Supplementary Materials

Agricultural Livelihoods, Adaptation, and Environmental Migration in sub-Saharan Drylands: A Meta-Analytical Review

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This Supplementary Material includes:

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A. Mobility patterns in sub-Saharan Africa

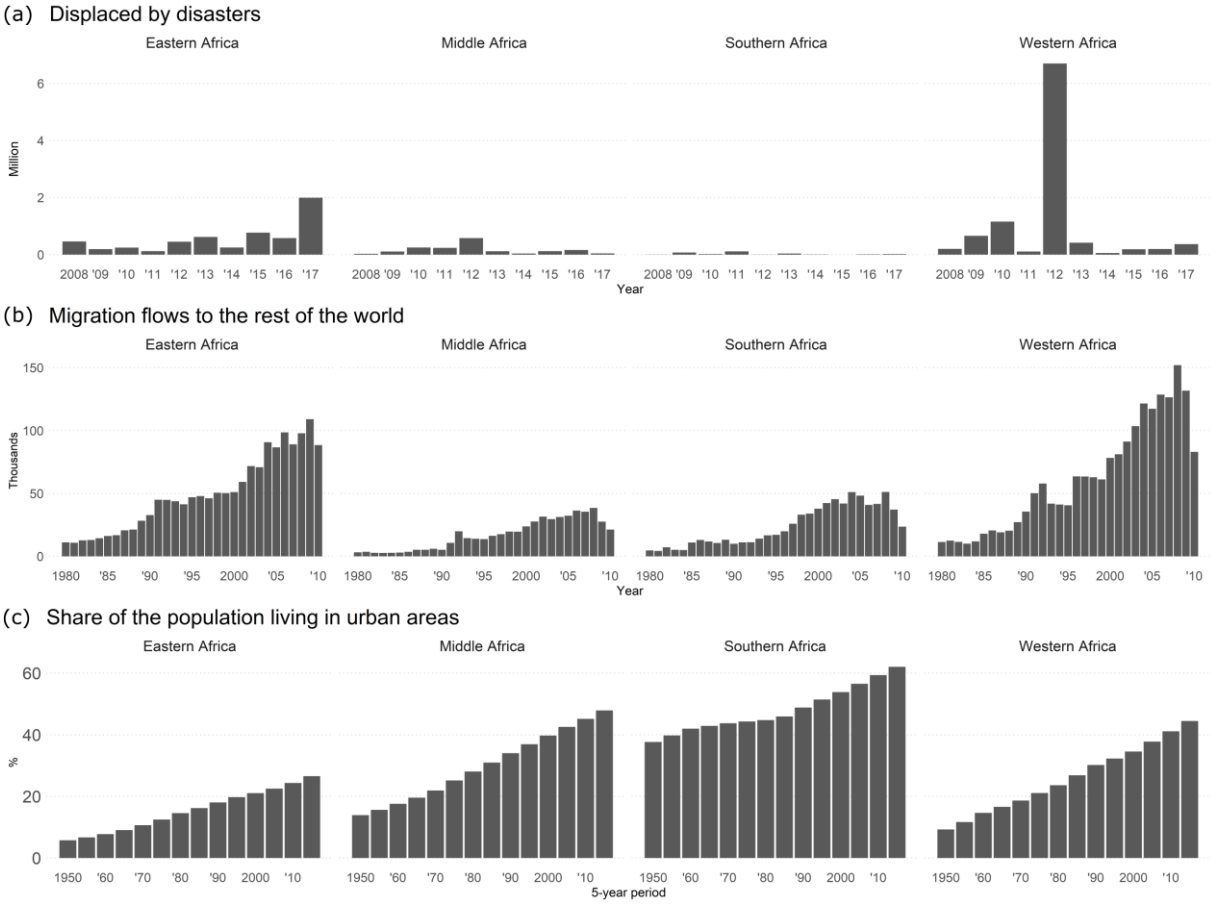

Figure S1 – Mobility patterns and trends in different regions in sub-Saharan Africa. The displaced regions (Eastern, Central, Southern, Western Africa) correspond to the regional classification shown in Figure 1 in the main text. Panel (a) shows the number of disaster displacements (in million) in the regions, (b) shows international migration flows (in thousands) from the countries belonging to a region, c) shows changes in the urbanization rate as share of the population (%) living in urban areas. Data: (a) IDMC (2021), (b) Cai et al. (2016), (c) United Nations (2019).

B. Literature search and screening

The literature search was carried out in the Web of Science using the following combinations of keywords and search terms:

