Migration response to drought in Mali. An analysis using panel data on Malian localities over the 1987-2009 period

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ONLINE APPENDIX

Appendix A - Tables and Figures

Table A1: SPEI variation under various sets of fixed effects

	R-squared				
	0.29	0.44	0.56	0.72	0.90
Period F.E	×	×	×	×	×
Locality F.E		×	×	×	×
Region×Period F.E			×		
District×Period F.E				×	
Municipality×Period F.E					×

Sample: Census from 1987, 1998 and 2009.

Table A2: Robustness checks: Droughts effects on standardized net migration rates using alternative model specifications

	(1)	(2)	(3)	(4)
		Men		
Nb. shocks from t-10 to t (June-Oct)	-0.013	-0.015	-0.000	-0.013
	(0.002)	(0.006)	(0.006)	(0.000)
Urban× shocks from t-10 to t (June-Oct)	0.009	0.009	0.014	0.009
	(0.005)	(0.010)	(0.014)	(0.000)
Observations	18,552	18,554	18,554	18,534
		Women		
Nb. shocks from t-10 to t (June-Oct)	-0.011	-0.012	-0.001	-0,011
	(0.002)	(0.006)	(0.004)	(0.000)
Urban× shocks from t-10 to t (June-Oct)	0.012	0.009	0.009	-0.012
	(0.003)	(0.009)	(0.013)	(0.000)
Observations	18,553	18,555	18,555	18,536
Village F.E	×	×	×	×
Year F.E	×	×	×	×
Region*year F.E		×		
District*year F.E			×	
Factor model $\lambda_j' F_t$				×

Sample: Census from 1987, 1998 and 2009. Note: Standard errors are in parentheses. From column (1) to column (3), standard errors are corrected for serial correlation over one period and for spatial correlation up to a distance cutoff at 500 km. We control by the size of age cohorts (10-19, 20-29, 30-39, 40-49, and 50-59) by village.

Table A3: Drought effects on standardized net migration rates

	Men	Women
	20-29	
Nb. shocks from t-11 to t (June-Oct)	-0.023	-0.005
	(0.004)	(0.003)
Urban× shocks from t-11 to t (June-Oct)	0.003	0.004
	(0.007)	(0.006)
Observations	18,533	18,525
	30-39	
Nb. shocks from t-11 to t (June-Oct)	-0.015	-0.012
	(0.004)	(0.003)
Urban× shocks from t-11 to t (June-Oct)	0.014	0.023
	(0.012)	(0.008)
Observations	18,499	18,527
	40-49	
Nb. shocks from t-11 to t (june-oct)	-0.010	-0.010
	(0.003)	(0.003)
Urban× shocks from t-11 to t (June-Oct)	0.017	0.020
	(0.011)	(0.008)
Observations	18,493	18,518
	50-59	
Nb. shocks from t-11 to t (June-Oct)	-0.003	-0.011
	(0.005)	(0.004)
Urban× shocks from t-11 to t (June-Oct)	0.018	0.021
	(0.010)	(0.010)
Observations	18,457	18,452
	60-69	
Nb. shocks from t-11 to t (June-Oct)	-0.006	-0.005
	(0.002)	(0.004)
Urban× shocks from t-11 to t (June-Oct)	0.011	0.018
	(0.012)	(0.012)
Observations	18,386	18,332
Village F.E	×	×
Period F.E	×	×

Sample: Census from 1987, 1998 and 2009. Notes: Standard errors in parentheses corrected for serial correlation over one period and for spatial correlation up to a distance cutoff at 500 km.

