Climate change and health vulnerability in informal urban settlements in the Ethiopian Rift Valley

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Abstract

Climate change in Ethiopia is occurring against a backdrop of rapid population growth and urbanization, entrenched poverty and a heavy burden of disease, and there is little information on specific health risks with which to approach adaptation planning and strengthen adaptive capacity. Using detailed household surveys (400 households, 1660 individuals, 100% participation) and focus groups in two informal urban communities in the Southern city of Shashemene, we identified locally relevant hazards and found that climate change is likely to intensify existing problems associated with poverty. We also showed that despite their proximity (situated only 1 km apart) the two communities differ in key characteristics that may affect climate change vulnerability and require nuanced approaches to adaptation. Detailed, community-level research is therefore necessary, especially where other sources of data are lacking, to ensure that adaptation activities in the world’s poorest communities address relevant risks.

Introduction

The urban population of Ethiopia, Africa’s second most populous country, is around 18 million and growing at 4.2% per annum [1]. Seventy per cent live in informal settlements, exposed to climate-sensitive health conditions such as diarrhoea, malnutrition and malaria [1, 2]. Such communities are highly vulnerable to climate change and have little adaptive capacity to meet its many challenges [3]. Building resilience is therefore urgent and requires information on population vulnerability, current and likely future climate-sensitive health risks, and climate-coping practices. Yet lack of data is common in developing countries, rendering locally critical features invisible and leading to possibly maladaptive practices. We assessed climate-sensitive health vulnerability in two informal urban communities within the city of Shashemene, where climate variability, especially in rainfall, is already a concern [4, 5].

The underlying characteristics of a population, such as its poverty, health, and governance, determine its vulnerability, that is, its predisposition towards being adversely affected by climate change. Vulnerability interacts with and is augmented by the physical hazards associated with climate variability and change (such as drought, flood, ecosystem impacts) and together these determine risk, which is the likelihood of adverse impacts occurring [6, 7]. For example, ‘social’ (non-climatic) factors, such as poor access to education and health services, rapid population growth and resource conflict, can enhance vulnerability and increase risk of malaria in ecologically suitable areas [8].

Climate change therefore threatens disadvantaged communities by exacerbating already difficult living conditions and contributing to poor health outcomes [9]. The health vulnerability of a population to climate change is shaped both by its exposure to hazards—and their effects on climate-sensitive health conditions (such as vector-borne disease)—and by the strategies employed by individuals and communities to cope with these. Across Africa, endemic poverty, limited infrastructure and technology, ecosystem degradation, conflict and poor health challenge capacity to adapt to climate change [10]. To the extent that
two informal urban communities (‘slums’) within the city of Shashemene, 240 km South of Addis Ababa in the Ethiopian Rift Valley. Here, very little data on health and climate hazards exists. Seasonal and interannual climate variability, especially in rainfall, is a characteristic of this marginally productive area, where small-scale agricultural activities provide food and income. For many, life is characterized by extreme poverty. Sanitation is limited and open defaecation is common, clean water is in poor supply, housing is impermanent and overcrowded, and services and infrastructure are limited. The two communities are located 1 km apart (figure 1), each composed of 200 households that identify as belonging to that particular community. The boundaries are well-defined—roads, laneways and rivers—with perimeters of about 600 m. Both communities have an internally recognized system of leadership and social support.

Methods

We analysed climate model outputs for future climate over the region, collected detailed social, demographic, economic, environmental and health data from community members, and brought these together to assess specific risks to climate change [19].

