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EDITED BY
Caroline Zickgraf,
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REVIEWED BY
Mumuni Abu,
University of Ghana, Ghana
Alex Arnall,
University of Reading, United Kingdom

*CORRESPONDENCE
Raphael Karutz
raphael.karutz@ufz.de

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Exploring the relationship between droughts and rural-to-urban mobility—a mixed methods approach for Pune, India

Raphael Karutz * and Sigrun Kabisch

Department of Urban and Environmental Sociology, Helmholtz Centre for Environmental Research – UFZ, Leipzig, Germany

Urbanization in the global South is intricately linked with the internal mobility of people and the impacts of climate change. In India, changing precipitation patterns pose pressure on rural livelihoods through the increasing frequency and severity of droughts, contributing to rural-to-urban mobility. At destination, however, insufficient information is available on the complex mobility backgrounds of the new arrivals. We employ a mixed methods approach to investigate mobility patterns to Pune, India, with a special focus on the role of droughts. Combining a household survey with in-depth interviews and monthly precipitation data on district level, we use descriptive statistics and qualitative content analysis to show a significant relationship between drought at origin and mobility to Pune. Particularly affected are recent arrivals, migrants of rural origin and from other states, and those currently living in informal areas. The link between droughts and mobility decisions is usually indirect, hidden behind economic conditions such as the loss of agricultural jobs. Paradoxically, migrants affected by droughts at origin face increased flood risk at destination. This risk, however, is often consciously taken in favor of better livelihood opportunities in the city. With climate scenarios projecting increasingly variable precipitation patterns, understanding the climate-mobility-urbanization nexus gains importance, especially for destination hotspots like the city of Pune.

KEYWORDS

climate mobilities, rural-to-urban mobility, drought, mixed methods, aspirations-capabilities, climate migration, Pune, India

1. Introduction

1.1. Linking urbanization, mobility, and the role of climate change

Urbanization and human mobility have historically been closely intertwined phenomena (Horwood et al., 2020). A clear quantification of rural-to-urban mobility's contribution to urbanization is difficult and greatly differs between countries. Especially in low-income countries, however, its share is significant, at times surpassing the role of natural growth (UNDESA, 2008; Rigaud et al., 2018). A majority of cities' newcomers originate from rural areas within the same country: Despite the prominent role of international cross-border migration in the public discourse, internal mobility is estimated to account for three times its volume with about 750 million people worldwide on the move within their

own country (Black et al., 2011; UNDESA, 2013). The urbanization-mobility complex is situated in the context of global environmental change (Adamo, 2010; Foresight, 2011). Climate change's slow-onset events (drought, erosion, sea-level rise) already today have severe impacts: between 2000 and 2019, over 1.4 billion people were globally affected by droughts alone (UNCCD, 2022). Scenarios presented in the Groundswell reports project that such extreme events may be associated with up to 40 million internal climate migrants by 2050 in South Asia, and 216 globally (Rigaud et al., 2018; Clement et al., 2021). Droughts have been found to have a particularly strong association with human mobility (Zickgraf, 2021). Climate change, however, not only fuels urbanization via increased mobility to cities but also poses increasing threats to cities' vulnerable population groups, including those who just arrived from affected rural regions (Dodman et al., 2022). In recent years, the debate has shifted from attempts to distinguish and quantify flows of "climate migrants" to the understanding of environmental change as the "new normal," i.e., one of many factors feeding into the mobility of people (Boas et al., 2019)—just as human mobility is viewed as a normal aspect of social change (De Haas, 2021). Increased attention has since been laid on the complex interplay of reasons and patterns of people's movements. In this context, climate mobilities are understood as a more inclusive term than migration, encompassing all forms of permanent and temporary, directional and cyclical movements of people, as well as their (temporary) immobility (Wiegel et al., 2019).[1] The concept rejects a simplistic notion of mono-causal linear movements across large distances often associated with the term climate migration (Baldwin et al., 2019). Consequently, concepts of clear-cut push- and pull factors are increasingly challenged as unduly deterministic, masking the complex interactions of structural and individual conditions leading to migration decisions (De Haan, 2011; Baldwin, 2016; Chung et al., 2022; Piguet, 2022).

In our analysis of rural-to-urban mobilities under climate stress, we draw on the aspirations-capabilities framework presented by De Haas (2010, 2021), building on work by Carling (2002) and others. Bridging functionalist (e.g., neoclassical migration theory, the new economics of labor migration—NELM) and historical-structural paradigms (e.g., dependency theory and critical globalization theory), it conceptualizes mobility decisions as the outcome of complex interactions between structural factors (capabilities shaped by political and economic constraints or climate stress) and agency of individuals (the intrinsic and instrumental aspiration to migrate; cf. De Sherbinin et al., 2022). The framework encompasses grades of voluntariness between free and forced (im-) mobility and describes mobility factors such as (the absence of) constraints or the access to resources in the form of positive and negative liberty. We apply the framework to the case of Pune, India, to better understand the complex patterns and motives of migrants, i.e., where the interplay of aspirations and capabilities has led to the decision and successful execution of migration to the city. We place special focus on the research question of what role droughts play in the mobility decisions of different migrant groups. To that end, a mixed methods approach is followed, coupling the results of a household survey with weather data, while in-depth interviews with a sub-sample of particular interest—informal dwellers from rural origin—complement the analysis with qualitative understanding.

Our results contribute to the understanding of the spatiotemporal association between drought stress at origin and mobility to the city. We find that certain migrant groups are disproportionately affected, namely recent arrivals, interstate migrants, and those from rural origin. In-depth interviews confirm the important role of droughts in migration decisions and illustrate how their effect in rural areas of origin is typically channeled through economic conditions.

The article is structured as follows: We first sketch out the climate-mobility-urbanization nexus for the case of India and revisit available data sets and previous work. We then introduce the case study of Pune and describe the mixed methods research design. The results provide insights on general mobility patterns to Pune and the overall association with droughts, as well as more targeted analyses of migrant subgroups. The article concludes with a discussion of results through the aspirations and capabilities framework lens.

