

## **Supplementary File 1:**

### **Methods for Assessing Climate Vulnerability in Africa across two decades: A Scoping Review**

#### **List of Authors**

Emily Odipo, Sharon A. Onyango, Moses C. Kiti, Robert W. Snow, Benjamin Tsofa, Jacob Mcknight, Peter M. Macharia, Emelda A. Okiro

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## Appendices

### Appendix I: Inclusion and exclusion criteria for the scoping review

Inclusion criteria	Exclusion criteria
Study area: Africa	Study area: not within Africa
Quantitative articles	Qualitative articles
Articles that identify an extreme weather event (e.g., drought, cyclone, extreme rainfall, extreme temperature) and an outcome influenced by the event through a vulnerability method.	No information about an extreme weather occurrence or focused on extreme weather event but not linked to an outcome
Articles that identify the methodology used to calculate a vulnerability index	Spatial-temporal climate variability and trends articles
Publication period: 2003 -2023 (20 years)	Scenario projection of climate change articles.
	Non-scientific articles (e.g., Commentary, Opinion)

## Appendix II: Search strategy

### PubMed:

(((((("Climate change" OR climate OR "climate risk" OR flood\* OR "extreme weather" OR "extreme temperature" OR "extreme rainfall" OR drought OR cyclone)) AND ((vulnerability OR disaster OR susceptibility))) AND ((Africa OR Algeria OR "São Tomé e Príncipe" OR Angola OR Benin OR Botswana OR "Burkina Faso" OR Burundi OR "Cape Verde" OR "Cabo Verde" OR Cameroon OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR "DRC " OR "Cote d'Ivoire" OR "Ivory Coast" OR Djibouti OR Egypt OR "Equatorial Guinea" OR Eritrea OR Eswatini OR Swaziland OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Guinea-Bissau" OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR "Sao Tome and Principe" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR (South\* Africa) OR "South Sudan" OR Sudan OR Tanzania OR Togo OR Tunisia OR Uganda OR Zambia OR Zimbabwe))) AND (English[Language])) AND (("2003/01/01"[Date - Publication] : "2023/12/31"[Date - Publication]))

### Ovid (Embase):

((("Climate change" OR climate OR "climate risk" OR flood\* OR "extreme weather" OR "extreme temperature" OR "extreme rainfall" OR drought OR cyclone) and (vulnerability OR disaster OR susceptibility) and (Africa OR Algeria OR "São Tomé e Príncipe" OR Angola OR Benin OR Botswana OR "Burkina Faso" OR Burundi OR "Cape Verde" OR "Cabo Verde" OR Cameroon OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR "DRC " OR "Cote d'Ivoire" OR "Ivory Coast" OR Djibouti OR Egypt OR "Equatorial Guinea" OR Eritrea OR Eswatini OR Swaziland OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Guinea-Bissau" OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR "Sao Tome and Principe" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR (South\* Africa) OR "South Sudan" OR Sudan OR Tanzania OR Togo OR Tunisia OR Uganda OR Zambia OR Zimbabwe)).af and English.lg and "2003 – 2023.yr.

### Ovid (Medline):

((("Climate change" OR climate OR "climate risk" OR flood\* OR "extreme weather" OR "extreme temperature" OR "extreme rainfall" OR drought OR cyclone) and (vulnerability OR disaster OR susceptibility) and (Africa OR Algeria OR "São Tomé e Príncipe" OR Angola OR Benin OR Botswana OR "Burkina Faso" OR Burundi OR "Cape Verde" OR "Cabo Verde" OR Cameroon OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR "DRC " OR "Cote d'Ivoire" OR "Ivory Coast" OR Djibouti OR Egypt OR "Equatorial Guinea" OR Eritrea OR Eswatini OR Swaziland OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Guinea-Bissau" OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR "Sao Tome and Principe" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR (South\* Africa) OR "South Sudan" OR Sudan OR Tanzania OR Togo OR Tunisia OR Uganda OR Zambia OR Zimbabwe)).af and English.lg and "2003 – 2023.yr.

