CLIMATIC CORRELATES OF HUMAN SUBSISTENCE: A GLOBAL ANALYSIS

DE SOUZA, R.G.*[1] – MIRAZÓN LAHR, M.[2]

[1] *Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural – INCAPER - Rod Br 262 Km94, Fazenda do Estado Domingos Martins, Espírito Santo, Brasil. CEP 29375-000 (phone:+55-27-3248-1195)*

[2] *Leverhulme Center of Human Evolutionary Studies, The Henry Wellcome Building University of Cambridge, Fitzwilliam Street, Cambridge, United Kingdom CB2 1QH (e-mail: mbml1@cam.ac.uk)*

**Corresponding author*
e-mail: roberta.souza@incaper.es.gov.br

(Received 29th May 2014; accepted 2nd Sep 2014)

Abstract. Subsistence links the behavioural and biological dimensions of human adaptability. We perform a cross-cultural investigation over an unpublished database containing approximately 2,700 ethnographic populations. The distribution of those *Basic Economies* is analysed by *Latitude, Temperature* and *Rainfall.* Results show unequal geographic distributions, although the climatic variables are not good discriminators in all cases. Two strategies (*Food production with fishing/foraging,* and *Foraging/fishing*) are distinct. The generalist form composed by extensive agriculture, coupled with foraging and fishing, is the most adaptable and widespread form of food acquisition. The exceptions are cold deserts, which foragers/fishers provide the best fit to the marginality concept.
Keywords: *subsistence strategies, hunter-gatherers, marginality, cross-cultural analysis*

Introduction

Subsistence and reproduction are the most apparent links between the behavioural and the biological dimensions of life. They are key to the understanding of human adaptation and adaptability to environmental conditions. In terms of subsistence, humans have developed a range of strategies based on different combinations of two basic activities: to produce their own food (by controlling the reproduction of either or both animals and plants) or to forage (by collecting food from the natural ecosystem). However, the climatic correlates of those choices remain poorly explored.

Review of Literature

The Ethnographic Atlas (Murdock, 1967) was a milestone in cross-cultural analyses of ecological constraints, social relations, biological diversity, and culture. Among its 229 hunter-gatherer populations, animal foods are relatively constant (26–35% subsistence), regardless of latitude (Cordain et al., 2000). In contrast, plant foods decrease with increasing latitude, reaching a threshold at 40° N or S. No human groups were found to rely mostly or wholly on gathering plants.

Kelly (1999) investigates the relationship between the plant component of human diet and climate further. He uses “Effective Temperature” (ET= 18W–10C/(W- C) + 8, where W= mean temperature of the warmest month, and C= mean temperature of the coldest month) and “Primary Production” (PP, a measure of plant biomass in the

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

environment) to predict gathering dependence of 123 North American foraging groups. Both variables are related to the percentage of plants in the diet ($r=0.75$, $p<0.01$), but not of meat. The resulting relationship between the dependence on plant foods and climatic and environmental patterns reveals the presence of dietary complements in the form of aquatic resources and traded foodstuffs. Arctic populations are an example. Living in an environment of high aquatic productivity, they seem to replace plants for aquatic animals. Other studies that have addressed the issue of what factors shape the geographic distribution of human subsistence strategies have used somewhat different climatic and/or environmental predictors. So Binford (2001) uses Mean Annual Temperature as environmental covariant in his analyses, and both him and Marlowe (2005) use Primary Biomass (kg/m^2) as a measure of environmental productivity. Similar to the results obtained by Kelly (1999), these studies provide further evidence for the increased importance of fishing and hunting near the Poles as primary biomass decreases.

Therefore, the most useful correlations between subsistence and the environment are revealed by meteorological phenomena. These variables are the least affected by human activity, and are systematically and continuously recorded (Ellen, 1982), and as the studies above show, they play a critical role in constraining the possible geographic extent of particular modes of subsistence, specially at the extreme ends of the environmental gradient.

While it may be expected that foragers are more vulnerable to climatic and environmental factors, agriculturalists also deal with environmental limitations. Decreasing ecosystem diversity and the reliance on a small number of species make farmers susceptible to environmental fluctuations. This raises the issue of how such potentially unstable systems could spread so widely around the World.

It is generally accepted that all contemporary foragers are aware of the techniques of food production in that they understand the process (means, timing, etc.) of the reproduction of the plants and animals they consume in a regular basis which would allow them to control productivity. Nonetheless, the transition from foraging to farming requires radical shifts in behaviour, which have high adaptive costs. The causes, conditions and circumstances surrounding the origins of agriculture have been and continue to be the subject of intense study. Although numerous and different local factors seem to have shaped the timing and nature of the transition in different parts of the world, it has become clear that the spread of agriculture is related to population densities. Hunter-gatherers live at a density of *ca.* $0.1/km^2$, while rice agriculturists in Java, for example, live at $1{,}000/km^2$, a ten-thousand-fold difference (Kennett and Winterhalder, 2006). Considering there are more than seven billion people alive (USCB), agriculture seems the inevitable means of food procurement. In spite of that, contemporary hunting and gathering is a reality under specific conditions, in particular, in ecologically marginal areas where farming is unsustainable. Thus, it is assumed that hunter-gatherers occupy these marginal areas as the result of being out-competed by agriculturalists for the more productive lands (Kormondy and Brown, 1998; Milton, 2000; Marlowe, 2005).

