

What drives the vulnerability of pastoralists to global environmental change? A qualitative meta-analysis

Feliu López-i-Gelats^{1,2*}, Evan D.G. Fraser³, John F. Morton⁴, Marta G. Rivera-Ferre¹

¹ Agroecology and Food Systems Chair, Environment & Food Dpt. - Faculty of Sciences and Technology, University of Vic-Central University of Catalonia (Spain) ² Center for Agro-Food Economy and Development (CRED-UPC-IRTA) (Spain) ³ Department of Geography, University of Guelph (Canada) ⁴ Natural Resources Institute, University of Greenwich (United Kingdom)

Abstract

The long-term viability of pastoralism has been a constant theme for discussions. The progress of knowledge on the sustainability of pastoralism under global environmental change has been notable in the last years. To better characterize this vulnerability, we have examined the existing scientific knowledge about the three dimensions of vulnerability, being exposure illustrated by the existing climate trends and non-climate transformations, sensitivity by the impacts of these on pastoral resources and pastoral land conversions, and adaptation by the adaptation strategies developed by the pastoral communities. A qualitative meta-analysis was conducted to explore patterns and trends across the literature. From this, six different pathways of vulnerability being followed by pastoral communities were identified: Encroachment, Re-greening, Customary, Polarization, Communal and No-alternative. The results point that the livelihood options of pastoralists are generally becoming narrower. Four major forces are identified as exerting determinant influence on the co-production of the vulnerability of pastoralism: (i) the double exposure to climate and non-climate transformations, (ii) the persistence of unfavorable development policies, (iii) the great vitality of adaptation, and (iv) the multifaceted role of markets. We point that it is crucial to distinguish between the component of vulnerability inherent in any economic activity devoted to the use of natural resources, which is the usual business of pastoralism, and the component of vulnerability linked to external forces that disturb the usual working of the pastoral production strategies.

Keywords: adaptation, climate change, land encroachment, Qualitative Comparative Analysis, high reliability system

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* Corresponding author. Tel.: +34 93 881 55 19. Fax: +34 938814307

E-mail address: feliu.lopez@uvic.cat (F. López-i-Gelats).

Agroecology and Food Systems Chair, Environment & Food Dpt. - Faculty of Sciences and Technology, University of Vic-Central University of Catalonia, C. de la Laura 13, 08500 Vic, Spain

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What drives the vulnerability of pastoralists to global environmental change?

A qualitative meta-analysis

1. Introduction

The long-term viability of pastoralism has been a continuous theme for discussions and the progress of knowledge on the survival of pastoralism under global environmental change has been notable since the mid-2000s. Thus, while some assert that pastoralism is disappearing due to internal causes - e.g. that the current climate change falls beyond its adaptive range (Steen, 1994; Markakis, 2004; Sandford, 2006) - others trace the foundations of the pastoral fragility back to its settings in marginal areas and unfavorable environmental conditions (Jónsson, 2010). This combination of factors is said to create “multiple stressors” that undermine pastoralism (Thébaud and Batterbury, 2001; Mihlar, 2008). Others disagree and argue that pastoralism is better suited than other land uses to do well under changing environmental conditions (Bradley and Grainger, 2004; Davies and Nori, 2008; Jones and Thornton, 2008). In line with this, greatly varying and sometimes directly contradictory advice, a range of policy recommendations oriented towards pastoral peoples coexist in the literature. There is great controversy whether the development policies directed to pastoralists, particularly from states and development agencies, to change their lives, settle and modernize, are adequate (Scoones, 1995; Chatty and Colchester, 2002; Morton, 2010a; Dong et al., 2011; Krätli et al., 2013). Opposed positions can be found on either the beneficial or the harmful effects of development interventions such as economic diversification, market integration, humanitarian relief, education or sedentarization schemes (e.g. Krätli and Dyer, 2009; Valdivia et al., 2010; Rivera-Ferre and López-i-Gelats, 2012). This does not help to stop the implementation of inadequate development policies, which eventually constitute additional barriers for pastoral livelihood and management. It is thus relevant to examine what drives pastoralists’ vulnerability to global environmental change and its implications. Specifically, little attention has been paid to the complex and location-specific nature of pastoralism (Hinkel, 2011), as well as to the implications of non-climate drivers on the continuity of pastoralism (Morton, 2010a; Below et al., 2012; McDowell and Hess, 2012). In view of that, the purpose of this paper is to identify both the multiple drivers affecting pastoralism under global environmental change and the diverse ‘pathways of vulnerability’ being followed by pastoralists, and defined as the diverse development trajectories followed by specific pastoral peoples under different global environmental change conditions. Patterns and trends across the literature on the viability of pastoralism under global environmental change were explored through a systematic review and meta-analysis. In particular, we focused on scientific literature comprising case studies based on primary data.

31 **2. The notion of pastoral vulnerability**

32 We start by recounting a brief genealogy of the most influential lines of thought in defining pastoral vulnerability. The first
33 studies can be traced back to the 1930s, 1940s and 1950s with the works of Troll (1931, 1966) on human geography of
34 extreme climates, and the ethnographic works of Evans-Pritchard (1940) and Stenning (1959) on pastoral organization in
35 arid and semiarid Africa. However, it was not until the 1970s and 1980s that pastoral research took off. Research was
36 dominated by cultural ecology approaches aiming to understand in what ways pastoralists responded to environmental
37 change. Attention was placed on the effects of environmental stress on the management and organization of pastoralists,
38 particularly in Africa and Mideast. Based on mobility, diversity of species and management flexibility, these studies
39 underlined the pastoral rationality in responding to changing and patchy resource distribution (Dyson-Hudson, 1972;
40 Dyson-Hudson and McCabe, 1985; Fratkin, 1986; McCabe, 1990). Despite the in-depth understanding provided by these
41 fieldwork-based studies, this social anthropological approach exerted a marginal influence on policy development (Morton
42 2010*b*). During that period development policies were fundamentally driven by the conviction that pastoral lands were
43 unoccupied or poorly utilized, justifying their appropriation for more appropriate land uses (Nori et al., 2008).

44 In contrast, the influence on policy arenas of the ecological approaches that followed Hardin's 'tragedy of the commons'
45 thesis (1968) was overwhelming. Following the Lotka-Volterra model of predator-prey dynamics, the tendency of
46 pastoralists to maximize their herds, together with growing populations, was regarded as leading to overgrazing,
47 desertification and environmental degradation. Pastoralism was viewed as disturbances in the rangeland system rather
48 than an inextricable part of it (Little, 1994). The notion of carrying capacity was brought to the fore. Pastoralism was then
49 pictured not only as economically unproductive, but also as environmentally damaging and socially backward (Swift, 1996;
50 Nori et al., 2008). Dismantling common property, destocking and endorsing commercial ranching were seen as the
51 fundamental pillars where policy interventions should rest to stop rangeland degradation and enhance the pastoralists'
52 socio-economic development (Lamprey, 1983; Simpson and Evangelou, 1984). Initiated in Western mentalities for Western
53 environments, this line of thought soon became the world dominant doctrine among policy-makers and developers and it
54 is still exerting a major influence nowadays.

55 Nonetheless, criticisms of this thesis emerged questioning the meaningfulness of the notion of carrying capacity in
56 changing environments and claiming the need to distinguish in land tenure between communal and open access. Building
57 on this, two main critical perspectives rejecting environmental determinism and stressing the role of wider driving forces in
58 understanding the pastoral-rangeland relations can be identified. The first one centered on political processes, which
59 described trends of economic stratification within pastoral groups because of the contact with sedentary agricultural states
60 and resultant processes of political encapsulation of pastoralists (Asad, 1970; Salzman, 1974; Marx, 1977; Equipe Écologie

61 et *Anthropologie des Sociétés Pastorales*, 1979; Beck, 1986; Bradburd, 1990; Khazanov, 1994). The second one stressed
62 that both pastoral rationality and policy development had to be rethought in light of the ecological evidence that most of
63 the rangelands are fundamentally unstable ecosystems, where the equilibrium theory does not apply and uncertainty is
64 the norm (Sandford, 1983; Ellis and Swift, 1988; Behnke et al., 1993; Behnke, 1994; Scoones, 1995). For the proponents of
65 the new range ecology the equilibrium assumption lying behind traditional range ecology and policy development, based
66 on enhancing predictability and single function system, through initiatives such as erecting fences, favoring sedentarization
67 and meat market orientation, is simply a replication of the dynamics and solutions more appropriate for temperate and
68 more predictable climates. They argue that because of decoupled plant-herbivore interactions, pastoralists have little
69 impact on rangelands (Fernández-Giménez and Allen-Diaz, 1999; Sullivan and Rohde, 2002; Lind et al., 2003; Derry and
70 Boone, 2010). Thus, pastoral vulnerability is fundamentally viewed as of external origin, being resource access more central
71 than stocking rates.

72 Based on the premises of the new range ecology, some authors have developed a pastoral economic model alternative to
73 the conventional risk-aversion archetype, which sees pastoralism as a high-reliability system (Roe et al., 1998; Krätli, 2008;
74 Roe and Schulman, 2008). Rather than picturing pastoralism as a coping strategy to deal with inadequate resource base, it
75 is seen as an economic strategy distinctive of unpredictable environments and developed to exploit the variable and
76 patchy resource distribution of rangelands. Pastoralism is seen as operating not by avoiding risk, but by employing it as the
77 very base of production. They believe that the pastoral economic system is 'proactive, methodical and geared at value
78 creation and maximization, rather than mere survival' (Krätli and Shareika, 2010). To them, analytical tools that highlight
79 stability and uniformity and consider asymmetric distribution of resources as undesired disturbances are not adequate to
80 analyze pastoral systems and design development policies. However, despite substantial progress in the understanding of
81 rangeland ecology and pastoral rationality, the emergence of climate change as a central policy issue, in conjunction with
82 the evidence of numerous pastoral development policy failures, is fueling once again a new wave of claims that question
83 the continuity of pastoralism as a result of its internal incapacity to deal with the current environmental variability and
84 prevent poverty (Sandford, 2006; Morton, 2010b).