Table A4: Drought effects on standardized net migration rates

	Men	Women
	20-29	
Nb. shocks from t-10 to t (June-Oct)	-0.023	-0.007
	(0.012)	(0.007)
Urban× shocks from t-10 to t (June-Oct)	0.007	0.006
	(0.016)	(0.013)
Observations	18,535	18,527
	30-39	
Nb. shocks from t-10 to t (June-Oct)	-0.017	-0.012
	(0.009)	(0.008)
Urban× shocks from t-10 to t (June-Oct)	0.017	0.023
	(0.021)	(0.016)
Observations	18,501	18,529
	40-49	
Nb. shocks from t-10 to t (June-Oct)	-0.010	-0.009
	(0.008)	(0.008)
Urban× shocks from t-10 to t (June-Oct)	0.017	0.016
	(0.017)	(0.016)
Observations	18,495	18,520
	50-59	
Nb. shocks from t-10 to t (June-Oct)	-0.002	-0.014
	(0.011)	(0.011)
Urban× shocks from t-10 to t (June-Oct)	0.018	0.019
	(0.019)	(0.018)
Observations	18,459	18,454
	60-69	
Nb. shocks from t-10 to t (June-Oct)	-0.007	-0.008
	(0.010)	(0.011)
Urban× shocks from t-10 to t (June-Oct)	0.009	0.019
	(0.019)	(0.022)
Observations	18,388	18,334
Village F.E	×	×
Period F.E	×	×
Region*Period F.E	×	×

Sample: Census from 1987, 1998 and 2009. Note: Standard errors in parentheses corrected for serial correlation over one period and for spatial correlation up to a distance cutoff at 500 km.

Table A5: Drought effects on standardized international migration rates

	(1) Total	(2) Bordering	(3) Africa	(4) OECD	(5) France
			Men		
Nb. of droughts last 5 years (June-Oct)	0.0436	0.0949	0.0235	-0.0050	0.0176
	(0.0095)	(0.0157)	(0.0086)	(0.0102)	(0.0098)
			Women		
Nb. of droughts last 5 years (June-Oct)	0.0271	0.0365	0.0084	-0.0022	0.0150
	(0.0086)	(0.0106)	(0.0082)	(0.0091)	(0.0076)
Village F.E.	×	×	×	×	×
Years F.E.	×	×	×	×	×
Observations	59,550	59,550	59,550	59,550	59,550
Number of villages	9,925	9,925	9,925	9,925	9,925

Sample: Census from 2009. Note: Standard errors are clustered at the district of origin and are reported in parentheses.

Table A6: Drought effects on standardized net migration rates by agro-ecological zone (ref: arid zone)

	Men aged 20-69	Women aged 20-69
Nb. shocks from t-11 to t (June-Oct)	-0.034	-0.026
	(0.006)	(0.005)
Shock*semi-arid	0.031	0.020
	(0.005)	(0.005)
Shock*semi-humid	0.014	0.016
	(0.007)	(0.004)
Village F.E	×	×
Period F.E	×	×
Observations	18,336	18,337

Sample: Rural localities. Census from 1987, 1998 and 2009. Note: Standard errors in parentheses corrected for serial correlation over one period and for spatial correlation up to a distance cutoff at 500 km.

Table A7: Drought effects on standardized international migration rates by agro-ecological zone (ref: arid zone)

	(1) Total	(2) Bordering	(3) Africa	(4) OECD	(5) France
Nb. droughts from t-5 to t (June-Oct)	0.1024	0.2784	0.0357	0.0318	0.0220
	(0.0411)	(0.0691)	(0.0379)	(0.0264)	(0.0365)
Nb. droughts from t-5 to t (June-Oct)×semi-arid	-0.0547	-0.1653	-0.0203	-0.0454	0.0048
	(0.0395)	(0.0601)	(0.0382)	(0.0259)	(0.0327)
Nb. droughts from t-5 to t (June-Oct)×semi-humid	-0.0149	-0.1569	0.0278	-0.0499	0.0176
	(0.0389)	(0.0593)	(0.0377)	(0.0256)	(0.0314)
Village F.E.	×	×	×	×	×
Years F.E.	×	×	×	×	×
Observations	37,602	37,602	37,602	37,602	37,602
Number of villages	6,267	6,267	6,267	6,267	6,267

Sample: Rural localities. Census from 2009. Note: Standard errors are clustered at the district of origin and are reported in parentheses.