This paper uses the principles disclosed by these earlier studies to address specific questions about the relationships between climate and mode of subsistence at a global scale. In particular, it aims to test whether different subsistence strategies occupy specific climatic ranges by analysing an unpublished cross-sectional database containing ethnographic information on populations from around the world. This design

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

also allows for inferences on the distribution of contemporary foragers and the spread of agriculture. The general objective is to clarify the environmental limits imposed on human adaptive options.

Material and Methods

The database used was constructed as part of the "King's College Human Diversity Project" (Foley and Mirazón Lahr, unpublished database). It contains anthropological and socio-economic information on *ca.* 2,700 ethnographic populations in Africa, East, Middle and West Asia, South, Central and North America and Oceania. The data were compiled from books, articles, compilations, and reports referring to early ethnographic observations (thus reflecting a recent past), when "intrinsic" patterns were more evident. The information used in the subsequent analyses includes location (latitude and longitude), subsistence strategies (basic economy), and language (family and primary branch).

Derived from the usually descriptive data in the source, a qualitative variable called *Basic economy* was created with four categories as defined in *Table 1*.

Table 1. *Categories of the variable Basic economy*

"*Basic economy*"*	
Category	**Description**
1.Food-production	Subsistence based on agriculture and/or herding of animals.
2.Food Production plus fishing/foraging	Subsistence based on food production (agriculture or herding) allied to hunting, gathering and/or fishing.
3. Foraging/fishing	Subsistence based on hunting and/or gathering plus fishing.
4. Foraging	Subsistence based on either hunting, gathering or on both.

*Throughout the text, categorical and continuous variables are in *italic* for better identification.

Language generally defines the sample unit (namely, the population), but sources are often unclear about whether they deal with a whole linguistic population, a tribe, a group, a subgroup, etc., and which units are related to each other. This is known as the Galton's Problem (Naroll, 1965), and it is minimized here by the large sample size of groups included, coupled with the search for general, broad patterns. Furthermore, many languages still show classification problems (Lewis et al., 2013), and as linguistic identity forms the main form of discriminating amongst peoples, this remains an issue. However, all the data were cross-checked against Murdock's Ethnographic Atlas (1967), the Encyclopaedia of World Cultures (Levinson, 1996), and the first volume of the "Guide of World's Languages" (Ruhlen, 1991).

The climatic data were derived from the "Global Ecosystems Database" (Kineman, 1992). This database provides information on temperature and rainfall at two degrees resolution throughout the world, and allows for matching to the coordinates of a central point within the distribution of each of the human groups in the database. *Mean Annual Temperature* is the average taken from monthly measurements, while *Total Annual Rainfall* expresses annual precipitation. Real latitudes were used instead of "absolute

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

latitude” because the northern and southern hemispheres are not mirror images either in the biophysical or in the anthropologic sense (Kummu and Varis, 2010).

The statistical analyses were performed using SSPS (9.0 for Windows). First, we describe the amplitude of *Latitude*, *Temperature* and *Rainfall* of each *Basic economy*. Second, the homogeneity of these distributions is tested using the Kruskal Wallis analysis of variance. Lastly, outliers are excluded and discriminant analyses used to test the extent to which climatic variables can discriminate between, and thus account for, different subsistence strategies in the recent (ethnographic) past throughout the world.

Results

General patterns

The global distribution of subsistence strategies is revealed when the coordinates of the 2,725 human groups are plotted according to their category of *Basic economy*. No *Basic economy* is restricted to a single region of the Globe, either by continent or by latitude. Yet, certain categories are clearly unevenly distributed along the latitudinal axis (*Figure 1*).