((((((((((TS=((Sub-Sahara OR 'Sub-Saharan Africa*' OR Angola* OR Benin* OR Botswana* OR Motswana OR Batswana OR Burkina* OR Burundi* OR Cameroon* OR 'Cape Verd*' OR 'Cabo Verd*' OR 'Central African Republic' OR Chad* OR Comor* OR Congo* OR 'Cote dIvoire' OR 'Ivory Coast' OR Ivorian * OR 'Democratic Republic of the Congo' OR Djibouti OR 'Equatorial Guinea*' OR Equatoguinean* OR Eritrea* OR Ethiopia* OR Gabon* OR Gambia* OR Ghana* OR Guinea* OR Guinea-Bissau* OR Kenya* OR Lesotho OR Mesotho OR Basotho OR Mauritania* OR Mauriti* OR Liberia* OR Madagascar OR Malagasy OR Malawi* OR Mali* OR Mozambi* OR Namibia* OR Niger* OR Nigeria* OR Rwanda* OR Sao Tome* and Principe OR Senegal* OR Seychell * OR 'Sierra Leone*' OR Somali* OR 'South Africa*' OR Sudan* OR Swazi* OR Tanzania* OR Togo* OR Uganda* OR Zambia* OR Zimbabwe*) AND ('environment* chang*' OR 'climat* chang*' OR 'ecological chang*'OR'land degrad*'OR'soil degrad*' OR 'soil erosion' OR 'resource* degrad*' OR 'environment* degrad*' OR 'rainfall variab*' OR 'climat* variab *' OR 'precipitation chang*' OR 'temperature*chang*' OR 'drought*' OR 'desertification' OR 'flood*' OR 'environmental stress*') AND (adapt* OR cop*) NOT (*biotic OR cell* OR molecul* OR photovoltaic OR photosynthe* OR pathogen* OR AMF OR genotype * OR 'plant invasion*' OR 'reef coral*' OR 'coral reef*' OR bioapatite OR cichlid* OR 'bird migration' OR 'carbon sequestration' OR hydrogeochemical OR Pliocene OR 'marine ecosystem*' OR 'tree recruitment' OR levallois OR 'fynbos biome*' OR 'Afromontane taxa' OR 'invasive alien tree*' OR Paleolithic OR Pleistocene OR 'urban metabolism' OR lepidoptera))))))))))
AND LANGUAGE: (English)
ANDDOCUMENTTYPES: (Article)
Refined by: [excluding] WEB OF SCIENCE
CATEGORIES:
(ENGINEERING CHEMICAL
OR GENETICS HEREDITY
OR PHARMACOLOGY PHARMACY
OR MEDICINE GENERAL INTERNAL
OR ORNITHOLOGY
OR ENDOCRINOLOGY METABOLISM
OR BIOTECHNOLOGY APPLIED
MICROBIOLOGY
OR TOXICOLOGY
OR PSYCHOLOGY CLINICAL
OR NEUROSCIENCES
OR PARASITOLOGY
OR CHEMISTRY APPLIED
OR CHEMISTRY ANALYTICAL
OR MARINE FRESHWATER BIOLOGY
OR ENTOMOLOGY
OR BIOCHEMICAL RESEARCHMETHODS
OR LIMNOLOGY
OR BIOCHEMISTRY MOLECULAR BIOLOGY
OR TROPICAL MEDICINE
OR PSYCHIATRY
OR PHYSIOLOGY
OR NUCLEAR SCIENCETECHNOLOGY
OR EVOLUTIONARY BIOLOGY
OR OCEANOGRAPHY
OR MICROBIOLOGY
OR INFECTIOUS DISEASES
OR CELL BIOLOGY
OR PALEONTOLOGY)
Timespan: All years. Indexes: SCI-EXPANDED, SSCI

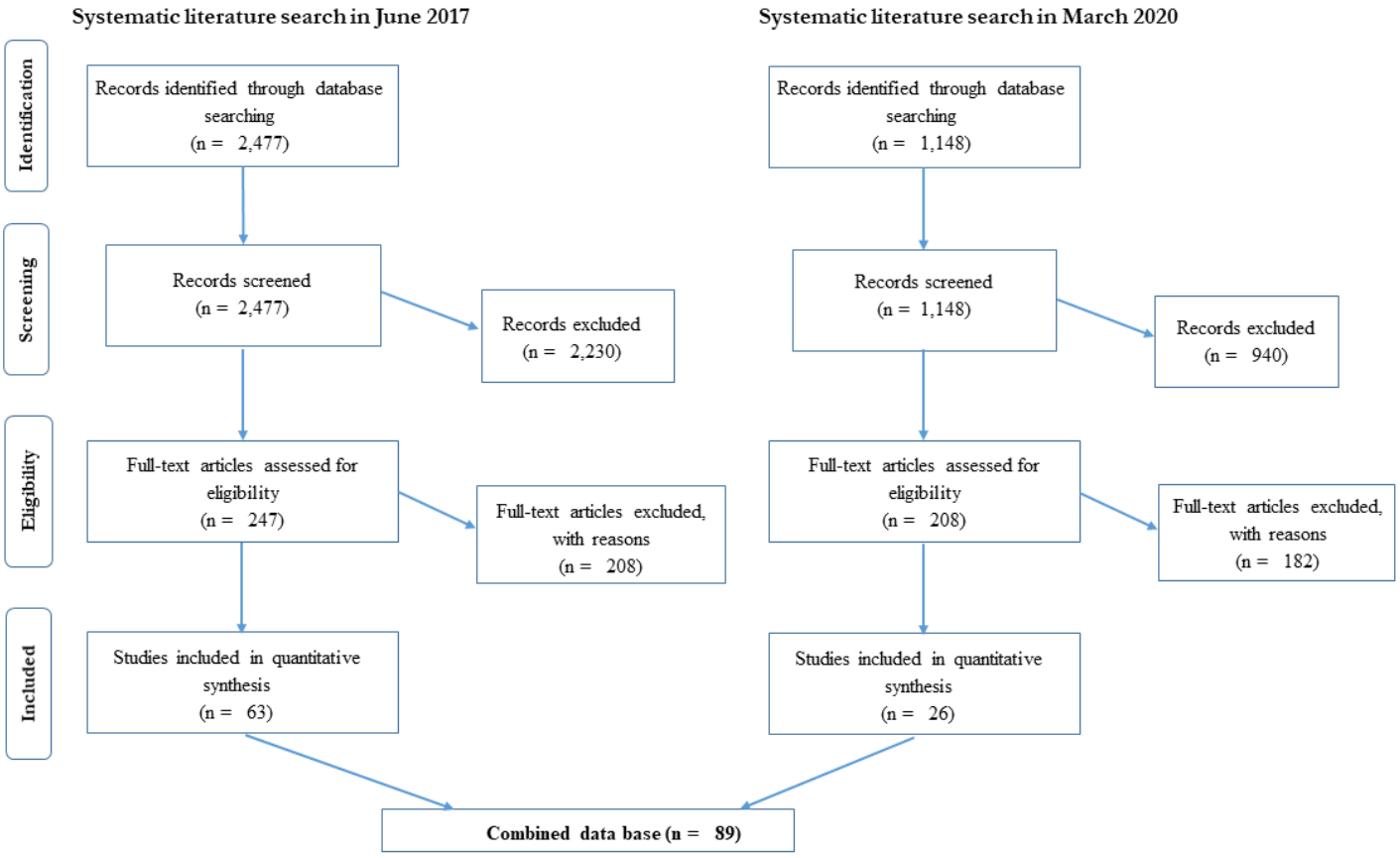

Figure S2 – PRISMA diagram. Adapted from: Moher et al., (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097.