1.2. Climate mobilities and urbanization in India

India features unique characteristics in terms of internal mobility and urbanization, as well as climate-change affectedness: The country remains one of the least urbanized countries in the world, with the latest census estimating that 31% (377 million residents) live in urban areas. Of these, 35% to 46% have a migration background (NSSO, 2007; Census, 2011). While human mobility has contributed only about one-fifth to the country's urbanization (Jiang and O'Neill, 2018), this implies a yearly net stream of about 2 million people moving from rural to urban areas, corresponding to approximately 20% of the total internal migration flows (Irudaya and Bhagat, 2021). While states like Maharashtra have received several million interstate migrants, almost 90% of India's internal mobility remains within the same state or even district (Bhagat and Keshri, 2021). Regarding climate change, India ranges among the ten most affected countries in the world (Eckstein et al., 2021) with large shares of the country experiencing consequences of climate change in terms of droughts and other extreme events. Especially the agricultural sector is susceptible to climate shocks, rendering rural communities particularly vulnerable (UNCCD, 2022).

These characteristics have sparked research interest in India's climate-mobility-urbanization nexus. Such analyses require appropriate data. In India, the primary data source is the decadal census, which captures information on place of birth, last place and type of residence (rural or urban), and duration of stay (Census, 2011). Census data, however, focuses on permanent migration, not fully capturing/distinguishing temporary (e.g., seasonal) mobility (Chandrasekhar and Sharma, 2015; Hoffmann et al., 2021) and tends to overlook informal residents (Horwood et al., 2020). Census data is aggregated in such a way that neither

1 In this article, we use the term mobility/mobilities in the sense defined by Wiegel et al. (2019). When referring to the concrete act of changing place of residence (e.g., from rural areas to Pune), we use the term migration. Where referencing data and literature such as the Census of India speaking of migration, we also adopt their wording.

information on migration origin beyond the state level nor the exact year of moving is provided. Further large-scale longitudinal data sets on national level in India are the National Sample Survey (NSSO, 2007) and the India Human Development Survey (IHDS; Desai and Vanneman, 2015). While holding more fine-grained information on seasonal migration and reasons (NSSO) as well as temporal patterns (IHDS), both face constraints related to spatial resolution and depth of analysis comparable to the census (Nayyar and Kim, 2018; Bhagat and Keshri, 2020). Despite their limitations, all three data sets have been used for econometric models analyzing the association between climate variability and internal mobility in India: Dallmann and Millock (2017) analyze direct and indirect effects of droughts and floods on bilateral interstate migration as per Census 1991 and 2001, finding that drought frequency, and to a lesser extent magnitude, are associated with interstate migration and that agricultural states and rural areas are more affected in terms of out-migration, driving urbanization. Kumar and Viswanathan (2013) estimate the role of monsoonal precipitation and temperature on temporary mobility based on NSS data. They show how temporary migrants—typically men working in agriculture—are disproportionately affected by weather variability. Šedová and Kalkuhl (2020) compare migration observations between the two IHDS rounds in conjunction with precipitation and temperature data, finding significant effects of droughts on rural, especially agricultural, out-migration. Due to the particularities of the IHDS data, however, the results exclude large groups of migrants such as temporary migrants, those younger than 15 or older than 65, and those moving for other than economic reasons. While these quantitative analyses provide ample evidence of the significant association between droughts and internal (particularly rural-to-urban) mobility, all three studies lament the fact that one end of the migration flow is always limited in spatial resolution to the state level. Local drought effects and impacts on individual destination cities, as well as a more nuanced analysis of mobility patterns, are outside these studies' scope.

Here, the largely qualitative stance taken by case studies provides important insights: On the origin side, Kattumuri et al. (2017) compare household responses of two villages in Karnataka to drought stress, showing how those with inferior access to irrigation opt for migration to cities more often and more long-term, and explicitly name lacking rainfall and associated issues as reasons to move. Similarly, villagers in Chhattisgarh recognize a clear link between precipitation, food security, and mobility (Murali and Afifi, 2012). In times of drought, many landless men temporarily move to cities to secure income, often following contractors and personal networks and settling in precarious conditions at the urban destination, a practice also observed among drought-affected farmers in Orissa (Jülich, 2011). Surie and Sharma (2019) depict the gradual transition of migrants from climate-stressed rural to urban livelihoods, identifying diverse mobility pathways through the rural-urban continuum. As another study in the same city highlights, informal settlements often serve as the entrances of (climate) migrants to the city (Chu and Michael, 2019). Most of these case studies, however, deepen the understanding of a particular phenomenon in a small population group, not allowing (or aiming for) a comprehensive city-wide picture of mobility patterns. This work builds on the existing analyses of internal (climate) mobilities in India. In light of the above-mentioned limitations of purely quantitative and qualitative approaches, we propose their combination in a mixed methods design to better understand mobilities to one of the cities most frequently sought by internal migrants—the Maharashtrian metropolis of Pune.

2. Materials and methods

2.1. Study site: Pune

The focal point of our analysis is the emerging megacity of Pune. The city has experienced massive demographic, economic, and spatial growth in the past, fueled by in-migration (Karutz et al., 2023). This growth is associated with increasing pressure on the city's natural resources and the provision of basic services to the residensts, such as continuous piped water supply (Karutz et al., 2022). The share of migrants in Pune's urban agglomeration increased from 44% in 2001 to 65% of the 5 million residents in 2011 (Census, 2011). Approximately half have arrived within the last 9 years. While historically, most newcomers had a rural background, new opportunities in the city's IT, pharmaceutical, and educational sectors have more recently attracted growing numbers of highly qualified migrants from other cities (Krishnamurthy et al., 2016; Butsch et al., 2017). Three-quarters of Pune's migrants originate from within Maharashtra and one quarter even from within the same district. Most of the remaining ones are interstate migrants, plus a few international ones (Census, 2011). Many of the new arrivals settle in peri-urban dwellings or one of the city's over 500 informal settlements ("slums"; Krishnamurthy et al., 2016). In previous work, we showed how the socio-economic status and resilience of migrants strongly depend on their place of origin and type of current residence: those who migrated from urban areas enjoyed 2 years of education more than those of rural origin, are more often living in formal urban housing (92% vs. 77%), and have three times as much water storage available (Link et al., 2021). Furthermore, migrants living in Pune's informal settlements have a significantly lower resilience than migrants living in formal areas. The least resilient group, ranging below any other migrant group and non-migrant residents, are consequently rural-to-urban migrants currently living informally (Link et al., 2021).

