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 communities adopt coping strategies for contemporary climate variability—such as selling livestock ('asset smoothing') and reducing consumption ('consumption smoothing') [11]—these react to acute problems rather than attempt to address the (relatively) less immediate threats of longer term climate change [10, 12].

The Ethiopian plateau generates a cooler, wetter climate than that of surrounding low-lying countries, with two distinct rainy seasons: during April there is a short rainy season (the 'little rains') and the wettest months of the year are July–September. The driest months occur over November–January. The wettest months generally have lower daily maximum and higher night time minimum temperatures and the driest months have higher daily maximum and the lowest night time minimum temperatures. Average daily maximum temperatures in Shashemene range between 19 and 23 °C across the year, with average night time minimums between 9 and 13 °C. Data since 1960 show that mean annual temperatures have increased by 0.28 °C per decade (0.32 °C during the wettest months, July–September) with increasing frequency of 'hot' days and decreasing frequency of 'cold' days [13], while rainfall has become more variable [10]. With further changes to climate and especially to rainfall, national agricultural yields may diminish [14], reducing food security and income [10], and malaria transmission may intensify and spread to new areas at higher altitudes [15, 16]. Adaptation to avoid the worst health consequences is thus urgently required [12], but it is unknown how specific regions or communities will be affected by climate change at the local level.

Lack of data and research capacity remain major problems here and in other developing countries. By necessity, rare data are typically interpolated over large spatial or temporal scales. Although this provides initial insight into potential hazards, it may not be meaningful at the scale at which people live. The world's most impoverished and vulnerable communities are therefore frequently neglected in climate impacts and adaptation research. Consequently, their risk from climate change is heightened further [17, 18], as failure to identify local hazards could promote adaptation activities that are poorly targeted, inadequate or even maladaptive. Community-based investigations of local climate hazards and climate-sensitive health outcomes thus provide essential information for effective adaptation in the most vulnerable communities, and offer insight into likely issues faced by other, similar communities. We aimed to determine the likely impacts of climate change on health in two neglected but especially vulnerable communities and to suggest potential adaptation strategies to minimize adverse outcomes associated with climate change.

We set out to identify climate-sensitive health conditions and the local hazards that may affect these in 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

Figure 1. *Location and boundaries of Shashemene and the two study communities, A and B.* Satellite images sourced from Google Maps. Shashemene is located at approximately 7.2°N, 38.6°E.

scenario to compare differences between contemporary (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.

Box 1. The IPCC AR5 Report describes four levels of radiative forcing which are used in modelling future climate change:

- RCP8.5 (business-as-usual): increasing greenhouse gas emissions over time, leading to high greenhouse gas concentration levels.
- RCP6.0 (stabilization): emissions rise quickly to 2060 and then decrease.
- RCP4.5 (global mitigation): emissions peak in 2040 and decline strongly until 2080.
- RCP2.6 (urgent, strong global mitigation): emissions decrease sharply from 2020 towards zero from 2080, in an attempt to limit global warming to below 2 °C.

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)