85 Academics from multiple disciplines have long been interested in understanding how nature and society are interlinked.
86 The notion of vulnerability we employ results from this endeavor, with recent integrated approaches, which picture the
87 nature-society interlinkages as coupled human-environment systems and highlight the double essence of vulnerability as
88 socially and naturally produced, being increasingly adopted to understand the implications of global environmental change
89 (e.g. Turner et al., 2003; Lonescu et al., 2009; Fraser et al., 2011; Ribot, 2011). Following this literature, to understand the
90 implications of global environmental change for the viability of pastoralism, we adopted an integrated notion of
91 vulnerability, which comprises exposure, sensitivity and adaptation as the three fundamental dimensions of vulnerability

92 (Kasperson et al., 2005; Adger, 2006; Gallopín, 2007). Exposure is seen as the extent to which pastoralism is subject to
93 perturbations. Here we considered both climate trends and non-climate transformations associated with global
94 environmental change. Sensitivity refers to the degree to which previous transformations impact on pastoralism. Here we
95 paid attention to impacts on pastoral livelihoods, specifically in terms of increased or decreased access to pastoral
96 resources and favorable or detrimental land conversions for pastoralists. Adaptation is conceived as the capacity of
97 pastoralists of minimizing the damage or benefiting from the impacts occurring. Finally, pathways of vulnerability are seen
98 as specific combinations of exposure, sensitivity and adaptation being undergone by certain pastoral peoples.

99 **3. Methodology**

100 Following recent advances in the investigation of global environmental change (Young et al., 2006; Polsky et al., 2007;
101 Rudel, 2008), we conducted a combination of systematic review and meta-analysis with the methodology of qualitative
102 comparative analysis (QCA). To do this, we used the actual published studies as our data (rather than the data used by each
103 study), and this enabled us to pool non-standardized and qualitative information (Hofmann et al., 2011). The QCA meta-
104 analysis enables the aggregation of findings of local studies to reveal general trends, which in this case are employed to
105 identify and characterize the diverse pathways of vulnerability being experienced by pastoral peoples. Despite increasingly
106 being used in the global environmental change field (e.g. Geist and Lambin 2004; Evans et al., 2011; van Vliet et al., 2012;
107 Lugnot and Martin, 2013), this approach has never been applied to pastoral issues.

108 The implementation of the QCA systematic review and meta-analysis followed these steps:

- 109 (1) characterization of the research question, namely 'what drives pastoralists' vulnerability to global
110 environmental change';
- 111 (2) description of the inclusion criteria for case studies, specifically containing primary and empirical data on the
112 three dimensions of vulnerability for a given pastoral community, that is exposure, sensitivity and adaptation;
- 113 (3) selection of the relevant literature, which was conducted through the Scopus and Web of Science
114 search engines on 14th October 2013 to select English-speaking papers published in peer-reviewed scientific
115 journals, by means of the following equations (*pastoral* OR herd**) AND ("*climat* chang**" OR "*climat* varia**")
116 AND (*adapt* OR vulnerab* OR risk OR resilient* OR uncertaint**), and (*pastoral**) AND ("*climat* chang**" OR
117 "*climat* varia**"); that is, we searched for papers containing the keywords of pastoralism or herd, and climate
118 change or climate variability, and adaptation or vulnerability or risk or resilience or uncertainty.
- 119 (4) extraction from the selected papers of the case studies fulfilling the inclusion criteria (table 1);
- 120 (5) selection of the yes/no variables characterizing the three dimensions of vulnerability, and coding of the case
121 studies with them accordingly, through a process of iterative rereading and recoding of the case studies;

122 (6) identification of the most significant constituents of exposure, sensitivity and adaptation, and the most
123 significant combinations of them that tend to be described in association, which we interpreted as pathways of
124 vulnerability, through statistical analysis of the characterization of the selected case studies by the selected
125 variables.

126 The literature search (step 3, above) resulted in the initial choice of 170 papers. A careful examination of the fulfilment of
127 the inclusion criteria reduced the initial selection to 74 papers, comprising the 75 case studies that integrate the final
128 selection (Table 1). Through meticulous reading and rereading of them, the variables characterizing the three dimensions
129 of vulnerability were identified and the case studies coded accordingly. Once a new element dealing with the vulnerability
130 of pastoralism was identified in the reading of a given paper, that is in the examination of a particular case study (e.g.
131 occurrence of droughts, reduced access to rangelands, or water storage as an adaptation strategy), it suddenly became a
132 new variable, and the rest of the papers were then reread and the rest of the case studies recoded considering this new
133 variable, specifically indicating the description or not of this new element. This iterative process resulted in the end in the
134 generation of 185 yes/no variables, with which the whole selection of case studies was finally coded. The dimension of
135 exposure specifically comprised evidence in the cases studies of the occurrence or not of both climatic and non-climate
136 transformations –embracing policy and institutional, sociocultural, economic, demographic or biophysical groups of
137 variables. Sensitivity included groups of variables on the occurrence or not in the case studies of impacts on pastoral
138 livelihoods, indicated as increased or decreased access to pastoral resources and the occurrence or not of land conversions
139 with either favorable or detrimental effects for pastoralists. The dimension of adaptation was covered by several groups of
140 variables concerning the description or not in the case studies of activities and practices developed to benefit pastoralists
141 from undergoing transformations or minimize undesirable effects on them of certain impacts –namely, mobility,
142 diversification, communal pooling, market exchange, intensification, storage, extensification and aid. Finally, three
143 additional variables indicating the recent evolution of the number of pastoral households in the case studies were also
144 used, distinguishing between increasing number, stable or no data available, and decreasing number.

145 To reveal the diverse pathways of vulnerability coexisting in our sample of case studies, a multivariable statistical analysis
146 was conducted, specifically a combination of Multiple Correspondence Analysis (MCA) and Cluster Analysis. MCA was
147 applied to reduce the initial quantity of variables to a set of new factors. Initially we removed any variables that had a
148 frequency lower than 5%, that is those variables that were identified in less than 5% of case studies. Then we used the
149 MCA to identify 32 first factors that explained 80.63% of the total explained variance. The Cluster Analysis, using Ward's
150 method based on Euclidean distance, was then carried out to organize the cases studies in different groups according to
151 their similarity using the factors obtained in the MCA. Stemming from the particular coding of the case studies comprising
152 each group, the groups were characterized by specific frequency distributions of the variables (see Appendixes). The

153 groups were interpreted as pathways of vulnerability. In order to describe each group, significant differences among them
154 and per each variable were checked using the Chi-square test. All statistical analyses were conducted with the software
155 package SPAD 5.5 (SPAD 5.5, 1996).

156 **4. Results**

157 The 75 case studies examined occur in nine regions. Mongolia, Himalaya-Pamir, Arctic, Western Africa and Eastern Africa
158 are the regions more represented in our sample. European mountains, Andes, Southern Africa and Northern Africa each
159 have fewer cases (Fig. 1). In terms of countries, Kenya, China, Ethiopia, Mali, Mongolia and Peru are those where most case
160 studies were documented. The pastoralists of the Horn of Africa and Mongolia are clearly those most present in the sample
161 of literature considered here, with Kenya, Ethiopia, China and Mongolia comprising nearly one-half of the reported case
162 studies (Fig. 2). Remarkably, so far, there are pastoral peoples that have been largely dismissed by the vulnerability
163 literature, such as Middle Eastern pastoralists, Turkmen and Kazakh pastoralists or Eastern Europe herders - see Blench
164 (2001) for an exhaustive list of world pastoral peoples.

165 [FIGURE 1 ABOUT HERE]

166 [FIGURE 2 ABOUT HERE]

167 The coding of the case studies comprised in our sample, with the 185 variables identified, provided an in-depth
168 characterization of the three dimensions of the vulnerability of pastoralism under global environmental change.
169 Concerning the exposure of pastoral peoples to climate trends, overall changes in the seasonality of precipitation and
170 drought were identified as the most likely ways that pastoral peoples are exposed to observed climate change. This was
171 followed by rising temperatures, floods, snowstorms, strong winds, glacier retreat, extreme winter and less snow. In our
172 sample pastoral peoples are also largely exposed to non-climate drivers, specifically ill-conceived or policies marginalizing
173 pastoralism, changing traditional institutions such as the dismissal of elders' councils, violent conflicts, increased
174 marketization, encroachment of agriculture on pastoral lands, population growth and emigration, expansion of animals
175 representing a potential damage for the interests of pastoralists, and forest and shrub encroachment on grasslands (see
176 Appendix A). As regards sensitivity, in revisiting our sample of case studies, the occurrence of multiple transformations on
177 pastoral peoples was notorious. In terms of impacts on pastoral livelihoods, decreased access to rangelands, growing
178 difficulties of moving and conducting customary management practices, decreased size of the herds, decreased health
179 status of the animals, and increased access to market should be mentioned. In terms of the effects of land conversions on
180 pastoral peoples, the detrimental effects of pastoral land degradation and privatization, and encroachment on pastoral
181 land by agriculture, nature reserves or urbanization processes should be underlined (see Appendix B). Regarding

182 adaptation, in our sample of case studies multiple strategies were described as being developed by pastoral peoples to
183 benefit from or to minimize the damage of the impacts coming along with global environmental change. Those
184 distinguished by being more commonly reported were herd mobility and changing grazing patterns, the combination of
185 pastoral activity with other gainful activities, reciprocal social relations among pastoralists and communal planning and
186 herding, further developing trade through market access, pasture enclosure, herd accumulation, abandonment of the
187 pastoral activity, and turning to governmental and non-governmental aid (see Appendix C). Finally, the recent evolution in
188 the number of pastoral households in our sample of case studies points towards a general decreasing trend (see Appendix
189 D).