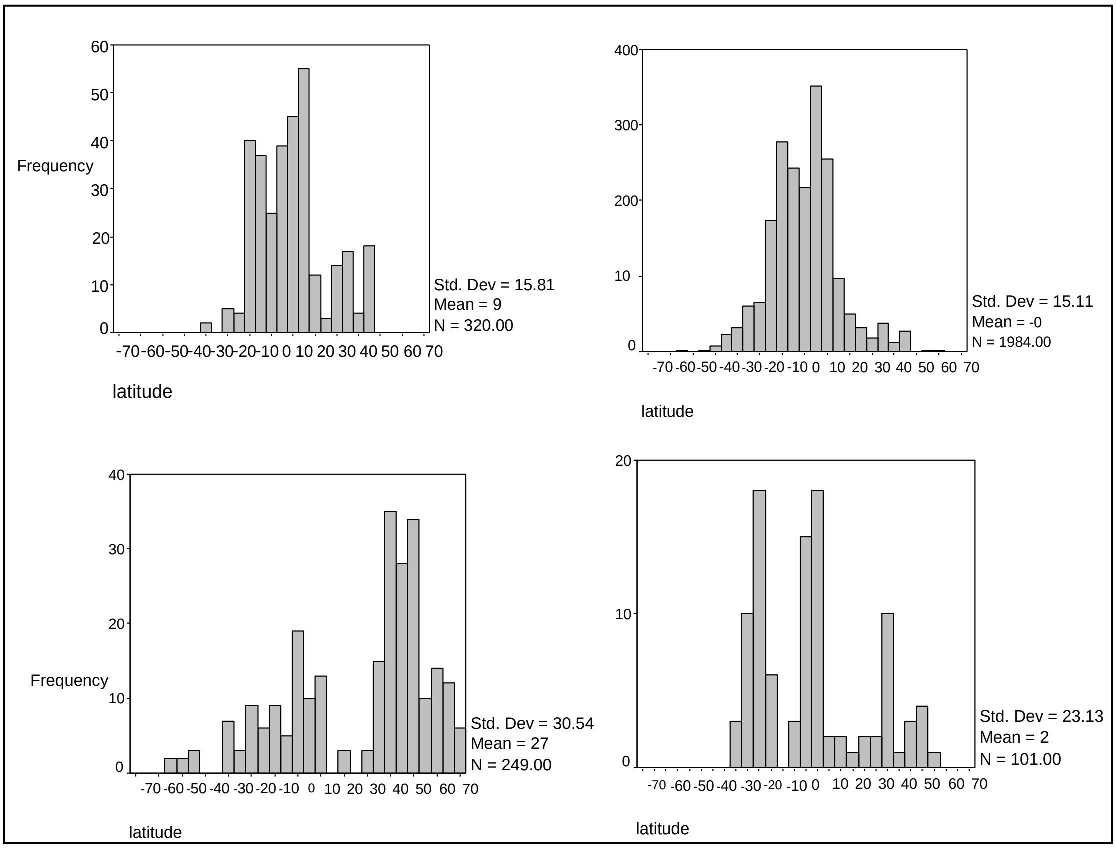

Figure 1. *Numbers and distribution of Basic economies by Latitude. Top left: Food production, Top right: Food production plus fishing and foraging, Bottom left: Foraging and fishing, Bottom right: Foraging.*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

The distribution of populations by latitude does not fit a normal curve (the ratios between skewness and kurtosis by the standard deviation are both greater than 2). In the recent past, there was a clear numerical dominance of *Food production plus fishing/foraging,* representing the mode of subsistence of 2,026 of the groups sampled (74.35 %). *Foraging* is the least frequent strategy, with only 121 populations (4.44 %). Complete dependency on *Food production,* i.e. without complementing the diet with foraging and/or fishing, occurs among 323 groups (11.85 %), while 255 populations (9.36 %) practice a mode of subsistence based on *Foraging/fishing*.

The distribution of each *Basic economy* along the latitudinal axis reveals the following patterns:

Food production - Most food producers are distributed between 10° and 20° N and between 0° and 10° S. In general, there are few food producers at very high latitudes.

Food production plus fishing/foraging – Observed at greater frequency in lower latitudes around the Equator, between 10° S and 10° N, but also present at higher latitudes.

Foraging/fishing - With a markedly skewed distribution, it is more frequent on the northern hemisphere. In both hemispheres, this strategy is present at very high latitudes, up to 70° N and 55° S.

Foraging – It has peaks around the Equator and around 30° both North and South. It is absent around 10° S, and reaches higher latitudes in the northern than in the southern hemisphere.

The results of the non-parametric Kruskal-Wallis analysis of variance show that categories of *Basic economy* occupy significantly different latitudinal ranges (X^2= 255.585, p=0.000***). Nevertheless, there are several exceptions to the pattern, and a box plot of *Latitude* per *Basic Economy* discloses outliers in the latitudinal distribution of populations whose economy is generalised, based on *Food production plus fishing/foraging.*

Distribution of Basic economy by Temperature

Figure 2 shows the distribution of each category of *Basic economy* according to *Mean Annual Temperature.* As expected given the relationship between latitude and temperature, the patterns revealed by the graph are compatible with those observed between latitude and economic strategy. Among these, the most relevant aspects are:

- *Food production* is not common where temperatures are too low; with the highest frequencies between 20° and 25°C. The maximum average monthly temperature at which food producers live (29.4 ^{o}C) is the highest observed among all *Basic economies*, while the minimum temperature at which sole dependence on food production is encountered (5.5 ^{o}C) is also the highest of all minimum temperatures found. This suggests that while a strategy that relies entirely on food production may be the most tolerant of high monthly temperatures, it is nevertheless unsustainable in areas where the minimum temperatures fall below a comparatively warm (5.5 ^{o}C) threshold.
- The addition of fishing and foraging to food production (*Food production plus fishing/foraging)* does not change significantly the spatial distribution, although its range stretches towards lower temperatures through a number of cases that, nevertheless, remain outliers of the main distribution.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

- *Foraging/fishing* is the form of economy observed at the lowest temperature (-16.20°C), with a modal temperature value of *ca.* 10 °C. Nevertheless, there is also a high concentration of cases around 25°C, and the maximum values approach 28°C.
- *Foraging* distribution is within the range of other *Basic economies*.

