

## Article

# Quantitative Analysis of Drought Management Strategies across Ethnographically-Researched African Societies: A Pilot Study

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**Abstract:** In this paper, we present a pilot study aimed at investigating the impact of subsistence strategies and environmental pressure on the distribution of ethnographically documented strategies to cope with drought and its effects across 35 current societies in Africa. We use freely accessible ethnographic databases to retrieve data on how a number of African societies deal with the circumstances of drought, and ascertain the impact of geography on their distribution in order to measure possible relationships between them, a set of subsistence choices, and proxies of environmental constraints. We use Canonical Correspondence Analysis to explore the emerging patterns and find that subsistence strategy strongly impacts the choice of drought management strategies, especially if considered with a proxy of local environmental condition. Spatial proximity and aridity per se have only marginal impact, highlighting other relevant processes of cultural transmission that at least partly transcend (a) the intensity of human interaction over geographic gradients and (b) local adaptation primarily dependent on water availability. This study supports the wide applicability of quantitative and replicable methods to cross-cultural evidence on a variety of adaptive strategies and uses ethnographic data to propose new hypotheses that can inform future archaeological research by showing recurrent and non-case-specific choices highlighting resilient practices and adaptive behaviour in Africa.

**Keywords:** cross-cultural studies; Africa; drought; databases; quantitative approach; ethnoarchaeology



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## 1. Introduction

### 1.1. Drought in African Ethnography and Archaeology

Sustainability and resilience are key topics in current debates about policy making, but human societies have always implemented strategies to cope with changes in the climate and the environments where they have lived. The ethnographic study of traditional societies provides an overview on how human agency and creativity have shaped the coping strategies and the responses to such natural phenomena. The current work is a cross-cultural study of 35 societies in Africa that aims at investigating the strategies adopted to prevent, mitigate, and manage drought and its effects at political, social and economic levels. Although drought can be defined in several ways, the consensus considers as drought a period when a given area receives less precipitation than the average, reducing soil moisture and groundwater. The effects of drought vary according to both

intrinsic (e.g., magnitude and duration) and extrinsic (e.g., geomorphological context) factors. The impact of drought, however, largely depends on the socio-economic and cultural systems of the society experiencing the period of reduced precipitation. Since drought is a recurrent climatic feature in most parts of the world, most human societies have developed strategies to cope with this phenomenon. Since the late 19th century, ethnographers and anthropologists started to record cultural practices and socio-economic mechanisms set in place to prevent the effects and to minimize the impact of drought. Most of the ethnographic studies on drought focused on Africa, since the continent is home to a large extent of drought-prone drylands [1]. Drylands are areas extremely sensitive to climatic oscillations, where minor shifts in rainfall can trigger dramatic changes in the environment, heavily affecting human societies. Being one of the most recurrent ‘catastrophic’ events, the notion of drought has played a fundamental role in the reconstructions of past cultural trajectories in African archaeology. Mainstream theoretical approaches for the African archaeological past assume—either implicitly or explicitly—that episodes of drought prompted demographic drops, mass migrations, societal collapses, and/or deep restructuring of human societies. Several hypotheses have been suggested with respect to the impact and effects of drought in past African societies, the challenges that it posed, and the responses of human groups. In particular, the study of Holocene climatic fluctuations, and the response of prehistoric societies, have characterised the last 30 years of research into the recent African past. From the 1990s [2] up to more recent investigations [3–7], African cultural trajectories have been reconstructed as a consequence of climatic shifts, supported by C14-based models of human occupation [8].

### *1.2. Aim of the Present Study*

The objective of this study was to test the use of quantitative-based approaches to explore how to detect patterns of human behaviour from a freely accessible ethnographic database. In this paper, we use published ethnographic data to build ‘general models’ [9] for investigating the explanatory role and interaction of certain economic, ecological and geographic factors in the development of drought-coping strategies by human groups. These quantitative-based and data-driven models may also hold implications for the interpretation of the archaeological record. Furthermore, we use statistical techniques to explore possible correlations between the adoption of drought-coping strategies and the type of economy or environment, and if geographic vicinity influences instances of cultural transmission in relation to drought.

As opposed to qualitative and particularistic studies that focus on one or few societies, the quantitative analysis of human behavioural traits represents a large-scale approach to the ethnographic present, that allows the tackling and analysis of ‘big’ datasets to identify behavioural patterns. Anthropology, since its beginnings, has been characterized by comparative and cross-cultural studies [10–14]. Archaeological and evolutionary studies of the last four decades have increasingly incorporated statistical methods and techniques [15–18] to move beyond single case studies or limited comparisons, and to build more general behavioural inferences. In cultural evolution studies, advanced statistical techniques have also been successfully adopted to explore human cultures diachronically or genealogically [19]. While cultural evolution studies and cross-cultural research aim at building a ‘science of human behaviour’, archaeological research needs an empirically grounded framework that can identify material evidence in connection to behavioural traits and historical processes. In this respect, the work of L. Binford [20] has been fundamental for developing such correlates and for exploring large datasets in ethnoarchaeology (herby defined as the study of the present for archaeological purposes). However, notwithstanding the recent increase of research in this area [21], quantitative approaches are still few in the discipline [22].

## 2. Material and Methods

### 2.1. Data Search and Dataset Generation

Ethnographic data related to coping with drought in African societies was retrieved from the eHRAF world cultures database (<http://ehrafworldcultures.yale.edu>, accessed on 15 January 2019), which includes more than one million pages of primary sources from approximately 400 different societies. The eHRAF contains parts of texts from ethnographic documents that have been labelled according to their content and following the list of predetermined topics contained within the Outline of Cultural Materials, or OCM [23]. For the present study, we carried out a simple search, limited to the African continent, for paragraphs mentioning the word “drought”, narrowing results to exclude societies labelled as “commercial economy” and also “hunter gatherers” (see below). As a whole, we collected 747 entries, corresponding to 35 societies. The paragraphs containing the word “drought” were surveyed to extract the relevant information (see Table 1). The strategies adopted to cope with drought were then classified into a set of categories (see Table 2 for a summary on the strategies). Once the strategies were classified, the subsequent quantitative analysis (see S1 for the code used) considered three external factors to explain the observed variability.