190 **4.1. Narratives of the diverse pathways of vulnerability of pastoralism**

191 In the interpretation of the results, it is worth noting that, as shown in section 2, there has been an evolution in the
192 dominant lens through which the viability of pastoralism is framed. Successive narratives show a bias towards different
193 aspects. It should be acknowledged that the current meta-analysis fundamentally covers the renewed interest in the
194 viability of pastoralism that is taking place since mid-2000s, with the emergence of climate change as a major policy issue.
195 However, this framing has not brought about uniformity in reporting or analyzing vulnerability factors. Using QCA and
196 Cluster Analysis, we have been able to identify from the reviewed papers on the viability of pastoralism, six distinct
197 pathways of vulnerability, that is six different specific combinations of exposure, sensitivity and adaptation, distinguished
198 as being experienced by pastoralists in different parts of the world (Table 1):

- 199 i. Encroachment, distinguished by the loss of control of pastoral land in a context of persistent unfavorable
200 development policies and declining operationalization of pastoral production strategies and institutions;
- 201 ii. Re-greening, distinguished by the incidence of afforestation in a context of acute non-climate
202 transformation and declining access to pastoral resources to which pastoral communities mainly respond
203 through emigration and diversification;
- 204 iii. Customary, distinguished by the larger preservation of pastoral production strategies and institutions, and
205 minor exposure to non-climate transformations, specifically those dealing with land, mobility and
206 agriculture;
- 207 iv. Polarization, distinguished by the shifting towards ranching, through the concentration of the pastoral
208 production strategies where conditions enable the adoption of intensive rearing and abandoning the rest of
209 the land;
- 210 v. Communal, distinguished by the great aptitude for adaptation to major non-climate transformations
211 through communal pooling;

212 vi. No-alternative, distinguished by the lack of economic options other than pastoralism in a context of
213 increased input use in the pastoral activity.

214

215 [TABLE 1 ABOUT HERE]

216

217 *i. Encroachment*

218 The first pathway that emerged from the MCA and Cluster analysis, which we labeled ‘encroachment’, refers to the way in
219 which pastoral lands are being broadly encroached upon by other activities. With 39.5% of the case studies, the declining
220 access to crucial pastoral resources and the political marginalization of pastoralists are defining features of this pathway. It
221 is fundamentally identified in Eastern Africa and Mongolia. Concerning exposure, drought and changes in seasonality are
222 identified as the most pressing climate trends in these case studies. Originating in either policy, economic, social or
223 ecological domains, non-climate transformations are also profusely described as playing a crucial role. It is reported that
224 land-use policies, sedentarization schemes and extension services are often implemented in ways that marginalize pastoral
225 livelihoods, while prioritizing other interests. The non-recognition of the land rights of pastoralists and the associated
226 encroachment upon rangeland areas of new land uses, such as agriculture, infrastructures, urban areas, ranching, tourism
227 or mining, is dramatically identified in these case studies (e.g. Wang and Zhang, 2012; Goldman and Riosmena, 2013). This
228 pathway is also characterized by increased integration of pastoralists within the market economy and by the occurrence of
229 remarkable transformations in traditional institutions. Complex demographic trends are also observed, mainly led by
230 population growth and emigration.

231 Concerning sensitivity, land privatization combined with the development of agriculture, irrigation schemes, ranching,
232 mining, nature reserves, game reserves and urbanization are mentioned as causing wide encroachment upon traditional
233 rangeland areas causing massive detrimental effects for pastoral groups. Thus dramatic land privatization and land
234 degradation are identified, which not only entail reduced availability of rangelands for pastoralists, but also undermine
235 their access to water, labor, mobility, social networks and even food. The quantity of livestock also diminishes, while its
236 productivity seems to rise. On the contrary, market access is strongly enhanced, but in combination with insecurity and
237 social unrest.

238 [FIGURE 3 ABOUT HERE]

239 Enhanced mobility, diversification and communal pooling, as well as market integration, are the main broad sets of
240 adaptation strategies being implemented by pastoral households undergoing this pathway. Herd mobility and changing
241 grazing patterns are described in all case studies. An important role is also played by wage labor migration and

242 remittances, as well as illegal grazing within protected areas and herd and household mobility (e.g. Ifejika Speranza, 2010;
243 Butt, 2011). The households try to combine the practice of pastoralism with other economic activities, through farm and
244 labor diversification, to manage risk. Other adaptation strategies linked to cohesion and reciprocal social relationships,
245 such as communal planning and herding, bartering, labor exchange and information gathering, including early warning
246 systems or improved weather forecasting, are reported. Enhanced market exchange is also broadly identified, mainly
247 conducted by improved market access and trade, but also through input purchase, and in case of need, by participating in
248 credit schemes and selling assets (e.g. livestock). Sedentarization and exiting pastoralism is also described as a common
249 adaptation strategy. Pasture enclosure, adoption of feed crop agriculture and stall feeding, and shifting to irrigated farming
250 are strategies less commonly implemented by these pastoral groups. This is also the case of receiving aid. Despite these
251 strategies, in this pathway of vulnerability the number of pastoral households is largely decreasing.

252 *ii. Re-greening*

253 The second pathway that emerged from the statistical analysis was characterized by the recent increase in the number of
254 trees observed in large areas of West African Sahel over the last 20 years. With 3.9% of the case studies, it is the least
255 common pathway among the case studies. We labeled this the 're-greening' pathway, being distinguished by large
256 biophysical transformations, specifically afforestation and drying lakes (e.g. Djoudi el al., 2013). This pathway is also
257 characterized by the major incidence of unfavorable policies for pastoralists and encroachment on pastoral land. Droughts,
258 changes in seasonality and sand-dust storms are the most critical climate trends identified. As in the previous pathway,
259 non-climate drivers play a central role. Additional non-climate transformations described include the implementation of
260 governmental and non-governmental policies oriented towards land management, sedentarization of pastoral groups, and
261 the provision of pastoral extension services and assistance. It is generally observed in these case studies that the
262 implementation of these policies tend to marginalize pastoral livelihoods and entail the provision of services in a manner
263 inadequate for pastoralists to benefit from them. Increased social unrest, emigration, agriculture expansion and
264 infrastructure development are also identified as generating major effects on pastoral livelihoods.

265 [FIGURE 4 ABOUT HERE]

266 As regards sensitivity, significant land conversions are reported in this pathway, specifically the detrimental effects on
267 pastoralists of rangeland degradation, rangeland privatization and conversion of rangelands into irrigated agriculture, and
268 the favorable effects for pastoralists of increased afforestation, which is seen as providing pastoralists with additional
269 fodder and forest product harvesting (e.g. Brockhaus et al., 2013). These impacts are described in combination with
270 notable decrease in the observance of customary pastoral practices, conservation of social networks and equity, pastoral
271 mobility, soil fertility, access to pasture, water availability, labor availability, and social protection. Food security and

272 human health are also reported as in decline. Slightly increased market integration and access to credit schemes are
273 described in this pathway.

274 Mobility and diversification are the main broad groups of adaptation strategies being implemented in this pathway.
275 Enhanced herd mobility, changing grazing patterns, migrations of pastoral households, wage labor migration and sending
276 remittances of members of the family, labor diversification, farm diversification and changes in livestock species
277 composition, herd accumulation and restocking are crucial strategies in this pathway. Increased herd and household
278 mobility, livestock diversification, adoption of diversified herd strategy managements, diversification in skill training,
279 participation in the sale of new products, augmented use of inputs, high-yield breeds and modern technology, and the
280 adoption of sedentary lifestyles are also widely observed adaptation strategies. Remarkable dependence on aid is also
281 usually mentioned. In all case studies comprising this pathway the number of pastoral households is reported to be in
282 decline.

283 *iii. Customary*

284 The third pathway identified in the statistical analysis was characterized by the existence of traditional pastoral practices
285 and institutions well preserved from transformations detrimental to pastoral interests. We labeled it “customary”. It
286 comprised 13.2% of the case studies, mainly present in Eastern and Southern Africa. This pathway is distinguished by the
287 fact that pastoral groups are exposed to fewer policies marginalizing them, which in turn goes with greater access to
288 pastoral resources. Regarding exposure, changes in seasonality, droughts and floods are the most critical climate trends.
289 The most prominent non-climate transformations to which pastoralists are exposed referred to inappropriate
290 implementations of policies - in the domains of aid assistance, education and extension; development of infrastructures
291 and population growth. However, the exposure to non-climate transformations in this pathway is minimal in comparison
292 with the rest. This is particularly remarkable in terms of fewer occurrences of land policies and sedentarization schemes
293 disregarding the pastoral interests, fewer changes in traditional pastoral institutions unfavorable to pastoralists, less
294 marketization of pastoral economics, low emigration rates and reduced agricultural expansion upon rangelands.

295 Concerning sensitivity, despite notable rangeland degradation, this pathway shows a relatively low effect on pastoralists of
296 unfavorable land conversions. The low incidence described of privatizations of pastoral land is particularly remarkable, as is
297 the notable incidence of conversions of pastoral land to agriculture and irrigated agriculture executed in a way
298 advantageous for pastoralists (e.g. Notenbaert et al., 2013). This is consistent with the maintenance of pastoral mobility
299 and social networks, as well as relatively low levels of land encroachment. Nonetheless, access to water and rangelands is
300 still reported as decreasing. Also increased hardship in attaining food security and impoverished human health are
301 commonly described in the communities undergoing this pathway.

302 [FIGURE 5 ABOUT HERE]

303 Diversification accounts for the majority of adaptation strategies reported in this pathway. Diversification in the allocation
304 of family labor, in farming activities and in the type of livestock raised is extensively described. This is identified together
305 with notable involvement of pastoralists in market-driven strategies, specifically improved market access and trade,
306 commercialization of new products, participation in credit schemes and destocking. In line with this, the identification in
307 the case studies following this pathway of adaptation strategies associated with infrastructure development (e.g. water
308 storage for agriculture), and the adoption of wage labor migration and child labor among pastoral families should be noted
309 (e.g. Banerji and Basu, 2010; Mark et al., 2010; Ng'ang'a et al., 2011). In contrast, pastoralists are reported as being less
310 likely to adopt strategies related to mobility and communal pooling than in the average of the selected case-studies.
311 Particularly relevant of this pathway is the low involvement of pastoralists in adaptation strategies of extensification or
312 intensification. A slight increase in the number of pastoral households is identified.