Table A8: Drought effects on standardized net migration rates by quintile of crop diversification index

	Men aged 20-69	Women aged 20-69
Nb. shocks from t-11 to t (June-Oct)	-0.017	-0.013
	(0.003)	(0.003)
shock*diversification 2	-0.010	-0.001
	(0.010)	(0.009)
shock*diversification 3	0.016	-0.000
	(0.004)	(0.006)
shock*diversification 4	0.003	0.002
	(0.006)	(0.005)
shock*diversification 5 (high)	0.018	0.011
	(0.004)	(0.004)
Village F.E	×	×
Period F.E	×	×
Observations	18,204	18,205

Sample: Rural localities. Census from 1987, 1998 and 2009. Note: Standard errors in parentheses corrected for serial correlation over one period and for spatial correlation up to a distance cutoff at 500 km.

Table A9: Drought effects on standardized net migration rates by wealth (ref: poorer localities)

	Men aged 20-69	Women aged 20-69
Nb. shocks from t-11 to t (June-Oct)	-0.080	-0.083
	(0.005)	(0.006)
Nb. shocks*wealth 2	0.049	0.056
	(0.005)	(0.005)
Nb. shocks*wealth 3	0.068	0.070
	(0.006)	(0.005)
Nb. shocks*wealth 4	0.087	0.092
	(0.006)	(0.006)
Nb. shocks*wealth 5 (rich)	0.106	0.114
	(0.007)	(0.009)
Village F.E	×	×
Period F.E	×	×
Observations	18,552	18,553

Sample: Census from 1987, 1998 and 2009. Note: Standard errors in parentheses corrected for serial correlation over one period and for spatial correlation up to a distance cutoff at 500 km.

Table A10: Drought effects on standardized international migration rates by wealth (ref: poorer localities)

	(1) Total	(2) Bordering	(3) Africa	(4) OECD	(5) France
Nb. droughts last 5 years	0.0385	0.0996	0.0126	0.0098	0.0111
	(0.0165)	(0.0240)	(0.0162)	(0.0116)	(0.0162)
Nb. droughts*wealth 2	0.0257	0.0196	0.0170	0.0017	0.0175
	(0.0204)	(0.0266)	(0.0205)	(0.0162)	(0.0129)
Nb. droughts*wealth 3	-0.0042	-0.0138	-0.0024	-0.0165	0.0210
	(0.0192)	(0.0221)	(0.0199)	(0.0153)	(0.0143)
Nb. droughts*wealth 4	-0.0095	-0.0373	-0.0028	-0.0135	0.0099
	(0.0212)	(0.0221)	(0.0225)	(0.0169)	(0.0142)
Nb. droughts*wealth 5 (rich)	0.0202	-0.0155	0.0403	-0.0495	-0.0095
	(0.0204)	(0.0232)	(0.0203)	(0.0186)	(0.0226)
Village F.E.	×	×	×	×	×
Years F.E.	×	×	×	×	×
Observations	59,550	59,550	59,550	59,550	59,550
Number of villages	9,925	9,925	9,925	9,925	9,925

Sample: Census from 2009.

. Note: Standard errors are clustered at the district of origin and are reported in parentheses.

Table A11: Number of droughts computed from observed and predicted SPEI

	Mean	Var	Min	Max
Simulated (RCP 2.6) nb. shocks from 2018 to 2037	1.652	3.000	0	13
Simulated (RCP 8.5) nb. shocks from 2018 to 2037	5.242	4.686	0	20
Simulated (RCP 2.6) nb. shocks from 2038 to 2057	8.124	3.465	1	20
Simulated (RCP 8.5) nb. shocks from 2038 to 2057	6.260	4.641	0	20
Simulated (RCP 2.6) nb. shocks from 2058 to 2077	5.400	4.528	0	18
Simulated (RCP 8.5) nb. shocks from 2058 to 2077	10.034	4.607	0	20

Sources: Observed SPEI and predicted SPEI (data from the IPSLCM-5A-LR model).