**Table 1.** Example of the type of information retrieved from the eHRAF database (Boolean search: “all cultures” + “drought”, “commercial economy” excluded) showing African subregion (a), community (b), Outline of World Cultures code for that community (c), socioeconomic strategy (d), original database (namely, EA–Ethnographic Atlas, SCCS–Standard Cross-Cultural Sample, PSF–Probability Sample Files and SRS–Simple Random Sample (e) (see a detailed explanation in <https://ehrafworldcultures.yale.edu/webhelp/#Sampling/sampling.html> accessed on 15 January 2019) and, finally, retrieved paragraph (f) (search was carried out in January 2019).

a. Sub-Region	b. Culture	c. OWC	d. Subsistence Type	e. Samples	f. Text
Central Africa	Teda	MS22	Agro-pastoralists	EA, SCCS	Section: THE HISTORY OF TIBESTI, Page: [p. 20-A]. Search Result: For the next three hundred years we hear almost nothing of the Teda. Dalloni believes that the “first conquering tribes”—by which he probably means the Tomaghera, Gunda, and Arna—arrived in Tibesti in the seventeenth or eighteenth century. Some of the events mentioned in the traditional clan histories belong to this period. The distribution of clans and dialects in regions south of Tibesti suggests that many Teda from the massif have recently migrated to the Jurab, Egei, the Bahr el Ghazal, and the Lake Chad area, for better pastures and for arable land. Presumably such migrations have taken place in times of drought and famine.
Eastern Africa	Ganda	FK07	Intensive Agriculturalists	EA, PSF, SCCS, SRS	Section: SUBSISTENCE AGRICULTURE IN BUGANDA, Page: 38. Search Result: It seems that famines were relatively frequent, and serious, even in wealthy, fertile Buganda. With very little provision made for the processing and storage of food, the Ganda were seriously short of food in a drought if annual crops failed and bananas became scarce. Rainfall, as has been suggested, while seemingly quite adequate when seen in terms of average years, varies greatly from year to year and from area to area.

**Table 2.** Labels for the identified strategies to cope with the advent of drought or its effects, their corresponding definitions, and examples from the database.

Code	Description	Example (#Entry, Society, Economy, Text, Reference)
SS	The society enables mechanisms of support to individuals or families (e.g., loans, gifts, hospitality), postpones social events (e.g., marriages, births) and prevents possible demographic growth	<p>Entry #486: Turkana, Pastoralists. Just as there are traditional means of coping with the stresses associated with drought, there are traditional means of helping families recover from drought. These include a shift of dependents from poorer families to more wealthy families, begging or borrowing livestock from friends and relatives, exchanging large stock for small stock, and marrying eligible daughters.</p> <p>McCabe, J. Terrence. 1990 "Success and Failure: The Breakdown Of Traditional Drought Coping Institutions Among The Pastoral Turkana Of Kenya" in <i>Journal Of Asian And African Studies</i> 25 (s 3–4). Leiden: 146–60. <a href="http://ehrafworldcultures.yale.edu/document?id=f117-045">http://ehrafworldcultures.yale.edu/document?id=f117-045</a> accessed on 15 January 2019</p>
SM	Changes in routes as well as increases or decreases in residential mobility to cope with altered resource distribution	<p>Entry #25: Rwandans, Agro-Pastoralists [ . . . ]. The Tutsi were not nomadic pastoralists. Cattle moved according to the seasons from valleys to hills, but usually in the same area. It might happen, however, that when the drought was particularly severe, herds had to be led to another area which might be some distance away. But this did not imply any change of residence for the owners of the cattle which were accompanied only by shepherds.</p> <p>Maquet, Jacques Jrme Pierre. 1961. <i>Premise of Inequality in Ruanda: A Study of Political Relations In A Central African Kingdom</i>. London: Oxford University Press for the International African Institute. <a href="http://ehrafworldcultures.yale.edu/document?id=fo57-006">http://ehrafworldcultures.yale.edu/document?id=fo57-006</a> accessed on 15 January 2019.</p>
MG	Migration to other areas when the original setting is no longer suitable	<p>Entry #593: Dogon, Intensive Agriculturalists [ . . . ]. On the plateau, and especially in the plains, the villages have become the centres of wide circles of desert, where the combined efforts of man and cattle have stripped the soil of its fragile vegetative cover. Migration has started towards the south of Mali, in Bambara country, and towards the Mossi area of Burkina Fasso.</p> <p>Van Beek, W. E. A. 1993. "Processes And Limitations of Dogon Agricultural Knowledge" in <i>Anthropological Critique Of Development: The Growth Of Ignorance</i>. London: Routledge. <a href="http://ehrafworldcultures.yale.edu/document?id=fa16-030">http://ehrafworldcultures.yale.edu/document?id=fa16-030</a> accessed on 15 January 2019</p>
EM	Temporary abandonment of traditional activity and shift to another type of economic activity (e.g., wage labour)	<p>Entry #344: Turkana, Pastoralists [ . . . ]. As a result of the drought, the family was split. Nari, his wives, and a widowed sister remained active pastoralists. The remaining half of the extended family sought other forms of subsistence.</p> <p>Dyson-Hudson, Rada, and J. Terrence McCabe. 1985. "South Turkana Nomadism: Coping with an Unpredictably Varying Environment." Hraflex Books, <i>Ethnography Series</i>. New Haven, Connecticut: Human Relations Area Files. <a href="http://ehrafworldcultures.yale.edu/document?id=f117-003">http://ehrafworldcultures.yale.edu/document?id=f117-003</a> accessed on 15 January 2019</p>
CR	Performance of rituals to prevent the risk and mitigate the effects of drought	<p>Entry #5: Azande, Horticulturalist [ . . . ]. In times of drought, when there is danger that the crops may die from lack of moisture, or in times of serious pestilence, a ceremony takes place at the suggestion of ghost diviners (aboro atoro) who are instructed to initiate it by directions from Mbori or from the ghosts of the dead in dreams, in cultivations and at sources of streams.</p> <p>Evans-Pritchard, E. E. (Edward Evan. 1936. "Zande Theology" in <i>Sudan Notes and Records</i>. [s.n.]. <a href="http://ehrafworldcultures.yale.edu/document?id=fo07-005">http://ehrafworldcultures.yale.edu/document?id=fo07-005</a> accessed on 15 January 2019</p>

Table 2. Cont.