Climate projections

We analysed future temperature and rainfall for Shashemene using KNMI Climate Explorer [20] for the three wettest (July, August, September) and driest (November, December, January) months of the year, and for the month of April which is the hottest month of the year and when the ‘little rains’ occur, before the rainy season begins in earnest. As we sought to assess future climate-related risks to health relative to ‘contemporary’ outcomes, we created time series graphs showing changes to maximum and minimum temperatures with regard to a ‘contemporary’ baseline of 1980–2010 for the three wettest months, the three driest months, and for the ‘little rains’ month of April. We used an ensemble of Global Climate Model (GCM) output within the Climate Model Intercomparison Project (CMIP5) framework. CMIP5 is a multi-model dataset that is freely available and intended for use in investigating climate change impacts [21]. The CMIP5 dataset consists of 42 climate models, detailed in Annex 1 of the IPCC Working Group I Report (p 1315) [22]. We analysed CMIP5 output for the study location at 7.2°N, 38.6°E for all four Representative Concentration Pathway (RCP) scenarios (RCP 8.5, 6.0, 4.5 and 2.6). These RCP scenarios are designed to denote a range of possible futures based on population growth, socioeconomic and technological change (Box 1) [21, 23, 24]. We then mapped changes in rainfall in each of the two rainy seasons and the dry season using monthly data from the same CMIP5 dataset and the RCP4.5
scenario to compare differences between contempor-
ary (1980–2010) rainfall and projected rainfall in the ‘near future’ (2030–2060) for Ethiopia, using relative percentage change for rainfall for the 5th, 50th and 95th percentiles.

**Community data collection**

We employed a mixed methods approach; pen and paper questionnaires conducted by interview of all 200 households in each community, and four focus groups, one of men and one of women in each community. From the questionnaire and focus group data we identified locally important climate-sensitive health conditions and related socioeconomic and environmental vulnerabilities.

The house-to-house surveys were conducted during the main wet season in September (2012 for Community A, 2013 for Community B), and focus groups during the dry (Community A, February 2013) and the wet (Community B, September 2013) seasons. The timing of data collection was driven by unavoidable constraints (local holidays and festivals). The household surveys included items on climate-sensitive health conditions, and economic and social characteristics and climate risks, while focus groups nominated health conditions and their relationship...
to current climate, alongside contemporary coping strategies.

The household questionnaire was developed with reference to health and livelihood studies in developing contexts [25–29] and the psychology of survey response [30], with particular consideration given to the design and conduct of household surveys in developing countries [31]. It contained 140 items aimed at capturing key community characteristics regarding sanitation; access to and use of resources such as food and energy; income, assets and financial credit; and demography, health and climate. The wording of the questions was specific and simple to improve the accuracy of the responses and avoid misinterpretation [30]. Multiple-choice responses for frequency ranges were used wherever possible, scales were kept similar throughout, and time periods were precisely specified. Items varied as to whether they were framed positively or negatively in order to mitigate acquiescence. The majority of questions referred to the household as a whole or to the opinion of the head of household, but data on several items—on health and educational attainment, for example—were collected for each individual household member. The questionnaire was translated into Amharic and piloted locally.

Five local interviewers, all university students from the two study communities, conducted the household questionnaires following training in survey and interview techniques and under ongoing supervision. Voluntary, informed written consent was obtained from all participants, usually heads of household. Participants were assured of individual confidentiality and were encouraged to answer all questions as best and as accurately they could, informed in particular that there were no ‘right’ or ‘wrong’ answers. Household interviews took place over a one week period in September 2012 (Community A) and September 2013 (Community B). The four questions relating to perceived climate hazards (droughts, floods, rising temperatures and climate change), however, were asked of both communities at the same time, in September 2013. Participation in the survey was 100%. Data were collected on all household members \((n = 1660)\) and were analysed using Pearson chi-square and t-tests (STATA 12).

Focus group participants were nominated by community leaders. Particular attention was given to the composition and degree of diversity of the participants in the focus groups, to ensure effective representation [32]. The focus groups were conducted using Participatory Rural Appraisal methods [33] and were structured using CRiSTAL, a community-based risk screening tool that is used to identify local climate and non-climate hazards, determinants of local adaptive capacity and contemporary coping strategies [32]. Each focus group took place over a day in February 2013 (Community A) and September 2013 (Community B). Focus group participants nominated important climate threats and climate-sensitive diseases and provided information about seasonal and interannual variation as well as their current coping strategies.

We then interpreted the data from the household questionnaires and the focus groups with reference to climate projections for the region to identify specific health risks and potential foci for adaptation.

The study was approved by the local community representatives, the development NGOs responsible for the intervention (WCDO and Kopin), and the University of Malta’s University Research Ethics Committee. Community leaders engaged with and supported the study throughout its development and conduct.

