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Climate change, collective shocks, and intra-community cooperation: Evidence from a public good experiment with farmers and pastoralists☆

Alexandra Krendelsberger[a,b,c,1,*], Francisco Alpizar[a], Mame Mor Anta Syll[d], Han van Dijk[b]

[a] *Environmental Economics and Natural Resource Group, Wageningen University and Research, The Netherlands*
[b] *Sociology of Development and Change Group, Wageningen University and Research, The Netherlands*
[c] *International Center for Tropical Agriculture (CIAT), Dakar, Senegal*
[d] *Department of Economics, University Gaston Berger, Senegal*

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ABSTRACT

Scholars and practitioners have long debated the effects of climate change on conflict, and more specifically on its precursors and constituent elements, such as (un)cooperative behavior. While harshening conditions linked to climate change carry collective risks that simultaneously affect whole communities and societies, the underlying conditions and responses might differ between groups and affect cooperative outcomes. In this paper, we explore whether collective and individual shocks undermine or enhance cooperation within farming and pastoral communities in the increasingly difficult conditions of the Sahel. We conducted a lab-in-the-field experiment based on a public good game in a farming area and pastoral area in Senegal. This study finds that (i) on average, pastoralists show higher levels of cooperation compared to farmers, (ii) overall, collective shocks decrease cooperation, while individual shocks increase cooperation, and (iii) effects of individual versus collective shocks are only significant for pastoralists but not for farmers. We suggest that individual shocks lead to more cooperation due to risk-sharing mechanisms, while collective shocks reduce cooperation due to risk aversion. Pastoralists' higher cooperation levels may be attributed to lower market integration, stronger reliance on social and trading networks, and greater prior exposure to collective risks. These results suggest that risk perceptions and contextual factors, in addition to the nature of the shock, influence responses to climate change. Pastoral areas, while more vulnerable to collective shocks, may also have greater potential for public good provision, which could serve as a potential entry point for climate change adaptation.

1. Introduction

Climate change has been projected to have a continuing disrupting effect in Africa, affecting agriculture-dependent livelihoods of small-scale farmers, pastoralists, and fishermen (IPCC, 2021). Climate change impacts are reflected in the increasing occurrences of extreme weather events, having damaging effects on small-holder agriculture and decreasing crop and livestock production (Clarke et al., 2022; Nelson et al., 2013; Stige et al., 2006; Wollburg et al., 2024). In West Africa, climate change is predicted to produce yield variabilities from −50 % to + 90 %, with projected yield losses of −18 % (Roudier et al., 2011). For pastoralists, changes in rainfall patterns affect the composition of herbs in pastures with even larger variability in the availability of pasture (Thornton et al., 2009). In addition, increases in average temperatures are predicted to pose water stress on crops and grasslands and impair metabolic processes responsible for plant growth (Kemp et al., 2022; Tubiello et al., 2007). In this context, relationships between farmers and pastoralists in the Sahel have started receiving mounting attention, as contemporary land-use arrangements are under pressure with changing climatic, as well as, social and economic conditions (Benjaminsen & Ba, 2019; Brottem & Turner, 2024).

Historically, sedentary farmers and semi-nomadic pastoralists have been co-dependent on cooperative arrangements in the form of exchanges of animal products for cereals, manure, and labor (Bukari et al.,

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* Corresponding author at: Wageningen School of Social Sciences, Wageningen University & Research, Hollandseweg 1, 6706 KN Wageningen, the Netherlands.
E-mail addresses: alexandra.krendelsberger@gmail.com (A. Krendelsberger), francisco.alpizar@wur.nl (F. Alpizar), mamemorantasyll@gmail.com (M.M.A. Syll), han.vandijk@wur.nl (H. van Dijk).
[1] ORCID-ID: https://orcid.org/0009-0004-9419-229X.

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2018; Moritz, 2010). Simultaneously, disputes between these groups have been occurring over crop damage, water and grazing opportunities (Brottem, 2016; Turner et al., 2011), and are receiving increasing attention over fears of further escalations of conflicts in the region (Brottem, 2020; Charbonneau, 2022). Yet, much less is known about the current dynamics of cooperation within each of these two inextricably linked communities, and even less about their reactions to increasing climate-related, political, and socio-economic risks. Understanding such reactions is key to preventing conflicts between these communities. This paper uses farming and pastoral communities as contrasting case studies to explore the intra-community response to external risks.

More broadly, intra-community cooperation is vital for sustainable and resilient development where formal institutions are largely absent (Aldrich & Meyer, 2015; Ostrom, 1990). This is of particular importance in low- and middle-income countries dealing with grave risks, such as extreme events posed by climate change (Aldrich, 2012). Carmen et al. (2022) stated that enhanced social capital can lead to resilience through intra-community bonding, and increased psychological and material support as strategies to cope with crises. To have a large set of risk-coping strategies available requires community members to interact and cooperate with each other (Béné et al., 2016). Examples of how agricultural communities hedge against risks are communal grain storages that effectively spread out risk over various farming households, and agricultural cooperatives collectively managing resources and providing insurance networks against individual-level risks (Kazianga & Udry, 2006; Kimball, 1988). As a result, cooperative intra-community interactions and resilience to risks can build stronger social cohesion within communities and limit the likelihood of inter-community conflict.

However, what if risks are not easily pooled because they are collective and co-varied risks that affect whole communities at once? A key characteristic of many disruptive, climate-related events, is that they carry collective risks affecting many individuals and whole communities simultaneously. The consequences of collective shocks such as droughts, heavy rainfall, and dry-spells, may go beyond their direct, weather-related effects. They can create lasting natural resource scarcities, abrupt changes in food prices, sharp rises in fertilizer and animal feed prices, and potentially trigger sudden outbreaks of conflicts (Burke et al., 2015; Hsiang et al., 2013; McGuirk & Burke, 2020).

In some cases, collective shocks have found to reduce cooperation in local public good provision (Cárdenas et al., 2017) and to decrease resource conservation efforts in groups under uncertainty (Safarzynska, 2017). In other cases, improved community resilience and reduced conflict-risk have been observed in the aftermath of natural disasters (Cassar et al., 2017; Slettebak, 2012) and environmental uncertainty stimulated cooperation in common pool resource dilemmas (Finkbeiner et al., 2018; Schill & Rocha, 2023) and created higher social cooperation in response to climate risk (Buggle & Durante, 2021). The variations observed across these findings indicate that possibly contextual factors are driving different cooperation outcomes. To our knowledge, no study up until now has systematically compared decision-making processes under different types of risk in contrasting social and geographic environments.

In this study, we explore whether collective shocks, such as climate-related shocks, for instance, affect intra-community cooperation within farming and pastoral groups in their distinct contexts. To address the outlined knowledge gaps, we conducted a lab-in-the-field experiment in a farming and a pastoral area in Senegal; both shaped by their different social and ecological characteristics. We measure changes in cooperative outcomes in responses to two types of shocks – individual and collective – by altering the standard parameters of the public good game and including a 50 % chance for individual and collective shocks, respectively.

Overall, we find that participants in the pastoral area show higher levels of cooperation in the public good experiment in individual and collective shock groups compared to participants in the farming area. On average, individual shocks lead to higher, and collective shocks lead to lower, levels of intra-group cooperation. When disaggregated, the effects of both types of shocks are only significant for participants in the pastoral area, not in the farming area. Our contributions are two-fold. We provide evidence on how shocks affect the decision-making of farmers and pastoralists in diverse contexts and provide various reasons for their differences in responses. Moreover, while most literature studies conflict between farmers and pastoralists, we provide a closer insight into understanding intra-community and contextual factors affecting cooperation within these two groups when facing decision-making under individual and collective risks. The breakup of intra-community and inter-community cooperation is a precursor of conflict, and a better understanding of the former will allow a better handling and prevention of the latter.