2.2. Mixed methods research design

The analysis presented in this work rests on a mixed methods approach combining three types of data: (1) results of a recent questionnaire-based household survey, (2) semi-structured interviews conducted in Pune's informal settlements, and (3) India-wide high-resolution monthly precipitation time series (Figure 1). With acquisition taking place broadly at the same time, data sets (1) and (2) are coupled via convergent design (also found in literature as concurrent or parallel design; Creswell and Plano Clark, 2018). Convergent designs are typically used for contextualization, cross-validation of sources, and the identification of causalities (Rädiker, 2020), hence suit the research objective well. As described in more

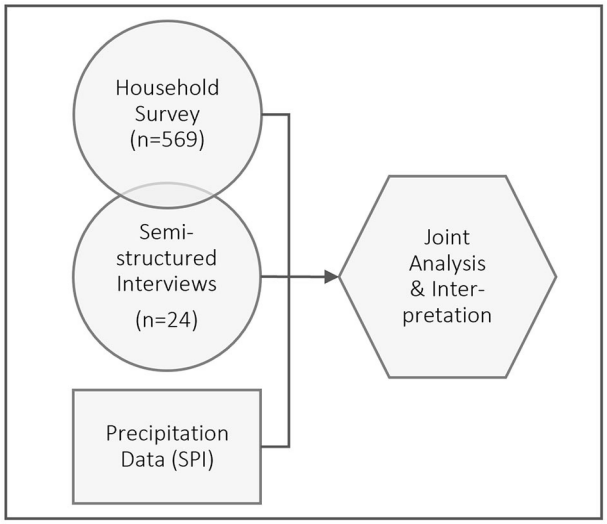

FIGURE 1
Convergent mixed methods research design with household survey data, interviews, and data on precipitation.

detail below, the chosen sampling method can be described as a combination of what Onwuegbuzie and Collins (2015) coined parallel and nested sampling: Parallel refers to independent samples from the same population, whereas a nested sample is the subset of a larger sample. Approximately half of the interviews also answered the household survey (nested), the remaining ones—though based on the same population—did not (parallel). The following sections provide detailed information on the three data sets as well as the conducted joint analysis.

2.3. Survey data

In 2019/2020, a household survey was conducted in Pune, providing closed-ended mobility information for the analysis at hand (Zhu et al., 2023). The survey, as well as the interviews, are part of the inter- and transdisciplinary research project FUSE,[2] focusing on the Food-Water-Energy Nexus in the rapidly urbanizing Bhima basin. Previous stakeholder workshops yielded migration to Pune as a major nexus driver (Karutz et al., 2022). Aiming for representativeness, the survey applied stratified random sampling (World Bank, 2009), randomly selecting households within city units predefined by their location and socio-economic characteristics. After a pilot run in 2019, the main phase surveyed 1,872 households in 2020. The survey was conducted in person in Marathi language at the respondents' homes. Results were translated to English and checked through several iterations of data cleaning. Mobility-related questions formed one part of the questionnaire. They were asked individually both for the respondent and, if applicable, their partner, assuming sufficient knowledge of the partner's biography for the level of inquiry. Questions encompassed socio-demographic details on the respondent, as well as place and type (rural/urban) of origin, year and pattern (permanent/temporary) of, and reasons for, mobility, as well as flood experience at the destination. Regarding reasons for migration, respondents were shown 28 options to choose from, and an open category to be specified. Up to three reasons could be named per person. The predefined reasons are based on the Census (2011) general, as well as NSSO (2007) more specific socio-economic, and Foresight (2011) environmental reasons. Of all surveyed households, 553 respondents answered that they, and or their partner, had changed their place of residence to Pune in the past. After excluding incomplete/implausible answers, 569 individuals (respondents and partners) remained for analysis (see approximate survey and interview locations in Supplementary Figure S1). In total, 972 responses on reasons (0–3 per individual) were recorded and pooled for further analysis.

2.4. Interviews

In parallel to the household survey, 24 targeted, open-ended interviews were conducted with rural-to-urban migrants living in Pune's informal areas. The concentration on this sub-group was motivated by pilot survey results, literature, and discussions with local mobility experts and practitioners, suggesting a particular affectedness of "rural-to-informal settlement migrants" by environmental pressures (Khairkar, 2008). Ten respondents additionally answered the household survey. Ten distinct informal settlements were visited for the interviews. They differed greatly in housing quality and access to basic services, ranging from solid brick houses to tin sheet huts, tents, and temporary roadside shelters. Interviewees were identified in person ex-ante by the collaborating local partner, MASHAL, a non-governmental organization working in Pune's informal settlements since 1985 and is well known and respected in the communities. The independent nature of the research was stressed, with no government involvement and full anonymity of the interviewees. No compensation was offered for the interviews, which were conducted at the respondent's place of residence by one MASHAL employee and the first author. The MASHAL colleague translated the interview simultaneously between Marathi/Hindi and English, explained the setting and intention of the interview, and created an atmosphere of trust. As part of the interview, respondents were asked to draw their migration trajectory from their place of birth to their place of current residence. The sketches served as orientation in the remaining interview. The recorded interviews were transcribed verbatim and translated into English. The translation was coded using the software MaxQDA. Qualitative content analysis was conducted, using a primarily deductive coding approach (Mayring, 2000) with categories defined a priori by the survey questionnaire (e.g., pattern and reasons for migration, flood experience). Additionally, new codes emerged during analysis regarding different migration modalities, conditions at origin and destination, and plans for future mobility.

