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4 **Climate-Induced Risk to Food Security in Two Indian Indigenous Communities: Evaluating Impact and**
5 **Association Through Community Perception**

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19 **1. Introduction:**

20 People living in climate-vulnerable regions face heightened risks of climate-induced food insecurity,
21 particularly the indigenous communities that rely on subsistence agriculture [1]. Despite these growing
22 challenges, there remains limited understanding of how such communities perceive and experience these
23 impacts [2]. Effective adaptation requires a nuanced understanding of how people are perceiving climate
24 exposure and how they are experiencing climate impacts in order to design community-led adaptation
25 solutions. This is highly relevant for socio-economically marginalised communities such as indigenous
26 farmers, whose voices are often ignored in broader adaptation processes [3]. Besides, the community's
27 coping and adaptation responses substantially depend on the way they frame climate exposure and
28 experience the impacts in their food production system [4]. Thus, assessing climate impacts through
29 community perceptions is essential to plan food system adaptation, based on local and indigenous
30 knowledge. Our paper presents concurrent case studies of two Indigenous, nature-dependent smallholder
31 farming communities in India, examining their experiences of climate exposure and perceived impacts on
32 food security in order to leverage locally-led adaptation solutions. This quantitative study assesses the
33 perceived exposure and impact indicators and tests the association with household-level food security in two
34 indigenous communities in India.

35 Agricultural production became significantly uncertain due to climate change impacts, hampering the
36 stability of the local food system and food affordability, and ultimately food security [5]. It is estimated that
37 agricultural output in developing countries will decline by 10–20% by 2080 [6] due to climatic changes,
38 making it a major driver of undernutrition, especially among children (World Nutrition Report 2021). Various
39 policies and programs of climate-smart technologies for agriculture have been implemented to adapt to the
40 changes. These interventions are based on meteorological prediction and contextually available technologies
41 and aim to improve agricultural production to strengthen food and nutritional security. However, the food

42 security situation is still suboptimal and even crucial in marginal environments such as hilly terrain, coasts,
43 and dry lands [7]. The situation further worsens amongst small-scale indigenous farmers who farm for
44 subsistence [8].

45 India's food demand is expected to rise due to climate change and population growth, mirroring the
46 worldwide trend [9]. An increase of 1-2°C in temperature will negatively affect grain crop yields in low-
47 altitude countries like India, affecting the population's nutritional status [10]. The interlinked dangers
48 illustrate that climate change functions not merely as an ecological stressor but also as a crucial element
49 affecting nutritional inequality, particularly for at-risk agricultural societies in countries like India. Global
50 evidence suggests that indigenous communities are experiencing severe climatic exposures, which are
51 adversely affecting their traditional food resources in terms of reducing crop yield, lowering livestock
52 production and increasing reliance on non-traditional food resources and potentially correlates with the
53 poverty-vulnerability relationship [11]. Food security is threatened by lower agricultural yields, with
54 projections revealing considerable yield declines for rice, wheat, and maize in South Asia under climate
55 change forecasts [12]. In response, communities adopted coping strategies such as altering cropping
56 patterns, changing irrigation practices and seasonal migration [13]. However, these measures are proving
57 increasingly unsustainable as the impacts of climatic shocks on indigenous communities are often beyond
58 the households' capacity to cope [14].

59 Though the food production system as a whole is extremely vulnerable to climate change impacts, we argue
60 that the climate change stressors are disproportionately impacting the structurally marginalised indigenous
61 farmers, whose experiences are often ignored in adaptation planning. The indigenous farmers in India, living
62 mostly in geographically hard-to-reach areas, are not well-equipped with climate-resilient technologies, are
63 highly dependent on natural resources and lack a relevant early warning system for slow and rapid changes
64 in the climate. Thus, facing moderate to severe climate exposure, which is impacting their food security

65 status. We examined perceived climate exposure and impacts on food security of two indigenous farming
66 communities- Am-beng Garo in Meghalaya and Gond in Madhya Pradesh, living in two distinct agro-ecological
67 settings in India. We assess communities' perception of how climate exposure such as rainfall, flood, drought
68 and dry spell are impacting their agricultural production, livestock and forest collection. We also examine the
69 association between those exposures and impacts and household-level food security. Findings revealed
70 severe perceived impacts of rainfall and heat on sources of food production, grading the households in
71 different food-insecure categories. The findings offer valuable insights to incorporate communities'
72 perceived impacts in climate-risk modelling for food security, which are often overlooked in the adaptation
73 discourse. We suggest immediate actions to build the adaptive capacity of the indigenous farmers based on
74 their perceived climate signals and contextual impacts to sustain agriculture and other food production
75 resources to protect them from further slipping into deeper food insecurity.

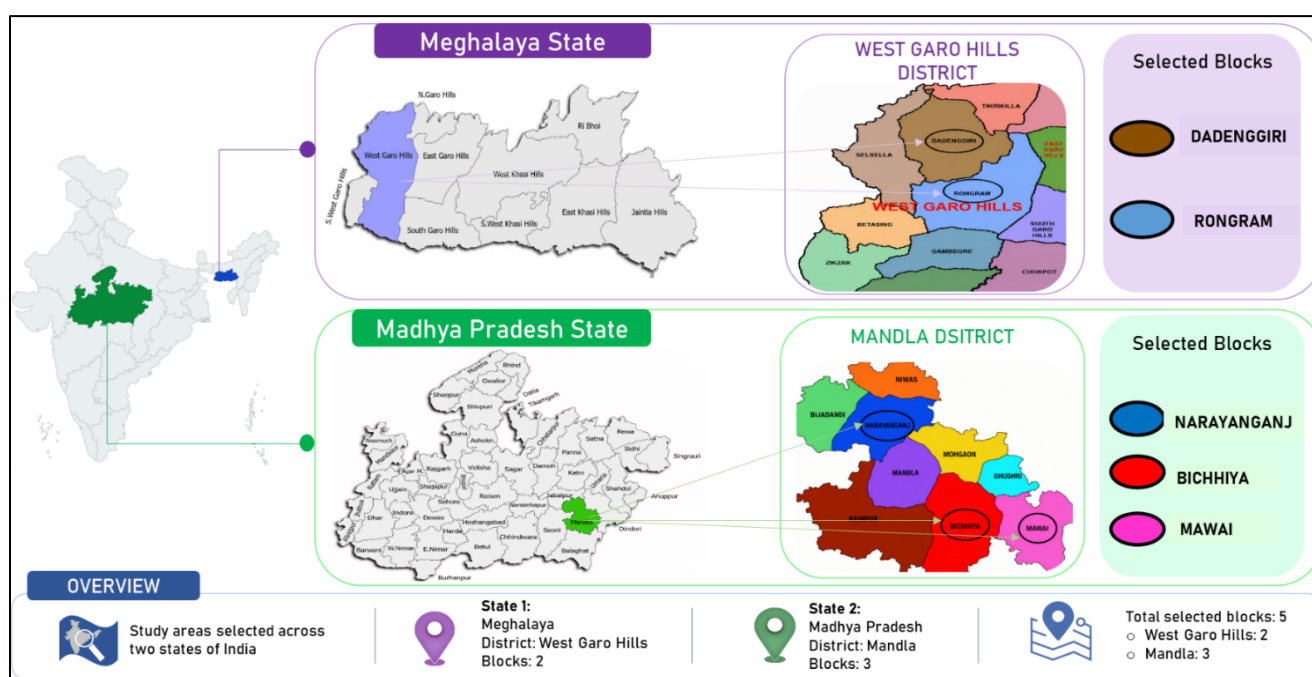
76 **2. Methodology**

77 This study forms part of the larger "Characterising, Reviving, Supporting, Monitoring and Managing
78 (CARISMMA) Sustainable Food Systems" project, a longitudinal cohort study that examines the drivers of
79 food systems, their interlinkages with nutritional outcomes, and sustainable pathways for food systems of
80 Indigenous communities in India.

81 **2.1 Study design, locale, and population**

82 This cross-sectional investigation employs a quantitative methodology to examine the relationship between
83 climate change-related perceptions and food security among two indigenous communities- the Am-beng
84 Garo in Meghalaya and the Gond in Madhya Pradesh. These communities were purposively selected to reflect
85 contrasting agro-ecological contexts, with the Am-beng Garo inhabiting hilly regions characterised by shifting
86 cultivation systems and the Gond residing in plains dominated by settled agricultural practice. Both

87 communities are not only different in agro-ecological contexts but also differ in socio-economic
88 characteristics. While Gonds are largely forest dependents, Am-beng Garos have greater flexibility in terms
89 of livelihood. Literacy rate among Am-beng Garos is higher than that of Gonds as per the 2011 Census. Am-
90 beng Garo community is more strongly connected with local governance as a part of a larger indigenous
91 community network across the North-Eastern states of India. Whereas, Gonds are surrounded mostly by non-
92 indigenous communities who are comparatively placed higher in the developmental ladder (Census, 2011).
93 Fig 1 depicts The locations of the study areas in detail.