313 *iv. Polarization*

314 The fourth pathway emerging from the MCA and Cluster analysis, which we labeled 'polarization', makes reference to the
315 observed coexistence in some regions, mainly in European mountains, of a double trend of concentration of agropastoral
316 land ownership into larger properties in marginal areas and land subdivision into smaller properties in central areas. With
317 7.9% of the case studies, the coexistence of a double development trend among pastoralists distinguishes this pathway,
318 first the adoption of intensive livestock rearing, and second land abandonment. Concerning exposure, the case studies
319 following this pathway reported changes in seasonality and, to a lesser extent, droughts, rising temperatures and less snow
320 as the most pressing climate trends. The existence of land-use and assistance policies affecting pastoralists, as well as
321 remarkable tourism development in pastoral regions, certain level of population decrease and forest and shrub
322 encroachment on pastoral land, are the most critical non-climate transformations to which the pastoralists following this
323 pathway are exposed.

324 As regards sensitivity, in the case studies of this pathway almost no advantageous land conversions for pastoralists are
325 reported, while detrimental effects for pastoral groups are described in association with rangeland abandonment and
326 forest and shrub encroachment on pastoral land (e.g. Fernández-Giménez and Fillat, 2012a). In contrast, this is the
327 pathway with the lowest level of rangeland degradation. This goes in line with the fact that these case studies show the
328 least detrimental effects on rangeland access for pastoralists, as well as reduced effects on pastoral mobility, minimal
329 social and food insecurities, and increase in forest access and wild fire risk. Market access is also on the rise.

330 [FIGURE 6 ABOUT HERE]

331 Concerning adaptation, the combination of extensification and intensification strategies is the most defining feature of this
332 pathway. Thus, abandonment of distant pastures and withdrawing pastoralism are adaptation strategies being reported in
333 these case studies together with adoption of stall feeding, use of larger land areas, implementation of feed crop agriculture
334 and shifting from feed crop cultivation to pasture. This also goes with notable embracing of diversification strategies,
335 indicating that when the conditions do not allow the intensification of pastoralism then this economic activity is conducted
336 in combination with others. A general decline in the number of pastoral households is also observed in this pathway of
337 vulnerability.

338 *v. Communal*

339 The fifth pathway identified by the statistical analysis, which we labeled 'communal', alludes to the capability of
340 pastoralists to deal with undesired transformations through adaptations based on communal pooling. With 6.6% of the
341 case studies, and mainly reported in Andes and Arctic regions, this pathway is characterized by a relatively successful
342 management by pastoralists of the unfavorable policies oriented towards them and the detrimental effect on them of the
343 encroachment of other activities upon pastoral lands. As regards exposure, rising temperatures, glacier retreat, changing
344 seasonality in precipitations and less snow are those most critical climate trends observed in the case studies comprising
345 this pathway. Remarkably not a single case of drought is reported in this pathway. The pastoral communities following this
346 pathway are exposed to a combination of non-climate transformations, comprising policy, sociocultural, economic,
347 demographic and biophysical trends. Specifically they include a persistent political marginalization of pastoralists, the
348 implementation of sedentarization schemes, changes in traditional pastoral institutions, existence of social conflicts,
349 increased marketization of the pastoral economy, development of infrastructures on pastoral land, expansion of mining in
350 pastoral lands, population growth and emigration, expansion of wild animals potentially damaging for livestock, extinction
351 of biodiversity and rising deforestation.

352 Concerning sensitivity, despite significant detrimental impacts in terms of reduced rangeland access and mobility,
353 degradation of customary practices, less water availability, deteriorated social justice, weakened social networks, and
354 limited access to forest and biodiversity; in this pathway it is also reported an increase in labor availability and a favorable
355 development of irrigated pastures (e.g. Young and Lipton, 2006; Postigo et al., 2008). The encroachment upon pastoral
356 lands of mining and infrastructures is also widely reported in the case studies comprising this pathway, as well as increased
357 marketization of the pastoral economics and social unrest.

358 [FIGURE 7 ABOUT HERE]

359 About adaptation, the leading role of the community as the organizing entity is widely reported in this pathway.
360 Communal-pooling-based adaptation strategies, such as reciprocal social relations among pastoralists, communal planning
361 and herding, communal infrastructure development or bartering, are thus those most characteristic of this pathway (e.g.
362 Postigo et al., 2008). However, the mobility and diversification groups of adaptation strategies are also extensively
363 observed, specifically enhanced herd mobility, changing grazing patterns, migration of pastoral households and
364 implementation of both farm and labor diversification. The commercialization of new products, adoption of sedentary
365 lifestyles, water storage, shifting to irrigated farming and withdrawing pastoralism are also adaptation strategies
366 extensively described in the case studies following this pathway. A general trend of increase in the number of pastoral
367 households is reported in this pathway.

368 *vi. No-alternative*

369 The last pathway identified in the statistical analysis, which we labeled 'no-alternative', alludes to a lack of livelihood
370 options other than pastoralism. With 28.9% of the case studies, and fundamentally described in Arctic, Himalaya-Pamir and
371 Mongolia regions, this pathway is distinguished by the absence of economic alternatives to pastoralism in a context of a
372 pastoral activity increasingly dependent on the use of purchased inputs. Regarding exposure, of the climate trends
373 reported in the case studies comprising this pathway, change in seasonality and, to a lesser extent, rising temperatures,
374 droughts and snowstorms are the most pressing ones. Whereas implementation of land use policies on pastoral lands,
375 political marginalization of pastoralists, changes in traditional pastoral institutions, infrastructure development on
376 rangelands and expansion of wild animals potentially damaging for livestock are the most critical non-climate
377 transformations to which pastoralists are exposed.

378 Concerning sensitivity, remarkable detrimental effects are described in these case studies in relation to decreased access
379 to rangelands, weakened capacity of pastoral mobility, damaged customary pastoral practices, decreased livestock
380 quantity and quality, and growing overgrazing (e.g. Naess, 2013). The magnitude of the detrimental effects on pastoralists
381 of rangeland degradation and land privatizations is also notable. It should be mentioned, however, that it is in this pathway
382 where the lowest level of manifestations of social injustice are reported.

383 [FIGURE 8 ABOUT HERE]

384 Adaptation of pastoralists to deal with the above-mentioned impacts is characterized by the relatively reduced
385 implementation of diversification strategies, particularly acute as regards farm diversification. A low tendency to embrace
386 wage labor migration and reciprocal social relationships is reported in this pathway; whereas mobility and communal
387 pooling are groups of strategies notably described, specifically enhanced herd mobility, changing grazing patterns and

388 communal planning and herding (e.g. Fu et al., 2012). Despite the limited adoption of strategies of enhanced market access
389 and trade and commercialization of new products, pastoralists in this pathway increasingly turn to market to get supplies
390 of inputs, high-yield breeds and technology. A moderate trend of decreasing the number of pastoral households is
391 observed in this pathway of vulnerability.

392 **5. Discussion**

393 The statistical approach conducted in this paper reveals a diverse range of pathways of vulnerability followed by pastoral
394 communities all over the globe. This illustrates a large spectrum of possible encounters between the climate trends and
395 the non-climate transformations associated with global environmental change, the impacts on pastoral livelihoods of these
396 trends and changes, and the adaptation strategies developed by pastoralists. To summarize the similarities and differences
397 between all six pathways identified, figure 9 shows the relative importance for each of them of the three dimensions of
398 vulnerability, being exposure illustrated by the number of climate trends and non-climate transformations reported,
399 sensitivity by the number of impacts on pastoral resources and pastoral land conversions observed, and adaptation by the
400 number of adaptation strategies described. From this we observe that the Encroachment pathway is characterized by
401 abundant non-climate transformations and impacts on pastoral resources. This is also the case of the Re-greening pathway,
402 which is also distinguished by going through numerous climate trends and abundant pastoral land conversions. The
403 Customary pathway is defined by scarce non-climate transformations, which go with fewer impacts on pastoral resources
404 and pastoral land conversions. The Polarization pathway is characterized by scarce impacts on pastoral resources and
405 pastoral land conversions. The Communal pathway is distinguished by undergoing numerous non-climate transformations
406 and minimal pastoral land conversions. Finally, the No-alternative pathway is defined by the limited number of adaptation
407 strategies developed.

408 [FIGURE 9 ABOUT HERE]

409 Despite the specificities among the different pathways, a number of commonalities have also been identified (Table 2).
410 Thus, four major forces have been distinguished as exerting crucial influence on the vulnerability of pastoralists: (i) the
411 double exposure to climate and non-climate drivers of transformation, (ii) the persistence of unfavorable development
412 policies, (iii) the great vitality of adaptation, and (iv) the multifaceted role of markets.

413 Despite the renewed interest in the vulnerability of pastoralism, as a result of the emergence of climate change as a major
414 policy issue, and regardless of the apparent difficulties in accurately attributing specific impacts to specific transformations;
415 the results of the QCA systematic review and meta-analysis indicate that the non-climate transformations to which
416 pastoral groups are exposed exceeds, at least in number, the climate transformations (Table 2). Although the specific

417 impacts of both kinds of exposure is difficult to determine, several studies mention the existence of a global commonality
418 of the pressures to which pastoralists are exposed (Fratkin and Mearns, 2003; Anderson and Nuttall, 2004), with particular
419 emphasis on non-climate drivers. All this is quite consistent with the thesis of the proponents of the new range ecology
420 (e.g. Behnke, 1994; Scoones, 1995), as well as those picturing pastoralism as a high-reliability system (e.g. Krätli, 2008; Roe
421 and Schulman, 2008), describing pastoral vulnerability as fundamentally driven by factors external to the standard pastoral
422 business. In fact, Nori (2007) underlines that adequate land rights are the major global concern for pastoralists. Thus, it is
423 not climate change by itself, but the combination of effects of climate change with additional policy, sociocultural,
424 economic, demographic and ecological drivers - specifically encroachment upon pastoral land, ecological degradation,
425 weakening of traditional systems of pastoral resource management and reciprocity, and economic stratification - that
426 explains the increased vulnerability of pastoral groups to climate variations. As mentioned by Dong et al. (2011),
427 pastoralism is experiencing a compound exposure.