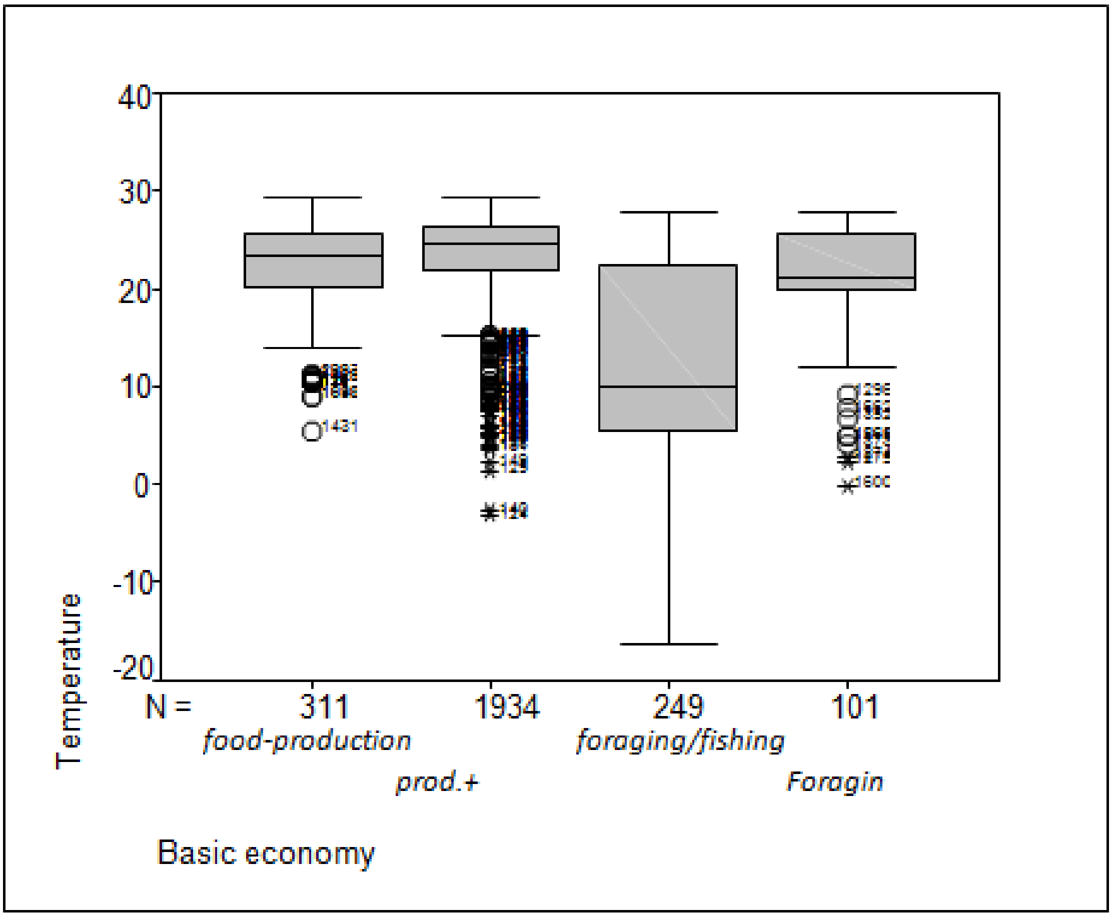

Figure 2. *Box plot showing the distribution, median values and outliers of temperature by basic economy.*

The results of a Kruskal-Wallis test suggests that the four categories *of Basic economy* differ significantly in relation to *Temperature* (X^2= 298.988, p=0.000***). Cases are mostly concentrated around the average, between 20°C and 25°C; *Foraging/fishing* is the exception, occupying a wider temperature range.

Distribution of Basic Economy by Total Annual Rainfall

Figure 3 shows the distribution of each category of *Basic economy* in relation to *Total Annual Rainfall*. The most relevant pattern is that, in general, all categories are concentrated at lower values of rainfall. This is especially the case for those which involve foraging, which are found in places with the lowest modal annual rainfall. *Figure 3* shows that all *Basic economies* have mean values of *Rainfall* between zero and 1,800mm/year, and that *Foraging/fishing* has the highest number outliers, including extremely high values of rainfall.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