Code	Description	Example (#Entry, Society, Economy, Text, Reference)
RC	Shift to cultivation of drought resistant species, until drought persists	<p>Entry #580 Bambara, Agro-Pastoralists. Since the 1973 drought, farmers in Kala have been shifting their resources out of long, and towards shorter, cycle crops that take only 60 to 80 days from sowing until ready to harvest, and groundnuts have lost their role as the main cash crop.</p> <p>Toulmin, Camilla. 1992. Cattle, Women, and Wells: Managing Household Survival in The Sahel. Oxford [England]: Clarendon Press?; Oxford University Press. <a href="http://ehrafworldcultures.yale.edu/document?id=fa08-010">http://ehrafworldcultures.yale.edu/document?id=fa08-010</a> accessed on 15 January 2019</p>
DT	Changes in food and alimentary habits to face food shortage generated by drought	<p>Entry #207: Nuer, Agro-Pastoralists. In famine years much greater attention is paid to the wild harvest. 'Wild dates' are then a great stand-by and people eat a wide range of fruits, ripening mainly in the early part of the drought, which they neglect when hunger is not severe, and make use of bush-yams and the seeds of wild sorghum and other grasses.</p> <p>Evans-Pritchard, E. E. (Edward Evan). 1940. Nuer: A Description of The Modes of Livelihood and Political Institutions of a Nilotic People. Oxford: At the Clarendon press. <a href="http://ehrafworldcultures.yale.edu/document?id=fj22-001">http://ehrafworldcultures.yale.edu/document?id=fj22-001</a> accessed on 15 January 2019</p>
LM	Changes in livestock management	<p>Entry #255: Somali, Pastoralists [ . . . ]. As drought intensifies, however, the Reer shifts its strategy from one of hoarding to one of selective depletion. The deliberate slaughter and sale of livestock is one indication of this shift.</p> <p>Cassanelli, Lee V. 1982. Shaping of Somali Society: Reconstructing the History of a Pastoral People, 1600-1900. Ethnohistory. Philadelphia: University of Pennsylvania Press. <a href="http://ehrafworldcultures.yale.edu/document?id=mo04-033">http://ehrafworldcultures.yale.edu/document?id=mo04-033</a> accessed on 15 January 2019</p>
CM	Changes in crop management (scheduling, programming)	<p>Entry #512: Libyan Bedouin, Pastoralists [ . . . ]. The farmer needs to know how much of the rainy season is left and, therefore, how much rain crops planted at a particular date are likely to receive before the summer drought sets in.</p> <p>Behnke, Roy H. 1980. Herders Of Cyrenaica: Ecology, Economy and Kinship Among the Bedouin Of Eastern Libya. Illinois Studies in Anthropology. Urbana: University of Illinois Press. <a href="http://ehrafworldcultures.yale.edu/document?id=mt09-014">http://ehrafworldcultures.yale.edu/document?id=mt09-014</a> accessed on 15 January 2019</p>
BD	Building of water harvesting/collection facilities (e.g., dams, barrages, wells)	<p>Entry #103: Konso, Intensive Agriculturalists [ . . . ]. In order to cope with drought, and to conserve the heavy rain that falls so unevenly, many cisterns and cattle pools have been dug and in a few places huge reservoirs have been constructed, to contain the rainwater for cattle in the dry months.</p> <p>Hallpike, C. R. (Christopher Robert). 2008. Konso of Ethiopia: A Study of the Values of an East Cushitic People. Central Milton Keynes: AuthorHouse. <a href="http://ehrafworldcultures.yale.edu/document?id=mp17-004">http://ehrafworldcultures.yale.edu/document?id=mp17-004</a> accessed on 15 January 2019</p>

1. The Subsistence Type (ST).
2. The environmental characteristics as expressed by the Aridity Index (AI).
3. The Spatial distance between societies (Sp).

#### 2.1.1. Variable 1: Subsistence Type (ST)

We examined only subsistence-oriented societies, as defined by the eHRAF (i.e., 'pastoralists', 'agro-pastoralists', 'horticulturists', 'intensive agriculturalists'), not considering the eHRAF categories 'commercial economy', in order to exclude market-oriented groups (i.e., not subsistence-oriented societies), and 'hunter-gatherers' (for more information about how eHRAF classifies societies according to their subsistence type see eHRAF user's guide



section at <https://ehrafworldcultures.yale.edu/webhelp/#Subsistence/subsistence.html> accessed on 15 January 2019).

Hunter-gatherers were excluded because only limited information was available (only two societies were retrieved from the eHRAF database when searching for drought-related information). When, for a given society, the eHRAF database indicated ‘other subsistence type’ we allocated the type of category ourselves (changes are indicated by an asterisk in Table 3) choosing the most appropriate category after careful examination of the original sources (for instance, the Hausa, who mainly raise crops and livestock, were classified as agro-pastoralists for the sake of this study).

**Table 3.** The dataset, names of the societies, the three variables analyzed in this study, ST, AI (expressed as the mean and the variance extracted from the polygons representing the territory of each society), and Sp, and the strategies adopted. Asterisks (\*) indicate the fields that were manually changed from the field retrieved in the eHRAF (see text).