428 Despite notable advancements in the comprehension of the rangeland dynamics and the rationality and sustainability of
429 pastoralism, as illustrated in section 2, the persistence of unfavorable development policies oriented towards pastoralists is
430 obstinate. As our results show, the occurrence of policies marginalizing pastoral groups, specifically concerning land issues,
431 is largely the most important among non-climate pressures on pastoralism. In fact, low incidence of ill-conceived policies –
432 as in the Customary pathway – and strong sense of community – as in the Communal pathway – are central features of the
433 pathways showing larger access to pastoral resources and less decrease in the number of pastoral households (Table 2).
434 The literature identifies several reasons to explain the constant determination in the implementation of unfavorable
435 development policies: (i) persistence of unfavorable narratives, representing pastoralism as economically unproductive,
436 ecologically damaging and culturally backwards, and justifying dispossession and/or no need for public investments (Swift,
437 1996; McPeak and Little, 2006; Reinert et al., 2008; Harris, 2010); (ii) difficulties of finding appropriate ways of delivering
438 public services for isolate, minority and mobile groups (Thébaud and Batterbury, 2001; Morton, 2010b); (iii) lack of political
439 representation (Lister, 2004; Brocklesby et al., 2010; Morton, 2010a; Raleigh, 2010); (iv) governments' desire to control
440 pastoral groups and the resources present in pastoral lands (Forni, 2003; Davies and Hartfield, 2007; Morton, 2010a;
441 Behnke and Kerven, 2013); (v) too much focus on technical investments, not always well adapted to the specific social and
442 ecological context of pastoralism (Scoones, 2004); and (vi) failures of well-intentioned policies, such as those ending in
443 economic security traps (Hausner et al., 2011). Thus, a combination of vested interests on pastoral lands with intentional
444 and unintentional ignorance on the pastoral ecological and economic rationality seems to lie behind the persistence of
445 unfavorable policies oriented towards pastoralists. The deficient provision of basic public services, such as road
446 infrastructures (Barton and Morton, 2001), education (Krätli and Dyer, 2009) or animal health services (Catley et al., 2004),
447 that pastoral groups suffer aggravates this situation.

448 [TABLE 2 ABOUT HERE]

449 As it is apparent that pastoralists all over the world are undergoing severe pressures, it is equally true that pastoral groups
450 are actively facing these transformations. The number and diversity of adaptation strategies identified in this meta-analysis
451 is remarkable, comprising different forms of mobility, diversification, communal pooling, market, storage, extensification
452 and intensification practices. In fact, a total of 52 adaptation practices have been identified (see Appendix C). However, the
453 great vitality of pastoral adaptation made evident by these results certainly blurs the distinction between coping and
454 adaptation strategies, since this distinction was often not made apparent in the case studies. Furthermore, it must be kept
455 in mind that pastoralism is an economic activity found in regions as different as mountains, drylands, tundra, deserts or
456 steppes, where the seasonality of climate makes resources only available in sporadic or periodical concentrations. The non-
457 exclusive tenure and land use system common to pastoralism (Behnke, 1994; Turner, 1999) is crucial to allow the
458 movement of herds towards these ephemeral concentrations of resources. In fact, most rangelands in the world have been
459 traditionally communally governed (Sandford, 1983; McCabe, 1990; Behnke et al., 1993; Fratkin, 1997). All this indicates
460 that the nature of pastoral practices, such as mobility or communal management, is not merely coping or adaptation, but
461 in some occasions is productive, characteristically of an economic activity specialized in exploiting transient concentrations
462 of resources. The vitality of pastoral adaptation identified seems thus to be a consequence of a combination of coping and
463 adaptation strategies with pastoral production strategies following the very rationality of the pastoral enterprise.

464 Trade and complementary production with neighbors is an essential part of the nature of pastoral livelihoods (e.g. Orlove,
465 1982; Abu-Rabia, 1994, Jina, 1999). However, as underlined by Khazanov (2009), while in the past they were not
466 deliberately oriented to profit but to use-value, nowadays whether they like it or not, they are increasingly becoming
467 involved in a monetary economy based on exchange value and livestock commoditization. The integration of pastoralists
468 within the global market has brought about a rising influence on trading exchanges of factors that pastoralists cannot
469 control. Also, the integration is often occurring in unfavorable conditions of state support for pastoralists (Khazanov, 2009).
470 Thus, further market integration seems not to be always entirely desirable for pastoralists (e.g. Valdivia et al., 2010). The
471 fact that in the coding of case studies conducted in this meta-analysis the market is conceptualized at the same time as a
472 non-climate driver of transformation, as an impact of the transformations, and finally also as an adaptation strategy,
473 illustrates the complex role market integration plays in the vulnerability of pastoralism. In some occasions it is seen as an
474 additional stressor constraining pastoral livelihoods, while in some other occasions it is pictured as a desirable adaptation
475 strategy to enhances pastoral livelihoods (Table 2).

476 [FIGURE 10 ABOUT HERE]

477 The livelihood options of pastoralists are generally becoming narrower. Despite more and more evidence of increased
478 climate change (Field et al., 2014), the increased overall vulnerability of pastoralists is also a consequence of non-climate
479 drivers, specifically political marginalization and encroachment on pastoral resources. The vulnerability of pastoralists to
480 climate change is thus not entirely attributable to pastoralism, but also to the obstacles it encounters to develop its
481 production strategies. Accordingly, it becomes critical to distinguish between different components of pastoral
482 vulnerability. There is an inherent vulnerability in any economic activity dedicated to the use of natural resources - which
483 often are irregularly distributed, scarce, etc. Managing this component of vulnerability is the usual business of pastoralism.
484 Another component of vulnerability is that stemming from external forces disturbing the usual working of the pastoral
485 system – encroachment on pastoral land, marginalizing policies, etc. - which undermine the operation of the pastoral
486 production strategies. Following Krätli et al. (2013), we call the former strategic vulnerability and the latter induced
487 vulnerability. As shown in figure 10, there takes place a co-production of the vulnerability of pastoralism between climate
488 and non-climate trends and transformations, which fundamentally mediate the strategic and induced components of
489 vulnerability, respectively. Non-climate transformations make adaptation to climate trends more difficult, and climate
490 trends also affect the ability of pastoral communities to adapt to non-climate transformations.

491 **6. Conclusions**

492 Despite the long-standing interest of the research community in the viability of pastoralism, the progress of knowledge on
493 the vulnerability of pastoralism under global environmental change has been remarkable since mid-2000s, with the
494 emergence of climate change as a major policy issue. Illustrative of this vitality is the coexistence of different, often
495 contradictory, lines of thought, picturing pastoralism either as an undesirable anachronism, as an experienced way to cope
496 with scarce and patchy resources in hostile environments, or as high-reliability system specialized in the exploitation of
497 ephemeral resources.

498 The QCA meta-analysis has proven to be an effective methodology to extract general lessons from the examination of
499 patterns and trends across the literature. In particular, six different pathways of vulnerability arose in the comparison of
500 the case studies, which show the varied circumstances that the diverse pastoral groups are currently coming across in
501 different parts of the world, according to the papers sampled. All through this characterization, four major forces emerged
502 with a determinant influence on the co-production of the vulnerability of pastoralists: (i) the double exposure of
503 pastoralists, which creates pastoral vulnerability to climate and non-climate trends and transformations; (ii) the
504 persistence of unfavorable development policies, fundamentally triggered by a combination of vested interests on pastoral
505 resources and a more or less unintentional ignorance on the pastoral ecological and economic rationality; (iii) the vitality of

506 adaptation, but with the caveat that what is often seen as adaptation in fact is a combination of coping measures,
507 adaptation strategies and economic practices; and finally (iv) the multifaceted role of markets.

508 Consequently, in order to strengthen pastoralism the development of enabling policies and the recognition of pastoral
509 rights and institutions become inescapable. To that end, improving the communication of well-informed narratives on
510 pastoralists, based on the existing scientific evidence, appears as critical: first, highlighting the multiple benefits that this
511 activity provides, such as environmental services, carbon sequestration or efficiency in human-edible protein production;
512 and, second, instead of associating pastoralism with economic strategies of risk-aversion for survival in unfavorable
513 environmental conditions, underlining the specialized nature of pastoralism in exploiting transient resources through high-
514 reliability organization. Stopping unfavorable policies aiming at pastoralists is crucial to diminish the induced component of
515 the pastoral vulnerability, which indirectly will also diminish the strategic component of vulnerability, and in turn will
516 enhance the capacity of pastoralism of exploiting non-equilibrium conditions through high-reliability organization in a
517 scenario of increasing changing conditions. Under unpredictable conditions, and specifically when failure is potentially
518 devastating, the reliability of a system becomes a much more desired feature than profitability.

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862 [TABLE HEADINGS AND NOTES]

863 **Table 1.** Pathways of vulnerability in pastoral regions.

864 Sources: 1, Goldman and Riosmena (2013); 2, Djoudi et al. (2013); 3, Zgang et al. (2013); 4, Joshi et al. (2013); 5, Osano et al. (2013); 6,
865 Naess (2013); 7, Notenbaert et al. (2013); 8, Brockhaus et al. (2013); 9, Haynes and Yang (2013); 10, Hou et al. (2012); 11, Sneath (2012);
866 12, Dieye and Roy (2012); 13, Fu et al. (2012); 14, Mogotsi et al. (2012); 15, Sulieman and Elagib (2012); 16, Wang and Zhang (2012); 17,
867 Freier et al. (2012); 18, Fernández-Giménez and Fillat (2012a); 19, Jianzhong et al. (2011); 20, Li and Huntsinger (2011); 21, Djoudi and
868 Brockhaus (2011); 22, Butt (2011); 23, Ouma et al. (2011); 24, Mwang'ombe et al. (2011); 25, Ng'ang'a et al. (2011); 26, Crane et al. (2011);
869 27, Owuor et al. (2011); 28, Blackwell (2010); 29, Ifejika Speranza (2010); 30, Crane (2010); 31, Wang and Zhang (2010); 32, Mark et al.
870 (2010); 33, Dougill et al. (2010); 34, Hadfdan Aase et al. (2009); 35, Marin (2010); 36, Forbes et al. (2009); 37, Dong et al. (2009); 38,
871 Eriksen and Lind (2009); 39, Eriksen and Lind (2009); 40, Rattenbury et al. (2009); 41, Keskitalo (2009); 42, Postigo et al. (2008); 43, Tyler et
872 al. (2007); 44, Young and Lipton (2006); 45, Christensen et al. (2005); 46, Ingram et al. (2002); 47, Galvin et al. (2001); 48, Beyene (2010);
873 49, Dominguez et al. (2010); 50, Kassam (2009); 51, Sternberg et al. (2009); 52, Muho et al. (2009); 53, La Rovere et al. (2005); 54, Little et
874 al. (2001); 55, Kyalo Willy and Chiuri (2010); 56, Biazin and Sterk (2013); 57, Fernández-Giménez and Fillat (2012b); 58, Vuojala-Magga et
875 al. (2011); 59, Cossins and Upton (1988); 60, Sendzimir et al. (2011); 61, Astigarraga and Ingrand (2011); 62, Hausner et al. (2011); 63,
876 Furberg et al. (2011); 64, Janes (2010); 65, Nettier et al. (2010); 66, Banerji and Basu (2010); 67, Smucker and Wisner (2008); 68, Xu et al.
877 (2008); 69, Gebresenbet and Kefale (2012); 70, Konstantinov (2010); 71, Pantuliano (2010); 72, Verzijl and Guerrero Quispe (2013); 73,
878 Yosef et al. (2013); 74, Lavrillier (2013); 75, Ole Seno and Tome (2013).