94 **Fig 1. Study Area: Selected Blocks in West Garo Hills and Mandla Districts, India**

95 2.2 Sampling Framework

96 The present study draws on a purposively selected subsample based on inclusion criteria from two of the
97 cohorts of the larger CARISMMA study, the Am-beng Garo community and the Gond community, based on
98 predefined inclusion criteria.

99 ***Inclusion Criteria***

100 Participants were required to be at least 40 years of age and to have resided in the same village for a minimum
101 of 20 years. These criteria were applied to ensure that respondents possessed sufficient lived experience to
102 reflect on long-term climatic changes, shifts in agricultural practices, changes in market dynamics, and
103 broader transformations within their food systems.

104 **2.3 Sample size**

105 The analytic sample for this cross-sectional analysis comprised 251 households from Am-beng Garo (n = 123)
106 and Gond (n = 128), purposively selected based on the inclusion criteria from the larger CARISMMA cohort.

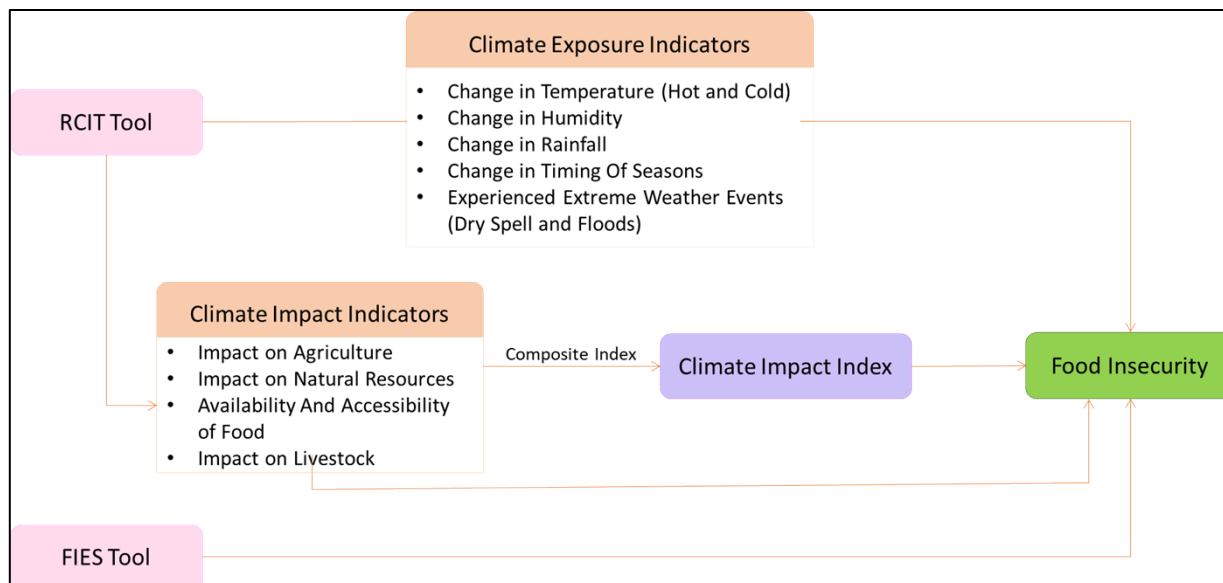
107 **2.4 Conceptual Framework**

108 Analyses were guided by a conceptual framework in which perceived climate exposures are linked to
109 perceived climate-related impacts on the food production system and how those are associated with food
110 security outcomes. In this framework, exposure was represented by increasing hot days, erratic rainfall and
111 intensity, dry spells, and floods. Impacts were reported as the influence of exposure indicators on different
112 dimensions of agriculture, natural resources, and livestock. We argue that the indigenous farming
113 communities who are facing moderate to severe climate exposure, their food production system are being
114 impacted by climate exposure like extreme heat and erratic rainfall. They have taken actions such as changes
115 in the crop and irrigation pattern as well as changes in their dietary choices. Despite the actions taken, the
116 households still face mild, moderate and severe food insecurity. The study did not utilise any framework to
117 assess community or household level vulnerabilities, but rather reflected on pathways of impact and
118 interrelationship between the climate exposure and impact with food insecurity as perceived by the
119 vulnerable communities. Fig 2 depicts the conceptual pathways of perceived impact and how we assess those
120 through various indicators:

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124 **Fig 2. Conceptual Framework for Assessing Climate Impacts on Food Insecurity Using Indicator-Based**
125 **Approaches.** *Climate exposure indicators and climate impact indicators were assessed separately in relation*
126 *to food insecurity. A composite Climate Impact Index derived from the climate impact indicators was*
127 *subsequently assessed in relation to food insecurity. Abbreviations: RCIT, Retrospective Climate Impact*
128 *Assessment Tool; FIES, Food Insecurity Experience Scale.*

129

130 **2.5 Data collection instrument and study variables**

131 **2.5.1 Retrospective Climate Impact Assessment Tool (RCIT)**

132 Data were collected using a structured Retrospective Climate Impact Assessment Tool (RCIT) capturing
133 household-level perceptions over a 20-year reference period.

134 **Climate Exposure Indicators**

135 Climate exposure was assessed using nine indicators derived from the Climate Impact Assessment Tool.
136 Respondents reported perceived changes in weather patterns over the preceding 20 years across the
137 following dimensions: increase in hot days; increase in humidity; increase in cold days; erratic rainfall; and

138 changes in the timing of seasons (each coded Yes/No from a multi-select item). Midday and nighttime
139 temperature trends were captured as three-category ordinal variables (getting hotter/not changed/getting
140 cooler), and rainfall amount and number of rainy days were similarly assessed on a three-point scale
141 (substantially increased/not changed/substantially decreased). Experience of dry spells and flood events over
142 the past 20 years was recorded as binary Yes/No indicators. All exposure variables were drawn directly from
143 the tool and required no transformation.

144 **Climate Impact Indicators**

145 Climate impact was assessed across four domains - agriculture, natural resources, availability and accessibility
146 of food, and livestock - using variables derived from relevant subsections of the tool. Several domain-specific
147 multi-select items were recoded to produce binary climate-attributable impact variables, as detailed below.

148 **Agriculture** - Respondents who reported any change in crop variety were asked to select the reason(s) from
149 a list. A binary variable, *crop change due to climate factors*, was derived by coding 1 if the respondent selected
150 either "new variety performs well in less rainfall" or "new variety can tolerate more droughts"; all other
151 reasons (higher yield, short crop cycle, better market value, better nutritional value) were considered non-
152 climate and coded 0. For respondents who reported changing their irrigation method, a binary variable,
153 *irrigation method change due to climate factors*, was derived by coding 1 if the respondent selected at least
154 one of the following: temperature change, change in rainfall pattern, or increase in frequency of extreme
155 weather events; other reasons (water scarcity, crop diversification, soil degradation, funding) were coded 0.
156 High in-season temperature decreasing yield and high in-season rainfall decreasing yield were retained as
157 originally coded (Yes/No/Don't know); for all analyses, "Don't know" responses were retained as a distinct
158 category in bivariate tables.

159 **Natural resources** - Impact on groundwater due to climate factors was assessed directly (Yes/No/Don't
160 know). For respondents reporting a decrease in forest collection, a binary climate-attributable variable was

161 derived: coded 1 if the respondent selected an increase in hot days, an increase in cold days, or a change in
162 rainfall pattern as causal factors; other causes (deforestation, land conversion, forest rights restrictions) were
163 coded 0. Soil fertility impact was similarly recoded: among respondents who reported any change in soil
164 fertility, coded 1 if change in temperature, change in rainfall pattern, or increase in extreme weather events
165 was selected.

166 **Availability and Accessibility of Food** - Three binary variables were retained as originally coded from the tool:
167 impact on food resources due to climate factors (Yes/No/Don't know), impact on food accessibility due to
168 climate factors (Yes/No/Don't know), and change in the availability of traditionally consumed food due to
169 climate factors (Yes/No/Don't know).

170 **Livestock** - Among respondents who owned livestock, impact on livestock due to climate factors was recorded
171 (Yes/No/Don't know). Among those reporting a climate impact on livestock, change in feed availability due
172 to climate factors was further recorded (Yes/No).