Culture eHRAF	Subsistence Type eHRAF	Aridity Index (Mean)	Aridity Index (Variance)	Longitude (Centroids)	Latitude (Centroids)	Strategies
Akan	Horticulturalists	0.8004	0.0362	−2.2633	7.1662	SM, CM
Amhara	Intensive Agriculturalists	0.5297	0.0423	38.4798	11.0738	CR, RC
Azande	Horticulturalists	0.9566	0.0264	26.4763	4.607	CR
Bambara	Agro-pastoralists *	0.3208	0.0162	−6.9646	12.8719	CR, RC, SS, LM, EM, CM
Bemba	Horticulturalists	0.5841	0.0077	29.1114	−11.6733	CR
Bena	Horticulturalists	0.883	0.0331	34.913	−9.242	CR
Berbers of Morocco	Agro-pastoralists	0.1558	0.0128	−6.3471	31.8819	SS, EM, CM, MG
Chagga	Intensive Agriculturalists	0.6448	0.1323	37.2273	−3.2373	CR
Dogon	Intensive Agriculturalists	0.1595	0.0023	−3.1987	14.4936	CR, SM, DT, SS, BL, CM, MG
Ganda	Intensive Agriculturalists	0.7268	0.0113	31.9222	0.6379	CR, RC, DT
Gikuyu	Intensive Agriculturalists	0.6771	0.1058	36.9819	−0.4119	CR, SM, SS
Hausa	Agro-pastoralists *	0.2886	0.0142	7.0046	12.3422	CR, SS, LM, CM, MG
Igbo	Horticulturalists	1.3348	0.0608	7.2916	6.0772	CR, DT, SS, CM
Ila	Horticulturalists	0.3989	0.0007	26.409	−15.387	DT, SS, CM
Konso	Intensive Agriculturalists	0.3049	0.0048	37.3794	5.3599	CR, SS, BL
Libyan Bedouin	Pastoralists	0.0186	0.0009	17.1782	28.1892	SM, SS, BL, LM, CM
Lozi	Agro-pastoralists *	0.3589	0.0036	23.4021	−16.0806	SM, SS, BL, EM, CM
Luo	Intensive Agriculturalists	0.6539	0.0211	34.3659	−0.4611	CR, RC
Maasai	Pastoralists	0.4319	0.024	36.4179	−2.9919	CR, SM, DT, SS
Mende	Horticulturalists	1.6731	0.0111	−11.5221	7.9944	MG
Mossi	Intensive Agriculturalists	0.3547	0.0187	−1.1199	12.7668	CR
Nuer	Agro-pastoralists	0.3997	0.0014	31.7942	8.3143	CR, SM, DT, SS

Table 3. Cont.

Culture eHRAF	Subsistence Type eHRAF	Aridity Index (Mean)	Aridity Index (Variance)	Longitude (Centroids)	Latitude (Centroids)	Strategies
Nyakyusa and Ngonde	Intensive Agriculturalists	1.0673	0.02	33.6828	−9.4388	CR, DT
Ovimbundu	Horticulturalists	0.6231	0.0265	15.4132	−12.7292	CR, DT, MG
Rwandans	Agro-pastoralists	1.0359	0.1065	29.306	−2.2449	CR, SM
Shilluk	Agro-pastoralists	0.2862	0.0033	32.0036	10.461	SS
Shona	Agro-pastoralists *	0.4029	0.0132	31.5266	−18.7024	CR, SM, DT, SS, LM, EM
Somali	Pastoralists	0.1322	0.0053	44.5681	5.7355	CR, SM, SS, LM, EM, MG
Tallensi	Intensive Agriculturalists	0.4283	0.0002	−1.6519	10.7669	CR, DT, SS
Teda	Agro-pastoralists	0.014	0.0002	17.5601	18.7242	CR, SM, EM
Tonga	Horticulturalists	0.356	0.0031	27.2591	−16.5172	CR, SM, DT, SS, LM, EM, CM, MG
Tsonga	Agro-pastoralists *	0.3657	0.0087	32.9101	−23.2757	DT, SS
Tuareg	Agro-pastoralists	0.0268	0.0008	6.3708	20.4567	SM, DT, SS, LM, EM, CM, MG
Turkana	Pastoralists	0.1754	0.0061	35.5107	3.3158	CR, SM, DT, SS, BL, LM, EM, MG
Yoruba	Horticulturalists	0.8469	0.061	4.1093	7.8462	SS