Results

Future climate

In Shashemene, maximum and minimum temperatures were projected to increase in the near future in both the wetter and cooler months (July–September) and the drier and warmer months (November–January), and in April (‘little rains’ season), which is both hot and wet (figure 2). The mean model projection for global mitigation RCP4.5 is for temperatures approximately \(1\) °C warmer than the contemporary baseline (1980–2010) by 2030 and \(2\) °C warmer by 2060, with slightly greater increase in minimum than maximum temperatures. All models show mean projected warming of approximately \(1\) °C by 2030, with warming rate slowing under the intense mitigation RCP2.6 by 2060. The scenario reflecting the highest carbon emissions shows a multi-model mean warming of approximately \(3\) °C in minimum temperatures and \(2.5\) °C in maximum temperatures by 2060.

Future rainfall patterns are less certain than future temperatures. Projections for Shashemene 2030–2060 for the wettest months range between a \(10–20\%\) decrease (5th percentile of the multiple models) and a \(20–30\%\) increase (95th percentile) with the median estimate showing a \(0–10\%\) decrease relative to baseline (figure 3). In the driest months, the selected models show a potential \(0–10\%\) decrease or a greater than \(50\%\) increase with a median estimate of a \(10–20\%\) increase. Estimated relative rainfall change during the ‘little rains’ season ranges between a decrease of \(20–30\%\) and an increase of more than \(50\%\) (median estimate: \(10–20\%\) decrease).

Community profile

All 400 households in the two communities participated in the survey, yielding data on 1660 individuals. Community A had 721 people (53% female) and Community B had 939 people (51% female). Age and sex structure of the two communities is shown in figure 4, and key sociodemographic characteristics of the two communities are shown in table 1.

Participants in the four focus groups were seven men (aged 28–60 years) and 12 women (19–61 years).
(Community A), and nine men (25–60 years) and eight women (25–45 years) (Community B), with nominated occupations including handyman, builder, teacher, hairdresser, farmer, business owner, pensioner, and student.

Climate and health vulnerability

The results from the household survey of factors that contribute to underlying vulnerability are summarized in tables 2–7. Water sources and sanitation facilities are shown in table 2, household deprivation in table 3, diagnosed health conditions are shown in table 4 and the burden on each community from specific illnesses in table 5. Perceptions of risk associated with climate hazards are shown in tables 6 and 7 shows perceptions of risk of climate-sensitive health outcomes.

Both communities relied on vendors for their water and used uncovered pit latrines (table 2). Households in Community A were more likely than those in Community B to have gone without essentials (water, fuel, medicine, income, food) (table 3). Malaria (in children) and typhoid (in children and adults) were reported as more common diagnoses by households in Community B while trachoma and tuberculosis among adults was reported as more common diagnoses in Community A (table 4). Malaria (in children and adults) and typhoid (only in adults) contribute to days spent sick (table 5). Community B households were more likely to name droughts as a serious risk while most households in both communities nominated floods as a serious risk (table 6). Nearly 9 out of 10 household heads in both communities reported that climate change was a problem in their community, and nearly 8 out of 10 reported that temperatures were increasing because of climate change. A number of climate-sensitive health conditions are seen as life-threatening by a majority in both communities (table 7).

Figure 2. Temperature observations and projections for Shashemene, 1980–2060. ‘Tmin’ is monthly minimum and ‘Tmax’ is monthly maximum temperature. Output was generated with KNMI Climate Explorer using the ensemble dataset within the CMIP5 (IPCC AR5 Atlas subset) project in three seasons showing with the four IPCC Representative Concentration Pathway (RCP) scenarios (RCP2.6, 4.5, 6.0 and 8.5) at 7.2°N, 38.6°E [20]. One line per model is shown for each scenario with the multi-model mean denoted by the thick line. The projected change for the period 2030–2060 is shown by the box and whisker plots which include the median (horizontal line), 25% and 75% (box) and 5% and 95% (whiskers). The temperature change is relative to a ‘contemporary’ baseline 1980–2010 (dotted line).
Focus groups in both communities nominated malaria and typhoid as significant threats, reporting the incidence of both diseases as more frequent during the dry season and with higher ambient temperatures. There is no data from health services or elsewhere against which to test these claims, but participant agreement was unanimous. No preventive measures were explicitly employed, but participants reported eating garlic (to treat malaria) or going to hospital (to seek treatment for typhoid) if they become sick.