Table S1 – Overview of studies included in systematic review and livelihood contexts of study populations

#	Authors	Pub. year	Journal	Country	Livelihood context	Cluster number
1	Chianu, J.N., Tsujii, H., Kormawa, P.	2004	Outlook on Agriculture	Nigeria	crop and livestock farmers (mainly mixed cropping)	2
2	Smucker, T.A., Wisner, B.	2008	Disasters	Kenya	agro-pastoralists	1
3	Smucker, T.A., Wisner, B.	2008	Disasters	Kenya	agro-pastoralists	2
4	Barbier, B. *et al.*	2009	Environmental Management	Burkina Faso	farmers and semi-nomadic herders	2
5	Mertz, O. *et al.*	2009	Environmental Management	Senegal	crop and livestock farmers	4
6	Gbetibouo, G.A., Hassan, R.M., Ringler, C.	2010	Agrekon	South Africa	crop farmers	5
7	Gbetibouo, G.A., Hassan, R.M., Ringler, C.	2010	Agrekon	South Africa	crop farmers	5
8	Gbetibouo, G.A., Hassan, R.M., Ringler, C.	2010	Agrekon	South Africa	crop farmers	5
9	Gbetibouo, G.A., Hassan, R.M., Ringler, C.	2010	Agrekon	South Africa	crop farmers	5
10	Osbahr, H. *et al.*	2010	Ecology and Society	South Africa	small-scale farmers	1
11	Osbahr, H. *et al.*	2010	Ecology and Society	South Africa	small-scale farmers	1
12	Osbahr, H. *et al.*	2010	Ecology and Society	South Africa	small-scale farmers	1
13	Motsholapheko, M.R., Kgathi, D.L., Vanderpost, C.	2011	Physics and Chemistry of the Earth, Parts A/B/C	Botswana	subsistence molapo or dryland farming and livestock	4
14	Motsholapheko, M.R., Vanderpost, C., Kgathi, D.L.	2012	Journal of Water and Climate Change	Botswana	mix of livestock husbandry and arable agriculture	1
15	Mertz, O. *et al.*	2012	Ambio	Burkina Faso, Mali, Nigeria	farmers and pastoralists	2
16	Mertz, O. *et al.*	2012	Ambio	Burkina Faso, Mali, Senegal	farmers and pastoralists	4
17	Mertz, O. *et al.*	2012	Ambio	Burkina Faso, Niger, Nigeria, Senegal	farmers and pastoralists	4
18	Silvestri, S. *et al.*	2012	Regional Environmental Change	Kenya	farmers, agro-pastoralists, pastoralists	5
19	Gebrehiwot, T., Veen, A. van der	2013	Environmental Management	Ethiopia	small-scale farmers (rain-fed agriculture, some livestock)	5
20	Haile, A.T., Kusters, K., Wagesho, N.	2013	International Journal of Global Warming	Ethiopia	crop and livestock farmers (rain-fed and recession crop cultivation) and agro-pastoralists	1
21	Yaffa, S.	2013	International Journal of Global Warming	Gambia	crop cultivation and livestock keeping	3
22	McKune, S.L., Silva, J.A.	2013	The Journal of Development Studies	Niger	semi-nomadic livestock herding and agricultural cultivation	3
23	McKune, S.L., Silva, J.A.	2013	The Journal of Development Studies	Niger	pastoralists	3
24	McKune, S.L., Silva, J.A.	2013	The Journal of Development Studies	Niger	semi-nomadic livestock herding and agricultural cultivation	3

25	McKune, S.L., Silva, J.A.	2013	The Journal of Development Studies	Niger	agro-pastoralists and pastoralists	3
26	Tambo, J.A., Abdoulaye, T.	2013	Regional Environmental Change	Nigeria	small-scale farmers (crops and livestock)	5
27	Tambo, J.A., Abdoulaye, T.	2013	Regional Environmental Change	Nigeria	small-scale farmers (crops and livestock)	5
28	Padonou, E.A. *et al.*	2014	Land Use Policy	Benin	farmers (agriculture and livestock)	4
29	Zampaligré, N., Dossa, L.H., Schlecht, E.	2014	Regional Environmental Change	Burkina Faso	pastoralists, agro-pastoralists, crop and livestock farmers	2
30	Zampaligré, N., Dossa, L.H., Schlecht, E.	2014	Regional Environmental Change	Burkina Faso	pastoralists, agro-pastoralists, crop and livestock farmers	2
31	Antwi-Agyei, P., Stringer, L.C., Dougill, A.J.	2014	Regional Environmental Change	Ghana	crop farmers, a few livestock farmers	1
32	Snorek, J., Renaud, F.G., Kloos, J.	2014	Global Environmental Change	Niger	transhumant and nomad pastoralism	2
33	Snorek, J., Renaud, F.G., Kloos, J.	2014	Global Environmental Change	Niger	agro-pastoralism (rain-fed agriculture)	2
34	Snorek, J., Renaud, F.G., Kloos, J.	2014	Global Environmental Change	Niger	farmers (dry season irrigated cultivation)	2
35	Yila, J.O., Resurreccion, B.P.	2014	International Journal of Climate Change Strategies and Management	Nigeria	smallholder farmers (rain-fed agriculture and livestock keeping most common)	2
36	Bola, G. *et al.*	2014	Physics and Chemistry of the Earth, Parts A/B/C	Zimbabwe	smallholder farmers; agriculture and livestock rearing (rain-fed dryland farming and flood recession agriculture)	1
37	Oyerinde, G.T. *et al.*	2015	Regional Environmental Change	Benin	crop farming, some livestock production and fish farming	1
38	Berhanu, W., Beyene, F.	2015	Sustainability	Ethiopia	pastoralists (predominantly milk-dependent cattle herding)	2
39	Ariti, A.T., van Vliet, J., Verburg, P.H.	2015	Applied Geography	Ethiopia	farmers, mainly subsistence, crop production (mainly rain-fed) and livestock	5
40	Opiyo, F. *et al.*	2015	International Journal of Disaster Risk Science	Kenya	pastoralists and agro-pastoralists	1
41	Dah-gbeto, A.P., Villamor, G.B.	2016	Ambio	Benin	crop and livestock farmers	4
42	Okpara, U.T., Stringer, L.C., Dougill, A.J.	2016	Ambio	Chad	crop and livestock farmers, combination of subsistence agriculture with use of lake water resources	4
43	Okpara, U.T., Stringer, L.C., Dougill, A.J.	2016	Ambio	Chad	fishing and crop cultivation, combination of subsistence agriculture with use of lake water	4
44	Okpara, U.T., Stringer, L.C., Dougill, A.J.	2016	Ambio	Chad	pastoralists and agro-pastoralists, combination of subsistence agriculture with use of lake water	4
45	Ng'ang'a, S.K., Wijk, M.T.V., Rufino, M.C., Giller, K.E.	2016	Regional Environmental Change	Ethiopia	agro-pastoralists	2
46	Feleke, F.B., Berhe, M., Gebru, G., Hoag, D.	2016	SpringerPlus	Ethiopia	livestock farmers	2