### Web of Science:

((((TS=("Climate change" OR climate OR "climate risk" OR flood\* OR "extreme weather" OR "extreme temperature" OR drought OR cyclone)) AND TS=(vulnerability OR disaster OR susceptibility)) AND TS=((Africa OR Algeria OR "São Tomé e Príncipe" OR Angola OR Benin OR Botswana OR "Burkina Faso" OR Burundi OR "Cape Verde" OR "Cabo Verde" OR Cameroon OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR "DRC " OR "Cote d'Ivoire" OR "Ivory Coast" OR Djibouti OR Egypt OR "Equatorial Guinea" OR Eritrea OR Eswatini OR Swaziland OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Guinea-

Bissau" OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR "Sao Tome and Principe" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR (South\* Africa) OR "South Sudan" OR Sudan OR Tanzania OR Togo OR Tunisia OR Uganda OR Zambia OR Zimbabwe))) AND PY=(2003-2023)

**Limiter** – Language: English

**EBSCOhost (CINAHL):**

( "Climate change" OR climate OR "climate risk" OR flood\* OR "extreme weather" OR "extreme temperature" OR "extreme rainfall" OR drought OR cyclone ) AND ( vulnerability OR disaster OR susceptibility ) AND ( Africa OR Algeria OR "São Tomé e Príncipe" OR Angola OR Benin OR Botswana OR "Burkina Faso" OR Burundi OR "Cape Verde" OR "Cabo Verde" OR Cameroon OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR "DRC " OR "Cote d'Ivoire" OR "Ivory Coast" OR Djibouti OR Egypt OR "Equatorial Guinea" OR Eritrea OR Eswatini OR Swaziland OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Guinea-Bissau" OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR "Sao Tome and Principe" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR (South\* Africa) OR "South Sudan" OR Sudan OR Tanzania OR Togo OR Tunisia OR Uganda OR Zambia OR Zimbabwe )

**Limiters** - Publication Date: 20030101-20231231; Language: English

**EBSCOhost (Medline):**

( "Climate change" OR climate OR "climate risk" OR flood\* OR "extreme weather" OR "extreme temperature" OR "extreme rainfall" OR drought OR cyclone ) AND ( vulnerability OR disaster OR susceptibility ) AND ( Africa OR Algeria OR "São Tomé e Príncipe" OR Angola OR Benin OR Botswana OR "Burkina Faso" OR Burundi OR "Cape Verde" OR "Cabo Verde" OR Cameroon OR "Central African Republic" OR Chad OR Comoros OR Congo OR "Democratic Republic of Congo" OR "DRC " OR "Cote d'Ivoire" OR "Ivory Coast" OR Djibouti OR Egypt OR "Equatorial Guinea" OR Eritrea OR Eswatini OR Swaziland OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR "Guinea-Bissau" OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR "Sao Tome and Principe" OR Senegal OR Seychelles OR "Sierra Leone" OR Somalia OR (South\* Africa) OR "South Sudan" OR Sudan OR Tanzania OR Togo OR Tunisia OR Uganda OR Zambia OR Zimbabwe )