Focus group participants identified water shortages, especially during the dry season, as a problem for washing and hygiene. Participants also identified flooding as a serious health hazard, with sewage and floating waste directly contaminating houses.

Participants in the focus groups perceived climate change to be a significant threat, noting in particular that temperatures had been increasing. They reported that these higher daytime temperatures rendered physical labour more difficult and prompted avoidance of work during the middle of the day.

Discussion

The underlying vulnerability of these two communities, their exposure to contemporary climate hazards, and the likely future climate of the region puts them at particular risk of adverse health impacts. The most likely threats to health arising from climate change in these communities are from increasing food insecurity and changes to infectious disease transmission. Nutrition here is already marginal, and quality food consumption could decline via direct climate impacts on food production (especially through increased rainfall variability producing droughts and floods), and relatedly via a loss of income. While there is some potential for increased atmospheric CO₂ to positively affect food crop yields [14, 34], this is unlikely to be of significance in a region where food production is limited and so closely tied to rainfall. Further, even if CO₂ fertilization increases yield, it may do this at the expense of the nutrient content [34]. Combined with potential threats to agriculture from climate change...
changes to rainfall, reduced labour associated with higher ambient temperatures could further limit food production and contribute to income decline. This could lead to increased malnutrition, especially among children as their growth and development needs are high and they are prone to infection-related malnutrition. Consumption smoothing activities such as the selling off of assets are the contemporary strategy used for coping with food shortages and income reduction.

The infectious diseases likely to be affected by climate change in these communities include malaria, gastrointestinal infections, trachoma and respiratory disease. Relationships between disease and climate are complex enough, and are made more so by uncertainty around future climate, especially rainfall. Malaria transmission is closely tied to the combined patterns of rainfall and temperature as well as features of the very local environment and is especially difficult to predict. Provided there is sufficient rainfall and humidity, malaria transmission will probably increase as warmer temperatures accelerate mosquito development, shorten intervals between feeds, enhance mosquito survival, and increase pathogen replication rate [35]. Higher night time minimum temperatures may extend transmission season by truncating periods that are too cool for mosquito activity (approximately <14 °C) [36]. Rainfall provides mosquito breeding habitat and higher humidity enhances survival, especially as temperatures increase [35]. Intense rainfall may initially reduce mosquito abundance by flushing out breeding sites, but subsequent standing water provides further sites. Decreased wet season rainfall may

Table 1. Key sociodemographic characteristics of the two communities.

|                      | Community A          | Community B          |
|----------------------|----------------------|----------------------|
| Mean age (years) (95% CI) | 23.6 (22.4–24.7)     | 18.0 (17.2–18.9)     |
| Mean number of people per household (95% CI) | 3.6 (3.3–3.9)        | 4.7 (4.5–5.0)        |
| Mean household income\(^a\) (USD per day) (95% CI) | 1.76 (1.55–1.96)     | 2.09 (1.83–2.35)     |
| Mean individual income\(^b\) (USD per day) (95% CI) | 0.48 (0.40–0.59)     | 0.44 (0.36–0.52)     |
| Education\(^c\) (%) |                      |                      |
| Preschool            | 97%                  | 45%                  |
| Primary              | 72%                  | 47%                  |
| Secondary            | 22%                  | 7%                   |
| Tertiary             | 5%                   | 1%                   |
| Ethnicity (%)        |                      |                      |
| Welaita              | 28%                  | 88%                  |
| Amhara               | 23%                  | 3%                   |
| Sidama               | 16%                  | 0                    |
| Oromo                | 13%                  | 4%                   |
| Other                | 20%                  | 5%                   |
| Religion (%)         |                      |                      |
| Christian Orthodox   | 54%                  | 18%                  |
| Christian Protestant | 40%                  | 72%                  |
| Christian Catholic   | 1%                   | 0                    |
| Muslim               | 5%                   | 5%                   |
| Other                | 0%                   | 5%                   |

\(^a\) Inflation is high in Ethiopia due to rapid economic expansion (approximately 10% GDP growth per annum). Income in USD was therefore adjusted for inflation to account for price differences between the two surveys.

