demonstration plots established with the National Irrigation Commission reinforced these lessons. As one member noted:

"When we see new seed, varieties tested on the demonstration plots, we can compare and decide to use them on our farms." (KII)

Access to resources and services

Cooperative inputs reduced adoption barriers. Members with access to inputs had a higher uptake of at least one climate-smart practice (69 %) than those without (41 %). Adoption was also higher among members with more than three years of tenure (66 %) compared to newer members (43 %). Credit and weather-indexed insurance provided additional security, enabling farmers to replant after losses.

Collective organisation and action

The cooperative coordinated joint water and infrastructure management, with 92 % of respondents participating in canal maintenance across the scheme's 2000 ha. During the January–April 2025 floods, about 300 ha (15 %) were affected, but recovery was accelerated through pooled labour and shared costs. As one officer stated: "Floods damaged hundreds of acres, but because we cleaned canals together, we restored water flow and replanted quickly." (Farm Manager, KII)

Governance

Decision-making was anchored in the AGM and an elected Board, supported by professional staff and overseen by an Internal Auditor. These structures enhanced accountability and facilitated collaboration with partners, including the National Irrigation Commission and TARI Dakawa.

4 Discussion

This section interprets the study's findings within the broader discourse on smallholder adaptation and cooperative governance. Results indicated that hydrological risks, particularly recurring flooding and waterlogging, are the principal constraints to irrigated rice farming in UWAWAKUDA. Consequently, farmers' adaptation strategies centred on drainage maintenance, adjustments to the planting calendar, and varietal selection. These outcomes reflect regional trends showing that in African irrigation systems, water variability and excess moisture often pose more immediate threats than temperature rise (Mentges *et al.*, 2023).

4.1 Study context, household and farm characteristics

The household and farm-level characteristics revealed by the survey illustrate both structural vulnerabilities and pathways for resilience. The predominance of small households (1–3 members) suggested labour constraints during peak agricultural periods, particularly for rice cultivation, which is a labour-intensive activity. However, smaller households may also be able to coordinate decisions more efficiently, a factor highlighted in adaptive capacity frameworks that link household size to adoption efficiency (Fazey *et al.*, 2007).

Low educational attainment (90 % with only primary schooling) limited the ability to interpret technical climate information, a constraint also observed in other smallholder settings (Li *et al.*, 2024). However, UWAWAKUDA's reliance on demonstration plots and farmer-to-farmer learning appeared to offset this disadvantage by embedding training in practical contexts. Similarly, the income distribution results, with concentration in mid-income groups and 13 % at the bottom, revealed stratified adaptive capacities. Without cooperative pooling of resources and bulk procurement, low-income households would face prohibitive input costs. This finding aligns with OECD (2022), which positions cooperatives as mechanisms for equalising access and reducing entry barriers to adaptation.

Livelihood diversification, through activities such as maize and cassava farming, bodaboda transport, and petty trade, provided partial buffers against agricultural shocks. This corresponds with the literature, which emphasises diversification as a resilience pathway (Mulwa & Visser, 2020). However, the limited scale of non-farm income in UWAWAKUDA confirmed that diversification alone is insufficient; stability of irrigated rice production remains central.

Taken together, these characteristics indicated that while UWAWAKUDA households faced constraints in labour, education, and income, cooperative membership mitigates these vulnerabilities by providing institutional support, thereby reinforcing their adaptive capacity.

4.2 Climate change challenges

The universality of reported flooding and crop damage underscored the exposure of irrigated rice systems to hydrological extremes. Members' accounts of prolonged rainfall and rising preparation costs illustrated how climate variability directly disrupts farming cycles. These findings resonate with resilience theory's definition of adaptive capacity as the ability to absorb disturbances while maintaining function (Mentges *et al.*, 2023).

The study reveals cascading climate risks. Floods trigger waterlogging and erosion, delaying planting, encouraging pest outbreaks, and reducing incomes. Such multi-domain impacts are consistent with evidence from East African irrigation schemes where climate shocks reverberate through production, markets, and household welfare simultaneously.