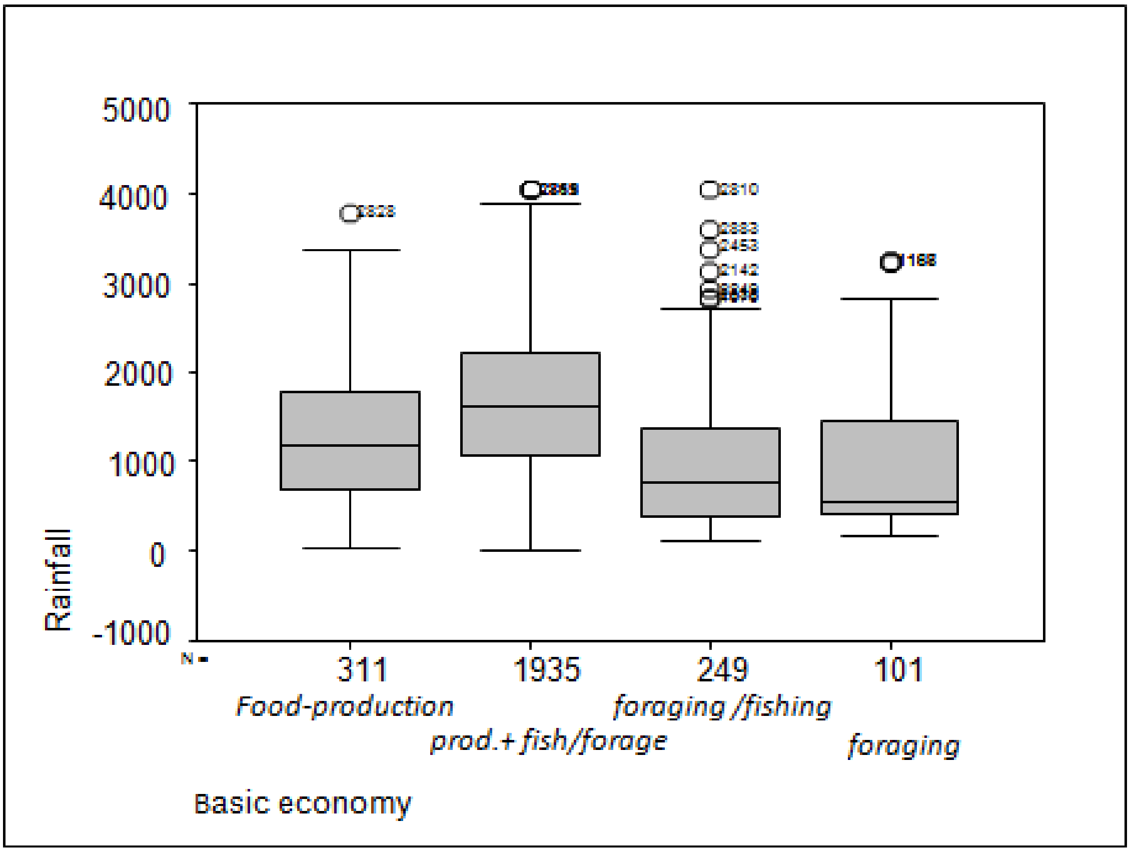

Figure 3. *Box plot showing the distribution, median values and outliers of rainfall by basic economy.*

Food Production is found across a wide range of rainfall patterns (from close to no rainfall to *ca.* 3400 mm/yr), but the majority of cases is restricted to low rainfall regimes between ~ 800-1800 mm/yr. The long tails to the distribution and outliers suggest that food producing may not be optimal, but is not limited by rainfall.

As the generalist strategy, *Food Production plus foraging/fishing* occupies the wider range of vales **(**from 6.40 mm/yr to 4038.10 mm/yr). However, it is interesting to note that although the range between the minimum and maximum rainfall in which 95% of cases of this subsistence is found is similar to food producers, the actual minimum/maximum limits differ, here being between ~1100 mm/yr and 2100 mm/yr. In other words, the complementation of food production with foraging and fishing does not widen the range of temperatures for the majority, but shifts the threshold of optimal tolerance.

Foraging/fishing has a markedly skewed distribution, with most cases at low values of rainfall, although a small number of outliers populate areas with rainfall that exceeds 3000 mm/yr.

Populations who depend solely on *Foraging* live in areas with the minimum average annual rainfall, while the highest rainfall value recorded amongst foragers is also the lowest maximum value among the four distributions (3234.80 mm/ yr).

The sample is skewed in relation to *Mean Annual Rainfall* (Skewness (0.456)/Std. Error (.046) > 2 (=9.9)). The results of a Kruskal-Wallis test again indicate that the variance of *Rainfall* is significantly different among the four categories (X^2= 234.406, p=0.000***).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

Discrimination of Basic economies by climatic variables

In order to investigate the potential interaction effects among the climatic and environmental variables, as well as to test whether it is possible to some extent to predict the form of economy from these variables, a discriminant analysis was performed. This analysis tests the capacity of climatic variables to discriminate among the *Basic economies* based on their global geographic distribution. Linear combinations of independent variables are formed (*Latitude*, *Temperature*, and *Rainfall*) to create predictive functions of cases within the categories of *Basic economy.*

Outliers were excluded, which makes results reliable even in the absence of normal distributions (Tabachnick and Fidell, 1996). We use Wilk's Lambda minimization and prior probabilities are calculated taking into account the differences in sample size between categories.

The results show that the three climatic/environmental variables combined are poor discriminators of human subsistence. The analysis employed all three variables; these have relatively weak patterns of covariation with the type of economy, with Eigenvalues well below 1 (N =2592) (*Table 2*).

Table 2. *Eingenvalues and other descriptive values of functions 1,2, and 3.*

Function	**Eigenvalue**	**% of Variance**	**Cumulative %**	**Canonical correlation**
1	.446	89.6	89.6	.556
2	.043	8.5	98.1	.202
3	.009	1.9	100.0	.096

Figure 4 illustrates the correlations between variables in Functions 1 and 2, which account for the highest proportion of the total variance (98.1%) that can be explained by these 3 variables. The horizontal axis represent Function 1, which shows a very strong positive correlation with temperature (>0.9), a strong negative correlation with latitude (>-0.7), and a relatively weak correlation with rainfall (<0.4). In other words, Function 1 expresses the fact that temperatures are highest at low latitudes and vice-versa, with rainfall tending to be higher in hot low latitude localities, but not particularly so. Function 2, represented by the vertical axis, is strongly influenced by *Rainfall* (>0.7), showing that very positive values of rainfall are to some extent inversely correlated with both *Latitude* and *Temperature*.

The fact that 89.6% of the variation explained by climatic variables is due to Function 1 expresses the relative importance of *Temperature* in shaping the distribution of types of subsistence strategy. Thus we observe that the type of basic economy of 77.9% of all cases was correctly classified through Functions 1, 2, and 3. At a first instance, this appears a strong result, suggesting that in 4 out of 5 cases the subsistence strategy of a population follows a distribution predictable through temperature, latitude and rainfall combined. However, a closer examination of the distribution of correctly and incorrectly classified cases across types of subsistence shows that this is not the case (*Table 3*).