\(^b\) Education is reported for individuals; Ethnicity and Religion are reported at the household level. For Education, more than one level could be nominated for each person.
trigger malaria decline by limiting breeding sites, but reduced flow of the adjacent rivers may transform them into suitable breeding pools. Indeed, participants noted that the dry season is when malaria is a greater problem. Decreased dry season rainfall, however, could potentially limit breeding habitat and mosquito populations may decline. If rainfall increases in the dry season—when temperatures are also higher—breeding and survival may be enhanced. It should be noted that not only is the direction of rainfall change uncertain for Shashemene, but that absolute changes projected in relative rainfall are very small, in the order of between −1 to 0 mm day\(^{-1}\) and 1 to 2 mm day\(^{-1}\) in the wet season (5th and 95th percentiles), between −0.2 to −0.1 mm day\(^{-1}\) and 1 to 2 mm day\(^{-1}\) in the dry season (5th and 95th percentiles), and between −0.5 to −1 mm day\(^{-1}\) and 1 to 2 mm day\(^{-1}\) in the ‘little rains’ season (5th and 95th percentiles). Land use practices, such as irrigation and cattle proximity, can also affect malaria transmission [37, 38] and these, too, may change with climate. The African highlands are where some of the most significant impacts on climate change on malaria will occur in both transmission intensity and in spreading to new areas [15, 16]. The uncertainty about future rainfall patterns may render the effect of climate change on malaria in these communities particularly difficult to predict, however any loss of income and increase in poverty and food insecurity will augment whatever the underlying level of risk.

Diseases related to poor hygiene and lack of safe water dominate in both communities. If rainfall decreases in either the wet or dry seasons, the risk of typhoid, polio, diarrhoea, trachoma and tuberculosis—all of which are contemporary diseases in these communities—may increase. Less water facilitates direct transmission of pathogens through reduced hand washing, along with minimal washing of clothes, linen and kitchen utensils. Where sanitation is poor, diarrhoea is associated with both flooding and drought [39]. Participants in this study reported that their houses are contaminated with visible waste during flooding, while typhoid is a particular concern in the dry season. Transmission of gastroenteric infections, such as typhoid, is also promoted by warmer ambient temperatures [40]. Less water increases airborne particulates (dust, pollutants) and could promote other infections such as trachoma, as well as otitis media (ear infection) consequent to a respiratory infection.

Such diseases are sensitive to climate, but largely preventable with improved sanitation, water supply, appropriate behavioural changes and, in some instances, vaccination. Capacity to cope with future climate risks is severely limited in these communities; households are already struggling to access basic resources.

| Water sources and treatment | Community A | Community B | \(\chi^2\) | Summary |
|----------------------------|-------------|-------------|----------|---------|
| Source ‘very often/always’ |             |             |          |         |
| Vendors                    | 36%         | 54%         | 13.530\(^{c}\) | Households in the two communities relied on various sources. Water was sourced primarily from vendors. A small number of households sourced their water from the river. One household (Community A) reported using a private well or rainwater. Very few households in either community usually treated their water. |
| Private tap elsewhere      | 29%         | 7%          | 32.541\(^{c}\) |         |
| Neighbour                  | 30%         | 1%          | 62.538\(^{c}\) |         |
| Public well                | 0%          | 19%         | 40.987\(^{c}\) |         |
| River                      | 4%          | 2%          | 31.539   |         |
| Treated ‘very often/always’| 3%          | 1%          | 10.346\(^{c}\) |         |

| Types of sanitation facilities used and their cleanliness | Type | Community A | Community B | \(\chi^2\) | Summary |
|----------------------------------------------------------|------|-------------|-------------|----------|---------|
| Own exclusive pit                                        | 23%  | 31%         | 5.355\(^{b}\) | No households in either community were connected to a septic tank or the sewer system. Uncovered pit latrines were frequently used for toileting in both communities. Only one household used a covered pit. Pits were reported as being never, rarely or only sometimes clean by majority of participants. |
| Own but shared pit                                       | 43%  | 22%         | 21.310\(^{c}\) |         |
| Neighbour’s pit                                          | 3%   | 7%          | 10.215\(^{c}\) |         |

Per cent (%) refers to percentage of households in each community. Values may not add to 100% due to rounding. \(\chi^2\) values marked.