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880 **Table 2.** Commonalities and specificities of the diverse pathways of vulnerability of pastoralism identified.

881 This table is based on the data available in Appendixes A, B, C and D.

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890 [FIGURE CAPTIONS]

891 **Fig. 1.** World pastoral regions.

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893 **Fig. 2.** Number of case studies recorded per country.

894 Note that some case studies transcend national boundaries.

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896 **Fig. 3.** The Encroachment pathway of vulnerability.

897 *Note:* The three dimensions of vulnerability are represented in the figure. Exposure is illustrated by climate trends and non-climate
898 transformations being experienced by the pastoral groups. Sensitivity is illustrated by impacts on pastoral resources and pastoral land
899 conversions. Adaptation is illustrated by the adaptation strategies described in each case. The bar chart referring to climate trends shows
900 the percentage of case studies comprising this pathway that report each of the nine trends described. Only those more frequent are
901 labelled. The pie chart of non-climate transformations shows the percentage of them belonging to each of the following subgroups of
902 drivers: policy and institutional, sociocultural, economic, demographic and biophysical. The number of non-climate transformations in
903 each case is in brackets. Sensitivity is represented by impacts on pastoral resources and pastoral land conversions. The bar chart of the
904 former illustrates the percentage of case studies where each of the eighteen most reported impacts were described. Negative percentage
905 indicates decreasing effects, while positive percentage indicates increasing effects. Only those most common are labelled. The bar chart of
906 pastoral land conversions shows the percentage of case studies where the nine most described land conversions were reported. Negative
907 percentage indicates the detrimental nature of this impact for pastoralists, while positive percentage indicates the opposite. Only those
908 most common land conversions are labelled. Concerning adaptation, the pie chart of adaptation strategies shows the percentage of them
909 that belongs to the following broad adaptation lines: mobility, diversification, communal pooling, market exchange, intensification, storage,
910 extensification and aid. In brackets the specific number of adaptation strategies in each case. Finally, in the middle there is the percentage
911 of case studies that reported recent increase or decrease in the number of pastoral households. This figure is based on information
912 available in Appendixes A, B, C and D.

913

914 **Fig. 4.** The Re-greening pathway of vulnerability.

915 See note to Fig. 3.

916 **Fig. 5.** The Customary pathway of vulnerability.

917 See note to Fig. 3.

918 **Fig. 6.** The Polarization pathway of vulnerability.

919 See note to Fig. 3.

920 **Fig. 7.** The Communal pathway of vulnerability.

921 See note to Fig. 3.

922 **Fig. 8.** The No-alternative pathway of vulnerability.

923 See note to Fig. 3.

924 **Fig. 9.** Performance in the main components of the vulnerability of pastoralism of the diverse pathways.

925 The scores of the figures are percentages, going from 0 in the centers to 100 in the extremes. Out of the total of items of the five
926 components of the three dimensions of vulnerability reported considering all case studies of our sample, the percentage indicates the
927 number of them that were reported in each pathway of vulnerability. The average scores are in black, while the scores specific for each
928 pathway are in grey. This figure is based on the data available in Appendixes A, B and C.

929 **Fig. 10.** Co-production of the vulnerability of pastoralism.

Table1

	ENCROACHMENT	RE-GREENING	CUSTOMARY	POLARIZATION	COMMUNAL	NO-ALTERNATIVE
Northern Africa	17, 49					
Eastern Africa	1, 5, 22, 27, 28, 29, 38, 39, 47, 48, 54, 55, 56, 67, 69, 71, 75		23, 24, 59			15, 52, 73
Western Africa	30, 46, 53	2, 8, 21	26	60		12
Southern Africa	33		7, 14, 25			
Himalaya-Pamir	68		50, 66	34		4, 6, 9, 13, 19, 37
Mongolia	11, 16, 20, 31, 45, 64					3, 10, 35, 51
Andes			32		42, 44, 72	
Arctic					36, 74	40, 41, 43, 58, 62, 63, 70
European mountains				18, 57, 61, 65		

Table2

	ENCROACHMENT (40%)	RE-GREENING (4%)	CUSTOMARY (13.3%)	POLARIZATION (8%)	COMMUNAL (6.7%)	NO-ALTERNATIVE (28%)
EXPOSURE (climate trends)	Seasonality, drought	Seasonality, drought, wind	Seasonality, drought, flood	Seasonality, drought, rising temperatures	Seasonality, rising temperatures, glacier retreat	Seasonality, rising temperatures
EXPOSURE (non-climate transformation)	Policy: land, marginalizing, sedentarization. Social: changes in traditional institutions, conflict. Economic: market, agriculture. Demographic: population growth, emigration.	Policy: land, marginalizing, aid, sedentarization, extension, centralized services. Social: changes in traditional institutions, conflict. Economic: agriculture, infrastructure. Demographic: emigration. Biophysical: drying lake, invasive species, afforestation	Policy: marginalizing. Demographic: population growth.	Policy: land. Social: less for conflicts Economic: market, tourism. Biophysical: afforestation.	Policy: land, sedentarization Social: changes in traditional institutions, conflict. Economic: market, mining, urbanization, infrastructure. Demographic: population growth, emigration. Biophysical: extinction of species, expansion of damaging species.	Policy: land, marginalizing. Social: changes in traditional institutions. Economic: market.
SENSITIVITY (pastoral resources)	Decreasing: rangeland, mobility, customary practices, livestock number, productivity, water, food security, social justice, labor, social network. Increasing: market, insecurity.	Decreasing: rangeland, mobility, customary practices, livestock number, water, food security, social justice, labor, social network, soil, humane health. Increasing: insecurity, forest.	Decreasing: rangeland, livestock number, productivity, water, food security, social justice, income, humane health.	Decreasing: livestock number, water, livestock health and conflict. Increasing: market, forest.	Decreasing: rangeland, mobility, customary practices, water, social justice, social network, forest. Increasing: market, insecurity, labor, demography.	Decreasing: rangeland, mobility, customary practices, livestock number, productivity, income. Increasing: overgrazing.
SENSITIVITY (land conversions)	Detrimental: degraded land, privatization, agriculture.	Detrimental: degraded land, privatization, Irrigated agriculture. Favorable: forest.	Detrimental: degraded land. Favorable: irrigated agriculture.	Detrimental: abandoned pastures.	Detrimental: mining, infrastructures. Favorable: irrigated pasture.	Detrimental: degraded land.
ADAPTATION	Mobility: herd, varying grazing patterns, household, remittances. Diversification: labor, farm, livestock. Communal pooling: reciprocity, herding, livestock loans. Market: improved market access, input purchase, new product sale. Intensification: pasture enclosure, sedentarization. Storage: herd, feed. Extensification: leaving pastoralism.	Mobility: herd, varying grazing patterns, household, remittances. Diversification: labor, farm, livestock, herd strategy, changes in species, skills. Communal pooling: conflict resolution. Market: new product sale. Intensification: increased input use, sedentarization. Storage: herd, restocking.	Mobility: herd, remittances. Diversification: labor, farm, livestock. Communal pooling: reciprocity, infrastructure, children labor. Market: improved market access, new product sale. Storage: water.	Mobility: herd, varying grazing patterns. Diversification: labor, farm, livestock, skills, changes in species. Market: improved market access, input purchase, new product sale. Intensification: feed cropping, stall feed, leaving distant pasture Storage: feed. Extensification: leaving pastoralism, land increase, shifting from feed crop to pasture.	Mobility: herd, varying grazing patterns, household, remittances. Diversification: labor, farm, livestock. Communal pooling: reciprocity, herding, infrastructure, labor exchange, bartering, conflict resolution. Market: improved market access, new product sale. Intensification: sedentarization. Storage: water. Extensification: leaving pastoralism.	Mobility: herd, varying grazing patterns. Diversification: labor, herding. Communal pooling: input purchase. Intensification: increased input use.
REGION	Africa, mainly Eastern Africa, and Mongolia	Western Africa	Eastern and Southern Africa, and Himalaya-Pamir	European mountains principally	Andes and Arctic	Arctic and Himalaya-Pamir, mostly, and Mongolia
Nº households	General decrease	Total decrease	Marginal increase	General decrease	General increase	General decrease