2 Further information: https://fuse.stanford.edu.

2.5. Precipitation data and SPI metrics

For the analysis of drought effects in relation to mobility, we use CRU's TS 4.06 data on monthly precipitation from January 1941 to December 2021 (University of East Anglia - Climatic Research Unit, 2022). The gridded data is clipped to India and averaged for administrative districts. Standardized Precipitation Index (SPI) as introduced by McKee et al. (1993), is subsequently calculated per month and both district and state. The SPI has become the most widely-used drought index, recommended by the World Meteorological Organization (WMO, 2012). Independent from absolute values, it allows for a comparison across different regions and seasons: Long-term precipitation records (in this case 80 years) are fitted to a gamma probability distribution which is then transformed into a standard normal distribution. The mean of the distribution is zero, the variance is one, and drought is defined by values below −1 (WMO, 2012). The SPI can be calculated for various time scales. We use monthly resolution (SPI-1) for our analysis. Based on SPI-1, three drought indices are derived: (1) *drought frequency*, i.e., the share of drought months during a given period, (2) *mean drought magnitude*, the mean SPI value of all drought months, and (3) *maximum drought duration*, the maximum number of subsequent drought months (cf. Zargar et al., 2011 for an overview on indices). In literature, different time periods and lags have been used to study the impact of droughts on mobility. For instance, Mueller and Osgood (2009), as well as Dallmann and Millock (2017) use drought periods of 5 years prior to migration for analyses in Brazil and India, respectively. Šedová and Kalkuhl (2020) use a period of 6–7 years around the time of migration. Others only take the year of migration into consideration (Wesselbaum, 2021). We use two time windows for the analysis: 1-year, i.e., the year of migration as indicated by the survey, and 5-year, the year of migration plus 2 years before and after. Wrapping the time window around migration instead of simply using the one and 5 years before migration is motivated by the understanding of climate mobilities as a fuzzy process, often associated with small first steps (e.g., to a nearby town) and temporary returns in the first years, heavily influenced by the conditions at origin. With these two time periods for each of the three drought indices, six metrics are analyzed in total.

2.6. Joint data analysis

All analyses combine at least two of the above data sources. For the understanding of general mobility patterns, migration flows are generated from the survey and contrasted with more detailed information from the interviews. With regards to drought effects on mobility, survey data on the year of migration and district and state of origin are coupled with the six drought metrics on the district and state level, generating twelve drought metrics for each of the 569 observations. First, paired *t*-tests are conducted between the district and state of out-migration, testing for differences in mean, i.e., whether the district suffered more or less frequent and severe droughts during the 1-yr and 5-yr periods around migration compared with the state average. The high temporal (yearly) and spatial (district-level) resolution of the survey data allows us to capture the impacts of comparatively small-scale precipitation anomalies. The comparison is conducted for the full sample, as well as a subsample ($n = 409$) of migrants who came to Pune between 2000 and 2019. For a more detailed exploration of drought effects, three groups of particular interest are compared via independent Welch's *t*-tests, the alternative to Student's *t*-test of independent samples applicable for groups of different variance. These groups are defined by (1) origin (rural/urban), (2) mobility type (intra-/interstate), as well as (3) the current area of residence (formal/informal). For the analysis of drought affectedness in relation to reasons for migration mentioned in the survey, reasons of migrants with higher drought affectedness are compared with those of lower affectedness. For simplicity, we only distinguish between high (=median or higher) and low (=below median) exposure to 5-year drought frequency and duration. All statistical analyses are based on the samples' (or subsamples') mean, not providing information on individual migrants' drought exposure or its effect on the mobility decision. For the subgroup of particular interest—rural-origin migrants currently living informally—this individual-level information is provided by the interviews. This allows testing for causalities, explaining effects, and locating them within the aspirations-capabilities framework.

3. Results

In the following, general mobility patterns to Pune based on the survey are presented first and contextualized with interview findings illustrating living conditions, perceptions, and expectations. Then, weather data is incorporated into the analysis to distill drought effects and, drawing on further interview material, explore their complex links with human mobility and locate them within the aspirations-capabilities framework.

3.1. Mobility patterns of Pune's migrants

According to the survey, over 80% of the migrants originate in Maharashtra, followed by the southern neighbor-state Karnataka and the large agricultural state Uttar Pradesh in northern India (for more details, see Supplementary Table S1). Within Maharashtra, the distribution of migration origin is not uniform: most moved from within the Pune district and from the southeast of Pune, where the Bhima basin, as well as the drought-prone region Marathwada lie (Figure 2). Almost three-quarters of the migrants have come during the last 20 years, i.e., since 2000. Approximately 90% of the mobility follows a permanent pattern. At the time of the survey, 17% lived in informal settlements, almost entirely originating from the three main states of origin—Maharashtra, Uttar Pradesh, and Karnataka. The interviews provide deeper insights into the migration patterns of rural-to-informal settlement migrants, showing a large diversity of mobility trajectories that rarely follow straight origin-destination links: 18 of the 24 interviewees had at least one transit location between origin and current place of residence, 10 had two or more. Typical transit locations are towns near the village of origin and informal settlements in Pune (Figure 2). This shows that at least for rural-to-informal settlement migrants, simple census-like questions about

their place of origin or last residence do not accurately capture the migrants' complex journeys. The choice of transit locations and destinations is shaped by many factors. In particular, networks play a major role: In 14 instances, former neighbors or relatives who had relocated previously offered information and assistance with starting up. A quote from interview 2 illustrates this: "He said the place is good, water supply is good, and we could get some kind of jobs" (I_2). In five cases, the interviewees acted as pioneers, supporting others in coming to Pune. Another typical mobility pattern, corresponding to Stark's (1991) NELM theory, is sending young men ahead to the city—to diversify the family's income, for education, or to scout the place before the remaining household would follow. If not through family and friends, employment-related mobility to Pune often involves labor contractors who hire workers in rural areas for construction or large-scale agricultural work. Similar to the survey, most interviewees have permanently settled in Pune. As some explained, however, seasonal migration had been a common pattern in the first years after moving, especially for those owning arable land in the village, typically going back to the village during the cropping season, and then returning to Pune: "[my parents] used to come here for a month or two for work and after that, they returned to the village" (I_18).