2. Background literature and hypotheses

Many studies have shown that the geographic and social environments affect social norms and pro-social attitudes (Gneezy et al., 2016; Kosse et al., 2020; Prediger et al., 2014; Szekely et al., 2021; Voigt, 2023) and ultimately community resilience (Adger, 2000). Examples of social environments include Gneezy et al., (2016), who studied differences in cooperation levels among lake fishermen and open sea fishermen, and concluded that fishermen in the open sea cooperate more as the workplace of open sea fishing requires joint work on large open sea boats, rather than individual lake fishing on small boats. Prediger et al. (2011) explored differences in cooperation between farmers in Namibia and South Africa with the same ethnic origins but different ecological and historical conditions, and found that Namibian resource users with a more sensitive system to over-grazing show higher levels of cooperation. As farmers and pastoralists have geographically and socially distinct spheres of operation, their reactions to shocks likely differ and possibly affect the interactions between them.

Although farming and pastoral communities inhabit different agro-ecological zones suitable for their livelihood production, they do not act in isolation. Farmers and pastoralists are connected in their livelihoods when pastoralists conduct their seasonal herd migrations in search of fresh pastures (Turner et al., 2011). Usually, farmer-herder relations are characterized through exchanges of animal products, cereals, and manure are cooperative, however, with increasing pressure on land-use arrangements, livestock can cause more crop damage than usual and create conflicts between these groups (Brottem, 2016; Moritz, 2010). As farmer-herder conflicts are increasing in numbers (Brottem, 2020; Turner et al., 2011; Walwa, 2020), diverse responses to shocks among farmers and pastoralists could possibly explain the reduction in intra- and inter-community cooperation.

2.1. Hypotheses

Departing from shocks whose risk is characterized as individual or idiosyncratic, the existing literature frequently highlights risk sharing as an active strategy to navigate such risks (Attanasio et al., 2012). Risk sharing is a form of social insurance and has been extensively documented in theoretical and empirical studies (Barbet et al., 2020; Charness & Genicot, 2009; Kimball, 1988; Suleiman et al., 2015). In developing countries, we observe that household incomes are characterized by large variations, while consumption is relatively constant. This points to the importance of informal risk-sharing networks, as formal insurance is largely absent in these contexts (Fafchamps & Lund, 2003). For example, in the case of communal grain storages, a group risk-sharing system, farmers benefit from avoiding selling their whole output at low prices immediately after harvest and instead sell later when prices are more favorable, and effectively spread out risks of post-harvest losses over various producers (Aggarwal et al., 2018). Generally, a reciprocal relationship underlies risk-sharing arrangements, although altruism towards peers through shared social identity – as through kinship links – inequality aversion, and social norms have been demonstrated as important factors (Barbet et al., 2020; de Weerdt & Fafchamps, 2011; Fafchamps, 2011). We hypothesize that:

H1: Individual shocks increase cooperation in a public good experiment.

In the case of collective risks, scholars have so far been unable to predict unerringly under which circumstances collective risk will either increase or reduce cooperation. Some studies find positive effects of collective risks on cooperation, for instance, in the context of natural disasters (Cassar et al., 2017) and common pool resource dilemmas (Finkbeiner et al., 2018; Safarzynska, 2017). Other studies suggest negative effects of collective shocks on cooperation (Andrews & Marcoul, 2023; Cárdenas et al., 2017). Several factors moderate these effects, such as the nature of the shock – high versus low perceived risk – as well as the measure of cooperation. Castillo et al. (2011) highlighted that extreme shocks undercut cooperation, while minor shocks can help cooperation. In the case of the Sahel, most shocks can be regarded as extreme and collective shocks given the high-risk environment with large co-variance of risks inducing vulnerability and increasing hazard exposure. We hypothesize that in the case of correlated risks and therefore the absence of risk hedging opportunities with other individuals,

H2: Collective shocks decrease cooperation in a public good experiment.

Further, we investigate whether individual shocks affect cooperation differently for farmers and pastoralists. It has been suggested that in heterogeneous geographic areas more possibilities for risk sharing are present than in homogeneous geographic areas (Buggle & Durante, 2021; Gelfand et al., 2011; Platteau, 1991). For instance, farming areas typically provide more diverse agricultural income opportunities including the planting of various crop varieties, integrating crop and livestock systems, and a better connectedness to markets and paved roads, necessary for the distribution of agricultural produce. On the other hand, the pastoral drylands are more spatially homogeneous areas characterized by vast pastures and sparsely populated areas. Individual risk is low, as it is intrinsically moderated by anticipated redistribution of livestock, for example in cases of marriage or death, but is limited to the same kin (van Dijk, 1994). Therefore, it seems that risk sharing is more likely to occur in farming societies and is of less relevance in pastoral societies.

H3: Farmers increase cooperation more in response to individual shocks compared to pastoralists.

Next, we turn to collective risks and outline our expectations for pastoral populations. In the case of Fulani pastoralists in Mali, Van Dijk (1994) found that in "uncertain ecological environments where the risk of herd depletion is highly correlated from one individual to another, the scope for pooling of risks via transfer of livestock is limited". This implies that, for instance, asset redistribution in the form of reallocating livestock is uncommon in practice, and for a rational pastoralist there is little incentive to behave altruistically in times of collective risk. Kazianga & Udry (2006) reported that no collective risk-sharing mechanisms, such as using livestock as buffer stock for redistribution, were observed during the 1980 s drought in Burkina Faso. A more common practice among pastoralists to cope with unpredictable fluctuations in resource supply is herd mobility (Bollig & Göbel, 1997). As the covariance of risks is high in a geographically homogeneous area such as the Sahel, the only risk pooling mechanism is the spreading of risk over a wider geographic zone or engaging in risk-diversifying activities. Following the arguments above, we assume that in geographically heterogeneous areas more risk-sharing is possible. Therefore, farmers living in more heterogeneous areas would be more cooperative when faced with covariate risks compared to pastoralists, as the latter inhabit highly homogeneous areas in which no collective risk hedging is feasible.

H4: Pastoralists reduce cooperation in response to collective shocks more than farmers.

3. Materials and methods

For this study, we chose a lab-in-the-field experiment as it allows us to draw conclusions from a controlled environment in a specific context in the field (Cardenas et al., 2009; Castillo et al., 2011). We use a public good game to obtain our data, as it serves as a proxy measure for understanding and building public policies. We first play a standard public good game and subsequently, in two treatment arms, alter the standard public good game by either adding an individual or a collective shock to the equation.

3.1. Standard public good game

For our baseline measure of cooperation, we implement a standard version of a public good game (PGG), played in teams of 2. Both players simultaneously decide on their respective contributions to the "private fund" and "public fund", the latter being our measure of cooperation. The individual's payoff structure is given by:

$$\pi_i = (E - g_i) + 0.75^*\left(g_i + g_j\right) \tag{1}$$

$$\pi_j = \left(E - g_j\right) + 0.75^*(g_i + g_j) \tag{2}$$

where π_i is the payoff of individual i and representing player 1 and π_j is the individual payoff of player j, in this case, player 2. E is the individual's endowment, $g_{i,j} (0 \leq g \leq 5000)$ the individual's contribution to the public fund, and g_j the partner's contribution to the public fund. The total contribution to the public good is denoted as $\left(g_i + g_j\right)$ We set E = XOF 5000[2] and the marginal per capita return (MPCR) is 0.75, which is determined by the multiplication factor (1.5) divided by the number of players. The multiplication factor of 1.5 was chosen as the participants had to be able to perform calculations easily. Standard economic assumptions predict the Nash equilibrium of all individuals making zero contributions to the public fund and choosing $g_{i,j} = 0$. In contrast, the social optimum is at $g_{i,j} = 5000$, as it would maximize the common payoff for both players. While a MPCR of 0.75 is considered to be high and can lead to above-average cooperation, the MPCR is constant across all games in both environments and does not affect the internal validity of the experiment. Participants are provided with a green and a white envelope to make their contributions to the public fund and the private fund, respectively (Schuch et al., 2021).