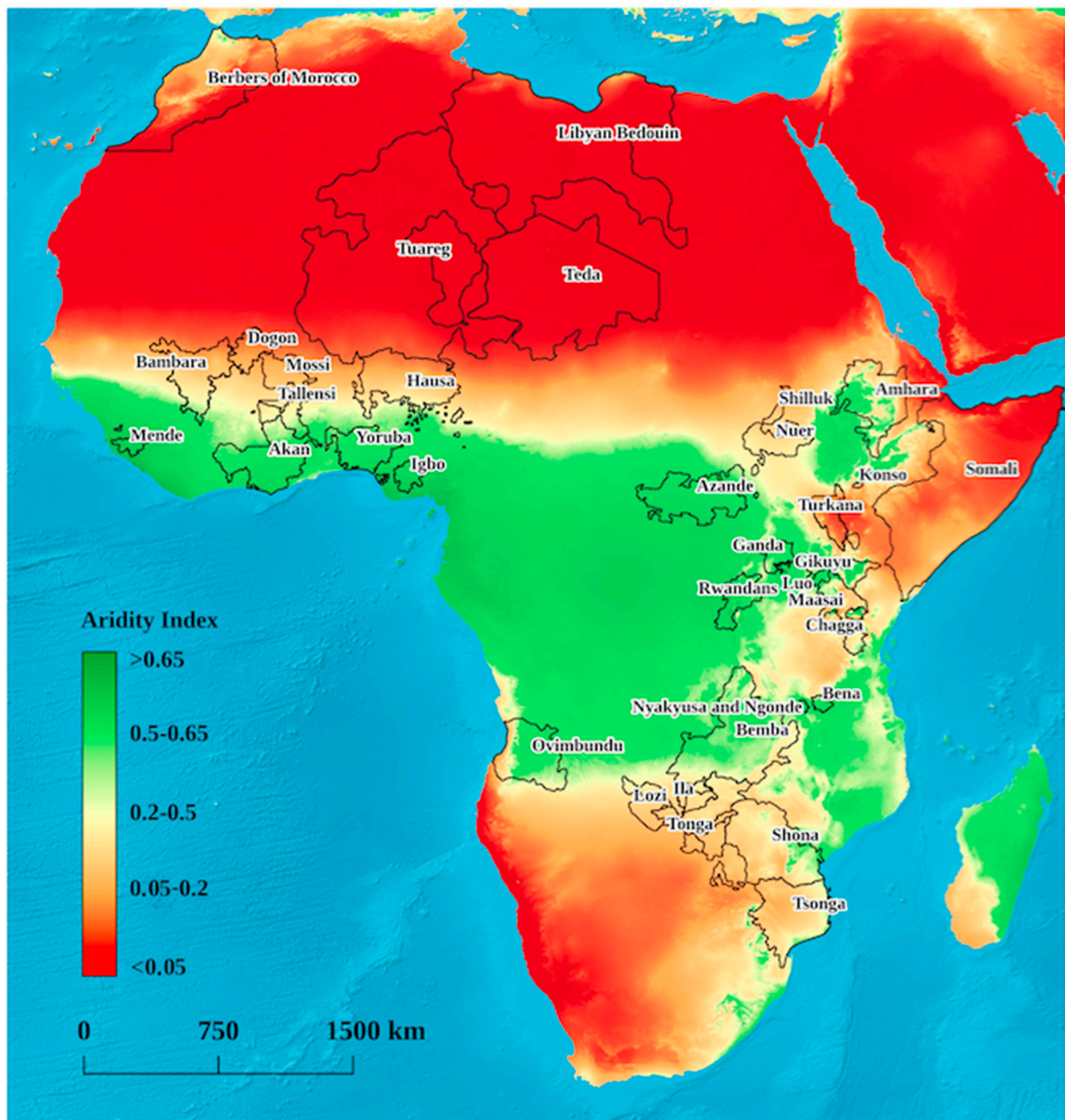
### 2.1.2. Variable 2: The Environmental Characteristics as Expressed by an Aridity Index (AI)

The 35 societies chosen for the study were identified in the Georeferencing of Ethnic Groups (GREG) dataset [24], which employs geographic information systems (GIS) to represent group territories as polygons, provided independently of state boundaries (Figure 1). An Aridity Index (AI), a numeric indicator of the degree of dryness, is applied to define the environmental conditions of each polygon. We used the Global Aridity Index [25,26] adopted by the United Nations Environmental Programme [27], which is expressed as  $AI = MAP/MAE$  (Aridity Index = Mean Annual Precipitation / Mean Annual Potential Evapo-Transpiration). According to these widely accepted values, five classes of climate can be distinguished: hyper-arid (AI: <0.05), arid (AI: 0.05–0.2), semi-arid (AI: 0.2–0.5), dry sub-humid (AI: 0.5–0.65) and humid (AI: >0.65). Table 3 reports the average value of the AI for each society's polygon and their variance.

### 2.1.3. Variable 3. The Spatial Distance between Societies (Sp)

Given that social networks facilitate cultural transmission, we considered that the choice of drought-coping strategies may be affected by the spatial distance between societies. Populations that are closer in space may exhibit a higher degree of similarity in many traits (including genetics, biological, linguistic, cultural), which could imply that societies that are geographically closer may adopt more similar strategies [18]. Indeed, inferences of cultural transmission can be present when different societies come into continuous contact. To assess the role of proximity, we adopted an equidistant projection (Pate Carrée) and calculated the minimum distance between the territories of influence of each society as represented by the polygons (see Section 2.1.2). Furthermore, the explanatory variables used to evaluate the role of proximity were generated through Principal Coordinates of Neighbour

Matrices (PCNM) [28], consisting of a spatial eigenfunction analysis which summarizes the geographic variation according to different (mutually orthogonal) spatial scales.



**Figure 1.** Map of Africa featuring the Aridity Index (25,26) and the polygons corresponding of the territories of the 35 studied societies. Sources: [27] and Natural Earth <https://www.naturalearthdata.com/> accessed on 1 June 2019.

## 2.2. Data Analysis

Exploratory analysis of the patterns emerging from the comparison between subsistence strategies, environmental proxies, spatial distance, and the dependent variables was carried out using a constrained (or canonical) ordination analysis generating a diagram that visually represents the association of the chosen variables with the societies under study and allowing to formally test the significance, and assess the relative importance, of the external variables in the configuration of drought-coping strategies.

We placed the drought-mitigation strategies on an indicator matrix of cases  $\times$  variables in which rows represent societies and columns the presence-absence of drought-coping



strategies, coded as dummy variables (i.e., expressing presence/absence through 0/1 values). The obtained data matrix was analysed using Canonical Correspondence Analysis (CCA), with subsistence type (ST), aridity (AI), and spatial proximity (Sp) as separated sets of explanatory variables. CCA was chosen because it preserves the chi-square ( $\chi^2$ ) distance between pairs of sampled societies, avoiding any association caused by the presence of shared absences (double-zeros; [29], p. 309). When using this method, the ordination space in which sampled societies can be explored is constrained by the chosen external explanatory variables. The final ordination dimensions of CCA are, in fact, those that are best explained by weighted linear combinations of the explanatory variables (via multiple regression; a complete description of the theory and algorithms can be found in [29–31]). Therefore, the restricted subspace of CCA is only a fraction of the total inertia (i.e., the total deviation of the indicator data matrix from a null model of independence between pairs of sites/pairs of variables) that can be obtained by using simple Correspondence Analysis. If the constrained inertia obtained by CCA is divided by the total inertia of the indicator matrix, the obtained index represents the proportion of total variation in the data explained by the chosen external variables and can be considered as a coefficient of determination ( $R^2$ ).