3.2. Drought occurrence in districts of origin

We explore the association between drought at origin and mobility statistically via a comparison of drought metrics between the district of origin with the surrounding state to test if there is generally an association between local drought occurrence and mobility to Pune. Six drought indicators are tested to estimate the correlation. As Table 1 shows, five of these confirm that during the period of migration, out-migration districts suffered greater droughts than the state average. Paired *t*-tests yield significant differences for drought duration and frequency for the 1-yr and 5-yr—periods, with differences in the mean between district and state across all observations ranging around 5–10%. Drought magnitude does not show a significant difference for the 1-yr indicator and a weak negative association (magnitude on district level below state average) for the 5-yr indicator. For all six indicators, the effect size Cohen's d is small (Cohen, 1992; Gignac and Szodorai, 2016). The results partly contradict the finding of Dallmann and Millock (2017), where drought frequency is most strongly associated with mobility while magnitude shows a weaker association and duration none. They used, however, slightly different definitions of the three metrics. Notably, the difference across the five indicators with the positive association is larger, more significant, and of greater effect size when limiting the sample to migrants who arrived in Pune since 2000 (see numbers in parenthesis in Table 1). Compared with the full sample, the mean district-state difference lies 47% higher for 5-yr duration and 77% higher for 5-year frequency. This could point to an increasing relevance of droughts for mobility decisions in recent years or for temporary mobility effects, where drought-affected migrants who had arrived in Pune earlier have already returned home or moved on with their journey at the time of the survey. The interview results confirm a strong association between drought at origin and mobility for the rural-to-informal settlement migrant subgroup: Half of the interviewees (12 of 24) reported water scarcity/drought as a factor contributing to migration. The described impacts are often extreme. One respondent recounts: "Everywhere was drought, like there was nothing to eat at [...] my parents farm all animals died because of no food, after that all left the village and came here to Pune" (I_12). Another explains: "The situation was such that we would have died due to starvation and hence we came here to survive" (I_9). The interviews evidence the causal effect of droughts on migration decisions for the chosen subgroup. Inference for other migrants, e.g., those coming from urban areas, would require further analysis.

3.3. Comparison between subgroups of migrants

In this section, the sample is clustered into groups along three distinctive features: rural/urban place of origin, intra-/interstate mobility type, and formal/informal area of current residence in Pune. We use the 5-year drought frequency metric for analysis in Table 2 and Figure 3 and provide some additional results on 5-yr duration in the text. The statistical results are conceptualized with findings from the interviews.

3.3.1. Rural vs. urban origin

Drought impacts occurred more frequently to migrants from rural areas of origin compared with urban origin. The effect is not observable for drought duration, suggesting that for rural communities, the repeated occurrence of drought may exhibit stronger links to permanent migration than singular extreme events. The interviews support this notion of a different response to individual vs. frequent drought events among rural households: During a severe drought in 1972, the entire family of one interviewee had moved to Pune, but all except her returned within 5 years since her village did not generally suffer from water scarcity and was able to resume rainfed agriculture in subsequent years (I_12). This is in line with previous findings of temporary mobility as drought adaptation (Kumar and Viswanathan, 2013). Interviewees from chronically dry regions such as Marathwada, on the other hand, pointed out that they did not see any future in the village due to constant water stress and hence permanently moved to Pune.

3.3.2. Intra- vs. interstate mobility

Migrants from outside Maharashtra experienced significantly greater drought impact both in terms of frequency and duration [$t_{(117)} = -4.12$ $p < 0.001$, d $= 0.36$] compared with intrastate migrants. This effect is enhanced when only looking at migrants arriving since 2000. In other words, long-distance internal mobility has a disproportionately high association with droughts. The effect corresponds to the finding by Šedová and Kalkuhl (2020) who note that deficit precipitation drives migrants to cities outside their state of origin. They suggest this may reflect the migrants' attempt to move to more prosperous states sufficiently far away from the