3.2. Public good game with individual shocks

In the first treatment arm, we included a possibility of an individual shock into the PGG, adding strategic uncertainty to the payoffs of the private and public funds. In the individual shock treatment group, players are faced with making a choice with an individual payoff function π_i of:

$$\pi_i = \begin{cases} 5000 - g_i + 0.75^*\left(g_i + g_j\right) & \text{if } S_i = 0 \wedge S_j = 0 \\ 0.75^* g_j & \text{if } S_i = 1 \wedge S_j = 0 \\ 5000 - g_i + 0.75^* g_i & \text{if } S_i = 0 \wedge S_j = 1 \\ 0 & \text{if } S_i = 1 \wedge S_j = 1 \end{cases} \tag{3}$$

Where $S_i = 1$ and $S_j = 1$ means that player i and j, respectively, experienced an individual shock. Under individual shocks, the payoffs of the standard PGG are now subject to a 50 % probability of a negative shock, S_i for Player 1 and S_j for Player 2, determined through a coin flip. The coin flip dictates, whether both the private and public contributions

[2] Participants are playing with false bills in denominations of XOF 2000, 2 * XOF 1000 and 2 * XOF 500 bills, to make all combinations between 0 and 5000 in 500 steps possible.

of a player are reduced to zero (if tails); or not affected (if heads). The coin is flipped for each player in a team independently of each other in two separate draws. In the case of player 1 experiencing a shock, $S_i = 1$, but player 2 not, $S_j = 0$, the payoff of player 1 is fully dependent on player 2′s contribution to the group fund $0.75^* g_j$. In the scenario that player 1 does not receive a shock but player 2 does, $S_i = 0 \wedge S_j = 1$, player 1′s payoff is determined purely through its contribution to the private and public fund. Based on the new payoff structure, players are expected to increase their contributions to the public good, as they can share risks.

3.3. Public good game with collective shocks

In the second treatment arm, the collective shock treatment, players are faced with a choice under correlated risk, meaning that the whole team, both player 1 and player 2, are now faced with a 50 % chance to experience a shock simultaneously, hence a collective shock. In the collective shock treatment, participants are faced with an individual payoff function π_i of:

$$\pi_i = \begin{cases} 5000 - g_i + 0.75^*\left(g_i + g_j\right) & \text{if } S_i = 0 \wedge S_j = 0 \\ 0 \text{ if } S_i = 1 \wedge S_j = 1 \end{cases} \quad (4)$$

A single coin flip dictates which of the following two outcomes comes into effect. If the coin shows heads, both players do not experience a collective shock, denoted by $S_i = 0 \wedge S_j = 0$, and nothing happens, meaning the individual payoffs of player 1 and player 2 are equivalent to the payoffs in the standard PGG. However, if the coin shows tails, the team experiences a collective shock, denoted by $S_i = 1 \wedge S_j = 1$, the total payoffs from the private and public contributions of both player 1 and player 2 are effectively zero. Hence, in the public good game with collective shocks, no risk hedging through the public fund is possible.

The expected payoffs of the individual and collective shock game are identical in both settings, making these games comparable in expectations. We use the outcome of the standard public good game as a baseline (control), which is being played by all participants right before being assigned to either of the two treatments – individual or collective risk PGG (Fig. 1). The experimental design is further explained in the subsequent section.

3.4. Experimental procedures

Each experimental sessions consisted of a sequence of three games, namely the standard public good game, the public good game with shocks – with either individual or collective risk – and a risk elicitation game; and a closing survey in form of a structured interview (see supplementary materials for game protocols and descriptions of survey measures).

We started each session with an explanation of the standard public good game, supported by example posters and demonstrations, and verified understanding of the games with a set of control questions. Participants were chosen at random from two unique socio-ecological contexts – from a farming area (Environment 1) and a pastoral area (Environment 2). More details on the study sites are discussed in the following section. We randomly assigned either the individual shock version of the PGG (Treatment 1) or the collective shock version of the PGG (Treatment 2) to each experimental session, meaning that sessions are clusters in our design.

First, participants played one round of the public good game, which we used as a baseline for cooperation in our analysis (see Fig. 1). Game payoffs were not revealed until the end of the experiment to avoid confounding effects. Next, four rounds of either the PGG with collective shocks or with individual shocks were played. After each round, the experimenter flipped a coin according to the individual or collective shock PGG version and anonymously announced which of the players received a shock.[3] We chose to play four rounds to reach a high likelihood (93.75 %) that each player experiences a shock at least once.[4] After each of the four rounds, we announced that the game pairs are reshuffled, hence we observe four rounds independent of the previously chosen strategy, making up four “one-shot” games. Further, as risk preferences have shown to affect behavior in experiments involving uncertainty (Crosetto & Filippin, 2013), we played an investment game to elicit attitudes towards risk based on Gneezy & Potters (1997). Participants were asked to allocate the initial endowment between a safe and a risky option. The investment that is allocated to the risky option could be kept for sure. The investment allocated to the risky option was either tripled or zero, which was determined by a coin flip. Each session was concluded with an existing survey obtaining socio-demographic characteristics of the participants.

In this experiment, all contributions and counterparts’ identities were kept anonymous at all times, and conducted as blind and symmetric games in the initial endowments. All game materials were translated into the respective local languages and back-translated to verify that the contents were communicated identically.

3.5. Study sites

The participants were recruited in two agro-ecological distinct areas as shown in Fig. 2, and are further denoted as Environment 1 (E1) and Environment 2 (E2). E1 is located in the region of Kaffrine and is a municipality characterized by agricultural expansion and groundnut production throughout the French colonialization period up until today and known as Senegal’s Groundnut Basin. The population of E1 is predominantly composed of farming households (86 %) with distinct social characteristics and mainly belonging to the ethnic group Wolof. Usually, farming households complement their farm income as shop vendors, as seasonal on– and off-farm labor in other farms or businesses, and with the transformation of agricultural produces into secondary food products such as jams, peanut butter, couscous, and yogurt, as well as, by raising small livestock such as goats and chicken. E2 is a municipality in the region of Louga, located in the sylvo-pastoral drylands in the Northern-Central part of Senegal known for its vast pasture areas used for livestock raising. E2 has been chosen as a suitable study location due to its cross-passing and departure point for seasonal herd migrations known as “*transhumance*”.

In E2, most of the population is involved in pastoral activities and a large part of the population identifies with the Fulani ethnic group. Communities in E2 are to a large extent pastoralists, meaning that their livelihoods depend on livestock raising but are also characterized by their unique socio-cultural norms, values, beliefs, and traditional knowledge of soils, climatic conditions, and animal husbandry (Davies & Bauer, 2010; Niamir-Fuller & Turner, 1999). Some have supplemented their daily activity with small-scale crop production in the form of growing staple crops or kitchen gardening and some with the transformation of milk. Particularly in this area, many pastoralists are agro-pastoralists due to their mixed livestock and cropping activities, but still express pastoralism as their dominant livelihood. Although through this study we refer to participants from E1 as ‘farmers’ and participants from E2 as ‘pastoralists’, we acknowledge that these are not in all cases purely homogeneous communities, however, can be studied as such for the comparisons made in this study.

The pilot and data collection for the experiment took place from

[3] To understand whether a shock has affected a player or not, every player received a tag card, which was only known to them and the experimenter. After each round the facilitator flipped a coin individually for each tag card. Like this every player was aware of whether a shock was received.

[4] We decided to not play more rounds to reach close to 100% probably of experiencing a shock at least once, as during various pilots, participants were stating fatigue of repeating draws for more than 4 times.