The significance of the relationship between the explanatory variables and the observed variability in drought-coping strategies was formally tested against the null hypothesis of independence by randomly permuting residuals of CCA ( $n = 9999$ ; [32]) and measuring the F ratio between the inertia obtained in the canonical analysis and that resulting from permutation (see [29], pp. 661–673). Significance level was set at  $\alpha = 0.05$  for a one-tailed test. Finally, we assessed the relative impact of each explanatory variable through variance partitioning using standard techniques [32,33]. We fitted the observed distribution of drought-coping strategies against all possible combinations of explanatory variables using Partial Canonical Correspondence Analysis (pCCA) and obtained a measure of unique and shared variance (adjusted  $R^2$ ) for each of them, which we used to identify the model that best explained variation in our dependent variable. The distribution of societies and drought-coping strategies in the new ordination space was visually explored using both asymmetric scaling focused on variables and symmetric scaling ([31], pp. 65–72).

### 3. Results

Results of permutation tests show that all three sets of explanatory variables were significantly associated with the distribution of drought-coping strategies (Table 4). As far as spatial proximity (Sp) is concerned, only the first PNCM vector yielded significant results.

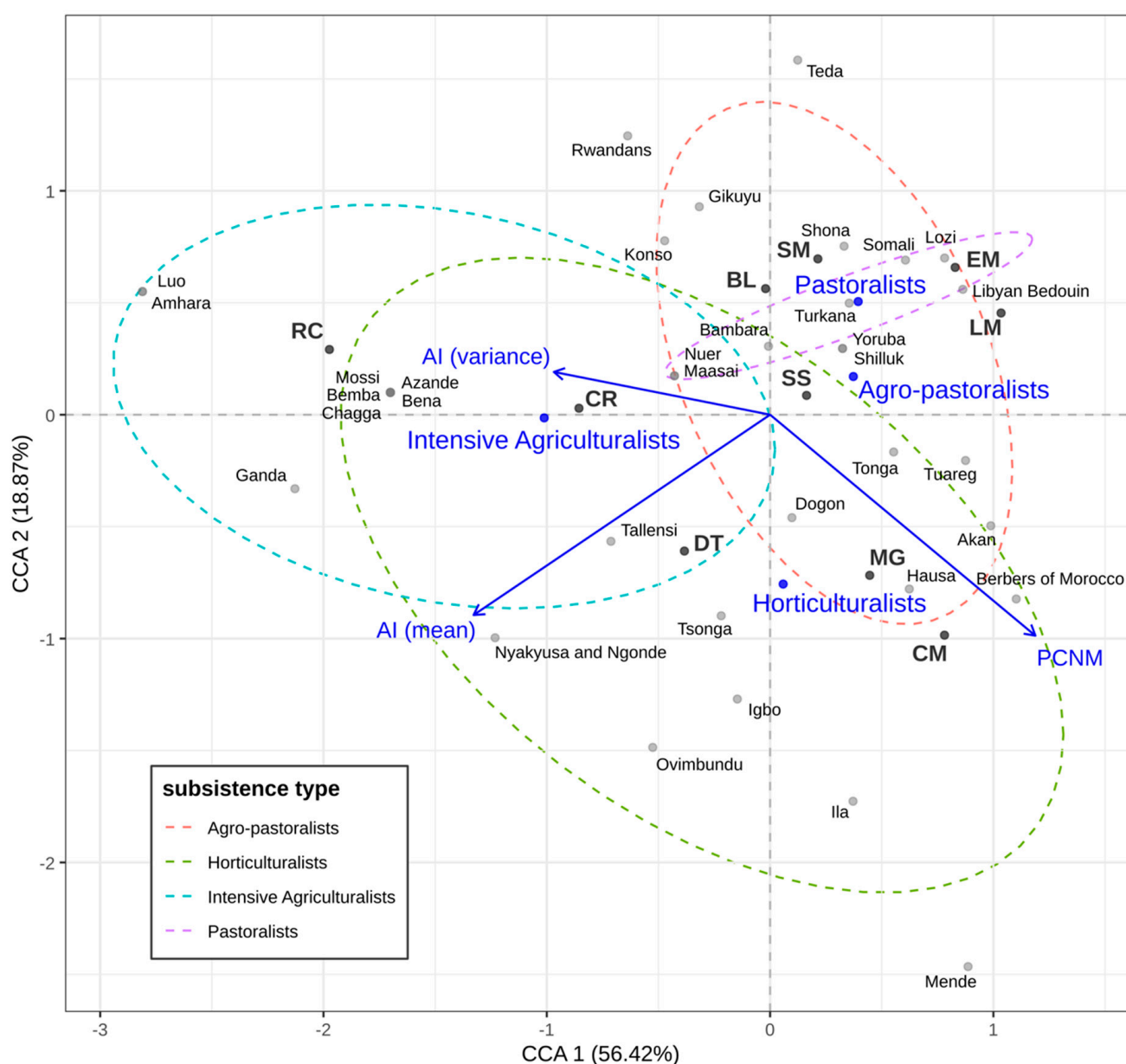
**Table 4.** Permutation test of the variables used in this study.

	<b>R2</b>	<b>adj. R2</b>	<b>p-Value</b>
Subsistence Type	0.1520	0.0711	0.0113
Aridity Index	0.1071	0.0525	0.0198
Spatial Component	0.0593	0.0311	0.0344
Full Model	0.2665	0.1118	0.0061

Turning instead to the fraction of total variance ( $R^2$ ) explained by each independent variable (ST, AI, and Sp), all of them, when taken individually, returned a rather low values (Table 4, while their relative importance suggests a comparatively higher relevance of Subsistence Type (15.20%), followed by Aridity Index (10.71%), and Geographic Distribution (5.93%). The full model comprising all three variables at once explains 26.65% of the total inertia (Table 4), and the result is once again significant ( $F [6,28] = 1.695$ ,  $p = 0.006$ ).