4.3 Adaptive strategies

The adoption of climate-smart practices, including tolerant varieties, adjusted planting calendars, crop rotation, IPM, drainage maintenance, and water harvesting, demonstrates that households are not passive recipients of climate stress. Adoption rates were substantially higher among members with cooperative training, access to input, or longer tenure. This pattern reflects resilience scholarship, which emphasises that institutions reduce transaction and learning costs, thereby accelerating the diffusion of adaptive innovations (Li *et al.*, 2024).

Economic adaptations, such as fish farming, bodaboda services, and agro-processing, reflected efforts to diversify income streams, although their scale is modest. Here, too, cooperatives played a mediating role by enabling access to credit and piloting weather-indexed insurance, echoing the OECD's (2022) findings that financial instruments enhance recovery capacity.

4.4 The role of the cooperative in building climate resilience

The UWAWAKUDA case illustrated how cooperatives act as resilience platforms that transform fragmented household coping strategies into system-level adaptation. Their role was evident in four dimensions. First, they served as knowledge brokers, providing training in adaptation, agronomy, financial literacy, and governance, while reinforcing these skills through demonstration plots. This aligns with Fazey *et al.* (2007), who emphasise iterative learning as central to adaptive capacity.

Second, cooperatives functioned as resource mobilisers, reducing adaptation costs through pooled procurement of inputs and access to financial services. OECD (2022) similarly highlights cooperatives as critical intermediaries for delivering credit and insurance at scale.

Third, they enabled collective action, especially in canal maintenance and flood response. Evidence from UWAWAKUDA indicates that 92 % of members participated in joint operations and maintenance (O&M), thereby enabling rapid recovery of water distribution systems. This supports Kulkarni's (2020) observation that cooperatives convert fragmented coping strategies into coordinated responses.

Finally, governance structures, AGMs, elected boards, professional staff, and external linkages provided institutional legitimacy. Partnerships with agencies like the National Irrigation Commission and TARI Dakawa ensured that technical and policy support were integrated into local adaptation. This echoes Araya *et al.* (2024), who argue that institutional legitimacy sustains cooperative-led adaptation over time.

Generally, the UWAWAKUDA cooperative exemplifies how collective institutions mediate climate resilience in smallholder irrigation systems. Through mechanisms of knowledge sharing, pooled resource access, collective action, and legitimate governance, the cooperative converts individual coping efforts into coordinated adaptation. These insights underscore the importance of embedding cooperative models within national strategies for climate-resilient agriculture.

5 Conclusions and policy implications

This study illustrates that smallholder rice farmers in Morogoro operate in a high-risk environment, where recurrent flooding and waterlogging challenge productivity and livelihoods. Cooperative membership in UWAWAKUDA helps transform individual coping efforts into coordinated, system-level resilience, reinforcing the stability of irrigation-dependent food systems.

The findings underscore the broader importance of institutional mechanisms in smallholder adaptation. Cooperatives serve as platforms for shared infrastructure management, collective learning, and financial facilitation, enabling households to overcome structural constraints such as limited labour, low income, and minimal education. By connecting farm-level practices into a cohesive system, these institutions enhance both the effectiveness and reach of adaptation strategies.

Policy implications include:

- Investing in cooperative-managed infrastructure maintenance, with accountability-linked incentives, to ensure functional irrigation networks.
- Strengthening inclusive training programmes that integrate climate information and field demonstrations, with attention to women and new members.
- Facilitating cooperative-based bulk procurement of climate-resilient inputs to reduce costs and broaden access.
- Promoting financial instruments, such as credit and weather-indexed insurance, through cooperatives to enhance risk management.
- Institutionalising monitoring systems at the scheme level to guide adaptive planning and track performance.

Taken together, these measures position cooperatives as critical instruments for embedding resilience into smallholder irrigation systems. The UWAWAKUDA experience offers a transferable model for similar hydrological and institutional contexts across sub-Saharan Africa, where coordinated adaptation is key to sustaining agricultural productivity and livelihoods under climate variability.

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Data availability statement

Data will be made available on request.

Conflict of interest

The authors declare no conflict of interest.

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