Table A12: Number of droughts and volume of net migration at the locality level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Men			Women			
	$\hat{\beta}_2$	$\overline{NMR_{j,[t-11,t]}}$	$NM_{j,[t-11,t]}$	$\hat{\beta}_2$	$\overline{NMR_{j,[t-11,t]}}$	$NM_{j,[t-11,t]}$	$droughts_{j,[1998,2009]}$
Mean	-0.035	0.082	-8.620	-0.032	0.102	-9.917	2.822
Min	.	-0.951	-5,374	.	-0.950	-6,514	0
Max	.	143.083	101,887	.	205.085	50,899	9

Sample: Census from 1987, 1998 and 2009. Columns (1) and (4) provide the estimated coefficients of our drought frequency variable in a regression where the left-hand side variable is the unstandardized net migration rate at the locality level, for men and women respectively.

Table A13: Population projection in Mali

Year	Men	Women
2009	7,313,414	7,293,186
2018	9,541,743	9,565,974
2038	16,637,405	16,834,048
2058	25,523,544	25,798,982

Source: United Nations, DESA.

Table A14: Projections of international outflows

Climate scenarios	(1) Total	(2) Bordering	(3) Africa	(4) OECD	(5) France
Observed 2004-2009	2,307	1,584	611.0	-528.0	607.8
	(674.9)	(276.7)	(429.8)	(232.6)	(299.2)
2018-2038					
RCP 2.6	2,226	1,938	429.3	-633.2	1,063
	(685.0)	(342.4)	(349.1)	(281.6)	(521.5)
RCP 8.5	4,186	3,735	880.6	-1,077	1,695
	(1,288)	(659.9)	(716.2)	(479.0)	(831.7)
RCP 2.6 +pop increase	2,912	2,535	561.6	-828.2	1,391
	(896.0)	(447.9)	(456.7)	(368.3)	(682.2)
RCP 8.5 +pop increase	5,476	4,885	1,152	-1,409	2,218
	(1,685)	(863.2)	(936.7)	(626.5)	(1,088)
2038-2058					
RCP 2.6	5,009	3,926	1,111	-1,294	1,798
	(1,541)	(693.8)	(903.1)	(575.4)	(882.1)
RCP 8.5	5,518	4,483	1,212	-1,396	2,037
	(1,698)	(792.2)	(985.7)	(620.7)	(999.3)
RCP 2.6 +pop increase	11,480	8,999	2,545	-2,965	4,122
	(3,532)	(1,590)	(2,070)	(1,319)	(2,022)
RCP 8.5 +pop increase	12,647	10,276	2,778	-3,199	4,669
	(3,892)	(1,816)	(2,259)	(1,423)	(2,290)
2058-2078					
RCP 2.6	5,009	3,926	1,111	-1,294	1,798
	(1,541)	(693.8)	(903.1)	(575.4)	(882.1)
RCP 8.5	7,001	5,699	1,661	-1,522	2,143
	(2,154)	(1,007)	(1,351)	(676.9)	(1,051)
RCP 2.6 +pop increase	11,480	13,797	3,903	-4,546	6,319
	(3,532)	(2,438)	(3,174)	(2,022)	(3,100)
RCP 8.5 +pop increase	24,603	20,025	5,838	-5,348	7,529
	(7,570)	(3,538)	(4,747)	(2,379)	(3,693)
Observations	49,240	49,240	49,240	49,240	49,240

Sample: Census from 2009. Note: Standard errors are clustered by village and are reported in parentheses.