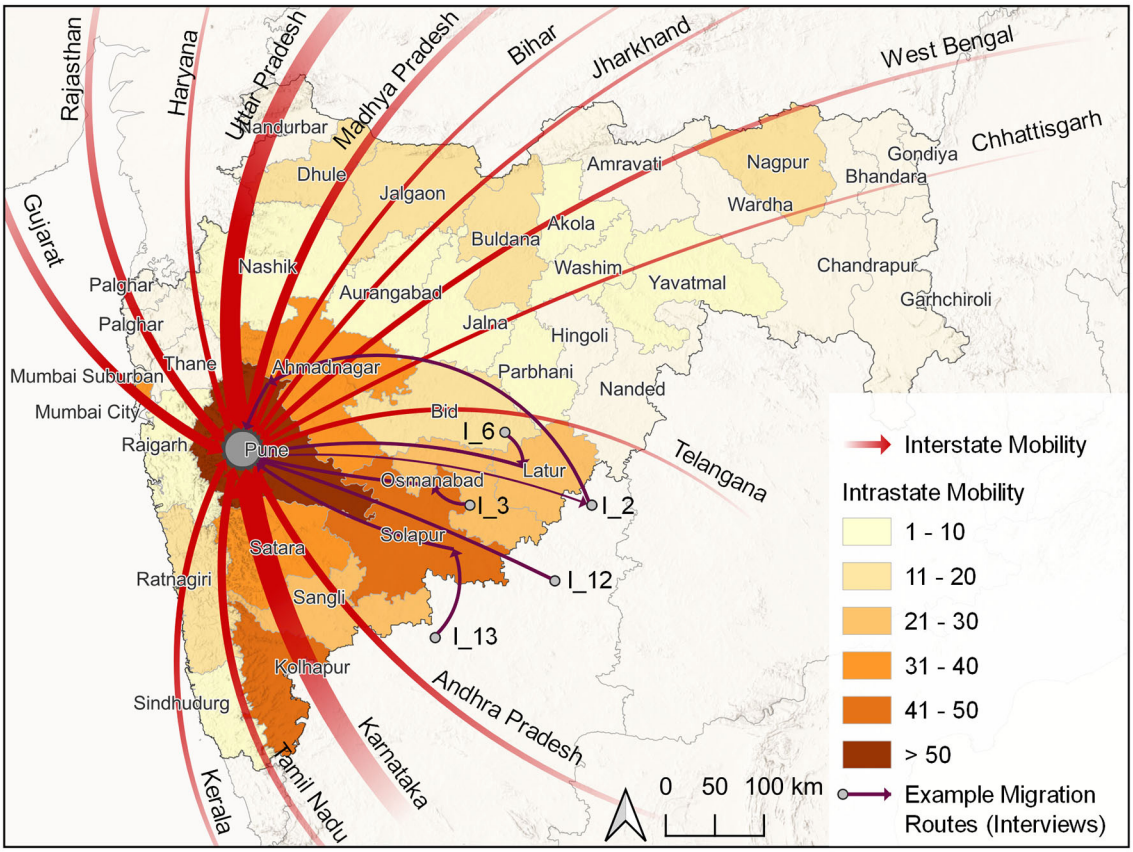

FIGURE 2
Mobility patterns to Pune. The map illustrates (1) interstate flows as per the household survey in form of red arrows (arrow width corresponding to the number of migrants), (2) intrastate flows as per the household survey by district (shade of the district corresponding to the number of migrants), and (3) example migration routes from interviews (purple arrows) that illustrate the actual routes with transit locations (e.g., I_3) and temporary return to the village (I_2).

TABLE 1 Comparison of six drought metrics by mean difference between district and state of origin at the period of migration via coupled *t*-tests.

Drought metric	Mean difference	df	*t*-value and significance	Effect size
1-Year Frequency	7.9% (15.3%)	568 (418)	2.26* (3.37***)	0.09 (0.16)
5-Year Frequency	5.1% (10.5%)	558 (408)	2.43* (3.77***)	0.10 (0.19)
1-Year Magnitude	1.6% (6.5%)	568 (418)	−0.69 (−2.30*)	0.03 (0.11)
5-Year Magnitude	−2.4% (−1.7%)	558 (408)	2.82** (1.79*)	0.12 (0.09)
1-Year Duration	9.2% (15.9%)	568 (418)	2.95** (4.01***)	0.12 (0.20)
5-Year Duration	8.7% (13.4%)	558 (408)	4.41*** (5.52***)	0.19 (0.27)

Numbers in parentheses correspond to the subsample of migration since 2000. For drought magnitude, negative *t*-values correspond to a positive association. Significance levels: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
Mean difference refers to the percentage, to which the average district-level drought metric across all survey observations is higher/lower than the state reference. *Degrees of freedom (df)* correspond to sample size - 1. The 5-year metrics exclude migration dates after 2017, reducing sample and df by 10. *T-value* corresponds to the difference relative to the sample's variance with larger values suggesting higher evidence for a difference in means. *Significance (p-value)* corresponds to the probability that the null hypothesis (equal means) is met. The effect size (Cohen's d) equals the difference between both means divided by the standard deviation.

drought region. The pattern, that droughts lead to excess labor in the affected area, reducing wages and alternative employment opportunities (Jülich, 2011), may be an explanation. An interviewee elaborates how during the drought, she and her husband initially searched for substitute employment in the region. They found work in the stone-crushing industry but were unable to secure sufficient income due to the low wages, ultimately opting to move to Pune (I_20). Our data suggest that the decision to move across state borders, coming with higher costs and uncertainties, may be taken less easily, i.e., only after repeated and long-lasting drought suffering and after testing intrastate alternatives. The distance of migration, in other words, can be viewed as a function of the migrants' aspirations. This effect, however, would need further investigation since at some point, it would contradict the

TABLE 2 Comparison of drought affectedness at origin (5-year frequency) by groups.

Comparison group	Mean difference	df	t-value and significance	Effect size (Cohen's d)
Origin: rural/urban	13.4% (10.5%)	540 (403)	2.44* (1.62)	0.10 (0.08)
Type: intrastate/interstate	−23.9% (−30.6%)	110 (72)	−3.41*** (−3.36***)	0.32 (0.39)
Residence: formal/informal	−10.1% (−18.0%)	126 (78)	−1.45 (−2.02*)	0.13 (0.23)

Results from independent Welch tests. The effect size (Cohen's d) equals the difference between both means divided by the standard deviation. Numbers in parentheses correspond to the subsample of migration since 2000. Significance levels: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
The *mean difference* refers to the percentage, to which the mean 5-year frequency of group 1 (e.g., rural origin) is higher/lower than the mean of group 2 (e.g., urban origin). *Degrees of freedom (df)* are calculated based on the groups' sample sizes and variances.

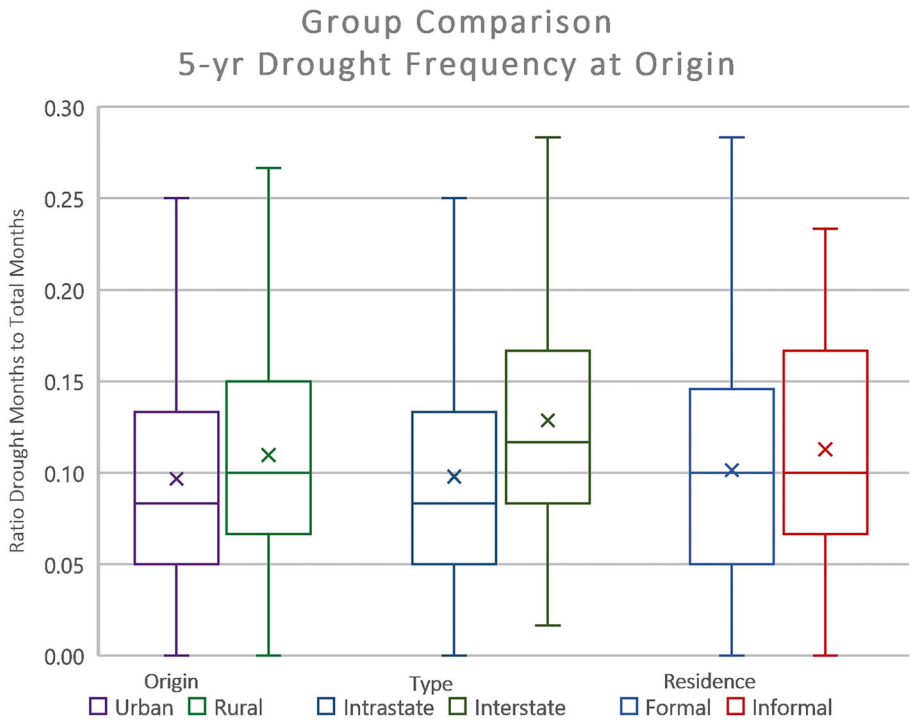

FIGURE 3
Comparison of migrants' drought affectedness at origin (5-year frequency) by mean (X marks) and median (horizontal lines). Grouped by origin, mobility type, and current residence. The Y-axis corresponds to the ratio of drought months in the district of origin to the total 5-year time period (example: 0.1 equals six drought months (SPI ≤ -1) in 60 months) before and after the year of migration. Outliers excluded.

assumption that frequent droughts erode the capabilities for long-distance mobility.