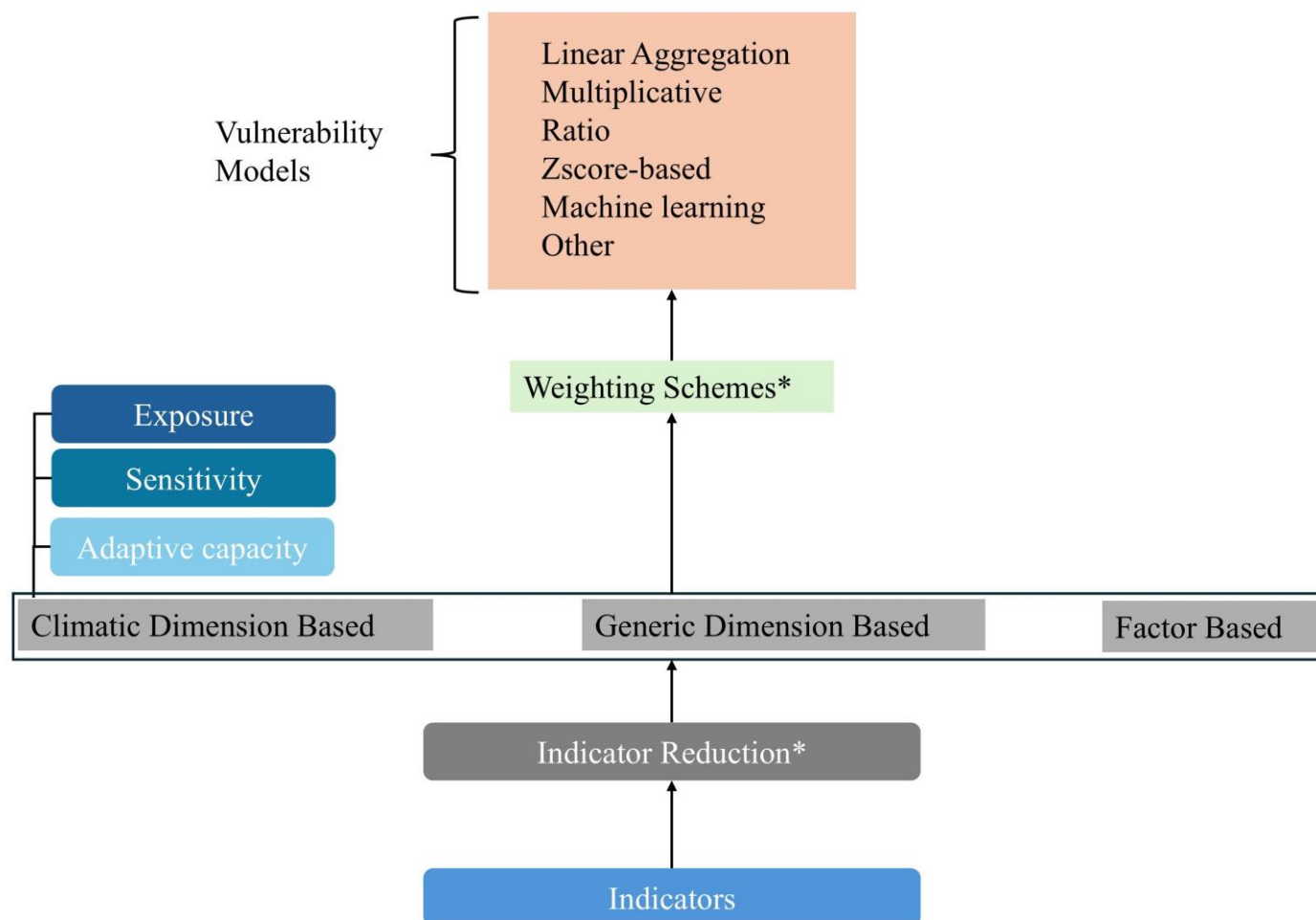
**Limiters** - Publication Date: 20030101-20231231; Language: English

### Appendix III: Regions/Countries covered in various articles

Regions / Countries Summary		
	Region / Country of Study	No. of Studies
Country-specific studies	Ethiopia	16
	South Africa	14
	Nigeria	8
	Ghana	7
	Kenya	5
	Zimbabwe	5
	Malawi	3
	Botswana	2
	Benin	2
	Cameroon	2
	Mozambique	2
	The Gambia	2
	Togo	2
	Uganda	2
	Algeria	1
	Chad	1
	Cote D'Ivoire	1
	Egypt	1
	Lesotho	1
	Mali	1
	Namibia	1
	Senegal	1
	Somalia	1
	Sudan	1
	Tanzania	1
Regional studies	Africa Region	4
	Sub-Saharan Africa Region	2
	West Africa Region	2
	Central Sahel River Basin Region	1
	Middle East and North Africa (MENA)	1
Global studies	All continents including Africa	1
	<b>Total</b>	<b>94</b>

**Footnote:** The articles were grouped into country-specific studies – focused on a particular country or an area within the country, regional studies – focused on various countries within the region and global studies – focused on countries within and beyond Africa

#### Appendix IV: Summary of vulnerability models



**Footnote:** Vulnerability models considered in the review. The \* on indicator reduction and weighting schemes means that not all the vulnerability models considered these techniques. “Other” in the methods list highlights an article that used a specific organization-based model, but the equation of the model is not clear. “Generic Dimension Based” group focused on models that used a domain-based approach different from the climate domains. Factor based means the indicators were not grouped in the vulnerability assessment.