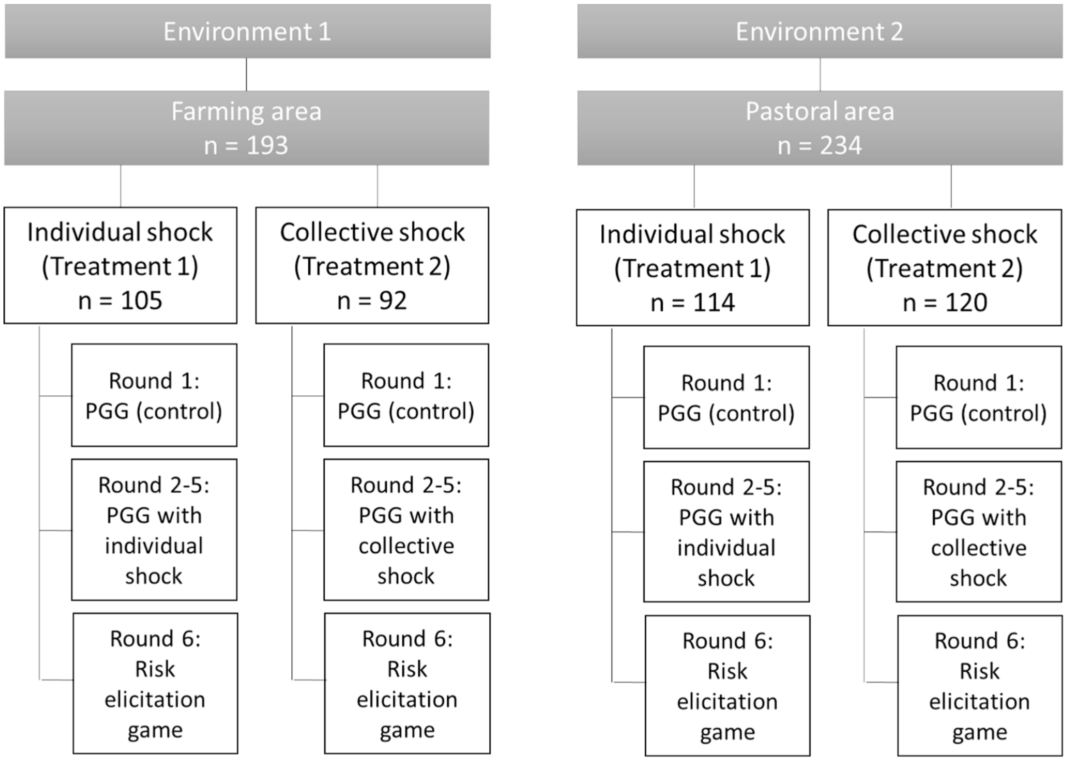

Fig. 1. A between-subject design to study responses in PGG with individual versus collective shocks comparing a farming area (Environment 1) with a pastoral area (Environment 2). A within-subject design was used for baseline comparisons.

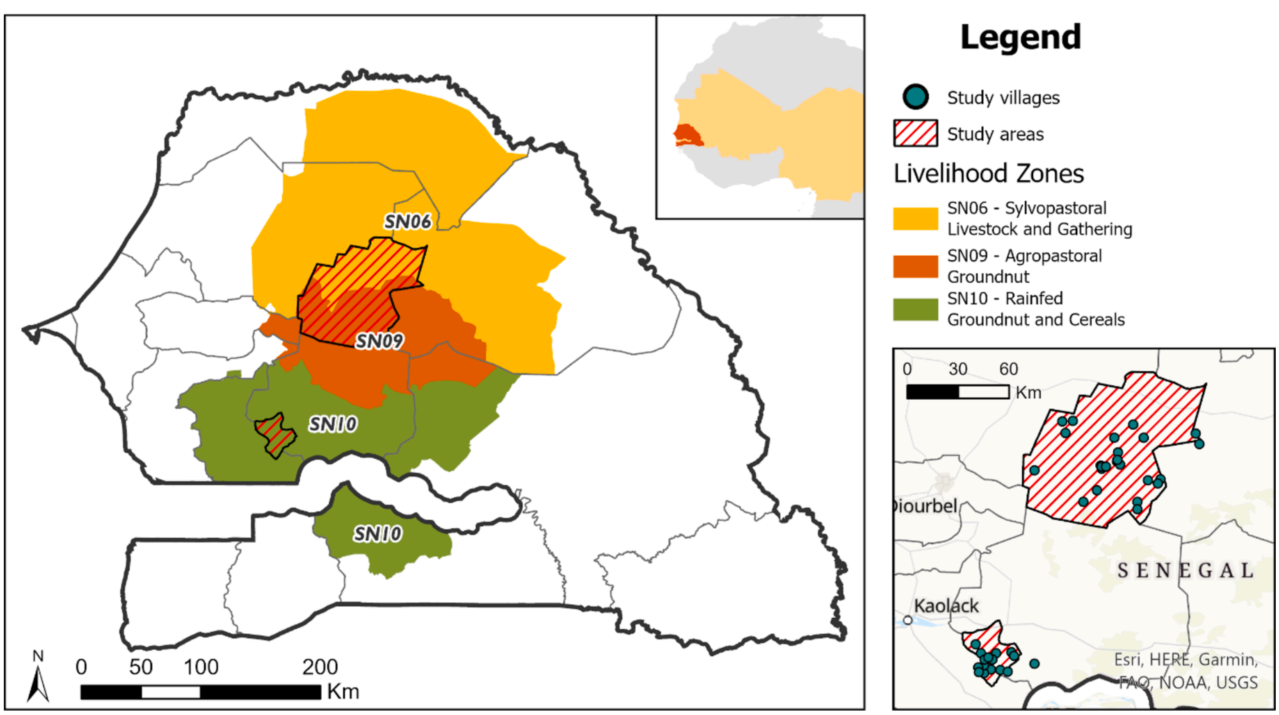

Fig. 2. Selected study sites were located in a farming area (green – Environment 1) and a pastoral area (yellow/orange – Environment 2) in Senegal. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

October-November 2022. A priori, a feasibility study involving semi-structured interviews was conducted from April-June 2022.

3.6. Sample selection and descriptive statistics

To gain a representative sample, we proceeded in two sampling stages. In the first stage, we randomly selected 200 participants from a pool of households from 16 villages in the farming area (E1) and 250 participants from a pool of households from 25 villages in the pastoral area (E2).[5] The reasons for the larger sample size and number of villages in the pastoral area are: (i) attrition is more likely in the pastoral area, as households are more spatially dispersed and sometimes face logistic constraints in attending sessions as they rely on shared transport (e.g. donkey cart), and (ii) poor cellphone coverage results in some participants not receiving the invitation to participate, and (iii) settlements are generally less densely populated. In E1, 197 participants attended and 194 provided complete data, and in E2, 234 attended the sessions and 230 provided complete data. In the second stage, we randomly assigned either the individual shock treatment (T1) or the collective shock treatment (T2) to a session.[6]

Participants were paid a participation fee of XOF 2000 at the spot and one game win was randomly selected of all the played rounds and was paid out after completing the experiment. The incentives were discussed with local extension agents, village chiefs and local researchers beforehand to choose incentives according to social norms and preferences of the study population. Participants were directly invited through their village chiefs. A closing survey in form of a structured interview was conducted after an experimental session was completed. The questionnaire solicited information on socio-demographic characteristics, experiences of shocks and conflicts, as well as, attitudinal measures of trust. Table 1 shows the mean statistics of all participants who took part in the experimental games and survey.

The average group size for the sessions ranges between 10–15 participants per session in the farming area and between 7–19 participants in the pastoral area. The group size we aimed at was 12, however, in some sessions, we faced logistical constraints as a result of long distances and difficult accessibility of certain locations which had to be accommodated. In our sample, 36 % and 30 % of participants were women in the farming area and pastoral area, respectively. In the farming area, 84 % are literate, and 59 % in the pastoral area. The difference in literacy is strongly correlated to the respective education system – participants following the French education system have higher literacy rates than people who follow Quranic education. In E2, purely Quranic education is more dominantly observed. Most of the participants in the farming area, 80 %, belong to the Wolof ethnic group. Contrastingly, 68 % of participants in the pastoral area are part of Fulani ethnic groups. This indicated that the occupations of farmers and pastoralists overlap along ethnic boundaries. In E1, 87 % of respondents are farmers, 10 % are agro-pastoralists, 1 % are pastoralists, and the remaining 2 % are dedicated to another principal livelihood activity. In E2, 37 % of participants are pastoralists, 39 % are agro-pastoralists, 20 % are farmers, and the remaining 4 % follow other occupations. The average household size is 16 members for farmers and 13–14 members for pastoralists. Both environments show high levels of trust with 0.79 and 0.76 in farming and pastoral areas, respectively. Participants were asked about their experience with conflicts over water access, grazing areas, and crop damage, and 31 % of farmers and 27 % of pastoralists have experienced conflicts in the past 1–5 years. Over the last year, 35 % of farmers and 50 % of pastoralists have experienced climate shocks such as heatwaves, droughts, dry spells, heavy rains, strong winds, and excessive rainfall.