3.3.3. Formal vs. informal residence and flood exposure

Residents of informal settlements experienced a higher frequency of droughts during the time of out-migration compared with formal residents. However, sufficient evidence for a significant difference is only found when limiting the sample to arrivals since 2000, where the effect size is also larger. There are several potential reasons for this effect, including (1) upward social mobility at destination, where new arrivals may initially settle in informal areas of the city and move to formal neighborhoods once the socio-economic status allows for it, and (2) disproportionately short-term informal mobility in response to droughts. Since the interviews were only conducted with those who remained in Pune's informal settlements, they do not offer a clear answer. Some, however, mention the dream of moving to formal apartments within the city or returning to the village. Linked to the type of residence is the exposure to hazards at destination. While a detailed analysis is beyond the scope of this article, it is noteworthy that 14 of the 24 interview respondents were affected by flood events in Pune—for 11 of these, water scarcity/drought had been a reason to migrate. A comparison of drought exposure between migrants with and without flood experience is difficult due to the small sample size. Results show a 16% higher frequency for those who suffered floods after coming to the city—although with low significance: $t_{(30)} = -1.69$ $p = 0.102$, d = 0.30. Pune's floods have

caused great damage, including many casualties in recent years. It is noteworthy, however, that the interviewees perceive the flood hazard as qualitatively different from droughts at origin. Droughts as slow-onset events erode livelihood opportunities and thereby heavily constrain coping capacities. With regards to urban floods on the other hand, the choice of residence has often been made in spite of the well-known hazard—to leverage superior access to the city's opportunities compared with less flood-prone, but more peripheral land. Several interviewees explain how they have gotten used to temporary relocation and repair of their homes in case of flood damage and that they have received compensation from the city, partly offsetting the losses. Flood exposure in that sense could be viewed as a risk people are consciously taking to improve their economic and social capital, which in turn reduces their vulnerability. In general, however, the often-claimed "double jeopardy" of climate migrants, disproportionally suffering both at origin and at destination (Foresight, 2011), is found in Pune too.

3.4. Drought-affectedness and reasons for migration

In the previous section, we have shown how droughts impact mobility decisions in different ways. Here, we contrast this with their perceived importance in terms of reasons named in the survey: Surprisingly, environmental reasons (almost entirely relating to water scarcity/drought) are rarely mentioned (2%), while economic and family-related ones dominate the picture. A comprehensive overview of the reasons provided by different migrant groups is found in Supplementary Table S4. Linking reasons to drought at origin, we do not find a strong association between high drought-affectedness and the mentioning of environmental reasons in the survey. Drought is, however, related to work-related reasons, particularly the search for employment.

On first glance, the survey results with their low relevance of environmental reasons contradict the observed drought differences at origin and the interview findings. This points to an effect discussed by previous studies: Particularly in agriculture, drought effects work through alterations of the economic conditions and are hence perceived in their ultimate manifestation—economic pressure. Several interviews elicit the causal chain between precipitation, agricultural production, income/employment, and mobility. In Maharashtra and northern Karnataka, where many interviewees originate, a large share of the agriculture is rain-fed and hence very susceptible to precipitation anomalies: "There was no rainfall. Nothing was getting cultivated [...] We didn't get the work of daily wages in the village" (I_1). "We got the work only when rain falls" (I_20). Other interviews confirm that employment for agricultural laborers is often directly dependent on rainfall. This drought-livelihood-mobility link is found for smallholder farmers as well as landless laborers. In some cases, the link is explained by the interviewees immediately. For instance, I_11 responds to the question if there were any more reasons why her family had moved: "No no, only because of water, there was not sufficient water for farming then what would we do there in the village?" Others initially just name lacking livelihood opportunities in the village as a reason for migration, explaining only upon further questions that water stress was the cause behind it. While water issues mostly referred to temporary (sometimes recurrent) droughts, they are also described to have caused the permanent erosion of soil and loss of the land's fertility in some cases. The problematic situation in many rural regions of India regarding potable water is rarely named in the survey, especially by rural-origin migrants, while several interviews show that lack of access to drinking water does play a role in the migration decision "We were not getting water to drink that's why we came here" (I_1).

4. Discussion

While consensus has emerged that climate change does not simply "push" people to cities, gaining an understanding of the complex mechanisms behind the climate-mobility-urbanization nexus is important. Our results show a significant association between mobility and the frequency and maximum duration of droughts at the district of origin. This complements previous studies finding the effect on state-level and highlights the local nature of droughts, affecting some districts within one state significantly more than others. The drought-mobility association is particularly strong for recent arrivals, rural communities of origin, interstate migration, and people living in informal settlements at destination.

Understanding the causal chain, i.e., how droughts act as "crisis catalysts", filtered through economic, social, and other conditions on the ground (Chu and Michael, 2019) is critical. Droughts exert stress often indirectly via the loss of income/employment and are hence less visible, leading to underreporting when superficially asking for reasons. This effect, previously described by Ahlquist and Baldiga (2019) is found throughout our data: Water scarcity/drought is almost never mentioned as a reason to migrate in the survey, while drought-affected migrants often refer to economic reasons for migration. The interviews, in which half of the respondents report water issues as a migration factor, provide further evidence of how economic stress and the need to search for alternative livelihood opportunities feed into the migration decision. We conclude that standard questionnaires on reasons for migration (as used by the census) cannot capture the complex interplay of conditions that lead to the decision of moving, implying an underestimation of environmental factors in official statistics.