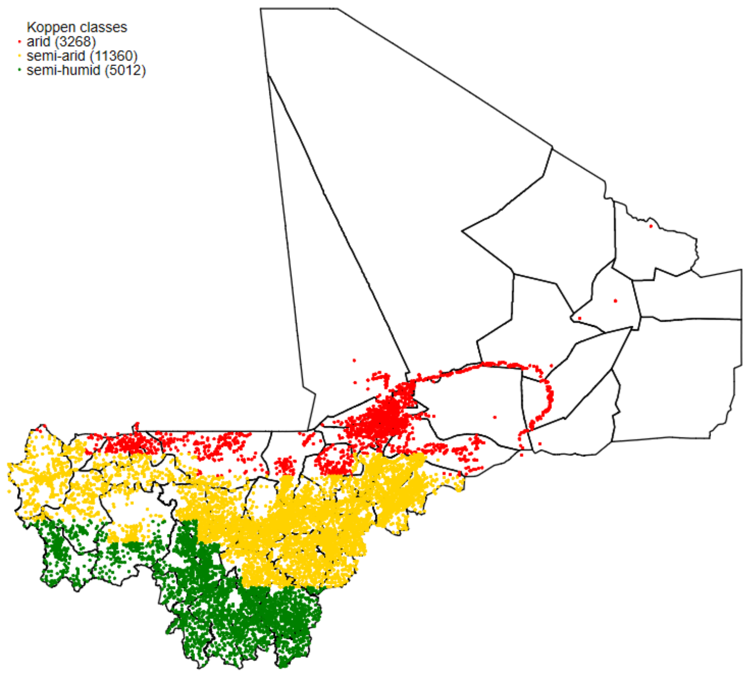


Figure A1: Agro-ecological zones in Mali.

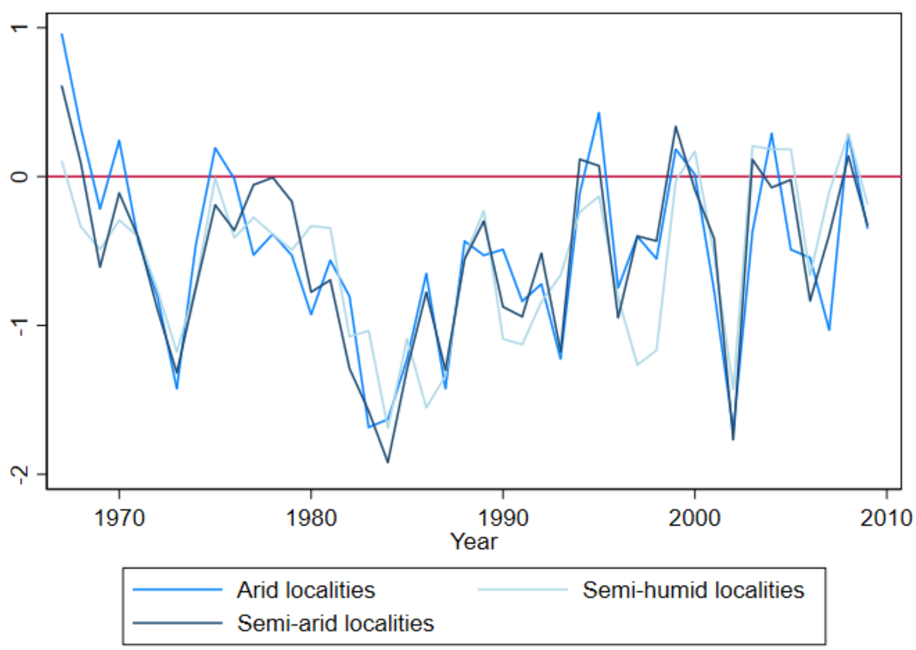
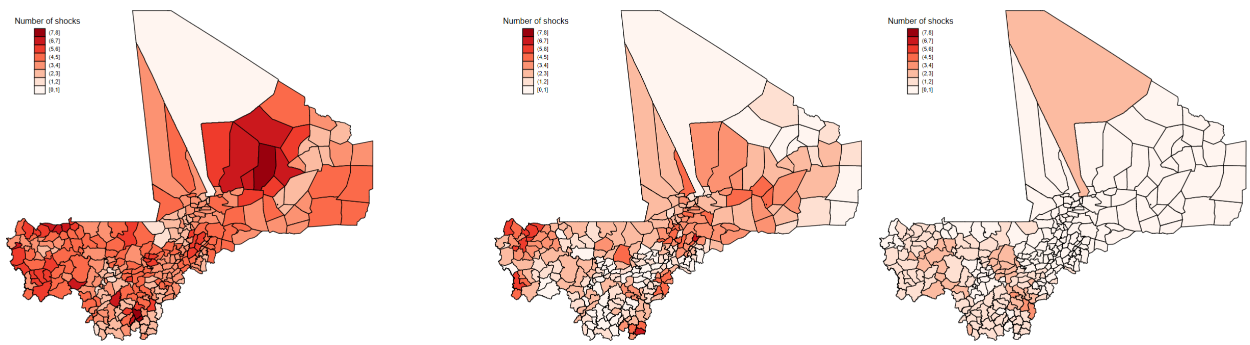


Figure A2: Evolution of the SPEI during the agricultural season (June-October) in Mali by agro-ecological zone.