Next, participants were asked which individual and collective shocks they have experienced over the past years (see Table 2). The most widely experienced individual shocks in the farming area were bad harvests (59 %), death or sickness of the main economic provider of the household (39 %), as well as death or illness of livestock (18 %) and livestock theft (16 %). In comparison in the pastoral area, 51 % reported to have faced livestock death or illness, 45 % have experienced bad harvests, and 30 % livestock theft. With regards to collective shocks, participants in the farming area have reported experiencing food price spikes (91 %), heat waves (19 %), and storms and strong winds (17 %) among others. Similarly in the pastoral area, 80 % of participants reported to have experienced food price spikes, 61 % experienced sudden increases in animal feed prices, 33 % have suffered from heat waves and 19 % from droughts. In addition, storms, strong winds, and wild fires were experienced by 28 % of participants in the pastoral area.

Data can be publicly accessed. Before the data collection, a pre-analysis plan was submitted, and the study underwent ethical review (Krendelsberger et al., 2022).

4. Results

Firstly, we present different factors characterizing the geographic and social environment of farmers and pastoralists. Secondly, we show findings from a lab-in-the-field experiment, where we compare contribution levels in the standard public good game between farming and pastoral areas. Thirdly, we examine how individual and collective shocks affect cooperation in a public good game with shocks. Fourthly, we analyze how responses to individual versus collective shocks differ between participants from the farming versus the pastoral area.

4.1. Social and geographic environment

In Table 3, we carefully summarized secondary information and empirical observational insights on the characteristics of both farming and herding areas recorded during the feasibility study and data collection itself. The farming area is geographically characterized through dense settlements and proximity to nearby villages and larger towns, as well as, depleted agricultural soils and the presence of water bodies in the rainy season. These spatial characteristics also shape the social environment and result in stronger market access with better road networks present in the area, better access to seasonal jobs, and overall better possibilities to diversify incomes. The pastoral area can be described as a homogeneous and dry landscape, mostly covered by pastures, and characterized by large distances between households, villages, and market outlets. Therefore, good exchanges with nearby households are a vital livelihood strategy for households in the pastoral area. Moreover, environmental conditions are harsher in the pastoral area than in the farming area, as dry seasons are longer and more intense, and the vegetation is only suitable for fresh grazing for a few months during the short rainy season in this area. As an adaptation strategy, pastoralists rely on seasonal herd mobility (“*transhumance”)* towards the farming area, once pastures in the North are exhausted. During the transhumance, pastoralists trade and exchange with farmers, and this lifestyle shapes their social environment.

4.2. Cooperation in farming and pastoral communities

Next, we present findings based on a lab-in-the-field experiment. We find that, on average, participants in the pastoral area are more cooperative than participants in the farming area.

Result 1: On average, pastoralists show higher levels of intra-community cooperation compared to farmers.

Based on contributions to the public fund in the standard public good game, we find that participants in the farming area contributed on average 47 % to the shared fund, while participants in the pastoral area

[5] Villages and participants were selected based on relevance for our study area, meaning that villages need to be predominantly farming and pastoral villages in E1 and E2, respectively. An important criteria was that the chosen villages should not have previously benefitted from climate adaption, agricultural extension or other development programs. We collected household lists from all selected villages. Household lists were retrieved based on the year the study took place or the previous year when a more recent list was not available. Such recent household lists have been easily available since a governmental support program required local administration to provide such information for enrollment in a national aid program.

[6] The experimenter flipped a coin at the beginning of each day to decide whether the first session would start with the collective shock or individual shock treatment. The afternoon session had the opposite treatment assigned to ensure a more balanced sample distribution between the two treatments.

Table 1
Summary statistics of participants in farming area and pastoral area.

	Farming area (E1)				Pastoral area (E2)			
	mean	sd	min	max	mean	sd	min	max
Group size	13.38	1.65	10.0	15.0	13.49	2.45	7.0	13.38
Number of sessions	7.53	0.50	7.0	8.0	9.00	0.00	9.0	7.53
Female (dummy)	0.36	0.48	0.0	1.0	0.30	0.46	0.0	0.36
Age	42.38	13.70	18.0	77.0	42.06	14.56	18.0	42.38
Literate (dummy)	0.84	0.37	0.0	1.0	0.59	0.49	0.0	0.84
Years of education (French or Arabic)	8.74	4.97	1.0	25.0	7.25	5.34	1.0	8.74
Wolof ethnic	0.80	0.40	0.0	1.0	0.20	0.40	0.0	0.80
Fulani ethnic	0.17	0.38	0.0	1.0	0.68	0.47	0.0	0.17
Number of household members	16.14	9.27	4.0	65.0	13.46	6.71	3.0	16.14
Farmer	0.87	0.34	0.0	1.0	0.20	0.40	0.0	0.87
Pastoralist	0.01	0.10	0.0	1.0	0.37	0.48	0.0	0.01
Agro-pastoralist	0.10	0.30	0.0	1.0	0.39	0.49	0.0	0.10
Trust index (0 = no trust; 1 = high trust)	0.79	0.10	0.4	1.0	0.76	0.12	0.4	0.79
Risk aversion	0.48	0.25	0.0	1.0	0.51	0.25	0.0	0.48
Experienced climate shock	0.35	0.48	0.0	1.0	0.50	0.50	0.0	0.35
Experienced conflict (past 1 to 5 years)	0.31	0.46	0.0	1.0	0.27	0.44	0.0	0.31
Observations	194				230			

Table 2
Individual and collective shocks experienced by farmers and pastoralists in the year 2021.

	Proportion of participants in the farming area		Proportion of participants in the pastoral area	
	mean	sd	mean	sd
Individual shocks				
Death/Illness of main economic support	0.39	0.49	0.13	0.34
Bad harvests[1]	0.59	0.49	0.45	0.50
Death/Illness livestock	0.18	0.38	0.51	0.50
Livestock theft	0.16	0.37	0.30	0.46
Sudden loss of non agricultural income	0.05	0.22	0.03	0.18
Collective shocks				
Epidemic	0.01	0.10	0.10	0.29
Drought	0.02	0.14	0.19	0.39
Strong out-of-season rains	0.03	0.16	0.07	0.26
Heat wave	0.19	0.39	0.33	0.47
Storms and strong winds	0.17	0.38	0.14	0.35
Wild fires	0.00	0.00	0.14	0.35
Sudden increase in prices for animal feed	0.07	0.26	0.61	0.49
Sudden increase in food prices	0.91	0.28	0.80	0.40
Sudden decrease in livestock prices	0.03	0.17	0.13	0.34
Sudden increase in fertilizer and seed prices	0.02	0.12	0.00	0.00
Political change	0.02	0.14	0.03	0.18

[1]In this study, bad harvests are regarded as individual shocks, as production yields depend on the farm's individual farming practices (e.g. fertilizer application, quality of seeds). On the other hand, bad harvests can be also due to collective shocks such as pests and unfavorable weather conditions. However, we did not discriminate between the causes of bad harvests and therefore regard this response as an individual shock.

Table 3
Description of relevant contextual factors in farming and pastoral area.