# Appendix V: Vulnerability index models highlighted in the review

No.	Model	Grouping	Domain grouping	Domain aggregation method	Vulnerability Function	Citation
1	Linear aggregation	Factor			$V = \sum_{i=1}^n w_i v_i$ <p>Where: w = equal weighting factor for all variables or indicators; v = each factor or indicator</p>	(1–16)
					$V = \frac{1}{n} \sum_{i=1}^n w_i * v_i$ <p>Where: w = equal weighting factor for all variables or indicators; v = each factor or indicator; n = sum of indicators</p>	(17–19)
		Domain	Climatic domain (E, S, AC)	<p>Average method:</p> $D = \frac{\sum_{i=1}^n W_{mi} M_{li}}{\sum_{i=1}^n W_{mi}}$ <p>Where: <math>M_{li}</math> are the major subcomponents and <math>W_{mi}</math> are the weights of each major sub-component</p>	$V = (E + S) - AC$	(20,21)
					$V = \sum \frac{[(E + S) - AC]}{n}$ <p>Where: n = no. of farmers interviewed</p>	(22)
				<p>Average method:</p> $CI = \frac{\sum_{ei=1}^n W_j Y_{ij}}{n}$ <p>Where: CI is the composite vulnerability index of exposure factor. <math>W_j</math> is the weight a single indicator, ei is exposure indicators; <math>Y_{ij}</math> is the normalised value of exposure indicator; n is the number of indicators</p>	$V = (E + S) - AC$	(23)
					$V = (E + S) - AC$	(24)
				<p>Average method/ arithmetic mean:</p> $f = \frac{1}{n} \sum I_{Sc}$ <p>Where: f is either exposure (E), sensitivity (S) or adaptive (A) factor, and n is the total number of indicators for the factor</p>	$V = \frac{S + AC}{n}$ <p>Where: n = no. of components or compound indices</p>	(25,26)
					$V = \frac{1}{3} (E + S + LoAC)$	(27,28)
					Average to produce V/ arithmetic mean of E, S, AC	(29,30)

					$V = \sum_{i=1}^5 \frac{1}{2} \left( \left( \frac{1}{2} \left( \frac{\text{Harvested area}_i}{\text{Harvested area total}} \times S + E \right) \right) + AC \right)$	(31)
				Average method- combination of crop yield indices at both national and subnational scale (specific equations for E, S and AC based on indicators used in crop yield)	$V = (E + S) - AC$	(32,33)
				Average method $E = \frac{\sum_{i=1}^n N_{sub,i} E_{sub,i}}{\sum_{i=1}^n N_{sub,i}}$ Where: E= Exposure to drought; N <sub>sub,i</sub> = number of sub-indices within the main index, and E <sub>sub,i</sub> = the average score of main index for exposure to droughts.	$V = (E + S) - AC$	(34)
				Linear aggregation/additive $V^{SVI} = \sum_{i=1}^n W_i^{svi} v_i^{svi}$	$V = AC - (E + S)$	(35,36)
					$V = E + S + (1 - AC)$	(37)
					$V = E + S + \left( \frac{1}{LoAC} \right)$	(38)
					Additive: $V = f(E, S, AC)$	(39)
					$V = f(SU, AC) - \text{weighted linear combination}$	(40)
					$V = \frac{1}{3} [E + S + (1 - AC)]$	(41-43)
					$V = \frac{(PVI + SVI)}{2}$ Where: PVI = physical vulnerability index; SVI = social vulnerability index	(44)
					<b>Weighted sum of E, S, AC</b>	(45)
					<b>Mean aggregate of E, S, AC</b>	(46)
					$V = \frac{\frac{E + S}{2} + (1 - AC)}{2}$	(47)
				Zscore method	$V = AC - (E + S)$	(48,49)
					$V = (E + S) - AC$	(50)
				Other: Combined into integrated index	$V = (E + S) - AC$	(51,52)