Figure1

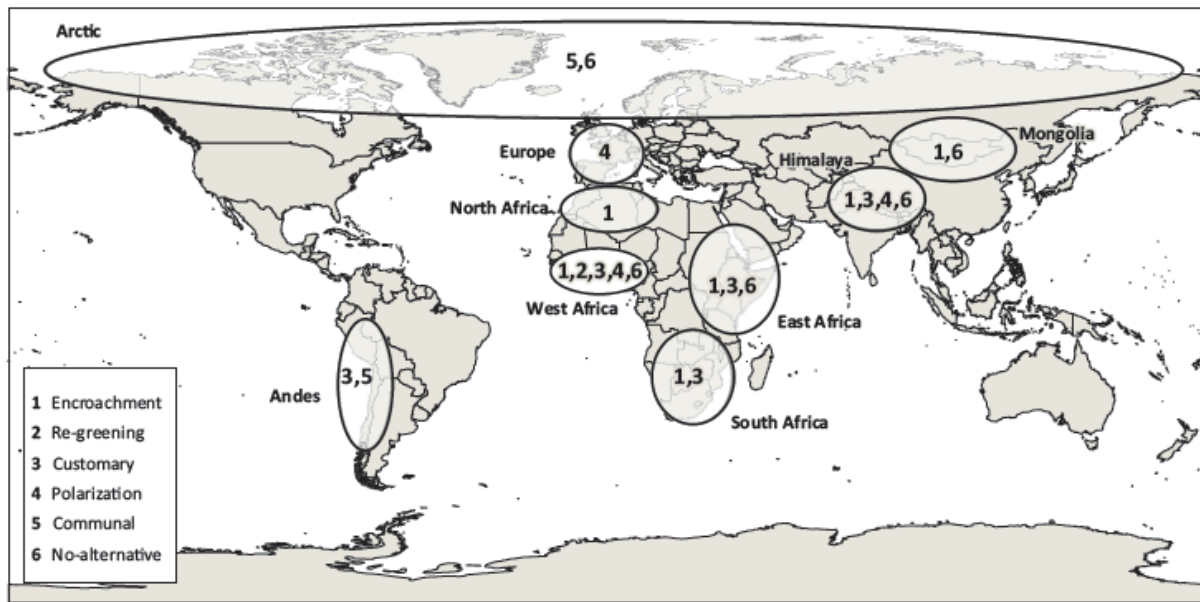


Figure2

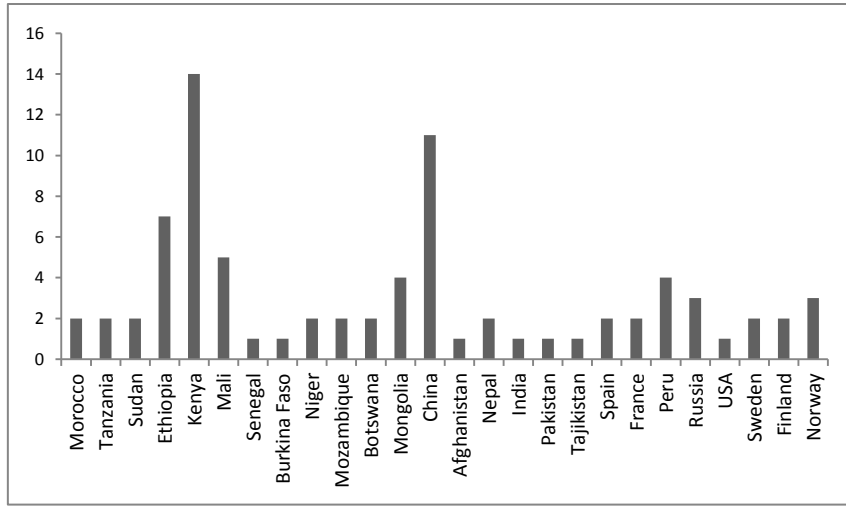


Figure3

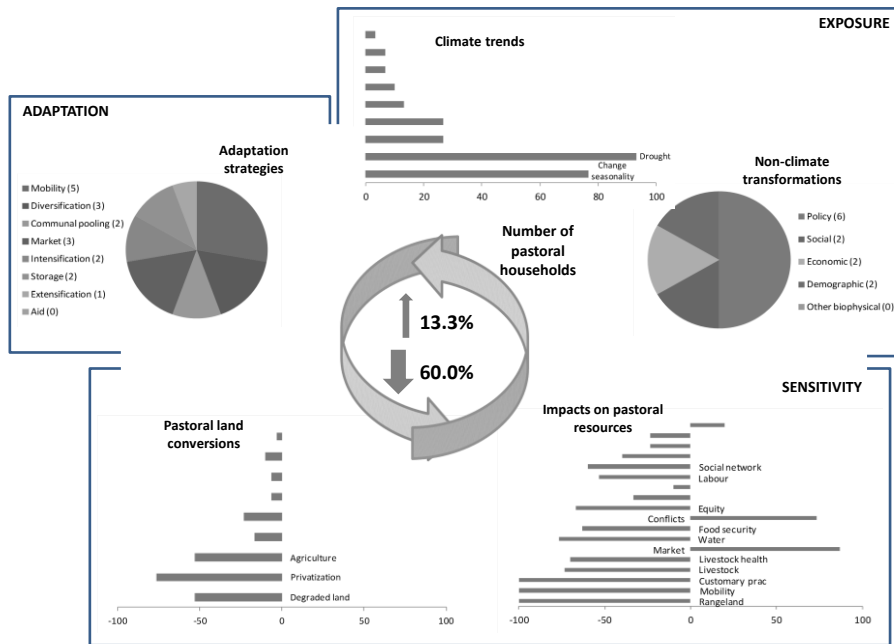


Figure 4

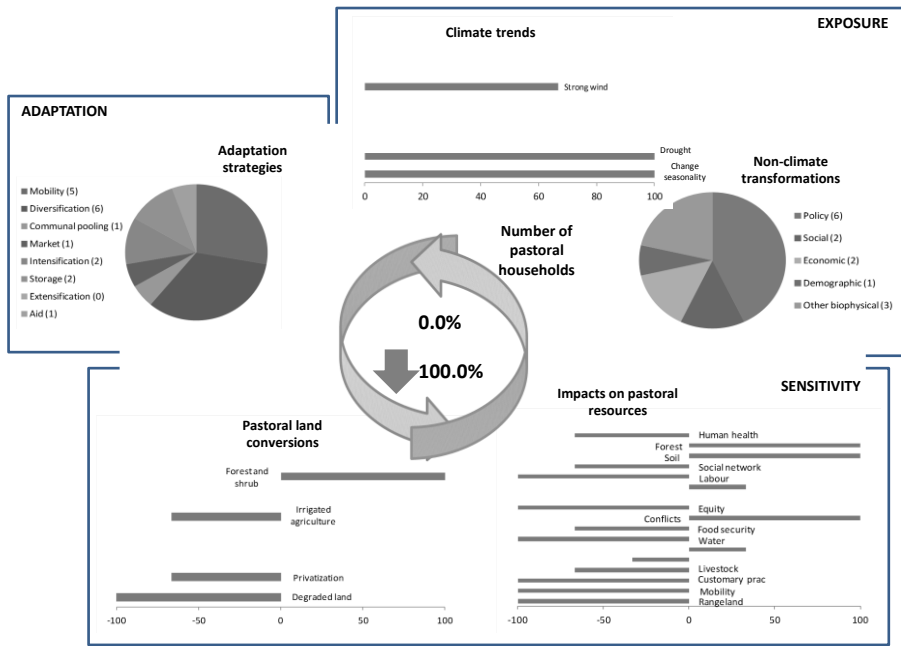


Figure5

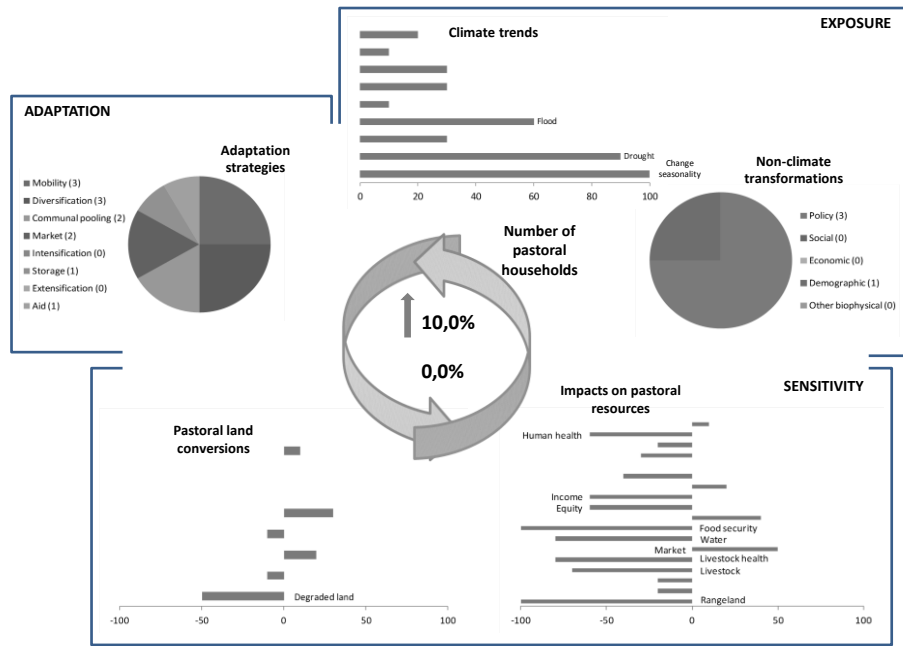


Figure6

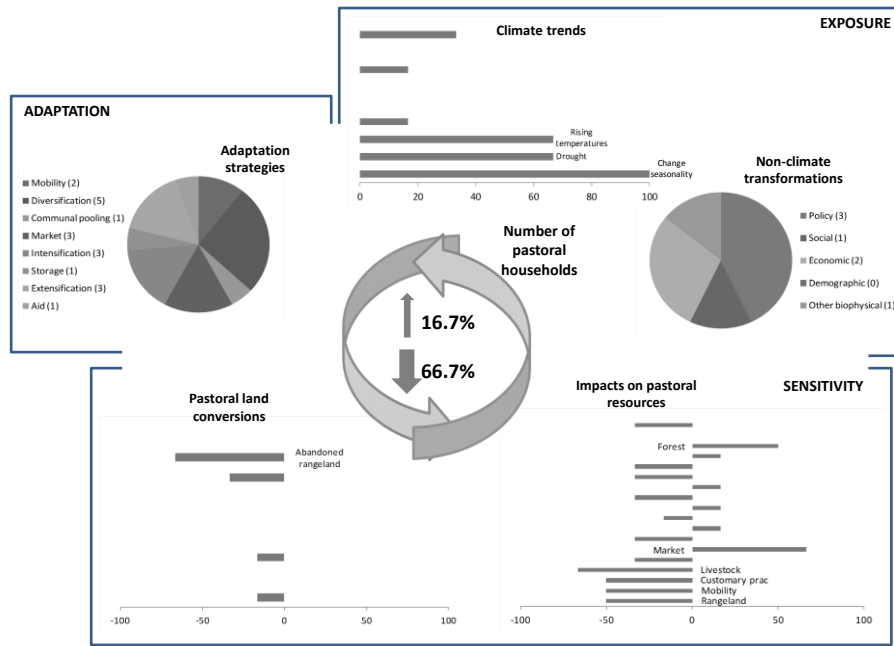