Farming area	Pastoral area
Environmental factors • Little rainfall (500 mm) • Nutrient-depleted soils • Rain-fed water bodies in wet season, semi-dry forests	***Environmental factors*** • Very little rainfall (300 mm) • Mostly pastures • Higher temperatures, dry conditions
Geographical factors • Dense settlements • Proximity to bigger towns	***Geographical factors*** • Remote from large markets • Spatially dispersed settlements
Social factors • Farming as main income source • More possibilities for diverse incomes • Mostly receiving transhumance • Seasonal migration for alternative jobs	***Social factors*** • Herd mobility as risk mitigation strategy • Most risks are collective • Transhumance and pastoralism as lifestyle • Trade and exchange with farmers crucial for livelihood
Economic factors • Stronger market integration • Better road network • Vast agricultural development • Located in major agricultural area	***Economic factors*** • Weaker market integration • Less developed road networks • Less government presence

contributed on average 55 % of their initial endowment to the public good. When examining the initial contributions in an OLS regression, participants in the pastoral area are on average around 9 % more cooperative than participants in the farming area when adjusting for control variables such as age, gender and literacy, risk aversion, and adding session fixed effects (see Table 4).

4.3. Individual and collective shocks

Fig. 3 shows that in comparison to the control round (Round 1, so the standard public good game), measuring cooperation without shocks, individual shocks increase cooperation and collective shocks decrease cooperation for both farmers and pastoralists. The difference between the contributions under a standard public good game and the public good game under shocks is significant for both shock scenarios for pastoralists but not for farmers (see Table A2).

Result 2: Collective shocks decrease cooperation, while individual shocks increase cooperation.

For pastoralists the differences are large and significant with a positive effect size of 3.4 % for individual shocks (Wilcoxon s.r.t. = 3.154, p-value = 0.002) and a negative effect size of 2.3 % (Wilcoxon s.r.t. = -2.220, p-value = 0.027) for collective shocks. For farmers, differences in individual and collective shock treatments are not significant.

Average cooperation for farmers in the standard public good game can be expressed as a share of 51.6 % and 42.5 % for the control groups and 52.2 % and 42.1 %, respectively, under individual and collective risk. For pastoralists, average cooperation in the individual shock group is 53.8 % in the control round and 57.2 % under individual risk, and cooperation in the collective shock is 56.1 % in the control round and 53.7 % under collective risk. For both groups, the average initial cooperation between the different treatment arms should be insignificant, however, this is not the case for the farmers in our sample. We have verified various explanations for possible self-selection, however, no inconsistencies in the experimental protocols are present, and balancing

Table 4
Determinants of contributions in a standard public good game.

Dependent variable: Contributions to public fund in standard PGG	(1)	(2)	(3)
VARIABLES	Naive regression	OLS with controls	Fixed-effects model
Pastoral area	0.08**	0.07**	−0.09***
	(0.03)	(0.03)	(0.01)
Risk aversion		−0.25***	−0.25***
		(0.05)	(0.05)
Group size		0.01	
		(0.01)	
Age		0.00	0.00
		(0.00)	(0.00)
Female (dummy)		−0.05**	−0.05**
		(0.02)	(0.02)
Literate (dummy)		−0.02	−0.02
		(0.03)	(0.03)
Constant	0.47***	0.47***	0.70***
	(0.02)	(0.11)	(0.04)
Observations	424	424	424
R-squared	0.027	0.124	0.252
Adjusted R-squared	0.02	0.11	0.18
Controls	No	Yes	Yes
Session fixed effects	No	No	Yes
F-Stat	6.125	8.154	27.08
Prob > F	0.019	0.000	0.000
Number of sessions	33	33	33

SE clustered by sessions
*p < 0.10; **p < 0.05; ***p < 0.01

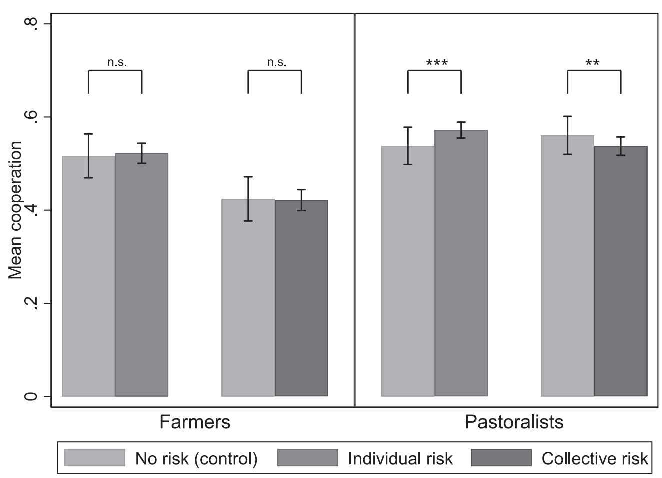

Fig. 3. Difference in contributions between farmers and pastoralists in control round (standard public good game) and individual and collective shocks. Significance for comparison between control cooperation and the respective shocks is based on Wilcoxon signed-rank test. *p < 0.10; **p < 0.05; ***p < 0.01. Significance tests can be found in Table A2.

tests have shown no significant differences in farmers' treatment samples (see Table A3.1 and Table A3.2). Therefore, we conclude that the difference in baseline cooperation has occurred at random. To have a coherent comparison base across treatments, we take the relative difference between collective and individual shock treatments in relation to the control round of each treatment arm in the subsequent analyses.

In Table 5, we observe that the differences between individual and collective shock treatment (treatment effect = 0.1 %), when normalized with the control condition, are not significantly different for farmers (Mann Whitney-U =1.429, p-value = 0.153), but we see a significant effect (treatment effect = 0.57 %) for pastoralists (Mann Whitney-U = 3.755, p-value = 0.000). Overall, we observe an increase in cooperation in response to individual shocks and a decrease in cooperation when subject to collective shocks in both environments.

Table 5
Testing for differences in mean cooperation between individual risk groups and collective risk groups for farmers and pastoralists after shock introduction (average of round 2 to 5).

	Individual risk	Collective risk	Diff.	Mann Whitney-U (p-value)
Relative change in cooperation to baseline (%) – farmers	0.006	−0.004	0.010	0.111
Relative change in cooperation to baseline (%) – pastoralists	0.034	−0.023	0.057	0.000***

*p < 0.10; **p < 0.05; ***p < 0.01.

Result 3: Effects of individual vs. collective risk treatments are only significant for pastoralists but not for farmers

Fig. 4 shows cooperation under shocks for farmers and pastoralists in a sequence of four one-shot games. We find that overall individual shocks increase cooperation and collective shocks decrease cooperation among both groups. Our evidence strongly confirms that farmers and pastoralists behave differently even though experimental procedures were identical. Under individual shocks, pastoralists increase their cooperation levels sharply, while farmers respond at a lower rate. For collective shocks, pastoralists respond with a decrease in cooperation, while farmers initially cooperate more in the first two rounds and only in round 4 and round 5 respond with a strong decrease in cooperation to collective shocks. As we are playing repeated one-shot games, the most precise estimate is in round 4, as participants have sufficiently understood the game and possible last-round effects are avoided. When examining findings in round 4 in detail, for farmers we observe on average a 0.01 increase in cooperation under individual shocks and a −0.02 decrease under collective shocks which are not significantly different from each other (Mann Whitney-U = 1.204, p-value = 0.229). For pastoralists, our findings show that under individual shocks, on average cooperation increases by 0.04, and under collective shocks decreases by −0.04, with a significant difference at a 5 % level (Mann Whitney-U = 2.311, p-value = 0.021). Significance tests can be found in Table A5.