			Generic domains	PCA	$V = \sum [PC_1, PC_2, PC_3 \dots PC_n]$ Where: PC = principal components	(53–57)
				Average method: $f = \sum_{i=1}^n w_i v_i$	$V = \sum_{k=1}^n W_k C_{i,k}$ Where: $W_k$ = weights assigned for the k component; $C_{i,k}$ = components	(58,59)
				Average method/ arithmetic mean: $f = \frac{1}{n} \sum I_{Sc}$	$V = f \cdot \left[ \frac{1}{n} (M_{DF} + M_{EF} + M_{SF}) \right]$ Where: $M_{DF}$ = index values of the demographic factors; $M_{EF}$ = index values of the economic factors; $M_{SF}$ = index values of the social factors; n = number of factors (major components) of social vulnerability	(60)
					$Vul_i^o = (Vul_i^{Phy} + Vul_i^{Soc} + Vul_i^{Eco} + Vul_i^{Env})/4$ Where: are respectively the average values of each ( $Vul_i^{Phy} + Vul_i^{Soc} + Vul_i^{Eco} + Vul_i^{Env}$ ) source of physical vulnerability index , social vulnerability index , economic vulnerability index and, environmental vulnerability index for the municipality	(61)
					$V = \sum_{k=1}^n W_k C_{i,k}$ Where: $W_k$ = weights assigned for the k component; $C_{i,k}$ = components	(62)
					$V = \frac{\sum_{i=1}^n w_i B_i}{\sum_{i=1}^n W_i}$ Where: $B_1 \dots B_n$ = indicating baskets; $w_1 \dots w_n$ = number of indicators in each basket	(63)
					$V = \frac{1}{4}(C+P+H+G)$ Where: C = climate-related hazard exposure; P = population density; H = household and community resilience; G = governance	(64)
					$V = f[F, W][C, S, R][E]$ Where: F = floor elevation W = material used for wall construction and its present nature C = school compound flatness S = soil type R = type of road to the school and distance from asphalt road E = evident effort by school to control or mitigate floods on school property. (Additive function)	(65)
				Average approach		(66)

2	Multiplicative model	Domain	Climatic domain (E, S, AC)	Average method: $D = \frac{\sum_{i=1}^n W_{mi} M_{li}}{\sum_{i=1}^n W_{mi}}$ Where: $M_{li}$ are the major subcomponents and $W_{mi}$ are the weights of each major sub-component	$V = (E - AC) \times S$	(67–80)
				Linear aggregation/additive: $V^{SVI} = \sum_{i=1}^n W_i^{SVI} V_i^{SVI}$	$V = E \left( \frac{1}{2} (S + LoAC) \right)$	(81)
3	Ratio model	Factor			$V = \sqrt[2]{\frac{G + SCR + BS + E + SLA + H_s + TR}{7}}$ Where: G = geomorphology; SCR = shoreline change rate; BS = beach slope; E = elevation; SLA = sea level anomaly; $H_s$ = significant mean wave height; TR = tidal range	(82)
		Domain	Climatic domain (E, S, AC)	Linear aggregation/additive	$V = \frac{E \times S}{Ac}$	(83–85)
				Average method: $f = \frac{1}{n} \sum I_{Sc}$ Where: f is either exposure (E), sensitivity (S) or adaptive (A) factor, and n is the total number of indicators for the factor	$V = \frac{E \times S}{Ac}$	(86,87)
				Average method: Specific functions provided for landscape E, S and AC	$V = \sqrt{\frac{E \times S}{1 + AC}}$	(88)
				Other: Specific aggregation method of the components not provided	$V = \frac{[(E + S)]}{AC}$	(89)
			Generic domains	Average method	$V = \frac{\sum_{p=1}^n S_{x,p,c}}{\sum_{p=1}^n T_{x,p,c}}$ Where: S = score (ND-GAIN or WRI) associated with the country of production p; T = amount (MT) of traded crop x; c = consuming country (The Gambia); n = number of supplying countries	(90)

4	Zscore based model	Factor			$CDVI_t = \frac{Y_t - \text{Mean}(Y)}{STD(Y)}$ <p>Where: CDVI = crop drought vulnerability index; <math>Y_t</math> = yield residuals for year t; Mean(Y) and STD(Y) are the mean and standard deviation of the yield residuals (Y)</p>	(91)
					$V = \sum_{i=1}^k [b_i (a_{ji} - x_i)] / S_i$ <p>Where: v is the vulnerability index, b is the weights from PCA 1, a is the indicator value, x is the mean indicator value, s is the standard deviation of the indicators, i is the indicators and j is the specific province</p>	(92)
4	Machine learning	Factor			Random forest, K-nearest neighbours, support vector machine and naïve Bayes	(93)
5	Other	Domain	Generic domains		Drought vulnerability evaluated using household vulnerability index developed by Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN) (equation not provided)	(94)