The ordination analysis shows that the first two axes represent 75.29% of the inertia captured by CCA. Sampled societies are unevenly distributed in the resulting ordination space (see Figure 2), and each subsistence strategy group exhibits a different degree of inner homogeneity. Horticulturalists are the most dispersed in the ordination space, followed

by Intensive Agriculturalists and Agro-Pastoralists, while Pastoralists are less dispersed. Intensive Agriculturalists and Horticulturalists partially intersect, although Intensive Agriculturalists are generally more segregated. Agro-Pastoralists slightly intersect with both groups (especially at the crossing of the ordination axes). Finally, Pastoralists look like a sort of subset of Agro-Pastoralists, since they do not occupy a defined space of their own. With respect to specific strategies (Table 5), change in the management of crops (CM) and the shift towards more resilient species (RC) are the strategies adopted by sedentary cultivators (top left of the diagram in Figure 2), while mobile pastoralists and agro-pastoralists tend to respond with livestock management (LM) and contraction/expansion of annual mobility (SM). In terms of agricultural practices, Horticulturalists focus on the strategy of managing the crops (CM) while Intensive Agriculturalists tend to adopt drought-resistant species (RC). Pastoralists and Agro-pastoralists seem to be prone to temporarily change their main occupation (EM) and, at least today or in the recent past, they seek employment when they experience heavy losses in livestock.



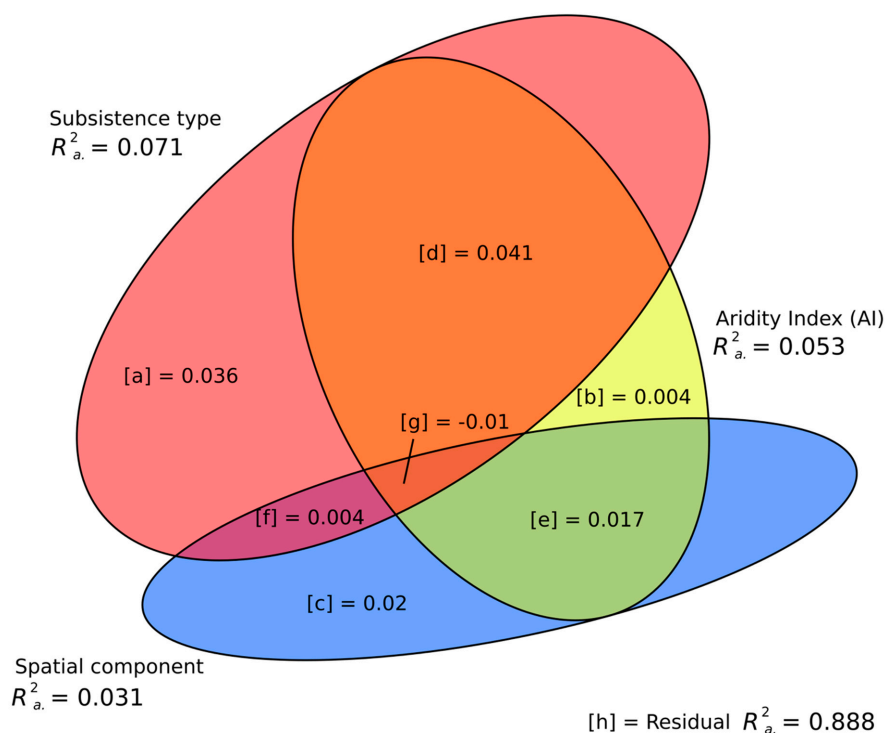
**Figure 2.** Canonical Correspondence Analysis (CCA), with symmetrical scaling and 0.68 confidence level for ellipses.

**Table 5.** List of strategies to cope with drought sorted by Subsistence Type (ST).

	CR	SM	RC	DT	SS	BL	LM	EM	CM	MG
Agro-pastoralists	6	6	1	4	9	1	4	6	5	3
Horticulturalists	6	2	0	4	4	0	1	1	4	3
Intensive Agriculturalists	10	2	3	4	4	2	0	0	1	1
Pastoralists	3	4	0	2	4	2	3	2	1	2

Strategies related to forms of social support (SS) are displayed at the centre of the diagram (Figure 2), highlighting that social support mechanisms are widespread in all investigated societies, regardless of their main subsistence type. The occurrence of ceremonies (CR) is mostly associated with Intensive Agriculturalists and refers to formal religious occasions to propitiate rains and good harvests. Finally, the construction of physical structures to harvest or store water (BD) occurs in a few cases across the different societies, and it is a strategy occasionally recorded throughout the continent.

A Venn diagram (Figure 3) is used to show the results of our analyses in an easy to read manner. Subsistence Type is the variable with the highest explanatory power, even when taken on its own. As shown in Figure 3, the intersection between ST and Aridity Index generates the largest explanatory area in the diagram space. Nevertheless, AI per se does not explain much of the variability, and it is consistently associated with Spatial component Sp, which in turns reflects a certain degree of spatial autocorrelation or proximity dependence for this environmental proxy. At the same time, intersection between ST and Sp is rather small, confirming an independence of the ST from the spatial structure of the dataset. Given the prominence of the Subsistence Type, our analysis suggests that the observed pattern can be attributed to social and cultural processes that do not entirely depend on geography and human interaction.



**Figure 3.** Venn diagram representing the result of variation partitioning. Each fraction of variation (letters [a] to [h]) show its corresponding value of adjusted R<sup>2</sup>. Diagram drawn using eulerAPE 2.0.3 [34].