In Table 6, we observe that collective shocks decrease contributions to the public fund. In all models, we control for cooperation in the standard PGG (round 1) to account for any initial difference in cooperation between participants. Model (1)-(4) confirm that collective shocks reduce cooperation in comparison to individual shocks. The effect sizes reach from −2% to −5.5 % decrease in cooperation measured in contributions to the public fund under collective shocks compared to individual shocks. Participants in the pastoral area are 4.3 % more cooperative than in the farming area, as shown in Model (1)-(3). In Model (4), a positive interaction term indicates that being a herder in the collective shock group compared to a farmer, increases cooperation by 5 %. Risk-averse participants contribute between 13.6 % and 14.7 % less to the public fund, which holds with high statistical significance (p-value = 0.000) across our models. Moreover, on average an increase in session group sizes by 1 participant increases contributions by 0.7 %. When a shock is experienced in the previous round, contributions on average decreased by 1.8 % in the subsequent round. Control variables such as round, age, gender, and literacy have no significant effect on cooperation responses under shocks in our models.

5. Diverse responses to shocks in farming and pastoral environments

In the previous section, we found that not only do pastoralists show higher levels of intra-community cooperation compared to farmers, but also pastoralists' responses to individual shocks increase intra-community cooperation, while collective shocks decrease such

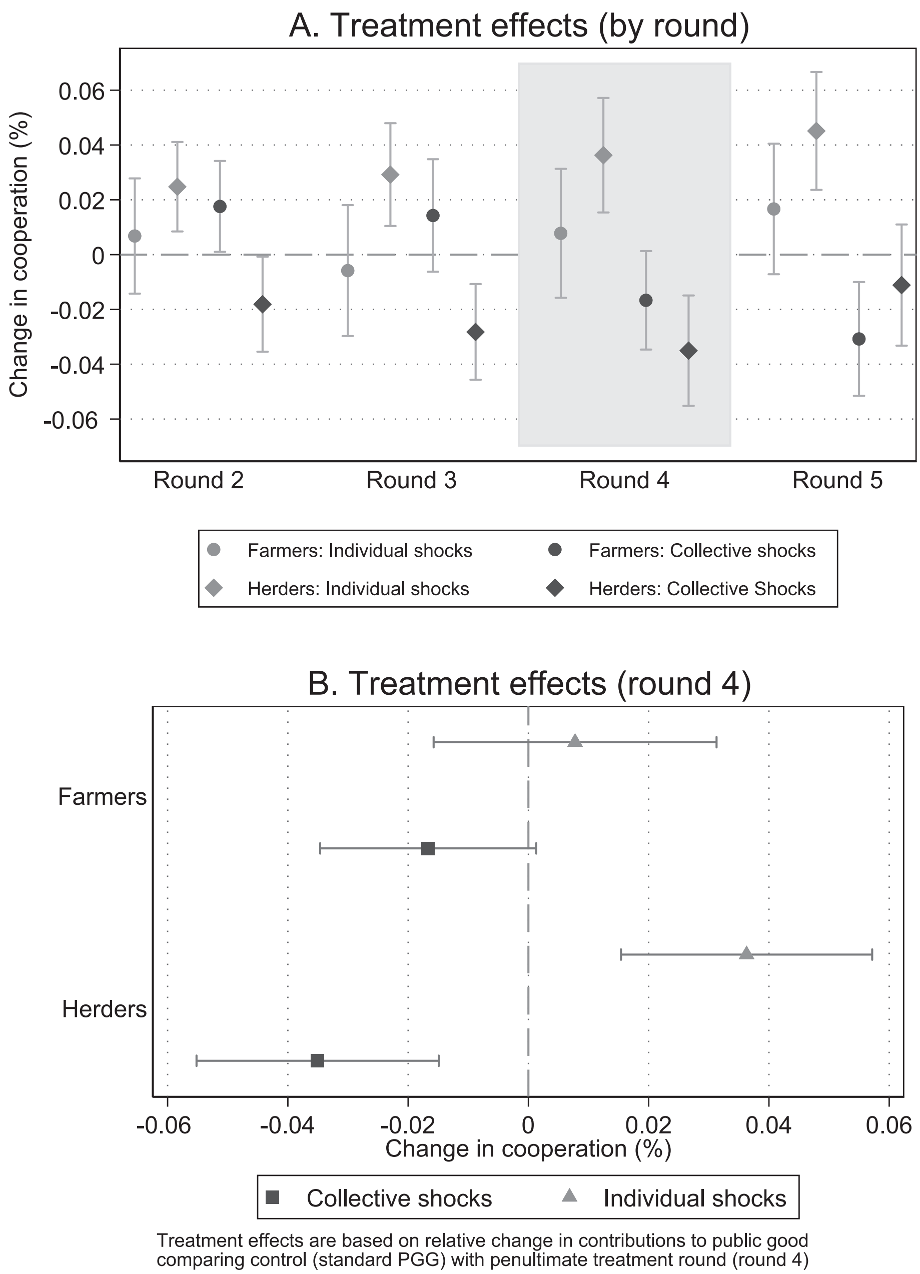

Fig. 4. Relative change in cooperation for individual and collective shocks for farmers (E1) and pastoralists (E2) across four consecutive one-shot games. Treatment effects are shown as relative changes in cooperation without risk treatment in the standard public good game.

cooperation significantly. We claim that farmers' and pastoralists' different responses can be explained through each of the contexts they operate in.

5.1. Perceptions of private and public goods

Our contrasting findings on social preferences from different environments have been observed in Henrich et al. (2001), who compared experimental findings from 15 small-scale societies. A possible explanation for the different cooperation levels among farmer and pastoral communities can be traced back to the attitudes to, and relations with the private and public goods central to the livelihoods, as described in Table 7.

Farmers primarily rely on agricultural goods for their livelihood production. Agricultural goods are crop harvests from groundnut, millet, sorghum, and corn, and seeds derived from these crops. Agricultural goods are consumption goods usually kept in the short-term for a maximum of one year and grown on the household's land. Hence, the daily goods such as agricultural produce and land resources of farmers are more relatable to private goods and can possibly explain why farmers generally show lower levels of intra-community cooperation. For pastoralists on the other hand, their main livelihood asset is their livestock. Pastoralists are very reluctant to sell animals as the ambition is to increase the value of the asset in the long term. In addition, Fulani pastoralists have culturally a strong relationship with their livestock (Adriansen, 2006). Even though pastoralists are responsible for a herd, the ownership of each animal is clearly defined and animals sometimes belong to other family or community members (van Dijk, 1994). Moreover, grazing land is jointly managed by pastoralists. The shared ownership of livestock and land resources has characteristics of a public good and possibly explains why pastoralists have higher average levels of contributions in a public good experiment compared to farmers.

Table 6
Determinants of intra-community cooperation in public good game showing the effect of being in the collective shock treatment compared to the individual shock treatment.

	Dependent variable: Contribution to public good (0–1)			
	(1)	(2)	(3)	(4)
	Naive Regression	OLS with game controls	OLS with socio-demographics	Fixed-effect model
Collective shock (dummy)	−0.050***	−0.055***	−0.054***	−0.020***
	(0.011)	(0.012)	(0.012)	(0.007)
Baseline cooperation (standard PGG)	0.507***	0.456***	0.462***	0.438***
	(0.039)	(0.042)	(0.041)	(0.046)
Pastoral area (dummy)	0.043***	0.043***	0.043***	0.013***
	(0.011)	(0.011)	(0.012)	(0.003)
Pastoral area x collective shock (dummy)		0.014	0.009	0.037***
		(0.021)	(0.020)	(0.007)
Risk aversion (0–1)		−0.136***	−0.136***	−0.147***
		(0.033)	(0.032)	(0.034)
Group size (persons)		0.007*	0.007*	
		(0.004)	(0.004)	
Shock in previous round (dummy)		−0.017*	−0.018*	−0.018*
		(0.010)	(0.009)	(0.009)
Round (in game)		0.002	0.002	0.002
		(0.004)	(0.004)	(0.004)
Age (years)			−0.001	
			(0.000)	
Female (dummy)			0.021	
			(0.014)	
Literate (dummy)			−0.008	
			(0.013)	
Trust index (0–1)			−0.025	
			(0.054)	
Constant	0.258***	0.260***	0.301***	0.342***
	(0.021)	(0.053)	(0.069)	(0.033)
Observations	1,693	1,693	1,693	1,693
R-squared	0.336	0.363	0.368	0.382
Adjusted R-squared	0.335	0.360	0.364	0.368
Controls	No	Yes	Yes	Yes
Session fixed effects	No	No	No	Yes
F-Stat	130.893	52.477	31.947	32.74
Prob > F	0.000	0.000	0.000	0.000
Number of sessions	33	33	33	33