1977-1987 period 1988-1998 period 1999-2009 period

Figure A3: Number of droughts in Mali.

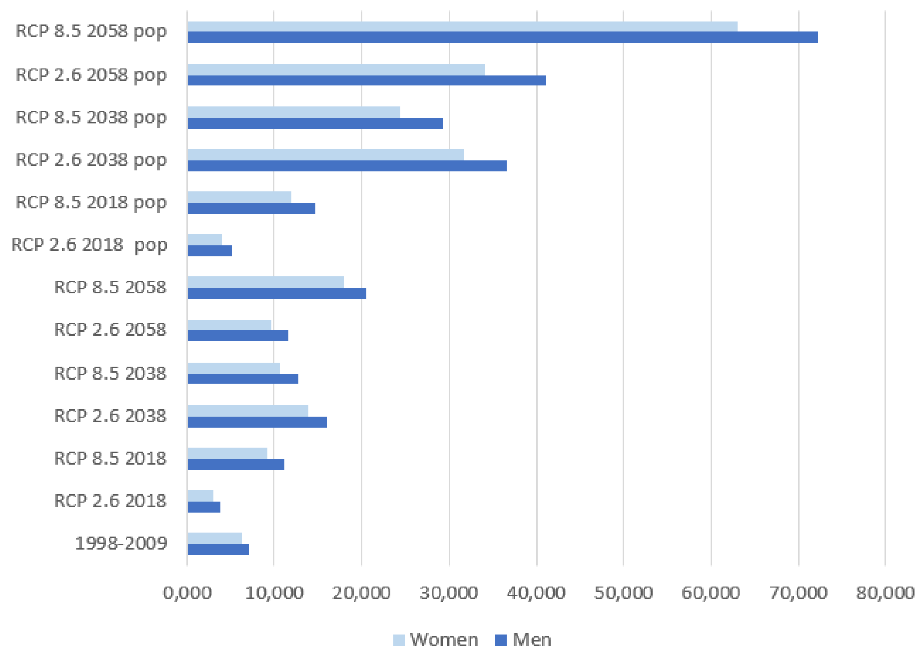


Figure A4: Estimated drought-induced net migration from rural areas for men and women aged 20-69.

Appendix B - Data

Measuring net migration rates at the locality level

Since Malian censuses do not have direct questions on migration (except a question on international migration in the 2009 census), we follow Iqbal and Roy (2015) and adopt the indirect method of estimating net migration described in UN (1970). The basic idea of this method, the so-called residual approach, is that the population increment between any two dates for any given geographic area is the result of natural increase (births minus deaths) and net migratory movements. Given the population of an area at two points in time and an estimate of natural increase during the interval, we can calculate the number that would be expected at the end of the interval in the absence of migration. Then net change due to migration is equal to the difference between observed and expected numbers of population at the end of the interval.

We use probability of survival to estimate the expected population. The net migration is then defined as:

$$NM_{j,a,[t,t+n]} = p_{j,a+n,t+n} - S.\ p_{j,a,t} \qquad \text{(A)}$$

where $NM_{j,a,[t,t+n]}$ is the net migration of survivors among persons aged a at the first census in a given area (they will be aged $a+n$ at the second census); $p_{j,a,t}$ is the population in the jth area in a particular age group a in the census year t; $p_{j,x+n,t+n}$ is the corresponding population n years older and S is the survival ratio. Given that 11 years separate two censuses in Mali, we calculate the net migration rate (NMR) between two census periods t and $t+11$ using the following formula:

$$NMR_{j,a,[t,t+11]} = \frac{NM_{j,a,[t,t+11]}}{p_{j,a,t}} \tag{B}$$

The estimate of net migration derived by equation B measures the combined effect of both internal and external migration. It should be considered as a lower bound estimate of total migration flows because it does not record short-term movements that may have taken place between censuses. As a result, it should be interpreted more as an indicator of long-term or permanent migration. Note that the data allows us to further disaggregate net migration rate at the locality level, since this variable is equal to the difference between the number of individuals who arrived in the locality during the intercensal period (which we can infer from the data) and the number of individuals who left the locality during the same intercensal period (which we can estimate by subtracting the volume of net migration from the number of incoming individuals). We can thus compute in-migration and out-migration rates at the locality level, in addition to net migration rates. Unfortunately, due to space limitations, we had to be selective in the choice of our regression results and decided to mainly focus on net migration rates.

For our empirical analysis, we compute net migration rates at the locality level for various age groups. To this end, we first compute age specific population data for each Malian locality using the two censuses of 1987 and 1998. We choose the following age groups: 9−58, 9−18, 19−28,..., 49−58. We exclude the youngest age group (0−8) because its size evolves over time with births, and we prefer to get rid of this source of variation for simplification purposes. We also exclude the oldest age groups (70 years old and more) for reasons that are provided below. We then associate these data with age specific population data computed on the same age groups eleven years later using the censuses of 1998 and 2009: 20−69, 20−29, 30−39, 40−49, 50−59, 60−69. We finally use the ten-year forward survival probability for each of our chosen age-groups. Ideally, we would like these probabilities to be district-wise specific, but they are not available. Therefore, we use country-wide survival ratios for all localities for all age-groups (see table B1). By so doing, we rely on the assumption of mortality equality across localities. While this is obviously a strong assumption, especially in a country such as Mali where the general mortality level is high, this is only a problem for our analysis if mortality rates are seriously impacted by extreme climatic events. By using a survival ratio estimated at the country level in a drought-affected locality, we are indeed under-estimating (resp. over-estimating) the number of deaths in the intercensal period (resp. the number of survivors), and hence under-estimating the locality's net intercensal migration (defined as the difference between the number of immigrants and the number of emigrants over the intercensal period). In order to reduce this source of bias in our analysis of the effect of climate factors on migration, we exclude two groups of population that are known to be especially vulnerable to drought events: the children and the elderly (see, e.g., Kudamatsu et al. (2012) for evidence). This does not mean that drought cannot affect the health of other categories of population: it surely can in a variety of ways including through threats to food and water security. But we rest on the assumption that this potential impact on health does not translate into significant change in mortality rates for them. In order to test the validity of this assumption, we use the data on the number of deaths in the previous 12 months contained in the three censuses. We compute standardized mortality rates in the past 12 months for all age groups for all localities and regress these standardized mortality rates on various specifications of our shock variables. We find no significant effect of drought episodes on mortality rates (see results in table B2).

Our final sample of localities for which we could combine data on net migration rates and frequency of droughts is composed of 9,282 localities. This is less than the 11,189 localities recorded in the latest census for reasons that are detailed below (see below *Sampling issues*).