173 Detailed rationale for the selection of the climate impact indicators is provided in S1 Table.

174 **Climate Impact Index development:**

175 A composite Climate Impact Index was constructed to quantify the overall burden of climate impacts
176 experienced at the household level. Twelve binary climate-attributable impact variables were selected,
177 spanning all four domains: crop change due to climate factors, high in-season temperature decreasing yield,
178 high in-season rainfall decreasing yield, and irrigation method change due to climate factors (agriculture);
179 groundwater impact due to climate, decrease in forest collection due to climate, and soil fertility impact due
180 to climate (natural resources); food resources affected by climate, food accessibility affected by climate, and
181 change in food availability and accessibility due to climate; and livestock impact due to climate and change
182 in feed availability due to climate (livestock).

183 Each variable was dichotomised as Yes = 1 and No / Don't know / Not applicable = 0. Not applicable responses
184 arose from skip patterns (e.g., respondents who did not own livestock, or those who did not report a change
185 in crops or irrigation) and were treated as an absence of that specific impact. The index was computed as the
186 unweighted sum of all twelve binary variables (range: 0–12), with higher scores indicating greater cumulative
187 climate impact.

188 The distribution of index scores was examined for both communities. Scores ranged from 1 to 12 in Am-beng
189 Garo and from 2 to 12 in Gond (Table 1).

190 **Table 1. Distribution of Climate Impact Index**

Statistic	Am-beng Garo (n=123)	Gond (n=128)	Total (n=251)
Mean \pm SD	7.44 \pm 2.64	7.84 \pm 2.25	7.64 \pm 2.45
Median (IQR)	8.0 (6.0–9.0)	8.0 (6.0–10.0)	8.0 (6.0–9.0)
Range (Min – Max)	1 – 12	2 – 12	1 – 12
Categorisation (based on score distribution)			
Low Impact (1–5)	29 (23.58%)	21 (16.41%)	50 (19.92%)
Medium Impact (6–9)	70 (56.91%)	72 (56.25%)	142 (56.57%)
High Impact (10–12)	24 (19.51%)	35 (27.34%)	59 (23.51%)

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192 Based on the score distribution and the need for adequate cell sizes for statistical testing, scores were
193 categorised into three groups: Low Impact (score 1–5), Medium Impact (score 6–9), and High Impact (score
194 10–12).

195 **2.5.2 Outcome: Food Insecurity**

196 The phenomenon of food insecurity was assessed by utilising the eight-item Food Insecurity Experience Scale
197 (FIES) developed by the FAO, wherein respondents articulated their challenges in securing adequate food
198 due to constrained resources over the preceding 12 months. Respondents were classified into four unique
199 stages of food insecurity, grounded in their personal experiences reported during the previous year.

200 Individuals who indicated they felt hunger but were unable to acquire sustenance, or who avoided eating for
201 a complete day, were categorised as experiencing severe food insecurity. Conversely, those who shared
202 experiences of omitting meals, cutting down on food intake, or having a scarcity of food supplies were
203 recognised as undergoing moderate food insecurity. Additionally, individuals who conveyed apprehensions
204 regarding insufficient food availability, thereby reporting their inability to maintain a healthy and balanced
205 diet or relying on a limited array of food options, were categorised under mild food insecurity. Those
206 participants who did not report any of the previously mentioned conditions were classified as food secure,
207 thereby indicating no food insecurity. Subsequently, food insecurity was recognised as an ordinal variable
208 that encompasses four categories (none, mild, moderate, and severe), with analysis undertaken using 'none'
209 as the reference point. The Rasch model was used to analyse the validity of the Food Insecurity Experience
210 Scale (FIES) scores, demonstrating that their infit (<1.3) and outfit (<2.0) figures remained within allowable
211 thresholds for all items.

212 **2.5.3 Statistical Analysis**

213 Descriptive analysis was performed separately for the Am-beng Garo and Gond communities, with a
214 combined total presented for contextualisation. Continuous variables are presented as mean \pm standard
215 deviation (SD). Categorical variables are presented as frequency and row percentage. Bivariate associations
216 between climate exposure indicators, climate impact indicators, and food insecurity were assessed using the
217 chi-square test of independence, with row percentages reported. Associations between the categorised
218 Climate Impact Index and food insecurity were similarly examined using chi-square. A Kruskal-Wallis test was
219 used to compare the continuous Impact Index score across the four food insecurity categories. Statistical
220 significance was set at $p < 0.05$. All analyses were conducted separately for the two communities. Statistical
221 analyses were performed using STATA 15.1.

222 **3. Results**

223 3.1 Study Population and Demographic Characteristics

224 A total of 251 respondents were enrolled, comprising 123 from the Am-beng Garo community and 128 from
 225 the Gond community. The mean age of respondents was 55.91 ± 11.43 years in the Am-beng Garo community
 226 and 55.48 ± 9.04 years in the Gond community (combined: 55.69 ± 10.26 years). In the Am-beng Garo
 227 community, men comprised 75.61% ($n = 93$) of respondents, whereas the Gond community was more
 228 balanced, with 55.47% ($n = 71$) men and 44.53% ($n = 57$) women (Table 2).

229 **Table 2: Demographic Characteristics and Climate Exposure Indicators of the Study Population**

Characteristics	Am-beng Garo (n=123)	Gond (n=128)	Total (n=251)
Individual-level characteristics			
Age (years)	55.91 ± 11.43	55.48 ± 9.04	55.69 ± 10.26
Gender			
Male	93 (75.61%)	71 (55.47%)	164 (65.34%)
Female	30 (24.39%)	57 (44.53%)	87 (34.66%)
Climate Exposure Indicators			
Increase in hot days	n = 119	n = 116	n = 235
Yes	100 (84.03%)	109 (93.97%)	209 (88.94%)
No	19 (15.97%)	7 (6.03%)	26 (11.06%)
Midday temperature (last 20 years)	n = 123	n = 128	n = 251
Getting hotter	123 (100.00%)	114 (89.06%)	237 (94.42%)
Not changed	0 (0.00%)	14 (10.94%)	14 (5.58%)
Getting cooler	0 (0.00%)	0 (0.00%)	0 (0.00%)
Nighttime temperature (last 20 years)	n = 123	n = 128	n = 251
Getting hotter	90 (73.17%)	96 (75.00%)	186 (74.10%)
Not changed	23 (18.70%)	22 (17.19%)	45 (17.93%)
Getting cooler	10 (8.13%)	10 (7.81%)	20 (7.97%)
Increase in humidity	n = 119	n = 116	n = 235
Yes	99 (83.19%)	4 (3.45%)	103 (43.83%)
No	20 (16.81%)	112 (96.55%)	132 (56.17%)
Increase in cold days	n = 119	n = 116	n = 235
Yes	37 (31.09%)	14 (12.07%)	51 (21.70%)
No	82 (68.91%)	102 (87.93%)	184 (78.30%)
Erratic rainfall	n = 119	n = 116	n = 235
Yes	95 (79.83%)	115 (99.14%)	210 (89.36%)
No	24 (20.17%)	1 (0.86%)	25 (10.64%)

Changes in the timing of seasons	n = 119	n = 116	n = 235
Yes	104 (87.39%)	99 (85.34%)	203 (86.38%)
No	15 (12.61%)	17 (14.66%)	32 (13.62%)
Experienced dry spells	n = 123	n = 128	n = 251
Yes	77 (62.60%)	28 (21.88%)	105 (41.83%)
No	46 (37.40%)	100 (78.12%)	146 (58.17%)
Experienced flood events	n = 123	n = 128	n = 251
Yes	78 (63.41%)	34 (26.56%)	112 (44.62%)
No	45 (36.59%)	94 (73.44%)	139 (55.38%)

230

231 **3.2 Perceived Climate Exposure (Table 2)**

232 Perceived changes in climate conditions over the past 20 years were highly prevalent across both
 233 communities. Among respondents who answered the weather-change sub-items (Am-beng Garo: n = 119;
 234 Gond: n = 116), increases in hot days were reported by 84.03% in Am-beng Garo and 93.97% in Gond. Notably,
 235 erratic rainfall was perceived by nearly all Gond respondents (99.14%) and a substantial majority of Am-beng
 236 Garo respondents (79.83%). Changes in the timing of seasons were reported at similarly high levels in both
 237 communities (87.39% Am-beng Garo; 85.34% Gond). All 123 Am-beng Garo respondents perceived that
 238 midday temperature was getting hotter, as did 89.06% of Gond respondents. Nighttime temperature was
 239 perceived as getting hotter by 73.17% and 75.00% of Am-beng Garo and Gond respondents, respectively. The
 240 majority of the perceived exposures are consistent with global climate change trends [15].