47	Feleke, F.B., Berhe, M., Gebru, G., Hoag, D.	2016	SpringerPlus	Ethiopia	livestock farmers	2
48	Feleke, F.B., Berhe, M., Gebru, G., Hoag, D.	2016	SpringerPlus	Ethiopia	livestock farmers	2
49	Mersha, A.A., Laerhoven, F.V.	2016	Regional Environmental Change	Ethiopia	mixed farming	1
50	Tesfaye, W., Seifu, L.	2016	International Journal of Climate Change Strategies and Management	Ethiopia	smallholder farmers	4
51	Tesfaye, W., Seifu, L.	2016	International Journal of Climate Change Strategies and Management	Ethiopia	smallholder farmers	4
52	Tesfaye, W., Seifu, L.	2016	International Journal of Climate Change Strategies and Management	Ethiopia	smallholder farmers	4
53	Tambo, J.A.	2016	International Journal of Disaster Risk Reduction	Ghana	rain-fed agriculture and livestock farming	4
54	Tambo, J.A.	2016	International Journal of Disaster Risk Reduction	Ghana	rain-fed agriculture and livestock farming	4
55	Tambo, J.A.	2016	International Journal of Disaster Risk Reduction	Ghana	rain-fed agriculture and livestock farming	4
56	Limantol, A.M., Keith, B.E., Azabre, B.A., Lennartz, B.	2016	SpringerPlus	Ghana	agriculture, mostly rain-fed	4
57	Dumenu, W.K., Obeng, E.A.	2016	Environmental Science & Policy	Ghana	subsistence/small-scale farmers (mostly rain-fed agriculture), some agro-pastoralists	4
58	Hooli, L.J.	2016	Regional Environmental Change	Namibia	subsistence farmers, most have livestock	4
59	Rankoana, S.A.	2016	Sustainability	South Africa	subsistence farmers (crops and livestock)	4
60	Sanogo, K. *et al.*	2017	Agroforestry Systems	Mali	mainly farmers and agro-pastoralists	4
61	Pauline, N.M. *et al.*	2017	Climate and Development	Tanzania	small-scale farmers, rain-fed agriculture and livestock keeping	4
62	Pauline, N.M. *et al.*	2017	Climate and Development	Tanzania	small-scale farmers, rain-fed and irrigated agriculture, livestock	4
63	Jiri, O., Mafongoya, P.L., Chivenge, P.	2017	International Journal of Climate Change Strategies and Management	Zimbabwe	dryland smallholder farmers	5
64	Gebru, B.M., Wang, S.W., Kim, S.J., Lee, W.-K.	2019	Sustainability	Ethiopia	farmers	4
65	Basupi, L.V., Quinn, C.H., Dougill, A.J.	2019	Journal of Arid Environments	Botswana	smallholder agro-pastoralists and pastoralists	1
66	Basupi, L.V., Quinn, C.H., Dougill, A.J.	2019	Journal of Arid Environments	Botswana	smallholder agro-pastoralists and pastoralists	1
67	Basupi, L.V., Quinn, C.H., Dougill, A.J.	2019	Journal of Arid Environments	Botswana	smallholder agro-pastoralists and pastoralists	1
68	Basupi, L.V., Quinn, C.H., Dougill, A.J.	2019	Journal of Arid Environments	Botswana	smallholder agro-pastoralists and pastoralists	1
69	Basupi, L.V., Quinn, C.H., Dougill, A.J.	2019	Journal of Arid Environments	Botswana	smallholder agro-pastoralists and pastoralists	1
70	Basupi, L.V., Quinn, C.H., Dougill, A.J.	2019	Journal of Arid Environments	Botswana	smallholder agro-pastoralists and pastoralists	1

71	Dapilah, F., Nielsen, J.Ø., Friis, C.	2019	Climate and Development	Ghana	crop farmers and pastoralists	2
72	Kumasi, T.C., Antwi-Agyei, P., Obiri-Danso, K.	2019	Environment, Development and Sustainability	Ghana	farmers	1
73	Oduniyi, O.S.	2019	Applied Ecology and Environmental Research	South Africa	small and emerging maize farmers	4
74	Röschel, L. *et al.*	2018	Water	Tanzania	smallholder farmers	4
75	Kgosikoma, K.R., Lekota, P.C., Kgosikoma, O.E.	2018	International Journal of Climate Change Strategies and Management	Botswana	agro-pastoralists and farmers	4
76	Rasmussen, L.V.	2018	World Development	Burkina Faso	farmers, agro-pastoralists, pastoralists	2
77	Menghistu, H.T., Mersha, T.T., Abraha, A.Z.	2018	Journal of Applied Animal Research	Ethiopia	crop and livestock farming, agro-pastoralists, pastoralists	4
78	Macnight Ngwese, N. *et al.*	2018	Sustainability	Ghana	farmers	1
79	Brottem, L., Brooks, B.	2017	Land Degradation & Development	Senegal	farmers, agro-pastoralists, pastoralists	4
80	Mohmmed, A. *et al.*	2018	Land Use Policy	Sudan	farmers	4
81	Mohmmed, A. *et al.*	2018	Land Use Policy	Sudan	farmers	4
82	Mohmmed, A. *et al.*	2018	Land Use Policy	Sudan	farmers	4
83	Mohmmed, A. *et al.*	2018	Land Use Policy	Sudan	farmers	4
84	Mohmmed, A. *et al.*	2018	Land Use Policy	Sudan	farmers	4
85	Mubaya, C.P., Mafongoya, P.	2016	Environment, Development and Sustainability	Zimbabwe	farmers	3
86	Mubaya, C.P., Mafongoya, P.	2016	Environment, Development and Sustainability	Zimbabwe	fishing and farming	3
87	Mkonda, M.Y., He, X.	2017	Sustainability	Tanzania	farmers	4
88	Mkonda, M.Y., He, X.	2017	Sustainability	Tanzania	farmers	4
89	Hänke, H., Barkmann, J.	2017	World Development	Madagascar	farmers	1