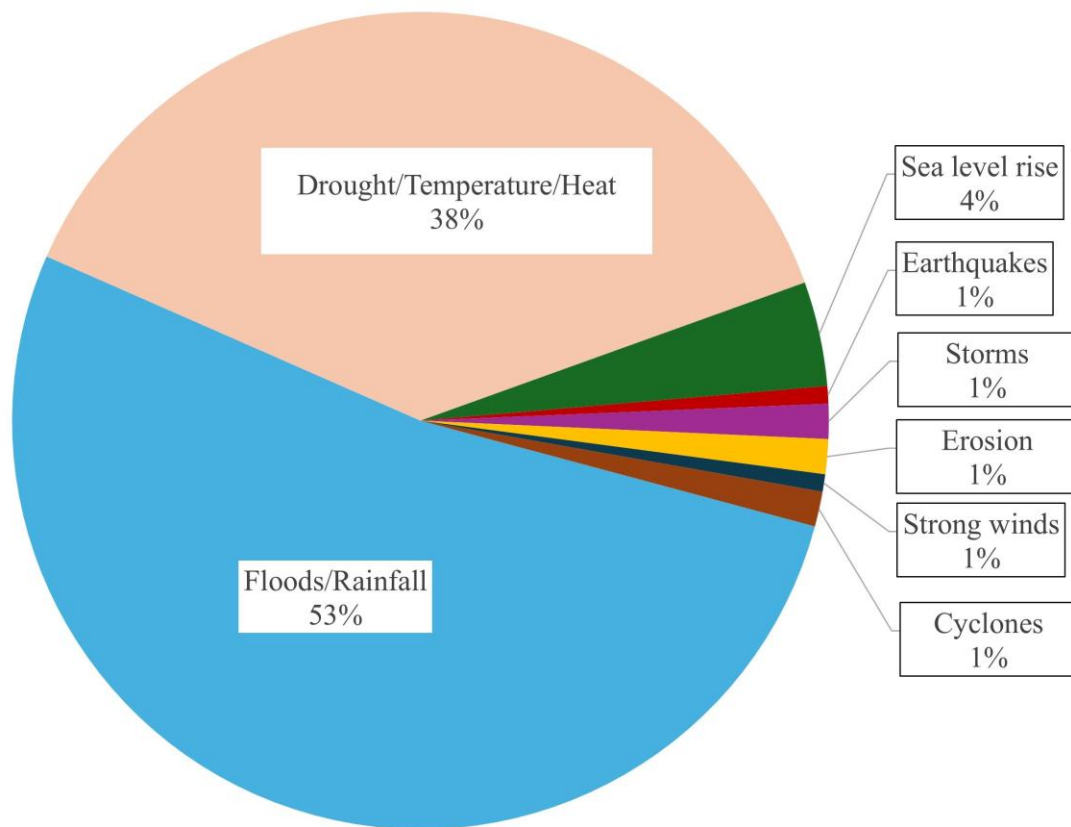
**Footnote:** Summary of vulnerability index equations. Each type of model was grouped based on factor, climatic domain and other domains. Factor based considered the individual indicators, climatic domains considered the exposure, sensitivity and adaptive capacity as the major components while generic domains considered varied groupings separate from climatic domains as the major components. Methods used to obtain the different domains is also provided in the domain aggregation methods column. Abbreviations: Exposure (E), Sensitivity (S), Adaptive capacity (AC), Vulnerability index (V)