Measuring international emigrant flows

The 2009 population census is the first Malian census containing an emigration module, in which the head or other reference member of a household is asked to name (former) household members who have left the country to live abroad in the last five years. After identifying the emigrants, the module gathers information on each emigrant such as age, sex, year and month of departure, destination country and reason for migration. From this module, it is possible to compute figures on the number of international emigrants who left Mali over the course of the 2004-2009 period, at various levels of disaggregation (region, district, locality, household, region x year, district x year and so on). There are however a number of issues in measuring international emigration with population censuses. First, in cases when the entire household emigrated or all the left-behind died, there is nobody left behind to report the emigration. Second, even when there is someone staying in the country to report on those who left, persons who left a long time ago may end up being omitted from the count. In our case, the maximum period between the time the emigrant left and the time of enumeration (five years) is not too long, so that emigration events should be recalled with accuracy. Third, our figures on international migration only account for those individuals who left Mali over the 2004-2009 period and were still absent at the time of the 2009 census. Those who came back before the census were Malian residents at the time of the census, and hence were not declared as emigrants. Four, there is a possibility of double counting an emigrant if the person who left belonged to more than one household in the country of enumeration. Even though the resulting biases go in both directions, it is generally considered that figures on emigration flows based on census data are lower-bound estimates. Something that could be specific to Mali is a downward bias in the estimated number of female emigrants since females who have left the country to live abroad on the occasion of their wedding may be considered as not belonging to their origin household anymore and as not yet part of their husband's family. Female emigration is hence likely to be under-estimated. In the empirical analysis that follows, we will use emigration rate at the locality level disaggregated by year and country of destination, and by sex.

Sampling Issues

The final sample of localities used in the econometric part of the paper is composed of 9,282 localities, meaning that we had to drop 1,907 localities from the latest census. The reasons that led us to drop some localities are the following ones:

First, the geographical coordinates of 969 localities mostly located in the Northern part of the country, in the regions of Tombouctou, Gao and Kidal, were missing in the data files transmitted to us by the Malian Statistical Institute. This is due to the fact that these regions are inhabited mainly by some nomadic ethnic groups (Tuaregs and Songhai). This means that we could not combine the census data for these localities with our climate data.

Second, as new localities were created and some existing ones were merged over the 1987-2009 period, we discovered some inconsistencies among censuses. Those localities created after 1987 were indeed found to have a null population in the year 1987 and a population of several dozens or hundreds of individuals in the following censuses, while the opposite was observed for those localities which were merged. This resulted in completely unrealistic net migration rates between censuses. We hence decided to drop these 596 localities. We may still have some inconsistencies in the data, due to measurement errors in population size at the locality level, especially when we disaggregate population size by sex and age cohort (since age may be measured with errors). However, as far as measurement errors are random with respect to our main variable of interest, this should not bias our estimates although they will be less precise.

Last, we found out that the level of disaggregation adopted in our analyses was inappropriate for urban conurbations which are composed of several urban localities. People may move from one urban locality to another one, while staying in the same urban conurbation. We have opted to focus on migration between "independent" urban or rural localities, that is localities which do not belong to a same urban conurbation. To this end, we aggregated 342 localities which are part of a same urban conurbation. As an example, Kayes, the main city of Mali's first region is composed of six localities. We merged those six localities, and hence consider the city of Kayes as one single urban locality in our analysis. For an in-depth discussion on the urbanization process in Mali and the methodological challenges it poses for the construction of a panel of localities, see Bernard et al. (2017). Since dropped localities have a lower-than-average population size, our final sample of 9,282 localities represent 91 per cent of the whole Malian population.

Table B1: Probability of surviving over the next 10 years (%)

Age-groups	10-20	20-30	30-40	40-50	50-60	60-70
	95.57	94.23	92.79	88.73	77.13	51.57

Sources: DESA, Population Division, United Nation. Notes: These probabilities are computed from the 2000-2010 period.

Table B2: Drought effects on standardized mortality rates

	(1)	(2)	(3)	(4)	(5)	(6)
		Men			Women	
Nb. shocks from t-5 to t (June-Oct)	-0.015			-0.008		
	(0.010)			(0.011)		
Nb. shocks from t-5 to t		-0.016			-0.011	
		(0.012)			(0.011)	
SPEI from june to oct. in t			0.014			0.032
			(0.020)			(0.022)
Village F.E	×	×	×	×	×	×
Year F.E	×	×	×	×	×	×
Observations	27,633	27,633	27,633	27,632	27,632	27,632
Number of villages	9,285	9,285	9,285	9,285	9,285	9,285

Sample: Census from 1987, 1998 and 2009. Note: Standard errors in parentheses corrected for serial correlation over one period and for spatial correlation up to a distance cutoff at 500 km. We control by the size of age cohorts (10-19, 20-29, 30-39, 40-49, and 50-59) by village.

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