C. Overview of adaptation strategies and actions

Table S2 – Classification of household adaptation measures in broader categories

#	Adaptation category	Examples of measures	% households [a]
1	Migration	International migration, labor migration, temporary relocation to government camps, rural-urban migration	22.7%
2	Crop management	Crop diversification, intercropping, crop rotation, crop irrigation, sharecropping, increase use of fertilizer, drought-tolerant or early maturing varieties, increase of farm size	41.2%
3	Livestock management	Fodder storage, herd diversification, livestock sale, drought-tolerant species, provision of shade, veterinary care, home feeding, transhumance, culling of sick animals	24.4%
4	Soil and water management	Terracing, erosion control, drainage ditches, ridges, micro-catchments, stone bunds, ploughing, digging of boreholes and wells, mulching, water storage, construction of small dams	21.5%
5	Income diversification	Petty trading, local wage-labor, off-farm employment, tourism-related income, pottery, fishing, hunting, sell bush products or charcoal	22.1%
6	Food and nutrition	Change diet, reduce food consumption, eat wild fruits, seek food aid, purchase fish, work for food, store food, plant food trees, use savings or sell assets to buy food	15.0%
7	Social support	Rely on support from relatives or friends, borrow money from neighbors, remittances, collaboration, send out children	13.7%
8	Humanitarian aid	Rely on or ask for humanitarian assistance provided by the government, NGOs, religious organizations	8.7%
9	Information	Consult extension officers, access weather forecast information, early warning system, join information group	4.7%
10	Religious activities	Prayer, go to the mosque, turn to faith and church groups, ritual ceremonies	1.7%
11	Financial strategies	Get loan or credit, insurance scheme, crop insurance, selling assets	7.6%
12	Reduce mobility	Sedentarization, reduced mobility, stop migration	4.2%
13	Other activities [b]	Measures to prevent inundation of houses, use of elephant deterrent, reduction of gifts to the poor	13.6%
14	No adaptation		7.8%

Notes: [a] The numbers in the last column show the average percent of households across studies who have adopted adaptation measures related to one of the 14 broad categories. [b] Other activities includes activities, which could not be assigned any of the other adaptation categories.

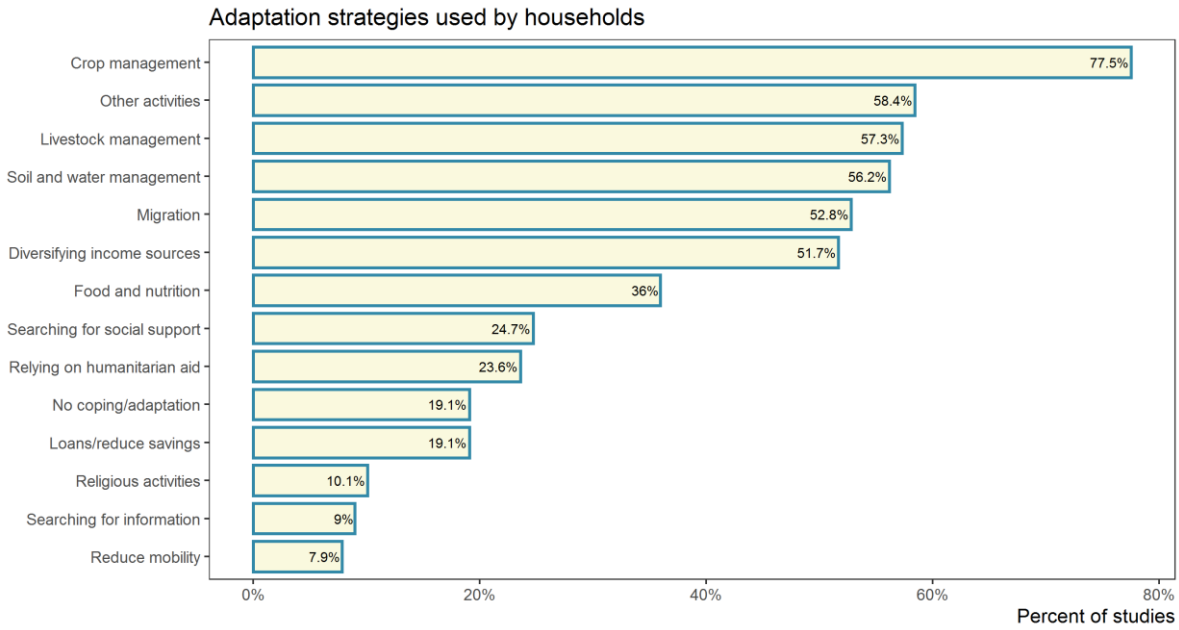

Figure S3 – Adaptation strategies reported in the 89 case studies. While the main analysis is based on information on the percentage of households employing different adaptation strategies, this graph is based on the second outcome, capturing whether any households in a study sample have used a certain strategy or not.

D. Further descriptive statistics

Table S3 – Summary statistics of adaptation strategies and reported environmental hazards

	Mean	SD	Min	Max	Range
Adaptation strategies					
Migration	0.227	0.295	0	0,947	0,947
No adaptation	0.078	0.202	0	0,894	0,894
Crop management	0.412	0.325	0	1	1
Livestock management	0.244	0.315	0	1	1
Searching for social support	0.137	0.268	0	0,971	0,971
Soil and water management	0.215	0.270	0	1	1
Diversifying income sources	0.221	0.289	0	0,95	0,95
Food and nutrition	0.150	0.259	0	1	1
Relying on humanitarian aid	0.087	0.187	0	0,755	0,755
Searching for information	0.047	0.159	0	0,77	0,77
Religious activities	0.017	0.085	0	0,72	0,72
Loans/reduce savings	0.076	0.190	0	0,8	0,8
Reduce mobility	0.042	0.151	0	0,72	0,72
Other activities	0.136	0.241	0	0,97	0,97
Reported hazards					
Changing temperatures	0.674	0.471	0	1	1
Changing rain amounts	0.719	0.452	0	1	1
Rain variability	0.483	0.503	0	1	1
Wind	0.101	0.303	0	1	1
Drought	0.416	0.496	0	1	1
Flooding	0.180	0.386	0	1	1
Land degradation	0.584	0.496	0	1	1
Water degradation	0.315	0.467	0	1	1
Livelihood strategies in sample					
Farmer	0.798	0.404	0	1	1
Agro-pastoralists	0.292	0.457	0	1	1
Pastoralists	0.247	0.434	0	1	1
Other livelihood	0.371	0.486	0	1	1
Regional characteristics					
Secondary education (%)	30.2	25.4	1.9	91.3	89.4
Electricity access (%)	35.1	24.9	2.3	97.6	95.3
Finished floor (%)	47.6	32.7	2.5	98.8	96.3
Agricultural occupation (%)	49.2	24.2	2	80.2	78.2