SE clustered by session
*p < 0.10; **p < 0.05; ***p < 0.01

5.2. Cooperation in high-risk environments

Another possible explanation of why pastoralists behave more cooperatively than farmers emerges from the characteristics of their social environment. Our findings are particularly comparable to Gneezy et al. (2016), who reported that cooperation results from workplace organization, as pastoralists are naturally dependent on cooperating with others for trading and accessing water and grazing opportunities. Cooperation is less likely attributable to acts of altruism but is rather a survival strategy (van Dijk, 1994). Buggle & Durante (2021) similarly concluded that high-risk settings, for example, regions with strong climate variability, result in high levels of trust and cooperation. Similarly, Szekely et al. (2021) provided experimental evidence on how strong social norms create 'tightness' in cultures exposed to high-risk environments. Prediger et al. (2011) highlighted that pastoralists living in more sensitive ecosystems, show better cooperation over shared resources, potentially explaining cooperation behaviour of pastoralists in Senegal.

Table 7
Goods in the daily lives of farmers and pastoralists.

	Farmers	Pastoralists
Main livelihood products:	Agricultural goods (harvest, seeds) *Examples:* groundnut, millet, sorghum, corn	Livestock herd *Examples*: cattle, goat, sheep
Relationship with land:	Farmers mainly work on their own pieces of land. The land is mainly used for household consumption.	Land is a community good as grazing areas are shared.
Time span:	Short-termAgricultural goods are usually continuously consumed and stored for up to one year in the form of seeds.	Long-termPastoralists are reluctant to sell or redistribute their livestock unless it is strictly necessary (e.g. in marriage, food shortages)
Relationship with good:	Agricultural goods are used for consumption and only a small part is kept as seed for the next year.	Ownership of each of the animals in a herd is clearly defined for each family and community member, but the responsibility to take care of the animals in the herd is a shared responsibility towards a large number of people.
Attitude towards good:	The principle is to produce a lot with fewer assets.	The principle is to sell less and let assets grow.
Type of 'daily' goods:	**Private good**	**Public good**

5.3. Risk-sharing and risk aversion

We found that individual shocks increase cooperation in a public good game and collective shocks overall decrease cooperation. Our findings on individual shocks are explained through a risk sharing mechanism, and for collective shocks through risk aversion. Our results are consistent with Cárdenas et al. (2017) who conducted a framed field experiment in four small-scale farming communities in Asia and Latin America, and similarly found that private risk increases contributions to the public good while collective risk decreases public good contributions consistently in all four study areas. Opposingly, in a common pool resource game other studies have found an increase in cooperation in response to random (collective) shocks to a resource (Finkbeiner et al., 2018; Safarzynska, 2017). Our results on collective shocks are driven by risk aversion. As risks are correlated, the perceived potential losses are larger, even if payoffs in terms of expected outcomes are the same across individual and collective shock groups. Overall findings on the effects of risk preferences on contributions in public good games are not conclusive across the wider literature. Kocher et al., (2015) observe that risk preferences do not have a significant effect on contributions, Cárdenas et al., (2017) report a modest positive effect of risk aversion on contributions, while Charness & Villeval (2009) and Schuch et al. (2021) find that risk-averse people invest less in the public good. Our findings are complementary with risk-averse participants investing significantly less in the public good both in the standard public good game and public good game with shocks. Therefore, risk aversion can potentially explain the decrease in cooperation in response to collective shocks in our study.

Lastly, we report that individual shocks and collective shocks have strong and significant effects for pastoralists, while against our expectations, effects for farmers are small and insignificant. On average pastoralists react with a larger increase in cooperation to individual shocks and a larger decrease in cooperation to collective shocks. Our findings are explained by the different characteristics of the social and geographic environment: Participants in the farming area experience a higher level of market integration and therefore a wider range of possibilities to fulfill their needs compared to participants in the remote and more isolated pastoral areas. Moreover, farmers are possibly less reliant on risk sharing as household-level strategies such as storing of grains might be a sufficient risk coping strategy. In contrast, pastoralists' sphere of operation is a high-risk environment, as pastoralism is a high-risk enterprise facing strong co-variant risks, making pastoralists more risk averse as a result of their prior exposure to collective shocks and possibly explaining stronger reactions to collective shocks (van Dijk, 1994). Therefore, a larger and more diverse sphere of operation to pool risks is needed to cope with shocks (Grimard, 1997).

Finally, we stress that our findings are highly context-specific, which is a typical feature of a lab-in-the-field experiment, and different conclusions might be drawn from another study population with farming and herding communities, for example, from another country in the West African Sahel. It is still under debate in which cases experimental findings are reflections of real-world outcomes, however, our study aimed to set an example of how to contextualize such findings in a real-life setting to increase their relevance.

6. Conclusions

Farmers and pastoralists have been exposed to changing environmental and political conditions for centuries. Both groups have been continuously adapting to these changes while relying on intra-and inter-community cooperation. However, climate change and its unpredictable extreme events are posing new forms of additional stress on such cooperative relationships and potentially increasing the likelihood of resource-related conflicts between these groups.

In this study, we show that intra-community cooperation breaks down under the impact of collective risks, which is particularly strong for pastoralists. This is a concerning finding, as collective risks are predicted to increase substantially under current climate change projections, for example, in the form of extreme weather events such as floods, heatwaves, and inter-seasonal droughts. Climate-induced collective risks can create natural resource scarcities and potentially push communities to rebel or into conflicts. Governments are better equipped to tackle more common collective shocks such as spikes in food and feed prices rather than highly unpredictable extreme climate events.

Our findings entail that collective shocks can have the capacity to reduce cooperation – both among farming and pastoral societies – meaning that protection mechanisms against collective shocks, for example, early warning systems, need to be put in place. High-risk settings are characterized by higher initial levels of cooperation, but also stronger reductions in cooperation when responding to collective shocks. This means that the focus of international, national, and subnational policies should be directed towards sustaining cooperation in high-risk environments because as soon as social cohesion is disrupted, stability becomes harder to uphold.

Currently, the Sahel region is faced with political turmoil, difficult economic conditions, and trespassing of its ecological boundaries, and is carrying a rising population with increasing pressures on food and ecosystems. As climate change poses additional stress on already strained systems, local communities cannot be left to their own devices when shocks affect whole communities and lead to decreasing intra-community cooperation; help is needed. External actors have an important role to play in aiding these communities to adapt to climate change. This includes hard investments to increase the climate resilience of productive systems (e.g. improved livestock health, stable market conditions, stress-resistant crop varieties, and irrigation systems), but also soft investments, for example, weather-based crop and livestock insurance. Moreover, local governments have a key role to play. For example, herd mobility for pastoralists is a proven management strategy to deal with changing climate conditions, but it requires the necessary infrastructure, institutions, and governance to create sustainable, non-violent land-use arrangements, even when cooperation itself is challenged by correlated stresses.

Lastly, we highlight that farming and pastoral communities react differently to shocks, which could affect the balance between these naturally connected groups and disrupt inter-group relations. In this study we focused on intra-community cooperation, however, ultimately our conclusions are also relevant for inter-community relations. Well-functioning in-group dynamics are crucial for sustaining peace, but at the same time, once risks affect whole communities, perceptions of in-group and out-group might change. Different reactions to risks among farmers and pastoralists may lead to stronger in-group and out-group perceptions and ultimately lead to conflict.

CRediT authorship contribution statement

Alexandra Krendelsberger: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Francisco Alpizar:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Mame Mor Anta Syll:** Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis. **Han van Dijk:** Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Supervision, Writing – review & editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2025.106941.

Data availability

Replication files are available for download.

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