241 A striking community-level contrast was observed for humidity: 83.19% of Am-beng Garo respondents
 242 perceived an increase in humidity, compared with only 3.45% in Gond. Am-beng Garo community reside in
 243 West Garo Hills, which has a tropical monsoon climate, whereas the Gond community reside in a hot,
 244 subtropical semi-arid climate. Perceived increase in humidity among the Am-beng Garo community,
 245 commensurate with the global trends of increase in humidity in the tropical monsoon region [16]. On the
 246 contrary, the Gond community expressed a real-time observation of a marginal increase in humidity. Most
 247 of the hydro climate modelling shows an increase in water vapour due to atmospheric demands, but

248 observational studies reflect near surface water vapour has not increased in arid and semi-arid areas [17].
 249 Thus, the observational experience of the Gond community might be in line with the real-world measurement
 250 of flattening of specific humidity [18]. This particular argument can be strengthened further with the dry spell
 251 experience of the Am-beng Garo community (62.60%) than the Gond (21.88%). Evidence suggests that
 252 despite the rise in specific humidity in tropical monsoon regions, there are prolonged dry spells and droughts,
 253 especially during pre-monsoon seasons [16]. Similarly, higher atmospheric moisture results in erratic but
 254 intense rainfalls, leading to sudden flooding (ibid). Thus, the Am-beng Garo community might experience
 255 more floods (63.41%) as compared to the Gond community (26.56%)

256 3.3 Perceived Climate Impact Indicators (Table 3)

257 **Table 3: Perceived Climate Impacts on Food Production Sources of the Study Population**

Climate Impact Indicators	Am-beng Garo (n=123)	Gond (n=128)	Total (n=251)
Crop Impacts			
Change in Crop	<i>n</i> = 119	<i>n</i> = 127	<i>n</i> = 246
Yes	42 (35.29%)	111 (87.40%)	153 (62.20%)
No	77 (64.71%)	16 (12.60%)	93 (37.80%)
Change in crop due to climate factors	<i>n</i> = 42	<i>n</i> = 111	<i>n</i> = 153
Yes	41 (97.62%)	89 (80.18%)	130 (84.97%)
No	1 (2.38%)	22 (19.82%)	23 (15.03%)
Change in irrigation method in the last 20 years	<i>n</i> = 119	<i>n</i> = 127	<i>n</i> = 246
Yes	20 (16.81%)	65 (51.18%)	85 (34.55%)
No	99 (83.19%)	62 (48.82%)	161 (65.45%)
Change in irrigation method due to climate factors	<i>n</i> = 20	<i>n</i> = 65	<i>n</i> = 85
Yes	20 (100.00%)	65 (100.00%)	85 (100.00%)
No	0 (0.00%)	0 (0.00%)	0 (0.00%)
High in-season temperatures decreased yield	<i>n</i> = 119	<i>n</i> = 127	<i>n</i> = 246
Yes	98 (82.35%)	113 (88.98%)	211 (85.77%)
No	15 (12.61%)	8 (6.30%)	23 (9.35%)
Don't know	6 (5.04%)	6 (4.72%)	12 (4.88%)
High in-season rainfall decreased yield	<i>n</i> = 119	<i>n</i> = 127	<i>n</i> = 246
Yes	67 (56.30%)	64 (50.39%)	131 (53.25%)
No	48 (40.34%)	62 (48.82%)	110 (44.72%)
Don't know	4 (3.36%)	1 (0.79%)	5 (2.03%)

Natural Resources Impacts			
Groundwater is affected due to climate factors	<i>n</i> = 123	<i>n</i> = 128	<i>n</i> = 251
Yes	63 (51.22%)	78 (60.94%)	141 (56.18%)
No	26 (21.14%)	15 (11.72%)	41 (16.33%)
Don't know	34 (27.64%)	35 (27.34%)	69 (27.49%)
Impact on soil fertility due to climate factors	<i>n</i> = 108	<i>n</i> = 103	<i>n</i> = 211
Yes	104 (96.30%)	93 (90.29%)	197 (93.36%)
No	4 (3.70%)	10 (9.71%)	14 (6.64%)
Decrease in forest collection due to climate factors	<i>n</i> = 115	<i>n</i> = 119	<i>n</i> = 234
Yes	110 (95.65%)	112 (94.12%)	222 (94.87%)
No	5 (4.35%)	7 (5.88%)	12 (5.13%)
Food System Impacts			
Food resources affected due to climate factors	<i>n</i> = 123	<i>n</i> = 128	<i>n</i> = 251
Yes	106 (86.18%)	86 (67.19%)	192 (76.49%)
No	11 (8.94%)	33 (25.78%)	44 (17.53%)
Don't know	6 (4.88%)	9 (7.03%)	15 (5.98%)
Food accessibility affected due to climate factors	<i>n</i> = 123	<i>n</i> = 128	<i>n</i> = 251
Yes	100 (81.30%)	31 (24.22%)	131 (52.19%)
No	23 (18.70%)	96 (75.00%)	119 (47.41%)
Don't know	0 (0.00%)	1 (0.78%)	1 (0.40%)
Types of food consumed changed due to climate factors	<i>n</i> = 123	<i>n</i> = 128	<i>n</i> = 251
Yes	102 (82.93%)	73 (57.03%)	175 (69.72%)
No	19 (15.45%)	52 (40.62%)	71 (28.29%)
Don't know	2 (1.63%)	3 (2.34%)	5 (1.99%)
Livestock Impacts			
Livestock impacted by climate factors	<i>n</i> = 117	<i>n</i> = 122	<i>n</i> = 239
Yes	62 (52.99%)	106 (86.89%)	168 (70.29%)
No	47 (40.17%)	13 (10.66%)	60 (25.10%)
Don't know	8 (6.84%)	3 (2.46%)	11 (4.60%)
Change in feed availability due to climate factors	<i>n</i> = 62	<i>n</i> = 106	<i>n</i> = 168
Yes	42 (67.74%)	93 (87.74%)	135 (80.36%)
No	20 (32.26%)	13 (12.26%)	33 (19.64%)

258

259 **Agriculture**

260 The majority of Gond respondents (87.40%) reported changing crop varieties, compared to 35.29% in Am-

261 beng Garo. Among those who changed the crops, 97.62% of Am-beng Garo and 80.18% of Gond respondents

262 attributed the change to climate-related reasons. Changes in irrigation method were reported by 16.81% of
263 Am-beng Garo and 51.18% of Gond respondents. Both the communities attributed such changes to climate
264 factors. High in-season temperature was perceived to decrease agricultural yield by 82.35% in Am-beng Garo
265 and 88.98% in Gond, while high in-season rainfall was linked to decreased yield by 56.30% in Am-beng Garo
266 and 50.39% in Gond.

267 ***Natural Resources***

268 Groundwater impact due to climate was affirmed by 51.22% in Am-beng Garo and 60.94% in Gond. A
269 substantial proportion of respondents are not aware of the climate and groundwater linkage in both
270 communities (Am-beng Garo 27.64% and Gond 27.34%, respectively). Among respondents who reported a
271 decrease in forest collection, climate factors were identified as the cause by 95.65% in Am-beng Garo and
272 94.12% in Gond. Change in the soil fertility was perceived by 87.80% of Am-beng Garo and 80.47% Gond
273 respondents. Those who reported the change mostly attributed the change to climate (96.30% in Am-beng
274 Garo; 90.29% in Gond).

275 ***Availability and Accessibility of Food***

276 Impacts on food system resources were more commonly reported in Am-beng Garo (86.18%) than Gond
277 (67.19%). Food accessibility was perceived to be affected by climate factors by 81.30% of Am-beng Garo
278 respondents, compared to only 24.22% of Gond respondents. Similarly, change in the availability of
279 traditionally consumed food due to climate was reported by 82.93% in Am-beng Garo and 57.03% in Gond.

280 ***Livestock***

281 Climate impact on livestock was reported by 52.99% in Am-beng Garo and 86.89% in Gond. Among those
282 reporting livestock impact, a change in feed availability due to climate factors was noted by 67.74% and
283 87.74%, respectively.

284 The findings revealed that both communities are perceiving the impacts of climate change in their food
 285 production system and in the accessibility and availability of food. They attributed climate exposures as a
 286 reason for decreasing forest cover, decreasing agricultural yield, and decreasing feed availability for livestock.
 287 However, there is a considerable difference between the two communities in terms of perceived impacts on
 288 the availability and accessibility of food. The reason behind this significant divergence needs to be studied
 289 further, as these communities are considerably different in their food practices and dietary patterns.

290 3.4 Bivariate Associations between climate exposure, impacts and food insecurity (Tables 4a and 4b)

291 In the Am-beng Garo community, several exposure variables were significantly associated with food
 292 insecurity (Table 4a).