Table S4 – Overlap in reported environmental stressors

Hazard	Rain amount	Temper-ature	Land degradation	Rainfall variability	Drought	Water degradation	Flooding	Wind	# of studies
Changing rain amounts	100.00%	84.38%	64.06%	50.00%	45.31%	32.81%	17.19%	12.50%	64
Changing temperatures	90.00%	100.00%	56.67%	56.67%	43.33%	36.67%	15.00%	13.33%	60
Land degradation	78.85%	65.38%	100.00%	50.00%	51.92%	42.31%	21.15%	11.54%	52
Rainfall variability	74.42%	79.07%	60.47%	100.00%	62.79%	32.56%	20.93%	4.65%	43
Drought	78.38%	70.27%	72.97%	72.97%	100.00%	40.54%	29.73%	8.11%	37
Water degradation	75.00%	78.57%	78.57%	50.00%	53.57%	100.00%	21.43%	21.43%	28
Flooding	68.75%	56.25%	68.75%	56.25%	68.75%	37.50%	100.00%	12.50%	16
Wind	88.89%	88.89%	66.67%	22.22%	33.33%	66.67%	22.22%	100.00%	9

Note: The table shows the overlap in reported environmental stressors. For all studies that reported an environmental stressor (in the rows), the column cells show the percentage of times another stressor was also mentioned. The last column shows the total number of studies reporting a stressor to be relevant for the population considered.

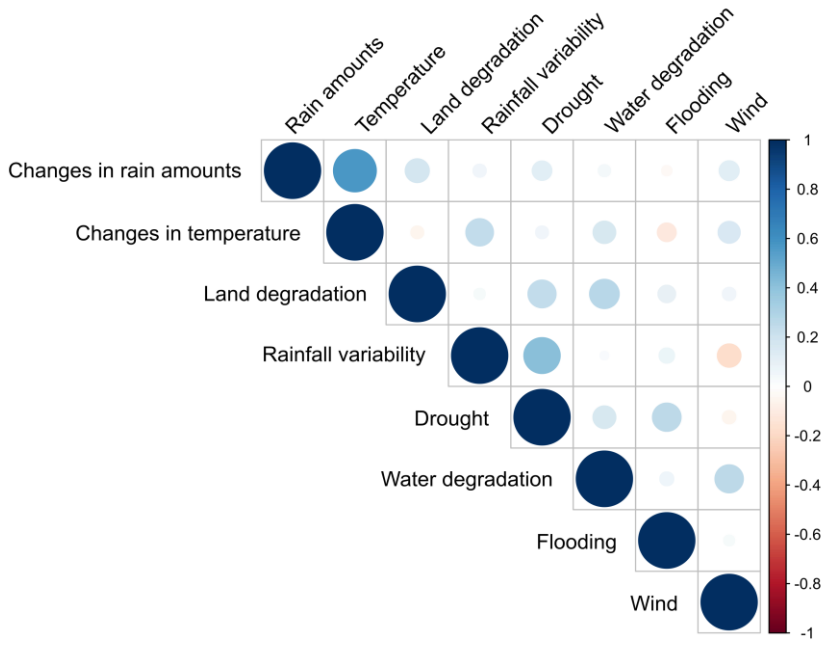

Figure S4 – Correlation between environmental hazard variables. The higher the correlation coefficients, the more likely two environmental stressors are reported to jointly affect a population in a study.

E. Detailed procedures for cluster analysis

In the following, we describe the different steps carried out in our cluster analysis, beginning with the preparation of the data, followed by the identification of the optimal number of clusters, the performing of the cluster analysis using the k-means algorithm, and the illustration of the resulting cluster assignment and findings.

As a first preparatory step, we selected the most common adaptation strategies reported in the studies. This allows to perform the clustering in an efficient and comprehensive way focusing on the most common forms of adaptation reported by the households. Strategies that are reported by less than 5% of all households (searching for information and religious activities) were subsumed under the category "other adaptation strategies". The highly correlated categories "searching for social support", "relying on humanitarian aid", and "loans and reduce savings" were combined in a new category "search for external support. This resulted in a total of 9 adaptation strategy categories which were used for the clustering assignment.

In a second step, we specified the number of clusters to be determined by the cluster algorithm. The goal was to define clusters such that (i) clusters explain a large share of the variation in the base variables used minimizing the total intra-cluster variation (i.e., the within-cluster sum of squares) and (ii) clusters are sufficiently distinct from each other to allow for a meaningful interpretation of the results. Depending on the number of clusters, a different assignment of cases to clusters is possible. Figure S5 illustrates different assignments for different numbers of clusters (k) plotting the cluster solution in a space with the two principal components of the considered adaptation variables on the x- and y-axis. This visual assessment provides a first idea of differences between different clustering solutions, but does not provide information about the optimal number of clusters.

For this, we follow two strategies in line with the two main goals of the cluster analysis outlined above. First, the within-cluster sum of squares (WSS) is calculated for clustering solutions with different numbers of clusters (k) displayed on the x-axis (Figure S6a). This measure shows to what extent the generated clusters are homogenous and contain similar cases. With an increase in k, the WSS gets typically smaller with decreasing marginal gains in WSS the larger the number of clusters. The aim is to identify when the gains in WSS are so small that a further increase in the number of clusters k is not justified. This is reflected in form of a bend in the plot, which can serve as an indicator of the appropriate number of clusters. In our application, the bend occurs at the value of a 5 cluster solution.

As second strategy for determining the optimal number of clusters, we consider the silhouette of the clusters, which reflects the quality of a clustering solution. If objects can be clearly assigned to one distinct cluster then this results in a high average silhouette width, which can serve as a second indicator for determining the optimal number of clusters. Figure S 6b plots the silhouette width for different values of k. Also using this method, a clustering solution with 5 distinct clusters is the one that produces the best results, maximizing the average silhouette width of the clusters.