APPLIED ECOLOGY AND ENVIRONMENTAL RESEARCH 13(2): 849-862.
http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

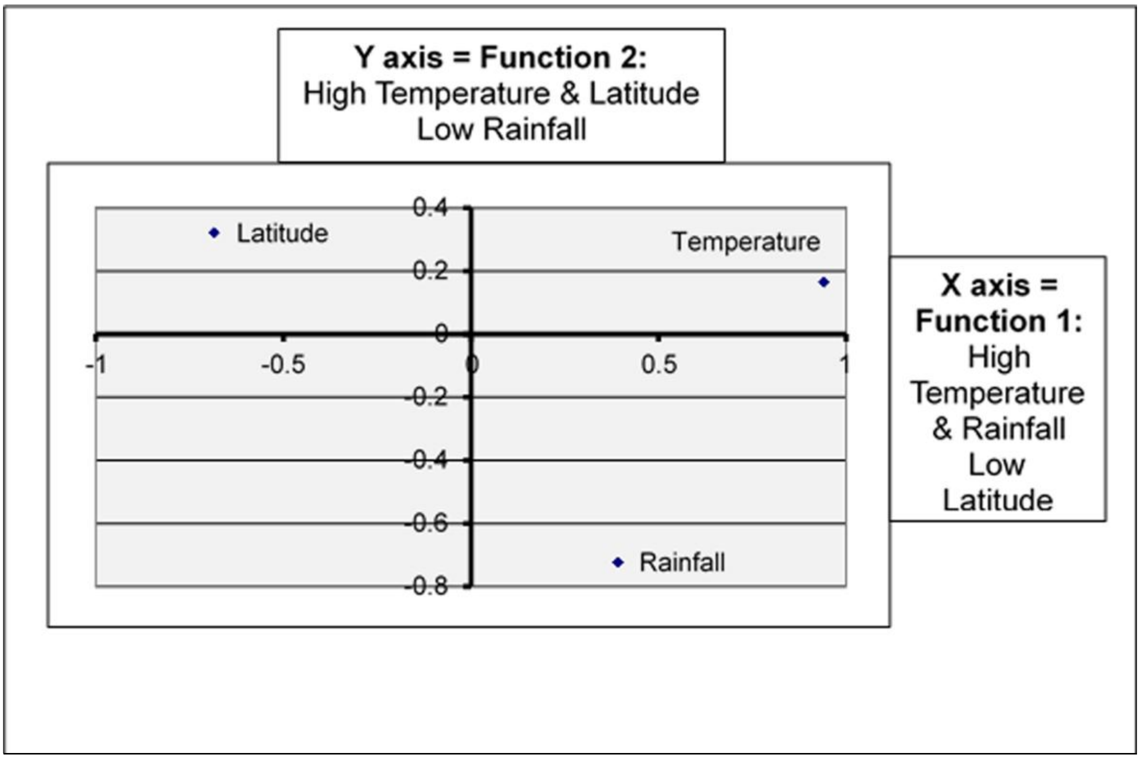

Figure 4. *Correlations between variables in Function 1, mostly influenced by temperature and latitude, and Function 2, determined mainly by rainfall.*

Table 3. *Percentage of cases that were correctly classified (in bold) through the discriminant analysis of Basic economies using climatic variables.*

	Predicted Group Membership					Total
%	***Basic economy***	***Food-production***	***Food-prod.+ fishing/foraging***	***Foraging/ & fishing***	***Foraging***	
	Food-production	**.0**	91.0	9.0	.0	100.0
	Food-prod.+ fishing/forage	.0	**96.7**	3.3	.0	100.0
	Foraging/fishing	.0	40.2	**59.8**	.0	100.0
	Foraging	.0	87.9	12.1	**.0**	100.0
	Ungrouped cases	.0	52.5	47.5	.0	100.0

The majority of correctly predicted cases corresponds to a single form of subsistence – the generalist *Food production plus fishing/foraging* which had nearly 100% of its cases correctly discriminated. Cases of *Foraging/fishing* also had moderately high levels of correct prediction at nearly 60% (*Table 3*). However, there were no correct classifications of *Food production* and *Foraging*, all of which were subsumed in the first two groups. In other words, the range of climatic and environmental conditions in

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

which both *Food production plus fishing/foraging* and *Foraging/fishing* are observed fully encompass those in which some populations engage solely in food production and/or foraging. The small percentage of correctly predicted cases across all types of economy, together with the low Eigenvalues obtained, confirm that the combination of *Latitude, Temperature, and Rainfall* is not sufficient to predict the different types of subsistence strategies. The possible reasons for such a heterogeneity in the influence of climatic factors is the subject of our discussion.

Discussion

Our sample reveals an unbalance in the distribution of cases between the northern and southern hemispheres that is consistent with the distribution of the human population. Around 87.5% of the global population live in the North and only 12.5% in the South (Kummu and Varis, 2010). The northern hemisphere has more land than the southern, as well as being relatively warmer, with winter averages around -40°C and -60°C in the North and South Poles respectively. Only in the northern hemisphere are there human groups beyond 60° latitude. This highlights the extent to which the two halves of the world are not mirror images of each other, and that the use of “absolute latitudes” instead of real latitudes, could be misleading (as in Marlowe, 2005, for example).

The fact that the distribution of groups of food producers who complement their diet through fishing and foraging, and to some extent that of foragers/fishers, can be predicted on the basis of the variables used in this study reflects their distinctive range width as well as absolute numbers. The first type of subsistence strategy is clearly numerically dominant in the sample (~ 68% of cases); they appear to be more demanding in terms of temperature, but highly adaptable concerning rainfall. Foragers who also fish live at all possible temperatures. This is clear in *Figures 2* and *3*, and is compatible with the mis-classification of cases from the other two categories. Wide ranges and high numbers stress the importance of adaptability to adverse conditions and of adaptive success.

The economic category of *Food production plus fishing/foraging* represents the majority of cases and broadest latitudinal distribution, enclosing in its climatic range both *Foraging* and *Food production* economies. This is a common, flexible and generalist, rather than specialist, strategy. It challenges the commonly held perception that the comparative specialists economies that depend solely on *Food production* represent either the majority of cases, or the prevalent evolutionary tendency.