\(^{a}\) are significant at \(p < 0.10\).
\(^{b}\) at \(p < 0.05\).
\(^{c}\) at \(p < 0.01\).
and services such as clean water, sanitation, food, fuel and medicines. Without intervention, vulnerable communities like these will be at greater risk of several communicable diseases. Increased rainfall variability will exacerbate contemporary problems of flooding and drought and may threaten food production (both for personal consumption and as a source of income), while rising temperatures may limit daytime working hours, further affecting community health and well-being. Activities that address food production, hygiene, water supply and income will be essential in limiting climate change impacts in these and similar communities.

Local level data is lacking in some of the most vulnerable regions, but is needed to identify local hazards and point to potential adaptation actions. Shashemene does not fall within a recognized flood risk zone [41], yet flood was identified by both communities as a significant local problem that affects their health and livelihoods. Climate change vulnerability, risks and adaptation needs may vary even over short distances. The two, nearly adjacent communities share important key characteristics (such as extreme poverty, informal housing, and lack of sanitation) but their exposures, behaviours, demography and disease profiles are not identical. Community B for example has, proportionately, 60% more children than Community A and thus climate hazards that principally affect children will be relatively more important here. Despite their proximity and shared weather and climate, Community B households were more likely to report drought as being a serious threat than Community A households. This may be due to differences in river volume and non-exclusive use of this resource. The river flowing through Community A has fewer upstream users and a greater

| Table 3. Deprivation of essential items. | Community A | Community B | $\chi^2$ | Summary |
|----------------------------------------|-------------|-------------|---------|---------|
| **Number of times a household has gone without enough of an item over the previous year** | | | | |
| **Clean water** | | | \begin{align*} 30\% & \quad 8\% \\ 39\% & \quad 45\% \\ 32\% & \quad 47\% \end{align*} | 31.277 | Houses in Community A reported having gone without essential resources more frequently over the previous year than those in Community B. The majority of households in both communities experienced at least occasional shortages in income, cooking fuel, medicine and clean water. Shortages in food were experienced by a majority of households in Community A but less than half of households in Community B. In Community A, four out of five households had gone without enough income at least several times over the past year |
| **Cooking fuel** | | | \begin{align*} 41\% & \quad 18\% \\ 32\% & \quad 35\% \\ 26\% & \quad 47\% \end{align*} | 28.929 | |
| **Medicine** | | | \begin{align*} 34\% & \quad 19\% \\ 20\% & \quad 40\% \\ 47\% & \quad 41\% \end{align*} | 23.968 | |
| **Income** | | | \begin{align*} 80\% & \quad 35\% \\ 13\% & \quad 40\% \\ 7\% & \quad 25\% \end{align*} | 82.169 | |
| **Food** | | | \begin{align*} 41\% & \quad 13\% \\ 29\% & \quad 28\% \\ 30\% & \quad 59\% \end{align*} | 49.296 | |

Per cent (%) refers to percentage of households in each community. Values may not add to 100% due to rounding. $\chi^2$ values marked.

a are significant at $p < 0.10$.

b at $p < 0.05$.

c at $p < 0.01$. 

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Table 4. Diagnosed health conditions.