The final results of the clustering are plotted in Figure S7, which shows the location of the five identified clusters along the two principal components (Figure S7a) and along two adaptation strategies commonly reported in the data (Figure S7b). For the latter, we consider the focus of the

case observations on agricultural in-situ adaptation (crop management) and migration. The illustration clearly shows the differences between the clusters, showing cases where households use limited migration, migration in combination with agricultural in-situ practices, and only migration. Finally, Table S5 shows different summary statistics highlighting further differences in adaptation between the five clusters.

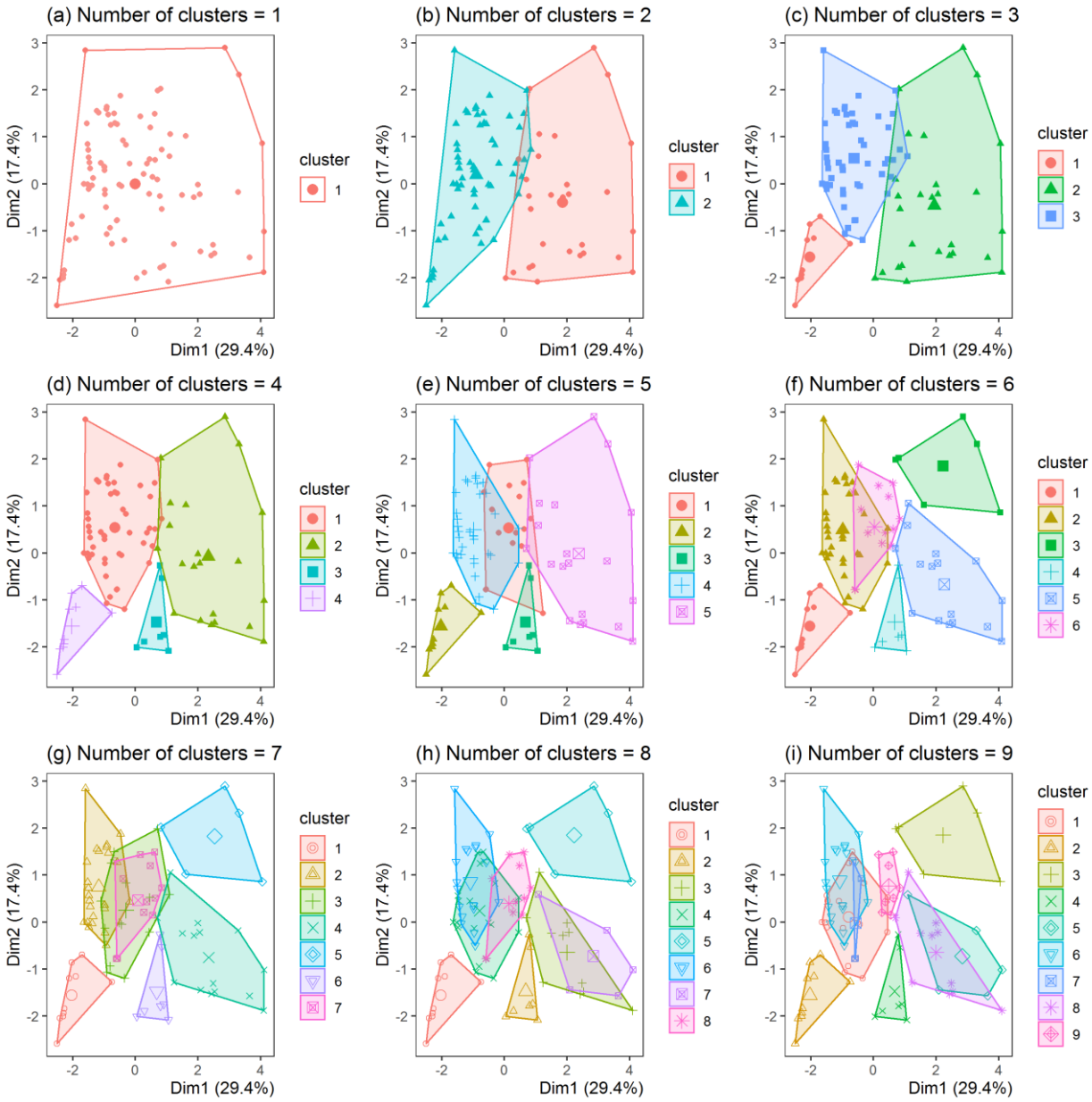

Figure S5 – Illustration of clustering solutions with different numbers of clusters

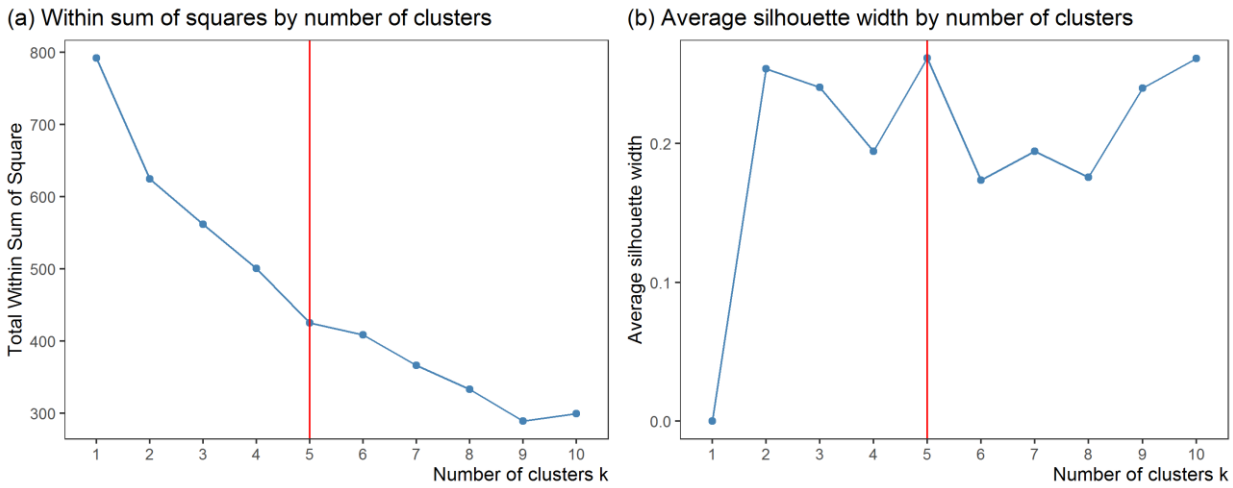

Figure S6 – Determining the optimal number of clusters considering changes in the Within Sum of Squares (Panel a) and the average silhouette width (Panel b) by the number of clusters (k)