Horticulture and agriculture both constitute forms of subsistence intensification in relation to foraging (Boone, 2002). The generalist nature of *Food production plus fishing/foraging* comes not only from the mix of food extraction and production, but also from the diversified form of cultivation represented by less intensive agriculture. This implies a mixture of different crops, including trees, shrubs, herbs and tubers, many of which, although poorer in proteins than seed crops, are less labour-intensive (Grigg, 1977), while their combination can be used to offset environmental constraints. The time spared can be employed in the acquisition of protein by hunting or fishing, or indeed trading, complementing nutritional needs.

A fundamental principle of human health and nutrition is that diverse diets increase the overall health patterns by lowering infant mortality rates and increasing average life expectancy (Hockett and Haws, 2003). That the most widespread form of food

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

production is an extensive and mixed strategy would account for the apparent paradox between the human necessity to buffer environmental fluctuations, best achieved by retaining a more generalist and flexible approach to food procurement, and the expansion of agriculture.

Despite the wide environmental range occupied by *Food production plus fishing/foraging*, most groups who depend solely on *Foraging/fishing* and *Foraging* live at the lower extremes of both *Temperature* and *Rainfall*. This could be accounted for by the fact that recent hunter-gatherers inhabit comparatively marginal environments (Kormondy and Brown, 1998; Milton, 2000; Marlowe, 2005). "Marginal ecosystems" refer to arctic, deserts, and rainforest habitats (Kormondy and Brown, 1998), and indeed both hot and cold deserts can be identified by low rainfall in our analysis.

In hot deserts, the distribution of *Food production* and *Foraging* overlaps, mainly reflecting the fact that the pastoralists of North Africa and West Asia represent most of the food producers in these places. Bedouins, for example, are known to acquire most of their water from milk and conserve it through behavioural adaptations (work schedule, robes, etc.) (Reader, 1988).

On the prevalence of foragers in hot deserts, our data show that hunter-gatherers are (or were) exclusive inhabitants of some of the world's deserts, such as those of Australia, for example, where subsistence strategies exploited the particular nature of plants in those ecosystems. Hunter-gatherers of hot deserts rely mainly on the gathering of plants that have a great capacity to storage water. Among the G/wi San in the Kalahari Desert, plants provide each individual with an average of 4.5 litres of fluid per day in the hot dry season (Silberbauer, 1981). Over 90 % of the Kalahari San water requirement comes from plant sources (Tanaka, 1976). In contrast, most crops cultivated through intensive agriculture, such as rice, wheat, and maize, are not adapted to conserve water. Rather, their production is highly water demanding (FAO, 2011). This inevitably raises the need for irrigation or methods to control and retain natural water in dry regions, but even this depends on the reliable presence of a water source. So for example, in Egypt, intensive agriculture based on elaborate artificial waterways to use river flood cycles for irrigation is ancient and remains sustainable (Wild, 1994), while in the Wadi al-Ajjal of the Central Sahara, the successful irrigation system of *foggaras* in antiquity could not be maintained as aridification intensified. Therefore, such high technological systems and their complex socio-economic correlates that allow the establishment of plant food production in hot deserts have developed several times in human history but only in a few places have they represented stable strategies.

In cold deserts, like the Arctic and Patagonia, people who survive through *Foraging/fishing* are the exclusive inhabitants, which accounts for the easy prediction of the type of economy of human groups in those environments. This distribution is compatible with other findings showing that foragers rely on fishing in regions with low vegetal biomass (Kelly, 1999; Cordain et al., 2000; Binford, 2001). The results show that *Foraging/fishing* is, apart from trading, the only way to obtain food in "cold deserts".

Foraging in the absence of fishing is present mostly in moderately low latitudes, with some groups also observed in boreal and temperate forests. For their distinct position in the group, these latter cases were identified as outliers. Considering both *Foraging* and *Foraging/fishing* as hunter-gatherers in the broader sense, foragers in cold deserts represent the strongest fit to the marginality concept.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

A third type of marginal environments is tropical rainforests. According to the marginality theory, foragers should account for most cases in these environments. In our database, *Foraging* is concentrated in the rainforests of Southeast Asia, South America, Oceania, and Africa, but symbiotic relationships with agriculturalists are frequently observed (see De Souza, 2007; Milton, 1984, for examples). According to Bailey et al. (1989), considering carbohydrates as the most limiting resource in those habitats, the presence of foragers would only be possible in close proximity to food producers. Nevertheless, it is worth noting that certain groups of hunter-gatherers are known to have circumvented the absence of carbohydrates in rainforest environments in other ways (Hill and Baird, 2003).

Researches have discussed the difficulties imposed by rainforests over all forms of subsistence strategies. Low soil fertility represents a barrier to full reliance on agriculture (Meggers, 1954), while fresh water fishing is subjected to periodic scarcity, since fishes can become highly dispersed during the rainy season (Roosevelt, 1980). Interestingly, our data show the occurrence of all four strategies in the main rainforest complexes of the World. The existence of complex trading networks between groups is a possible explanation (Kelly, 1999), but the highly generalist strategy *Food production plus foraging/fishing* is by far the most frequent in the rainforests as in other regions of the World.