293 **Table 4a: Associations between perceived climate exposure, impact indicators and food insecurity among**
 294 **the Am-beng Garo community**

Variable / Category	Food Insecurity				p-value
	None n (%)	Mild n (%)	Moderate n (%)	Severe n (%)	
Climate Exposure Indicators					
Increase in hot days (n = 123)					
Yes	17 (16.67%)	41 (40.20%)	28 (27.45%)	16 (15.69%)	<0.01
No	1 (4.76%)	2 (9.52%)	13 (61.90%)	5 (23.81%)	
Midday temperature (n = 123)					
Getting hotter	18 (14.63%)	43 (34.96%)	41 (33.33%)	21 (17.07%)	N/A
Not changed	N/A	N/A	N/A	N/A	
Getting cooler	N/A	N/A	N/A	N/A	
Nighttime temperature (n = 123)					
Getting hotter	14 (15.56%)	35 (38.89%)	23 (25.56%)	18 (20.00%)	<0.01
Not changed	1 (4.35%)	4 (17.39%)	15 (65.22%)	3 (13.04%)	
Getting cooler	3 (30.00%)	4 (40.00%)	3 (30.00%)	0 (0.00%)	
Increase in humidity (n = 123)					
Yes	17 (16.67%)	41 (40.20%)	28 (27.45%)	16 (15.69%)	<0.01
No	1 (4.76%)	2 (9.52%)	13 (61.90%)	5 (23.81%)	
Increase in cold days (n = 123)					
Yes	5 (13.16%)	11 (28.95%)	17 (44.74%)	5 (13.16%)	0.35
No	13 (15.29%)	32 (37.65%)	24 (28.24%)	16 (18.82%)	
Erratic rainfall (n = 123)					

Yes	12 (12.37%)	42 (43.30%)	27 (27.84%)	16 (16.49%)	<0.01
No	6 (23.08%)	1 (3.85%)	14 (53.85%)	5 (19.23%)	
Changes in timing of season (n = 123)					
Yes	17 (16.35%)	40 (38.46%)	28 (26.92%)	19 (18.27%)	<0.01
No	1 (5.26%)	3 (15.79%)	13 (68.42%)	2 (10.53%)	
Dry spells / Drought (n = 123)					
Yes	11 (14.29%)	32 (41.56%)	18 (23.38%)	16 (20.78%)	0.02
No	7 (15.22%)	11 (23.91%)	23 (50.00%)	5 (10.87%)	
Flood / Cyclone (n = 123)					
Yes	15 (19.23%)	36 (46.15%)	17 (21.79%)	10 (12.82%)	<0.001
No	3 (6.67%)	7 (15.56%)	24 (53.33%)	11 (24.44%)	
Climate Impact Indicators					
Change in Crop (n = 119)					
Yes	8 (19.05%)	24 (57.14%)	8 (19.05%)	2 (4.76%)	<0.001
No	10 (12.99%)	18 (23.38%)	32 (41.56%)	17 (22.08%)	
Crop change due to climate (n = 42)					
Yes	8 (19.51%)	23 (56.10%)	8 (19.51%)	2 (4.88%)	0.86
No	0 (0.00%)	1 (100.00%)	0 (0.00%)	0 (0.00%)	
Change in Irrigation Method (n = 119)					
Yes	2 (10.00%)	13 (65.00%)	4 (20.00%)	1 (5.00%)	0.02
No	16 (16.16%)	29 (29.29%)	36 (36.36%)	18 (18.18%)	
Irrigation changes due to climate (n = 20)					
Yes	2 (10.00%)	13 (65.00%)	4 (20.00%)	1 (5.00%)	N/A
No	N/A	N/A	N/A	N/A	
High temp decreased yield (n = 119)					
Yes	13 (13.27%)	35 (35.71%)	32 (32.65%)	18 (18.37%)	0.20
No	2 (13.33%)	5 (33.33%)	7 (46.67%)	1 (6.67%)	
Don't know	3 (50.00%)	2 (33.33%)	1 (16.67%)	0 (0.00%)	
High rainfall decreased yield (n = 119)					
Yes	4 (5.97%)	23 (34.33%)	26 (38.81%)	14 (20.90%)	<0.01
No	11 (22.92%)	19 (39.58%)	13 (27.08%)	5 (10.42%)	
Don't know	3 (75.00%)	0 (0.00%)	1 (25.00%)	0 (0.00%)	
Ground water affected by climate (n = 123)					
Yes	6 (9.52%)	28 (44.44%)	15 (23.81%)	14 (22.22%)	<0.001
No	2 (7.69%)	2 (7.69%)	16 (61.54%)	6 (23.08%)	
Don't know	10 (29.41%)	13 (38.24%)	10 (29.41%)	1 (2.94%)	
Decrease in forest collection due to climate factors (n = 115)					
Yes	16 (14.55%)	37 (33.64%)	37 (33.64%)	20 (18.18%)	0.45
No	0 (0.00%)	3 (60.00%)	2 (40.00%)	0 (0.00%)	
Soil fertility changes due to climate factors (n = 108)					
Yes	17 (16.35%)	39 (37.50%)	30 (28.85%)	18 (17.31%)	0.66
No	1 (25.00%)	1 (25.00%)	2 (50.00%)	0 (0.00%)	

Food resources affected by climate (n = 123)					
Yes	16 (15.09%)	39 (36.79%)	32 (30.19%)	19 (17.92%)	0.29
No	2 (18.18%)	1 (9.09%)	7 (63.64%)	1 (9.09%)	
Don't know	0 (0.00%)	3 (50.00%)	2 (33.33%)	1 (16.67%)	
Food accessibility affected by climate (n = 123)					
Yes	16 (16.00%)	41 (41.00%)	32 (32.00%)	11 (11.00%)	<0.001
No	2 (8.70%)	2 (8.70%)	9 (39.13%)	10 (43.48%)	
Don't know	N/A	N/A	N/A	N/A	
Types of food consumed changed by climate (n = 123)					
Yes	15 (14.71%)	37 (36.27%)	31 (30.39%)	19 (18.63%)	0.49
No	3 (15.79%)	6 (31.58%)	8 (42.11%)	2 (10.53%)	
Don't know	0 (0.00%)	0 (0.00%)	2 (100.00%)	0 (0.00%)	
Livestock impacted by climate (n = 117)					
Yes	12 (19.35%)	30 (48.39%)	8 (12.90%)	12 (19.35%)	<0.001
No	6 (12.77%)	10 (21.28%)	25 (53.19%)	6 (12.77%)	
Don't know	0 (0.00%)	1 (12.50%)	7 (87.50%)	0 (0.00%)	
Feed availability changes due to climate (n = 62)					
Yes	9 (21.43%)	22 (52.38%)	7 (16.67%)	4 (9.52%)	0.03
No	3 (15.00%)	8 (40.00%)	1 (5.00%)	8 (40.00%)	

295 *p*-value: chi-square test; *p*<0.05 = statistically significant; row percentages shown; N/A = insufficient
 296 observations; Agriculture variables restricted to farming households; Conditional impact variables use their
 297 respective subgroup denominators.

298

299 Respondents who reported an increase in hot days' show distributions across mild (40.20%), moderate
 300 (27.45%) and severe food insecurity (15.69%). Households that reported an increase in nighttime
 301 temperature showed more or less similar trends in food insecurity distribution (Table 4a). Erratic rainfall
 302 (43.30% mild, 27.84% moderate and 16.49% severe food insecurity) and an increase in humidity (40.20%
 303 mild, 27.45% moderate and 15.69% severe food insecurity) also showed similar trends, indicating climatic
 304 exposures are impacting the food security situation at the household level. In case of extreme weather events
 305 such as dry spells and floods, households reported mild to severe food insecurity (Table 4a).

306

307 Among climate impact indicators, change in crop variety was significantly associated with food insecurity (p
 308 < 0.001). Respondents who had changed crops predominantly fell in the mild category (57.14%), while those
 309 who had not changed crops fell largely in the moderate (41.56%) and severe (22.08%) food insecurity
 310 categories. Change in irrigation method showed a similar association (p = 0.02), where those who changed
 311 irrigation are in the mild category (65.00%) as compared to those who did not change the irrigation methods.
 312 ‘High in-season rainfall decreasing yield’, ‘changes in the groundwater level’ and ‘impact on food accessibility’
 313 were associated with more severe food insecurity outcomes (p < 0.01). Similar association also seen in
 314 ‘impact on livestock’ (p < 0.001) and ‘change in feed availability’ (p = 0.03). The finding's considerable
 315 association between climate exposure and impacts. It also demonstrates that those who adopt coping
 316 strategies, like a change in crop or irrigation pattern, have a reduced effect on food security outcomes.

317 Surprisingly, none of the climate exposure indicators showed a statistically significant association with food
 318 security in the Gond community (all p > 0.05; Table 3b). Among climate impact indicators, change in crop
 319 variety was significantly associated with food insecurity (p = 0.02). Respondents who had changed crops had
 320 a more favourable situation in the food security outcome (37.37% none, 34.34% mild). ‘High in-season
 321 temperature decreasing yield’ also showed a significant association (p = 0.04) with food insecurity (Table 4b).