## 4. Discussion

### 4.1. General Scope and Limitations of the Current Study

The current study is based on one of the few big data repositories for ethnographic information, the eHRAF. Despite its richness, the eHRAF cannot be considered an exhaustive record of instances of drought-related strategies, because drought events are often unpredictable and erratic, and they might have escaped direct observation by ethnographers. Such a character implies that these events might not have been recorded in a consistent manner. Furthermore, earlier ethnographies might not have recorded environmentally related practices because an interest in environmental transformations and changes in natural resources in respect to societal dynamics only started to be appreciated from the 1960s, together with the popularization of the concept of ecology at large. The combination of the theoretical shift and the sequence of droughts afflicting Africa between the end of the 1960s and the early 1980s made droughts a topic of relevance for the continent and highlighting Africa as prone-to-drought area. Although 35 societies represent an acceptable sample from a statistical point of view, they do not include all the societies that compose the African continent. Taking into consideration these shortcomings, the current paper represents a test to critically explore the potential and the limitations of a quantitative-based approach to study the complexity of human behaviour from legacy data of an ethnographic database.

The investigation of such a database using our methodology allows us to create ethnographically grounded models to generate or corroborate hypotheses for the interpretation of the archaeological record. In our work, we do not aim at providing a direct analogy from the ethnographic present to the past. Rather, we employ a statistical approach to identify behavioural patterns that can be used to generate frames of reference for the study of the past. Ethnoarchaeology has traditionally focused on the material correlates of human behaviour, mostly dealing with artefacts, their production, use, and discard. However, recent expansions in scope and aims (see [21] for a thorough review) shows that ethnoarchaeology can approach all dimensions of human societies by diversifying the interpretative level to include gender dimensions, consumption processes, the ritual aspect, and labour investment, and actively contribute to a global understanding of human societies. The identification of human behavioural patterns represents a first step towards achieving this goal, allowing association of these patterns with the empirical record to which they are connected.

### 4.2. Implication for Understanding the Present

The results of this study shows that among current African ethnographic societies there is a certain degree of similarity in the strategies adopted to cope with drought, that such strategies are often linked to the type of subsistence and that environmental conditions, and are significant in the development of such strategies. The combination between ST and AI provides a higher degree of explanation of the strategies adopted, showing that these two variables (and their interactions) are key in determining human responses to drought. However, we determined that the strategies adopted by societies, while influenced by the environmental settings, are shaped by human agency. The lower explanatory value associated with the environmental conditions (AI) alone clearly shows that the environmental settings per se play a lesser role in shaping such strategies, while it becomes significant when associated with a social variable (the type of economy–ST). The physical distance between societies (Sp) generally explains only a small fraction of the total variability in drought-coping strategies, even when associated with other variables (ST and AI). This suggests that cultural transmission between societies that are geographically close does not play an important role in shaping the response to drought, at least for the societies of our study sample.

Further insights from our results are related to the distribution of specific strategies in the different socio-economic groups of our sample. In general, cultivation with sedentism (and the associated issues of land tenure) decreases the range of implemented strategies. Settled cultivators (Intensive Agriculturalists and Horticulturalists), for whom the primary

resources are fixed in space (e.g., the fields), seem to implement a narrower set of options focusing on in situ management of the negative effect of drought to protect the invested capital (e.g., the seeds/crops) (RC, CM). On the contrary, societies whose subsistence is mainly linked to livestock are by nature more mobile and also more prone to (nonpermanent) changes in lifestyle. Livestock represents mobile capital, and it can be temporarily relocated to better environmental settings in case of drought (LM, SM). Such strategies allow maintenance of a certain level of economic security (the herd is kept alive and therefore there is no major loss of capital) while waiting for the amelioration of the environmental conditions. This approach has a higher degree of flexibility in respect to those than can be put in place by societies fully involved in cultivation. In addition, the spatial flexibility of societies with an important pastoral component (Pastoralists and Agro-Pastoralists) gives the possibility to people to take advantage of job opportunities outside their usual settled areas (EM).

The widespread importance of Social Support (SS) arising from our analysis reveals that relief mechanisms related to adverse conditions permeate all types of societies of our sample. Social rules and habits can be molded to or re-arranged in the event of drought, in order to lower food consumption (for instance most celebrations such as those related with marriages are cancelled), to foster cooperation (in case of difficulties in keeping the herds alive, some animals can be given as a present, which in return build reciprocity nets), or by adopting other measures that lower the population density and pressure over water resources (such as postponing marriage and birth-related ceremonies, or by sending children with relatives in other less affected areas). The role of 'religious acts' in psychologically coping with disasters or negative events has recently been re-examined [35]. When in our study sample we take into consideration ceremonies and rituals (CR), it is obvious that the use of religious acts (intended in the widest definition) for dealing with adverse external conditions is an important strategy. This strategy is embodied in a set of diverse rituals mostly connected to rain-making and/or for propitiating the harvest, and it is clearly more developed by Intensive Agriculturalists and Horticulturalists.

## 5. Conclusions

The results from this paper show the potentials and the limitations of the application of cross-cultural studies from ethnographic legacy databases in analysing human behaviour. Ethnographic databases are an underexploited resource for envisaging a different approach in ethnoarchaeology, one based on quantitative data. They unlock the opportunity offered by large datasets that, albeit collected in the present (or in the recent past), represent an extensive archive of human behaviour. Statistical approaches applied to such databases can help in the understanding of social and cultural dynamics at a large (global) scale. The African ethnographic present used in this study is key to building models to explore past historical dynamics in the continent and beyond. The expansion of land prone to drought is a critical issue during current climate change conditions, and an explorative approach to ethnographic data at the continental or global scale can boost our understanding of human agency with respect to such change, overcoming limiting and deterministic approaches. Drought, beyond being a negative circumstance, can be an initiator of social and economic change. The responses given by African societies to drought are part of a still poorly known repertoire of ecological knowledge that deserves far more attention, not only historically and anthropologically, but also from other disciplines, such as ecology, agronomy, and livestock management. Generating substantial knowledge about management of drought and the historical depth of such management is of wider concern, since it includes the study of the factors (the type of economy and the environment) that hold relevance in sustainably managing such arid spells. There is no need to say that reconstructing the past with ephemeral and scarce material evidence is a hard task, but the identification of patterns of behaviour, such as the strategies to cope with drought, and their understanding, can provide a reliable interpretive framework also for designing sustainable and acceptable futures.



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