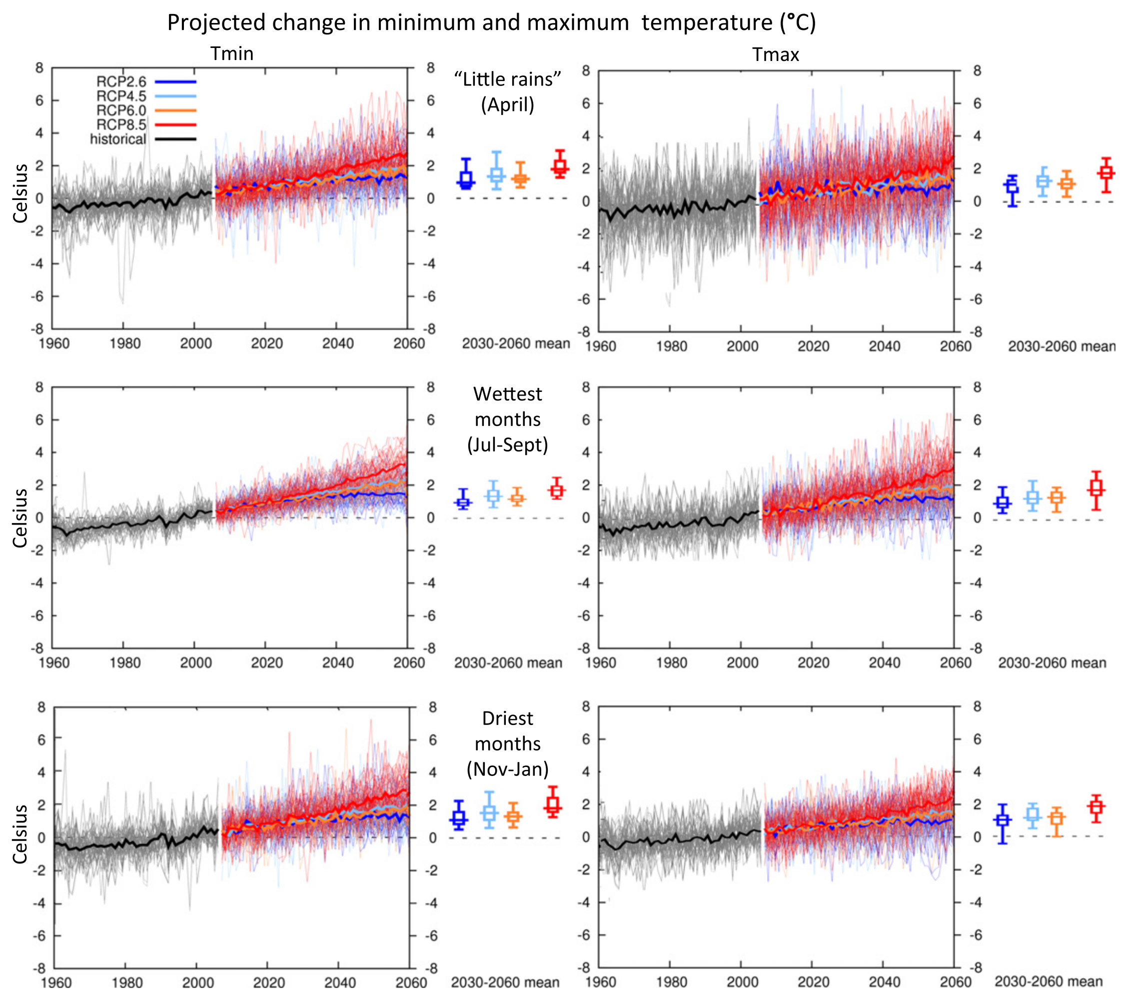

Figure 2. *Temperature observations and projections for Shashemene, 1980–2060.* 'Tmin' is monthly minimum and 'Tmax' is monthly maximum temperature. Output was generated with KNMI Climate Explorer using the ensemble dataset within the CMIP5 (IPCC AR5 Atlas subset) project in three seasons showing with 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).

(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).