Previous works on climate mobilities to cities have often chosen a particular narrative, either framing climate mobilities as a "sign of successful adaptation and upward social mobility," portraying migrants as active agents of change who improve their livelihood opportunities by moving, or focusing on migration as a "route toward onward precarity and climate vulnerability", highlighting structural conditions and the often-found marginalization of migrant communities (Chung et al., 2022, p. 13). In line with De Haas' (2021) aspirations-capabilities framework presented in the introduction, our results support both standpoints: Most

interviewees describe their moving—albeit not free of pressures and constraints—as a conscious and sovereign decision, emphasizing agency in terms of aspirations to improve their livelihoods and opportunities for their children. The findings further suggest that rural-origin migrants who frequently suffer droughts develop greater aspirations to permanently leave home compared with those affected by a single long drought event. Similarly, the distance willing to migrate appears to increase (domestically) with increasing drought duration and frequency. In other words, the further migration leans toward involuntary mobility—in this case the displacement by severe droughts—the more distant and long-term it seems to become. At what point droughts impede capabilities to migrate and reverse the trend of growing distance, would need further investigation. On the other hand, the living conditions of rural-to-informal settlement migrants at destination are highly precarious and those who currently live in informal settlements were exposed disproportionally to droughts at origin. In cruel irony, many of these were subsequently hit by urban floods. Linking back to the observed channeling of climate stress through economic conditions, mobility decisions seem to be made rather in terms of improving one's coping capacities—better jobs and education—than to reduce the exposure to environmental hazards itself. In the words of one interviewee: "If at least I'll have money, then I can buy water but I didn't get money in the village" (I_1).

The interlinking of three very different data sources in our study helps balance out individual weaknesses and limitations: The household survey can be viewed as a more detailed and recent version of the census, providing important information on origin and date of migration, but lacking depth on mobility trajectories and factors leading to the decision. The weather data, on the other hand, is an ideal complement to the survey for a joint analysis of meteorological anomalies related to mobilities. Neither data set, however, explains causalities and contextual conditions in the mobility decisions. This is achieved by augmenting the analysis with in-depth interviews. Though limited to a particular population group, it fleshes out complex journeys and reasons behind the migration decision. Nonetheless, this work has limitations: While carefully balanced, the survey sample is not representative of the entire Pune metropolitan area, remaining largely within Pune and Pimpri Chinchwad municipal corporations, partially disregarding surrounding villages. Many rural-origin migrants, however, initially settle in the urban fringe, where land zoning is less strict and prices are lower. This implies a potential underrepresentation of rural-origin migrants, especially those who recently arrived and live informally. The statistical analyses do not account for many factors shaping mobility decisions beyond the exposure to droughts, especially in terms of socio-economic and political conditions at origin, which can only partly be compensated for by the interviews since they cannot explain patterns of formal-destination and urban-origin mobility and the overlap between survey and interviews is too small to warrant meaningful comparisons of data pairs. The chosen cross-sectional destination perspective only looks at those who have made it to the city and remain present until the time of the survey. This biases the sample in terms of who moved initially from the origin. Temporary/seasonal migrants are likely underrepresented by the survey and the approach completely disregards those who did not arrive in Pune, maybe never left their place of origin due to voluntary or involuntary immobility, e.g., through lack of economic or social capital (cf. Mallick and Schanze, 2020). It should be kept in mind that large shares of the Indian rural communities have experienced the effects of climate change in the past, while only a fraction has resorted to migration.

5. Conclusion

Internal mobility and the role of climate factors have received great interest in the last few years. Many analyses focus on regions of origin or bilateral flows. We study mobility from the perspective of a destination hotspot, the emerging megacity of Pune. Meaningful analyses on the city level require a more nuanced perspective than provided by census and other large data sets and a broader database than typically found in qualitative analyses. Our mixed methods approach is based on a unique data combination with a large household survey providing mobility data in fine temporal and spatial resolution, country-wide monthly precipitation data on district level, and in-depth interviews with a subsample of particular interest. Through their combination, a rich picture emerges of the diverse patterns, reasons, and narratives of mobility to Pune. The employment of the aspirations-capabilities framework has proven well-suited for the analysis of the multi-faceted picture encountered among Pune's migrants. The results provide further evidence of the relationship between droughts at origin and mobility to cities. While the overall effect is evident—and in line with previous work—the comparison of different drought metrics and migrant groups highlights how diverse and complex the relationship is. In particular, the strong association with economic factors in rural agriculture needs recognition: Droughts are usually not single "push" factors for people to move to cities. They often however, deteriorate economic conditions and limit livelihood opportunities as hidden stressors, especially when occurring in high frequency. Shedding light on channels through which drought pressure works, may help to design tailored policies and support schemes directed at different points of leverage. These could target the resilience of farmers at origin, e.g., through advanced irrigation systems or drought-adapted crops, or the economic diversification of drought-prone regions. They could also target those who resorted to migrating, e.g., in the form of support mechanisms for temporary mobility or as start-up help for those permanently relocating to the city. Metropoles like Pune are likely to remain mobility magnets in future when weather anomalies in India and other parts of the world become more frequent and severe. Migrants are often particularly vulnerable to climate hazards at destination. Therefore, an in-depth understanding of mobilities to the city, drawing on the various available data and methods, is critical. It serves the interest of both long-term urban planning and the design of support systems for vulnerable population groups.

Data availability statement

The original contributions presented in the study are included in the Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

RK designed the study, conducted the empirical work as well as the formal analysis, and wrote the original draft of the article. SK supervised the research and contributed to the manuscript in terms of review and editing. All authors contributed to the manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2023.1168584/full#supplementary-material

SUPPLEMENTARY DATA SHEET 1
Provides an overview of the Supplementary material, including Figure S1 and Tables S1–S4.

SUPPLEMENTARY FILE 1
Provides all SPI metrics generated for the analyses.

SUPPLEMENTARY FILE 2
Provides the survey data and all associated statistical analyses conducted in this study.

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