## Appendix VI: Vulnerability index and the various major sub-component of the indicators

Vulnerability index	Dimensions /Major sub-components
Children climate	Adaptive capacity (Education, Poverty, WASH, Communication assets and social protection); Sensitivity (Child health and nutrition)
Climate	Adaptive capacity (Institutional development, Natural capital, Social capital, Education, Financial capital, Human capital, Physical capital, Income level diversification); Exposure (Climate, Climate hazards, Climate variability); Sensitivity (Livestock farming, Culture, Consumption, Natural resources, Agricultural, Poverty and Hunger, Health, Demographic, Disaster related, Food security)
Climate risk	Adaptive capacity, Exposure, Sensitivity
Climate security	Governance and political violence, Population, Household and community resilience, Physical exposure
Climate-water conflict	Adaptive capacity (Socio-demographic, Physical/natural assets, Livelihood income strategies, Social/political network); Exposure (Climate variability, Water conflict); Sensitivity (Lake water variability)
Coastal community	Adaptive capacity; Exposure; Sensitivity
Community	Adaptive capacity; Exposure; Sensitivity
Crop drought	Infrastructure, Resources, Human, Governance, Economic
Crop yield	Adaptive capacity (Socio-economic); Exposure (Climate drivers of drought); Sensitivity (Crop yields)
Drought	Adaptive capacity; Exposure; Sensitivity
	Human and civic resource, Economic, Renewable natural capital, Infrastructure and Technology
Ecological	Adaptive capacity; Exposure; Sensitivity
Farmers	Adaptive capacity; Exposure; Sensitivity
Farmers household	Adaptive capacity; Exposure; Sensitivity
Farming	Adaptive capacity (Social capital, Physical capital, Human capital, Financial capital); Exposure; Sensitivity
Flood	Adaptive capacity (Social, Economic, Physical, Environmental); Exposure (Physical/environmental, Social, Structure population, Economic, Physical); Sensitivity (Physical/environmental, Social, Structure population, Economic, Physical)
	Social, Morphometric parameters, Technological, Flood causative, Ecological, Exposure to hazards, Method of mitigation, Sanitation and disease, Income, Economic
Gender	Adaptive capacity; Exposure; Sensitivity (Socio-economic, Agro-environmental, Water)
Health	Adaptive capacity (Physical capital, Financial capital, Social capital, Human capital); Exposure (Climate); Sensitivity (Natural capital)
Household	Adaptive capacity; Exposure; Sensitivity
	Natural assets, Human capital, Social assets, Physical assets, Financial assets
Integrated coastal	Physical, Socio-economic
Landscape	Adaptive capacity; Exposure; Sensitivity
Livelihood	Adaptive capacity (Natural capital, Assets, Training and support, Livelihood diversification, Literacy, Perception and willingness, Financial capital, Socio-demographic, Social capital, Human capital, Physical capital, Farm inputs, Demographic, Social, Sustainable livelihood capital/assets, Social institutions or networks, Livelihood strategy, Water, Access to services, Wealth, Infrastructure, Social networks, Food); Exposure (Natural disaster, Climate hazards, Climate variability, Drought, Water variability, Climate, Weather and climate events, Water variability, Natural hazards); Sensitivity (Natural capital, Runoff, Health security, Socio-economic, Production, Biophysical environment, Health, Food security, Stability, Food and nutrition, Water security, Surface water storage, Agricultural, Biophysical, Income and food access, Water storage capacity)
Maize yield	Adaptive capacity; Exposure; Sensitivity
Multi-hazard	Adaptive capacity (Physical, Management and institutional, Social, Economic); Exposure (Economic, Physical); Sensitivity (Economic, Physical, Social)
Multivariate agricultural drought	Adaptive capacity (Socio-economic); Exposure (Climate); Sensitivity (Physiographic and environmental, Biophysical drought)
Population	Adaptive capacity; Exposure; Sensitivity
Rural community	Adaptive capacity (Physical planning and engineering, Economic capacity, Management and institutional capacity, Societal capacity); Exposure (Structure, Population economy); Sensitivity (Social, Physical/demographic factor, Environmental, Economic)
Rural household	Adaptive capacity; Exposure; Sensitivity
Sectoral vulnerability	Human habitat, Ecosystem services, Infrastructure, Water, Health, Food
Social	Adaptive capacity; Exposure; Sensitivity

	Population density, Vulnerability preparedness, Access to resources, Land-related, Access and distance to infrastructure and services, Demographic, Household characteristics, Employment, Economic, Income-related, Access to services, Land use and green space, Rurality, Socio-economic, Social, Climate change related, Family structure, Vulnerable populations
Socio-ecological	Ecological, Economic, Infrastructure, Social
West Sudanian Community	Adaptive capacity (Ecosystem robustness, Coping capacity); Exposure (Ecological, Social system); Sensitivity (Poverty and dependency, Housing conditions, Health and Nutrition, Public infrastructure)

## Appendix VII: Climatic hazards and extreme weather events



*Footnote: Climatic hazards and extreme weather events discussed in the various articles.*

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