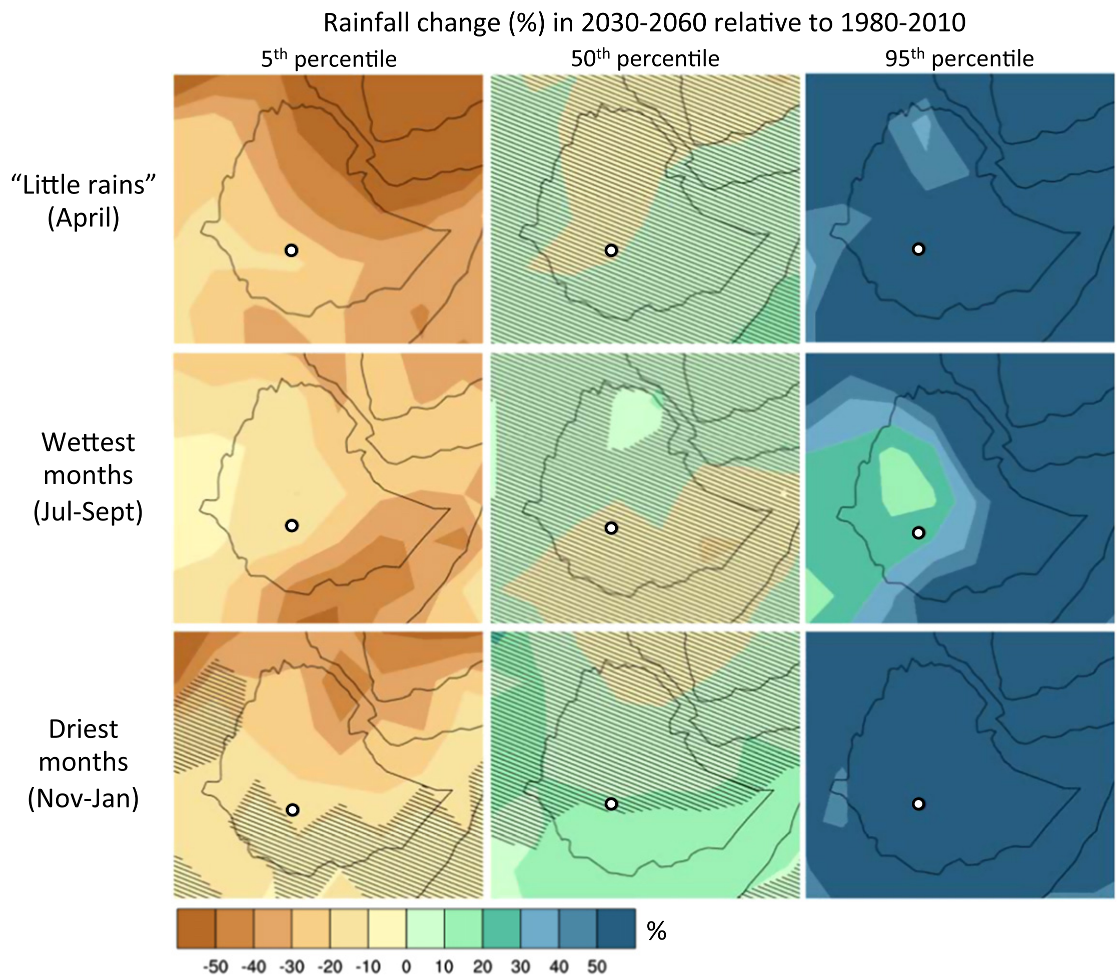

Figure 3. *Projected rainfall change (%) in Ethiopia for 2030–2060 relative to 1980–2010.* The 5th, 50th and 95% percentiles of the multi-model estimates are shown. Maps were generated with KNMI Climate Explorer for monthly data using the ensemble dataset within the CMIP5 (IPCC AR5 Atlas subset) project for the RCP 4.5 scenario in three seasons [20]. Areas where the signal is smaller than one standard deviation of natural variability are hatched. National borders are depicted using solid black lines. The location of Shashemene is shown by the white circle outlined in black.

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 CO_2 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 CO_2 fertilization increases yield, it may do this at the expense of the nutrient content [34]. Combined with potential threats to agriculture from

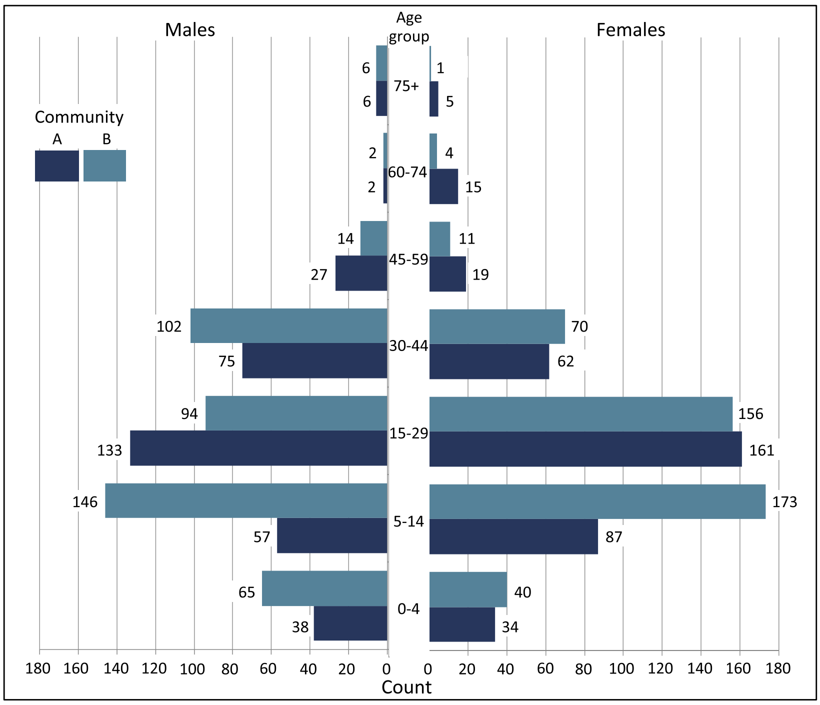

Figure 4. *Sex and age group structure in the two communities.* Community A is shown in dark blue, Community B in light blue. Counts are shown at the end of each bar.