322 **Table 4b: Associations between perceived climate exposure, impact indicators and food insecurity among**
 323 **the Gond community**

Variables/Category	Food Insecurity				p-value
	None n (%)	Mild n (%)	Moderate n (%)	Severe n (%)	
Climate Exposure Indicators					
Increase in hot days (n = 115)					
Yes	35 (35.71%)	32 (32.65%)	19 (19.39%)	12 (12.24%)	0.78
No	4 (23.53%)	7 (41.18%)	4 (23.53%)	2 (11.76%)	
Midday temperature (n = 115)					
Getting hotter	36 (34.95%)	34 (33.01%)	20 (19.42%)	13 (12.62%)	0.83
Not changed	3 (25.00%)	5 (41.67%)	3 (25.00%)	1 (8.33%)	
Getting cooler	N/A	N/A	N/A	N/A	

Nighttime temperature (n = 115)					
Getting hotter	31 (35.23%)	30 (34.09%)	19 (21.59%)	8 (9.09%)	0.47
Not changed	5 (27.78%)	5 (27.78%)	4 (22.22%)	4 (22.22%)	
Getting cooler	3 (33.33%)	4 (44.44%)	0 (0.00%)	2 (22.22%)	
Increase in humidity (n = 115)					
Yes	2 (50.00%)	2 (50.00%)	0 (0.00%)	0 (0.00%)	0.58
No	37 (33.33%)	37 (33.33%)	23 (20.72%)	14 (12.61%)	
Increase in cold days (n = 115)					
Yes	4 (28.57%)	6 (42.86%)	2 (14.29%)	2 (14.29%)	0.84
No	35 (34.65%)	33 (32.67%)	21 (20.79%)	12 (11.88%)	
Erratic rainfall (n = 115)					
Yes	36 (34.62%)	36 (34.62%)	20 (19.23%)	12 (11.54%)	0.80
No	3 (27.27%)	3 (27.27%)	3 (27.27%)	2 (18.18%)	
Changes in timing of season (n = 115)					
Yes	31 (34.83%)	32 (35.96%)	17 (19.10%)	9 (10.11%)	0.55
No	8 (30.77%)	7 (26.92%)	6 (23.08%)	5 (19.23%)	
Dry spells (n = 115)					
Yes	9 (39.13%)	5 (21.74%)	5 (21.74%)	4 (17.39%)	0.54
No	30 (32.61%)	34 (36.96%)	18 (19.57%)	10 (10.87%)	
Floods (n = 115)					
Yes	12 (35.29%)	11 (32.35%)	9 (26.47%)	2 (5.88%)	0.45
No	27 (33.33%)	28 (34.57%)	14 (17.28%)	12 (14.81%)	
Climate Impact Indicators					
Change in Crop (n = 114)					
Yes	37 (37.37%)	34 (34.34%)	19 (19.19%)	9 (9.09%)	0.02
No	1 (6.67%)	5 (33.33%)	4 (26.67%)	5 (33.33%)	
Crop change due to climate (n = 99)					
Yes	29 (37.18%)	26 (33.33%)	17 (21.79%)	6 (7.69%)	0.53
No	8 (38.10%)	8 (38.10%)	2 (9.52%)	3 (14.29%)	
Change in Irrigation Method (n = 114)					
Yes	22 (36.07%)	23 (37.70%)	10 (16.39%)	6 (9.84%)	0.51
No	16 (30.19%)	16 (30.19%)	13 (24.53%)	8 (15.09%)	
Irrigation changes due to climate (n = 61)					
Yes	22 (36.07%)	23 (37.70%)	10 (16.39%)	6 (9.84%)	N/A
No	N/A	N/A	N/A	N/A	
High temp decreased yield (n = 114)					
Yes	35 (33.98%)	37 (35.92%)	17 (16.50%)	14 (13.59%)	0.04
No	1 (12.50%)	2 (25.00%)	5 (62.50%)	0 (0.00%)	
Don't know	2 (66.67%)	0 (0.00%)	1 (33.33%)	0 (0.00%)	
High rainfall decreased yield (n = 114)					
Yes	21 (35.00%)	21 (35.00%)	9 (15.00%)	9 (15.00%)	0.42
No	17 (32.08%)	18 (33.96%)	13 (24.53%)	5 (9.43%)	
Don't know	0 (0.00%)	0 (0.00%)	1 (100.00%)	0 (0.00%)	

Ground water affected by climate (n = 115)					
Yes	24 (33.80%)	24 (33.80%)	12 (16.90%)	11 (15.49%)	0.65
No	5 (35.71%)	6 (42.86%)	2 (14.29%)	1 (7.14%)	
Don't know	10 (33.33%)	9 (30.00%)	9 (30.00%)	2 (6.67%)	
Decrease in forest collection due to climate factors (n = 107)					
Yes	35 (34.65%)	34 (33.66%)	20 (19.80%)	12 (11.88%)	0.77
No	3 (50.00%)	2 (33.33%)	1 (16.67%)	0 (0.00%)	
Soil fertility changes due to climate factors (n = 91)					
Yes	31 (36.90%)	32 (38.10%)	13 (15.48%)	8 (9.52%)	0.68
No	2 (28.57%)	3 (42.86%)	2 (28.57%)	0 (0.00%)	
Food resources affected by climate (n = 115)					
Yes	25 (33.33%)	30 (40.00%)	13 (17.33%)	7 (9.33%)	0.50
No	12 (37.50%)	7 (21.88%)	8 (25.00%)	5 (15.62%)	
Don't know	2 (25.00%)	2 (25.00%)	2 (25.00%)	2 (25.00%)	
Food accessibility affected by climate (n = 115)					
Yes	8 (29.63%)	11 (40.74%)	4 (14.81%)	4 (14.81%)	0.78
No	30 (34.48%)	28 (32.18%)	19 (21.84%)	10 (11.49%)	
Don't know	1 (100.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	
Types of food consumed changed by climate (n = 115)					
Yes	22 (32.84%)	23 (34.33%)	15 (22.39%)	7 (10.45%)	0.78
No	16 (34.78%)	16 (34.78%)	7 (15.22%)	7 (15.22%)	
Don't know	1 (50.00%)	0 (0.00%)	1 (50.00%)	0 (0.00%)	
Livestock impacted by climate (n = 110)					
Yes	34 (35.05%)	35 (36.08%)	18 (18.56%)	10 (10.31%)	0.25
No	4 (40.00%)	0 (0.00%)	3 (30.00%)	3 (30.00%)	
Don't know	1 (33.33%)	1 (33.33%)	1 (33.33%)	0 (0.00%)	
Feed availability changes due to climate (n = 97)					
Yes	29 (33.72%)	33 (38.37%)	15 (17.44%)	9 (10.47%)	0.57
No	5 (45.45%)	2 (18.18%)	3 (27.27%)	1 (9.09%)	

324 *p-value: chi-square test; $p < 0.05$ = statistically significant; row percentages shown; N/A = insufficient*
 325 *observations; Agriculture variables restricted to farming households; Conditional impact variables use their*
 326 *respective subgroup denominators.*

327

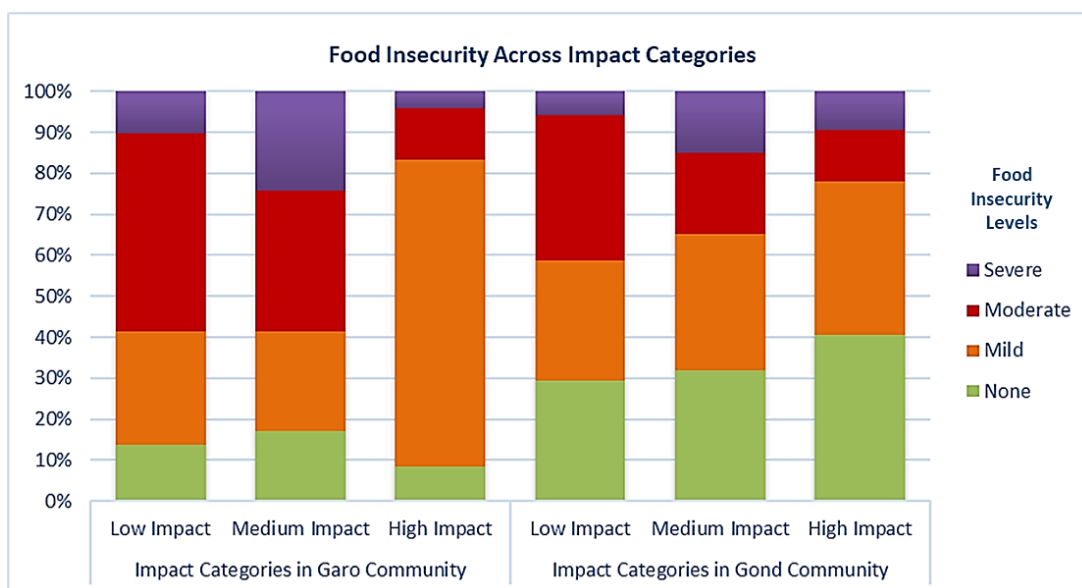
328 All other climate impact indicators, such as groundwater impact, forest collection, soil fertility, food
 329 accessibility, food resources, food type change, livestock impact, and feed availability, were not statistically
 330 significant in association with food insecurity in Gond.