|                  | Community A | Community B | $\chi^2$ | Summary                                           |
|------------------|-------------|-------------|----------|--------------------------------------------------|
| **For each individual household member:** |             |             |          |                                                  |
| Malaria          |             |             |          |                                                  |
| Children         | 5.1% (11)   | 11.5% (53)  | 6.924$^c$| Children in Community B were significantly more likely than those in Community A to be reported as having been diagnosed with malaria and/or typhoid |
| Adults           | 15.5% (78)  | 18.5% (88)  | 1.616    |                                                  |
| Typhoid          |             |             |          |                                                  |
| Children         | 1.4% (3)    | 5.8% (27)   | 6.860$^c$|                                                  |
| Adults           | 10.3% (52)  | 14.5% (69)  | 3.949$^c$|                                                  |
| Trachoma         |             |             |          |                                                  |
| Children         | 0.0% (0)    | 0.8% (3)    | 1.402    | More adults in Community B than Community A were reported as having been diagnosed with malaria |
| Adults           | 3.2% (19)   | 1.7% (7)    | 5.011$^c$|                                                  |
| Tuberculosis     |             |             |          |                                                  |
| Children         | 0.5% (1)    | 0.25% (1)   | 0.304    | More adults in Community A than Community B were reported to have been diagnosed with trachoma and tuberculosis |
| Adults           | 2.2% (11)   | 0.2% (1)    | 7.835$^a$|                                                  |
| Anaemia          |             |             |          |                                                  |
| Children         | 1.9% (4)    | 1.1% (5)    | 0.677    |                                                  |
| Adults           | 3.2% (16)   | 1.7% (8)    | 2.271    |                                                  |
| Poor growth      |             |             |          |                                                  |
| Children         | 2.3% (5)    | 2.2% (10)   | 0.013    |                                                  |
| Adults           | 0.6% (3)    | 0.4% (2)    | 0.144    |                                                  |
| Polio            |             |             |          |                                                  |
| Children         | 0.5% (1)    | 0.4% (2)    | 0.003    |                                                  |
| Adults           | 0.4% (2)    | 0.4% (2)    | 0.004    |                                                  |

Per cent (%) refers to percentage of children or adults in each community who have ever received a certain diagnosis. 'Children' are aged 0–14 years, 'adults' are 15 years and over. $\chi^2$ values marked.

- $^a$ are significant at $p < 0.10$.
- $^b$ at $p < 0.05$.
- $^c$ at $p < 0.01$.

Table 5. Illness burden.

|                  | Total number of sick days | Total people in the community | Mean (95% CI) | t value | Summary                                           |
|------------------|----------------------------|-------------------------------|---------------|---------|--------------------------------------------------|
| **For each individual household member:** | | | | |                                                  |
| Malaria          | | | | |                                                  |
| Children         | 31 | 462 | 0.067 (0.000–0.134) | −1.356 | In Community B as a whole, children spent 31 days sick with malaria in the previous month and adults spent 70 days. No children were reported as having been sick with typhoid in the previous month, but there were 21 adult sick days in the community from typhoid |
| Adults           | 70 | 476 | 0.147 (0.053–0.241) |         |                                                  |
| Typhoid          | | | | |                                                  |
| Children         | 0 | 462 | 0.046 (−0.016–0.109) | −1.431 |                                                  |
| Adults           | 21 | 476 |                     |         |                                                  |

Mean (95% CI) with t-test.

Total number of sick days community-wide and means (95% CI) are shown for children and adults separately. 'Children' are aged 0–14 years, 'adults' are 15 years and over. This question was only asked of Community B. The differences between adults and children were not statistically significant with $p > 0.10$ for both malaria and typhoid.
volume of water reaching the community. It is precisely these sorts of very local features that may be critical in determining best approaches to adaptation.

**Limitations of the study**

Although ambient temperatures will most certainly increase in these communities, the extent to which this may occur—and during which season or time of day—is less certain. Uncertainty remains in particular for future rainfall, which is consistent with other climate projection studies in Ethiopia [13].

Using climate projections for a given latitude-longitude may create a false impression of precision. While we used a GCM for this study, Regional Climate Models that use dynamically downscaled data (and are driven by GCMs) [21] produce very similar projections and uncertainties over the study region [42], and debate remains as to the value they can currently add to impact assessments [21, 43]. Regardless of the type

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### Table 6. Perceived climate risk.