Figure7

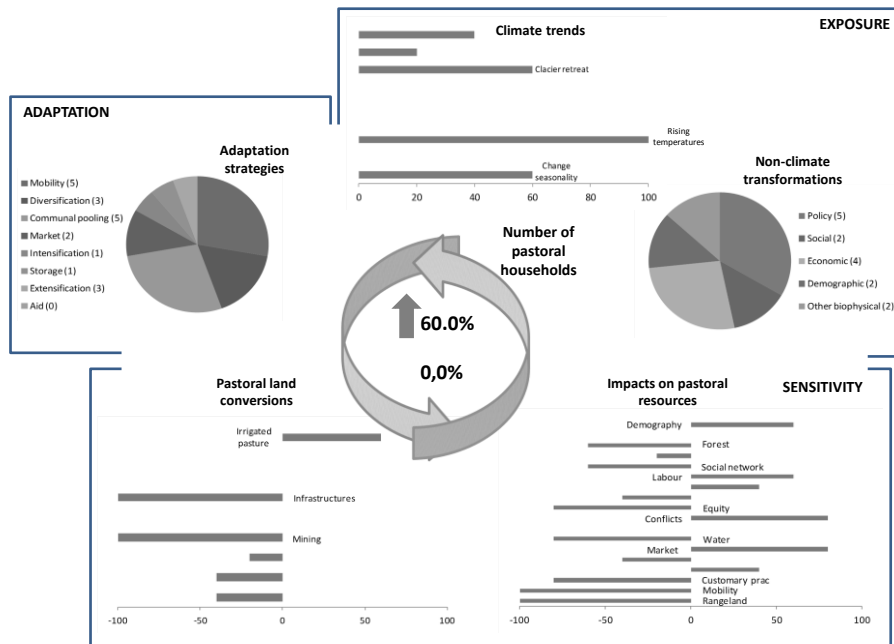


Figure 8

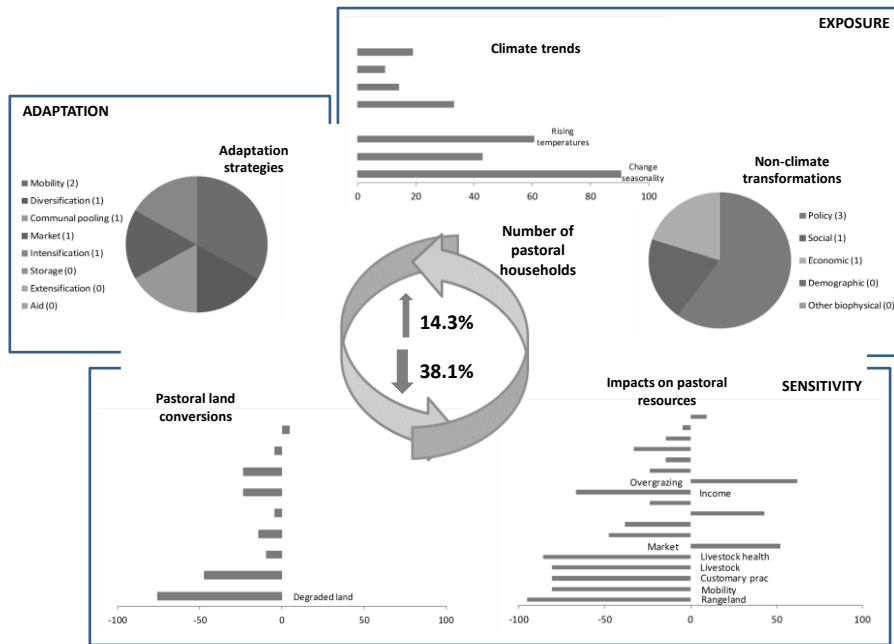


Figure9

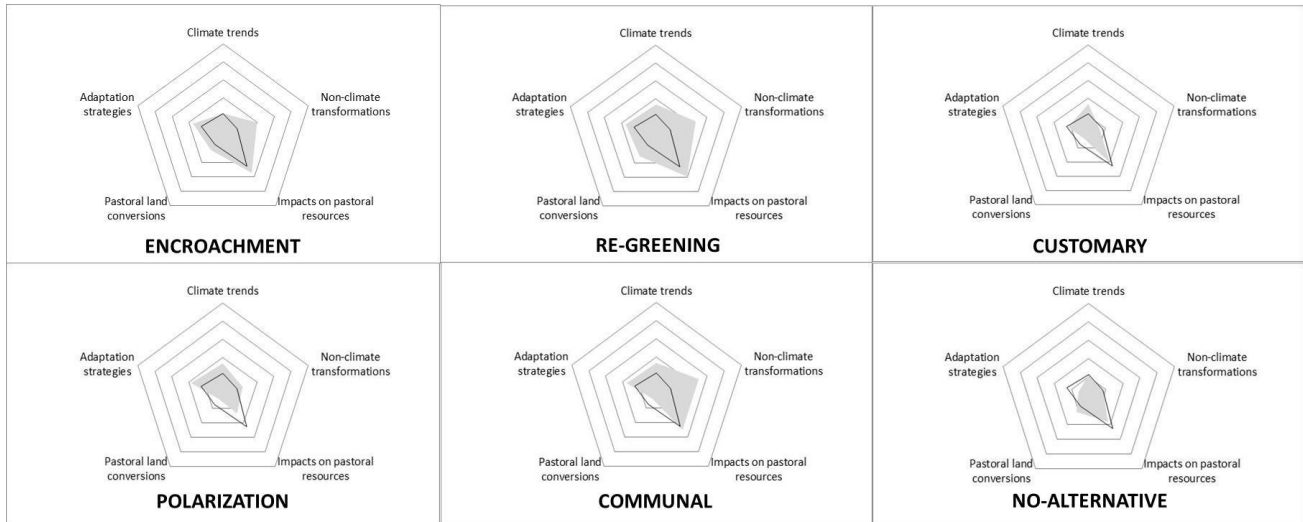
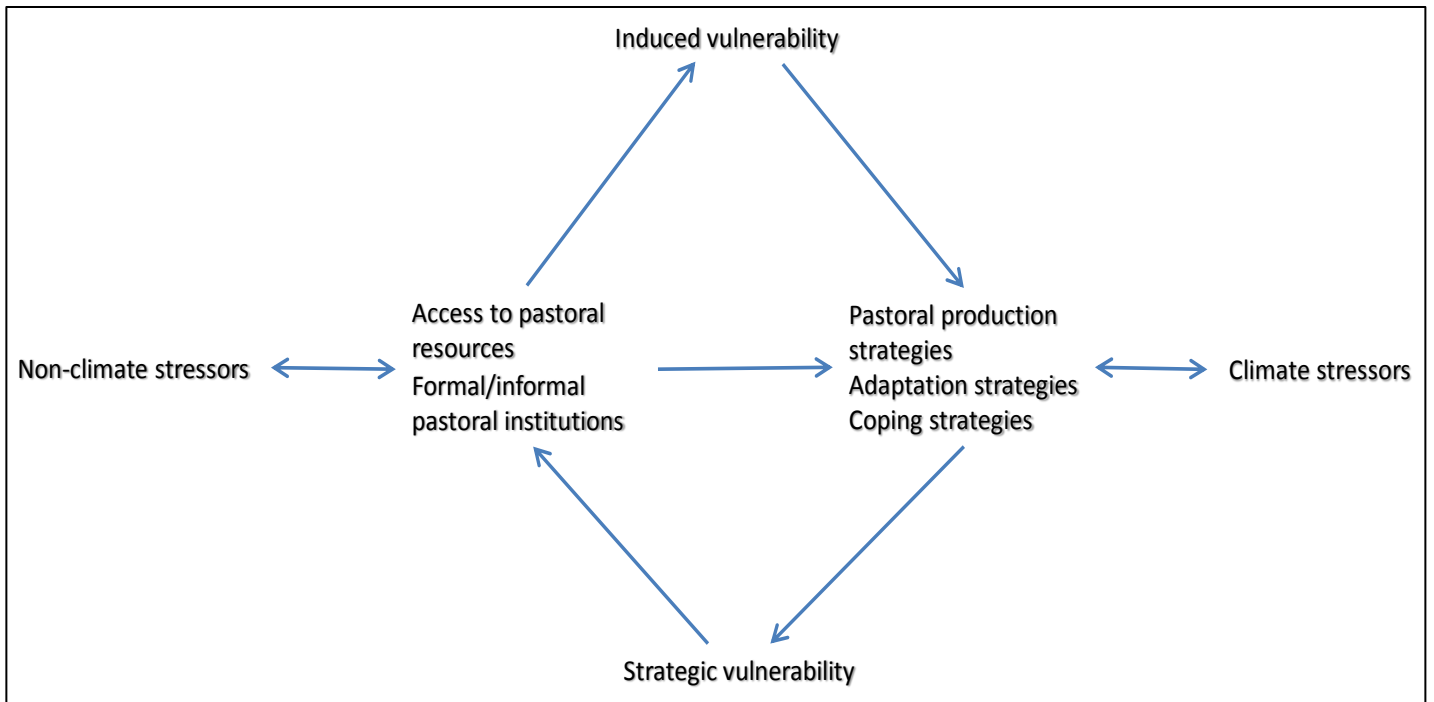


Figure10



Supplementary Material

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