331 Both communities articulated their experiences of climate exposure and its impacts on food production
332 systems with proficiency. However, the Gond community did not report a statistically significant association
333 between climate exposure and food security outcomes. In quantitative research, non-significant findings
334 should not be reported as evidence. However, we argue that given the heightened vulnerability of the Gond
335 community to climate-related impacts, adaptation planning should incorporate diverse community
336 perceptions and lived experiences, rather than relying exclusively on statistically significant associations for
337 decision-making.

338 3.5 Climate Impact Index and Food Insecurity

339 The Climate Impact Index — a composite score summing 12 binary perceived climate-attributable impact
340 variables (range: 0–12) — showed a significant association with food insecurity in the Am-beng Garo
341 community but not in the Gond community (Table 4), as expected.

342 In the Am-beng Garo community (n = 123), the distribution of food insecurity across Impact Index categories
343 differed significantly ($p < 0.001$). Among those in the High Impact category (score 10–12), 75.00% fell in the
344 mild food insecurity category. The rest of the households, which are in the High Impact Category, fell within
345 moderate or severe insecurity (Fig 3).



346 **Fig 3: Distribution of food insecurity severity across impact categories in Am-beng Garo and Gond**
347 **communities, expressed as percentages within each category.**

348

349 In contrast, households which are in the Low Impact category showed a notably higher prevalence of
350 moderate food insecurity (Fig 3) in comparison to mild categories. The medium Impact group showed the
351 greatest concentration of severe food insecurity. The mean Impact Index score was highest among those with
352 mild food insecurity (8.53 ± 2.96) and lowest among those with moderate food insecurity (6.39 ± 2.28),
353 suggesting that the relationship between climate impact and food insecurity in this community is not strictly
354 monotonic. The Kruskal-Wallis test confirmed that this difference in continuous Impact Index scores across
355 food insecurity groups was statistically significant ($p < 0.01$). In the Gond community ($n = 115$), no statistically
356 significant association was observed between the Impact Index category and food insecurity ($p = 0.55$). The
357 food insecurity distribution was broadly similar across Low, medium, and high impact groups, and mean
358 Impact Index scores did not differ meaningfully across food insecurity categories (Fig 3).

359 Overall, food insecurity in the Gond community was predominantly distributed in the none and mild
360 categories regardless of climate impact level, reflecting a different baseline food security context relative to
361 the Am-beng Garo community. One probable reason for such non-association might be the small sample size;
362 however, there might be more layered factors which create multilinear relationships between the exposure
363 indicators and food security outcome.

364 **4. Discussion**

365 The present investigation elucidates that indigenous communities in India encounter significant exposure to
366 climate change, which is impacting their food production system, and one of the communities perceived the
367 detrimental association between those impacts and food security outcomes. Consistent evidence from the
368 perceptions of both the indigenous communities suggests a significant intensification of climatic exposures

369 over the last two decades, characterised by increasing temperatures, changes in humidity, rainfall
370 unpredictability, floods and prolonged dry spells. The findings commensurate with global climate impact
371 trends reported by national and international meteorological evidence [19]. The study established that
372 communities' experiential and observational knowledge can inform locally relevant meteorological
373 parameters for early warning and adaptation planning.

374 The analysis also identified that food resources, agricultural production, natural resources and livestock are
375 highly sensitive towards those climate exposures. Both the communities perceived the impacts, and one of
376 the study communities could associate those impacts with food insecurity. Both communities are taking
377 actions by changing crop and irrigation patterns, but are still facing mild to severe food insecurity. These
378 assertions strengthen the prevailing prediction and evidence that climate change is adversely affecting food
379 security in a few communities, particularly in marginalised agrarian and nature-dependent communities
380 [20,21]. The study documented that both indigenous communities are taking actions according to their
381 perceived impacts to reduce the burden on household food security, but still face some degree of food
382 insecurity as the exposures are severe and multidimensional.

383 On a global scale, climate change disrupts all four dimensions of food security—availability, access, utilisation,
384 and stability. Community perceptions align with these pathways: diminishing but erratic rainfall adversely
385 influences agricultural productivity and accessibility to forest resources, whereas the increasing heat and
386 humidity significantly impact crop viability and livestock health [20]. Likewise, a similar study asserted that
387 rising temperatures and modified rainfall trends compress agricultural cycles and enhance yield volatility,
388 producing increased risks of food security in developing regions [20]. Our studied communities perceived and
389 reported similar impacts on their food production system, indicating significant alignment with global
390 evidence.

391 Our findings are congruent with extensive evidence from India that underscores the climate impacts on food
392 systems. Projections at the district level indicate considerable yield reductions for staple crops under mid-
393 and end-century scenarios, particularly in rainfed areas [22]. By analysing two tribal communities, our
394 research contributes such micro-level evidence reinforcing the link between perceived climatic change, food
395 production and food security.

396 Both the indigenous communities reported strategies including diversification of crops, alterations in
397 irrigation practices and changes in dietary choices. Despite these strategies, they constantly display mild,
398 moderate and even severe food insecurities, indicating that the communities might be approaching their
399 adaptive threshold [6,23]. Evidence from other rural settings in India indicates that such short-term
400 mechanisms may jeopardise long-term food insecurity outcomes and heighten dependence on external
401 markets [23]. Over time, failure of such strategies is likely to exacerbate vulnerability, engendering a cycle of
402 chronic food insecurity.

403 Interestingly, two communities that significantly differ in socio-economic and agro-climatic parameters
404 differed in perceiving the degree of climate impacts on their food production system. Am-beng Garo with
405 better literacy and governance accessibility reported nuanced impacts on agricultural production, livestock
406 and forest collections and clearly spelt out the associations with food security. By contrast, the Gond
407 community—being relatively more marginalised across socio-economic indicators—did not report a clear
408 association, even though they described exposures and impacts in greater detail. This indicates a variety of
409 factors related to either small sample size or conceptual translations of the questions. We consider these
410 factors as study limitations, as the sample sizes in both communities were relatively small compared to the
411 population. Translating and questioning during the data collection were also hampered due to language
412 barriers between the interviewers and the interviewee. Though we employed local resources who were
413 familiar with indigenous languages, gaps still persist in the interpretation of climate exposure and impacts.

414 Also, the cross-sectional nature of the study design constrains causal interpretations, and the dependence
415 on self-reported perceptions of climatic alterations may introduce recall bias. Such limitations indicate the
416 necessity of longitudinal assessment with a qualitative component to get familiarize with the context to
417 identify the complex interplay of climate exposures, related impacts and measurable outcomes. Future
418 studies need to blend in longitudinal research methods, reviews of nutritional diversity, qualitative
419 exploration and spatial vulnerability assessments to strengthen causal conclusions and policy outcomes.

420 Our findings underscore the pressing needs of incorporating community's lived experiences and observations
421 in climate modelling, early warning systems, and policy imperatives. This research enriches the expanding
422 corpus of empirical investigations addressing climate-food interrelations in India from the perspectives of
423 vulnerable communities. In contrast to extensive ecological studies, our micro-level examination
424 encapsulates the lived realities of climate repercussions, particularly among indigenous populations
425 frequently overlooked in conventional datasets [6,22,24]. Our findings suggest that climate vulnerability is
426 highly localised, often varying even within the same community depending upon the coping and adaptation
427 measures taken by the households. As perceptions lead to actions, a deeper knowledge of how communities
428 perceive climate impacts and act upon those impacts is essential to tailor locally relevant adaptation
429 solutions. Rather than top-down technocratic solutions, we urge formulating interventions based on
430 indigenous knowledge and practices which are culturally sensitive and ecologically sustainable. Our
431 experience working with vulnerable indigenous communities suggests there are multiple layers of impacts
432 and outcomes, which may not always be linear. Therefore, a mixed-method approach might suit better while
433 working with socio-economically marginalised communities.

434 **5. Conclusion**

435 In summary, our findings underscore that climate change constitutes a vital determinant of the food
436 production system among indigenous communities in India, as perceived by the communities themselves.