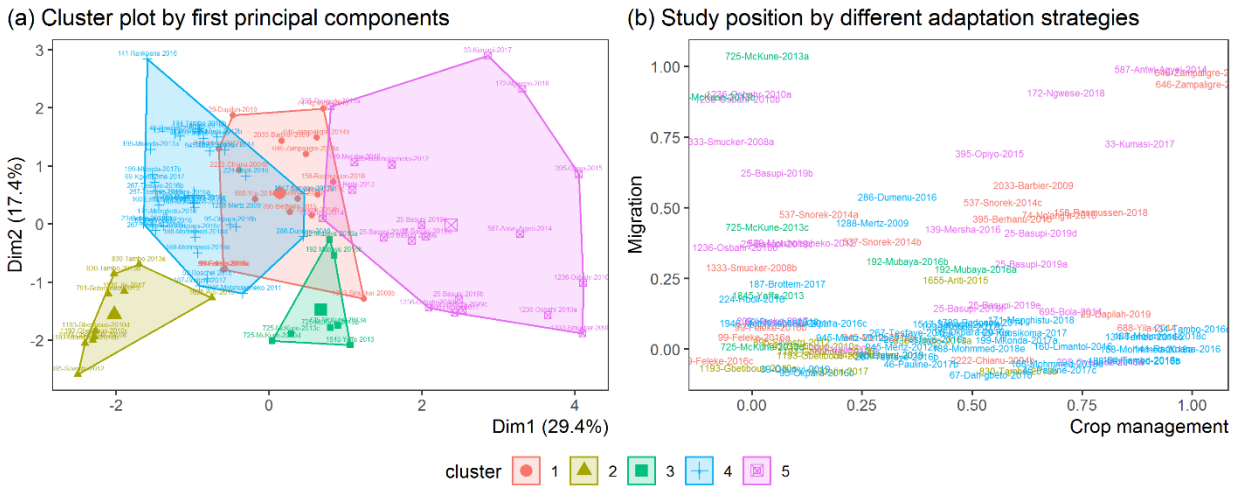

Figure S7 – Illustrating position of clusters in variable space. Panel a shows the location of clusters along the two first principal components. Panel b shows the value of cases for two commonly reported adaptation strategies, migration and crop management

Table S5 - Summary statistics for the five identified clusters

Cluster	Adaptation strategy	n	mean	sd	median	min	max	range
1	Migration	20	0.47	0.31	0.46	0.00	0.90	0.90
	Crop management	20	0.39	0.35	0.47	0.00	0.95	0.95
	Soil and water management	20	0.24	0.36	0.00	0.00	1.00	1.00
	Livestock management	20	0.37	0.33	0.33	0.00	1.00	1.00
	Searching for external support	20	0.99	0.48	0.99	0.00	1.90	1.90
	Diversifying income sources	20	0.62	0.24	0.64	0.00	0.95	0.95
	Food and nutrition	20	0.31	0.29	0.26	0.00	0.85	0.85
	No adaptation	20	0.02	0.11	0.00	0.00	0.48	0.48
	Other activities	20	0.51	0.39	0.48	0.00	1.25	1.25
2	Migration	17	0.34	0.30	0.43	0.00	0.88	0.88
	Crop management	17	0.49	0.35	0.60	0.00	1.00	1.00
	Soil and water management	17	0.24	0.24	0.22	0.00	0.63	0.63
	Livestock management	17	0.68	0.22	0.63	0.37	0.99	0.62
	Searching for external support	17	0.10	0.19	0.00	0.00	0.67	0.67
	Diversifying income sources	17	0.19	0.20	0.15	0.00	0.52	0.52
	Food and nutrition	17	0.06	0.13	0.00	0.00	0.35	0.35
	No adaptation	17	0.00	0.01	0.00	0.00	0.05	0.05
	Other activities	17	0.06	0.21	0.00	0.00	0.85	0.85
3	Migration	7	0.44	0.32	0.30	0.11	0.95	0.84
	Crop management	7	0.13	0.22	0.00	0.00	0.46	0.46
	Soil and water management	7	0.06	0.10	0.00	0.00	0.26	0.26
	Livestock management	7	0.00	0.00	0.00	0.00	0.00	0.00
	Searching for external support	7	0.22	0.41	0.00	0.00	1.11	1.11
	Diversifying income sources	7	0.16	0.28	0.00	0.00	0.66	0.66
	Food and nutrition	7	0.73	0.14	0.68	0.61	1.00	0.39
	No adaptation	7	0.00	0.00	0.00	0.00	0.00	0.00
	Other activities	7	0.02	0.05	0.00	0.00	0.13	0.13
4	Migration	35	0.05	0.13	0.00	0.00	0.54	0.54
	Crop management	35	0.49	0.31	0.45	0.00	0.99	0.99
	Soil and water management	35	0.27	0.26	0.22	0.00	0.91	0.91
	Livestock management	35	0.05	0.09	0.00	0.00	0.38	0.38
	Searching for external support	35	0.10	0.22	0.00	0.00	0.62	0.62
	Diversifying income sources	35	0.08	0.15	0.00	0.00	0.63	0.63
	Food and nutrition	35	0.02	0.06	0.00	0.00	0.32	0.32
	No adaptation	35	0.01	0.04	0.00	0.00	0.18	0.18
	Other activities	35	0.17	0.25	0.00	0.00	0.79	0.79
5	Migration	10	0.02	0.07	0.00	0.00	0.23	0.23
	Crop management	10	0.25	0.20	0.19	0.00	0.55	0.55
	Soil and water management	10	0.03	0.03	0.03	0.00	0.10	0.10
	Livestock management	10	0.10	0.11	0.05	0.00	0.34	0.34
	Searching for external support	10	0.02	0.06	0.00	0.00	0.20	0.20
	Diversifying income sources	10	0.01	0.02	0.00	0.00	0.06	0.06
	Food and nutrition	10	0.04	0.13	0.00	0.00	0.40	0.40
	No adaptation	10	0.60	0.18	0.61	0.35	0.89	0.54
	Other activities	10	0.03	0.03	0.03	0.00	0.07	0.07

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