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[a] (USD per day) (95% CI)	0.48 (0.40–0.59)	0.44 (0.36–0.52)
Education[b] (%)		
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.

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 2. Water and sanitation.

		Community A	Community B	χ^2	Summary
Water sources and treatment	*Source 'very often/ always'*				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
	Vendors	36%	54%	13.530[c]	
	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' Yes	3%	1%	10.346[c]	
Types of sanitation facilities used and their cleanliness	*Type*				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 exclusive pit	23%	31%	5.355[b]	
	Own but shared pit	43%	22%	21.310[c]	
	Neighbour's pit	3%	7%	10.215[c]	
	Clean				
	Never	30%	25%		
	Rarely/ sometimes	38%	53%		
	Always/very often	33%	22%	9.644[c]	

Per cent (%) refers to percentage of households in each community. Values may not add to 100% due to rounding. χ^2 values marked.
[a] are significant at $p < 0.10$.
[b] at $p < 0.05$.
[c] at $p < 0.01$.

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 −2 mm day^{-1} and 1 to 2 mm day^{-1} 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

Table 3. Deprivation of essential items.

		Community A	Community B	χ^2	Summary
Number of times a household has gone without enough of an item over the previous year	*Clean water*				Households 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
	At least several times	30%	8%		
	Once or twice	39%	45%		
	Never	32%	47%	31.277[c]	
	Cooking fuel				
	At least several times	41%	18%		
	Once or twice	32%	35%		
	Never	26%	47%	28.929[c]	
	Medicine				
	At least several times	34%	19%		
	Once or twice	20%	40%		
	Never	47%	41%	23.968[c]	
	Income				
	At least several times	80%	35%		
	Once or twice	13%	40%		
	Never	7%	25%	82.169[c]	
	Food				
	At least several times	41%	13%		
	Once or twice	29%	28%		
	Never	30%	59%	49.296[c]	

Per cent (%) refers to percentage of households in each community. Values may not add to 100% due to rounding. χ^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 in Community B has a reduced flow and a greater number of users upstream who access the water before it reaches the community. The river flowing through Community A has fewer upstream users and a greater

Table 4. Diagnosed health conditions.

		Community A	Community B	χ^2	Summary
For each individual household member:	*Malaria*				
'Has a doctor ever said that this person has…?'	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
Percentage (n) of individuals with χ^2 test.	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[b]	
	Trachoma				
	Children	0.0% (0)	0.6% (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[b]	
	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[c]	
	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. χ^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: Number of days spent sick in the last month due to malaria or typhoid (Community B only).	*Malaria*					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
	Children	31	462	0.067 (0.000–0.134)		
	Adults	70	476	0.147 (0.053–0.241)	−1.356	
	Typhoid					
	Children	0	462	0		
	Adults	21	476	0.046 (−0.016–0.109)	−1.431	
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.

Table 6. Perceived climate risk.

		Community A	Community B	χ^2	Summary
Perceived risk of specific climate hazards in the community	*Droughts are a serious risk*				Droughts were seen as a risk in their community by fewer participants in Community A than Community B. More than two-thirds of the participants in both communities 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
	Agree	43%	57%		
	Disagree	50%	30%	13.369[c]	
	Neither agree nor disagree	7%	13%		
	Floods are a serious risk				
	Agree	71%	69%		
	Disagree	24%	18%	0.833	
	Neither agree nor disagree	5%	13%		
	Climate change is a problem				
	Agree	89%	87%		
	Disagree	8%	11%	0.983	
	Neither agree nor disagree	3%	2%		
	Temperatures are increasing				
	Agree	74%	77%		
	Disagree	26%	22%	1.065	
	Neither agree nor disagree	0%	1%		

Per cent (%) refers to percentage of heads of household in each community. χ^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.

		Community A	Community B	χ^2	Summary
Perceptions of risk of specific climate-sensitive health conditions: per cent who agree with the statements '…is a life-threatening disease in my community'	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. χ^2 values marked.
[a] are significant at $p < 0.10$.
[b] at $p < 0.05$.
[c] at $p < 0.01$.

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 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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