437 Rising temperatures, erratic precipitation, and extreme weather events are heavily straining food systems,
438 putting these communities in danger of outpacing their coping capabilities. Blending scientific and
439 experiential knowledge for climate prediction and adaptation actions is essential. Immediate interventions
440 that promote locally-led adaptation measures, reinforce climate-sensitive social safety nets, and revive
441 traditional food resources are crucial. The alignment of such initiatives with India's commitments to the
442 Sustainable Development Goals (SDGs 2 and 13) will be critical to ensure that the most vulnerable
443 populations are not marginalised amid the escalating challenges posed by climate change. A road map
444 towards a planetary food system framework has immense potential in such a marginalised context.

445 **6. Acknowledgements**

446 The authors would like to express their sincere gratitude to all study participants from the Gond and Am-
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448 Community Advisory Committee members for their valuable guidance, support, and engagement throughout
449 the study. Their contributions were instrumental in the successful implementation of this research.

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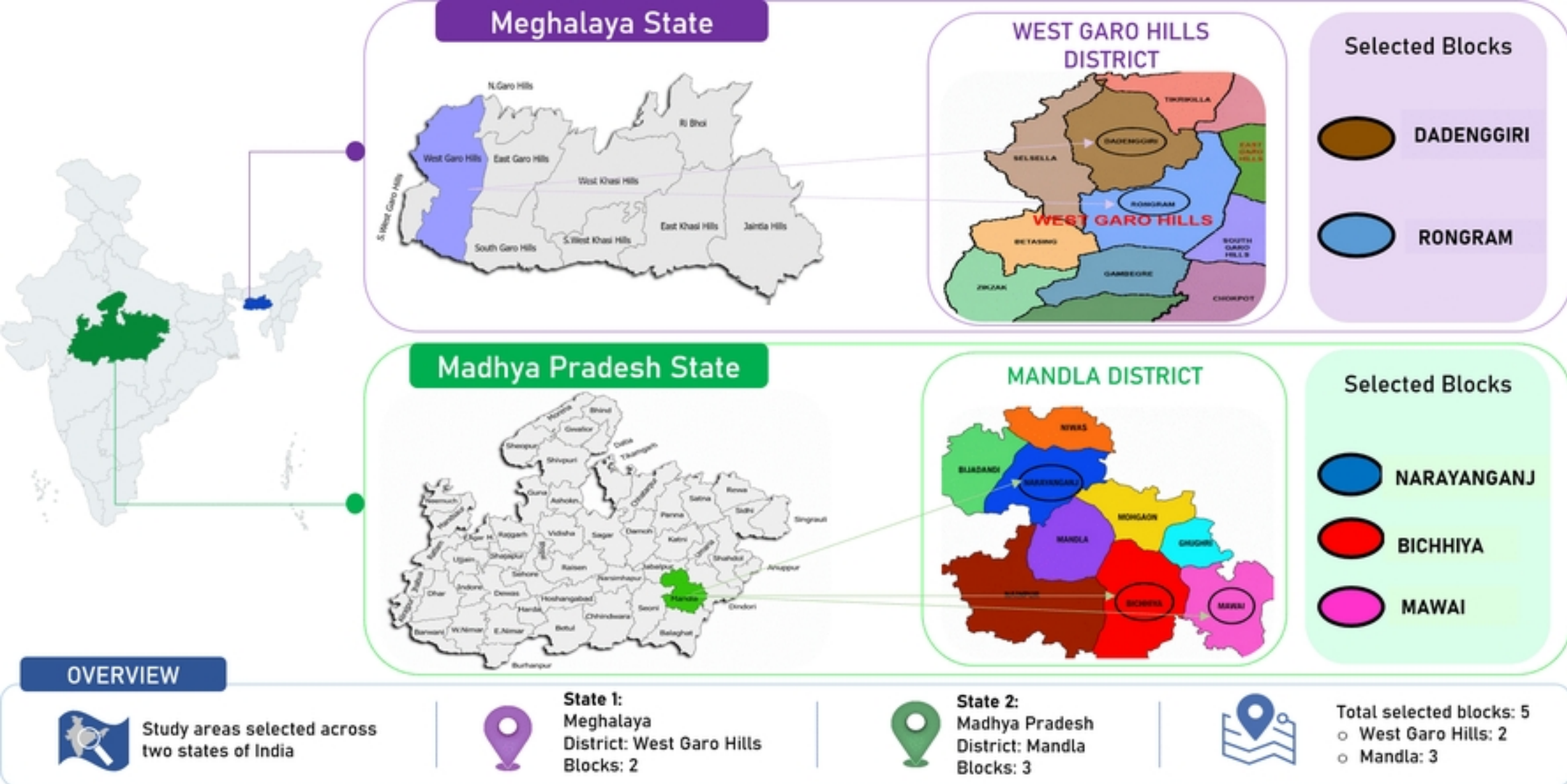
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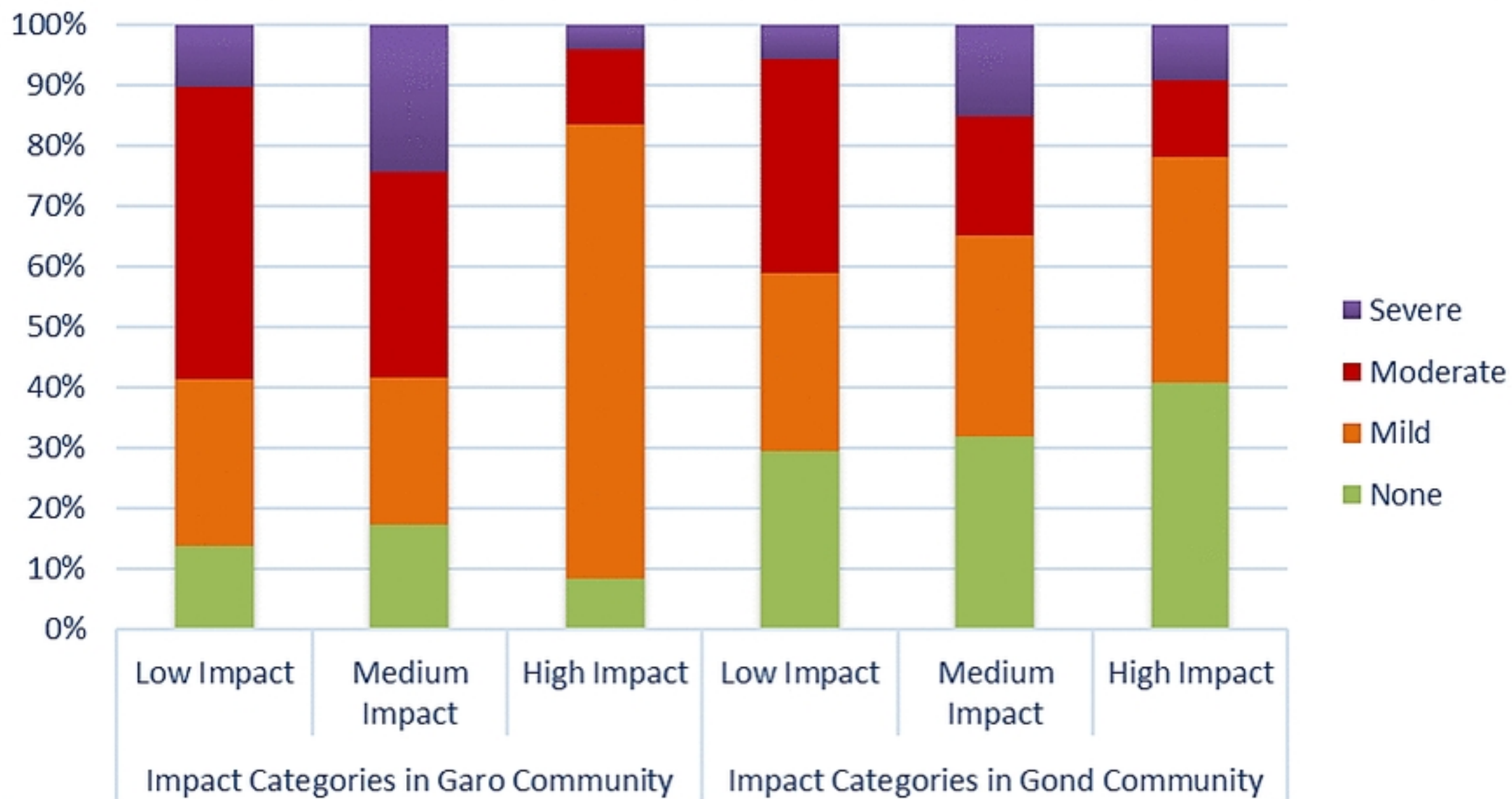
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