| Perceived risk of specific climate hazards in the community | Community A | Community B | \( \chi^2 \) | Summary |
|------------------------------------------------------------|-------------|-------------|---------------|---------|
| **Droughts are a serious risk**                            |             |             |               |         |
| Agree                                                      | 43%         | 57%         | 13.369\(^c\) | More than two-thirds of the participants perceived floods to be a serious risk. Nearly nine out of ten participants perceived climate change to be a problem in the community and around three-quarters of the participants thought that temperatures had been increasing from year to year |
| Disagree                                                   | 50%         | 30%         |               |         |
| Neither agree nor disagree                                  | 7%          | 13%         |               |         |
| **Floods are a serious risk**                              |             |             |               |         |
| Agree                                                      | 71%         | 69%         | 0.833         |         |
| Disagree                                                   | 24%         | 18%         |               |         |
| Neither agree nor disagree                                  | 5%          | 13%         |               |         |
| **Climate change is a problem**                            |             |             |               |         |
| Agree                                                      | 89%         | 87%         | 0.983         |         |
| Disagree                                                   | 8%          | 11%         |               |         |
| Neither agree nor disagree                                  | 3%          | 2%          |               |         |
| **Temperatures are increasing**                            |             |             |               |         |
| Agree                                                      | 74%         | 77%         | 1.065         |         |
| Disagree                                                   | 26%         | 22%         |               |         |
| Neither agree nor disagree                                  | 0%          | 1%          |               |         |

Per cent (%) refers to percentage of heads of household in each community. \( \chi^2 \) values marked.

\(^a\) are significant at \( p < 0.10 \).

\(^b\) at \( p < 0.05 \).

\(^c\) at \( p < 0.01 \).

### Table 7. Perceived risk of climate-sensitive health conditions.

| Perceptions of risk of specific climate-sensitive health conditions: per cent who agree with the statements ‘…is a life-threatening disease in my community’ | Community A | Community B | \( \chi^2 \) | Summary |
|---------------------------------------------------------------------------------------------------------------------------------|-------------|-------------|---------------|---------|
| Typhoid                                                             | 96.0%       | 100.0%      | 7.147\(^c\)  | The majority of participants in both communities agreed that malaria is life-threatening. Other diseases linked to climate through access to clean water—typhoid, diarrhoea, polio and trachoma—were also agreed by a majority to be life-threatening, with more participants in Community B than Community A agreeing with this statement for typhoid, diarrhoea and trachoma |
| Malaria                                                             | 90.5%       | 85.4%       | 2.485         |         |
| Diarrhoea                                                           | 88.0%       | 98.0%       | 12.963\(^c\) |         |
| Polio                                                                | 94.0%       | 95.7%       | 0.570         |         |
| Trachoma                                                            | 93.8%       | 98.9%       | 7.147\(^c\)  |         |
| Tuberculosis                                                        | 97.5%       | 98.8%       | 0.892         |         |

Per cent (%) refers to percentage of heads of household in each community. \( \chi^2 \) values marked.

\(^a\) are significant at \( p < 0.10 \).

\(^b\) at \( p < 0.05 \).

\(^c\) at \( p < 0.01 \).
of model used, there is agreement that temperatures in the region will increase, and rainfall in Shashemene is already highly variable, across the year and between years, and it might be that this variability increases with climate change. The GCM ensemble used here is based on grid side of 100 km which may, if anything, underestimate the propensity for local variability [21]. Higher temperatures and possibly increasingly variable rainfall will exacerbate existing health problems in these two communities.

The absence of routinely collected health data for these communities, such as health service use, means that baseline relationships between climate and health outcomes cannot be established nor can claims regarding seasonality of disease in the community be independently and quantitatively verified.

**Conclusion**

Climate change will intensify existing health problems in communities such as these, where extreme poverty, and especially poor access to clean water and sanitation, renders them already vulnerable to food insecurity and infectious disease. The precise effects of future climate on health depend on underlying vulnerability and local hazards. Community-based activities specifically targeting local needs—in this case water, sanitation, food security and more reliable income generation—are an important strategy for minimizing the adverse impacts of climate change in the world’s most vulnerable communities. Detailed local research can inform national policies; where data is lacking or where the scale of existing data heightens the potential for local inaccuracies, community-based research provides essential information on climate hazards and associated health conditions, and thus the types of adaptation activities that are urgently needed.

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**Author contributions**

SM, HB and MB designed the study. SM and HB conducted the fieldwork. MB and SM constructed the database. HB analysed and interpreted the data. HB, SM and MB co-wrote the paper.

**Competing financial interests**

The authors have no competing financial interests.

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