Conclusions

Human subsistence strategies are not equally distributed throughout the World. A generalist strategy composed of agriculture, foraging and fishing is the most adaptable and widespread form of food acquisition. Our findings suggest that such a combination was practiced by the first food producers and is responsible for the cooperative relations, reproductive success and expansion of agriculturalists to, virtually, everywhere. The exception are cold deserts, where foraging coupled with fishing is the only possible subsistence strategy in the absence of trade. Some degree of marginality occurs in hot deserts as well, where foragers co-exist with a small number of food-producers, mainly pastoralists. The marginality concept does not apply to rainforests, where the most abundant form of subsistence is, again, extensive food production complemented by the gathering of wild animals and forest products such as honey.

The World population is concentrated between 20° and 40° North (Kummu and Varis, 2010). In contrast, our sample has its greatest density between 15° South and 5° North, closer to the Equator. This suggests that the distribution of traditional/indigenous peoples is different from that of the world population as a whole, and in turn, that the marginalization concept might fit most ethnic minorities and not just foragers. Due to the intensification of commercial relations and technological improvements in food production, figures are probably very different today, and climatic parameters are, presumably, even weaker predictors of the distribution of contemporary subsistence strategies. Both environmental and historical factors have interacted to shape our physical and social world, with the latter playing an even stronger role in the last centuries.

Aknowledgements. We would like to thank Andrea Bamberg Migliano, Ila Fazzio, Camila Storto and Ian Collard for their contribution to the database used in this study, and Robert Foley for his usual bright guidance.

REFERENCES

[1] Bailey,R.C, Head, G., Jenike, M., Owen, B., Rechtman, R., Zechenter, E. (1989): Hunting and gathering in tropical rain forest: is it possible? - American Anthropologist 91:59-82.

[2] Binford, L.R. (2001): Constructing frames of reference: an analytical method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets. – University of California Press, Berkeley.

[3] Boone, J.L. (2002): Subsistence strategies and early human population history: an evolutionary ecological perspective. - World Archaeology 34(1): 6–25.

[4] Cordain, L., Miller, J.B., Eaton, S.B., Mann N., Holt, S.H.A, Speth, J.D. (2000): Plant-animal subsistence ratios and macronutrient energy. - American Journal of Clinical Nutrition 71:682–692.

[5] De Souza, R.G. (2007): The origin of hunter-gatherers' foods. - Journal of Human Ecology 21(2): 87-93.

[6] Ellen, R. (1982): Environment, subsistence and system: the ecology of small scale social formations. - Cambridge University Press, Cambridge, UK.

[7] FAO (2011): The state of the world's land and water resources for food and agriculture (SOLAW) - Managing systems at risk. - Food and Agriculture Organization of the United Nations, Rome and Earthscan, London. Available online: http://www.fao.org/nr/solaw/the-book/en/ Accessed on 23 Oct. 13.

[8] Foley, R., Mirazón Lahr, M.: King´s college human diversity project: unpublished database.

[9] Grigg, D.B. (1977): The agricultural systems of the world, an evolutionary approach. - Cambridge University Press, Cambridge, UK.

[10] Hill, R., Baird, A. (2003): Kuku-yalanji rainforest aboriginal people and carbohydrate resource management in the wet tropics of queensland, Australia. - Human Ecology 31: 27-52.

[11] Hockett, B., Haws, J. (2003): Nutritional ecology and diachronic trends in paleolithic diet and health - Evolutionary Anthropology 12:211–216.

[12] Kelly, R.K. (1999): The foraging spectrum: diversity in hunter-gatherer lifeways. - Smithsonian Institution Press, Washington and London.

[13] Kennett, D.J., Winterhalder, B. (eds) (2006): Behavioral ecology and the transition to agriculture. - University of California Press, Berkeley.

[14] Kineman, J.J. (1992): Global ecosystems database, version 1.0 (on CD-ROM): EPA Global climate research program, NOAA/NGDC Global Change Database Program: user's guide. - University of California Libraries, Berkeley.

[15] Kormondy, E. J., Brown, D. E. (1998): Fundamentals of human ecology. - Prentice Hall, New Jersey.

[16] Kummu, M., Varis, O. (2011): The world by latitudes: A global analysis of human population, development level and environment across the north e south axis over the past half century. - Applied Geography 31(2): 495-507., doi: 10.1016/j.apgeog.2010.10.009

[17] Levinson, D. (Ed.) (1996): Encyclopaedia of world cultures. Vols. I-X.- Hall & Co., Boston, MA

[18] Lewis, M.P., Simons, G.F., Fennig, C.D. (Eds.) (2013): Ethnologue: languages of the world, Seventeenth edition. - SIL International, Dallas, Texas: Available online version: http://www.ethnologue.com. Accessed on 10 Nov 2013.

[19] Marlowe, F.W. (2005): Hunter-gatherers and human evolution. - Evolutionary Anthropology 14:54–67.

[20] Meggers, B. J. (1954): Environmental limitation on the development of culture. - American Anthropologist 56:801-24.

[21] Milton, K.(1984): Protein and carbohydrate resources of the Maku Indians of north western Amazonia. - American Anthropologist 83: 534-548.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862

[22] Milton, K. (2000): Hunter-gatherer diet: a different perspective. - American Journal of Clinical Nutrition 71:665–7.
[23] Murdock, G. (1967): The Ethnographic Atlas: A Summary. - Ethnology 6(2).
[24] Naroll, R.(1965): "Galton's problem: The logic of cross cultural research". - Social Research 32: 428–451.
[25] Reader, J. (1988): Man on Earth. - University of Texas Press, Austin.
[26] Roosevelt, A. C. (1980): Population, health, and the evolution of subsistence: conclusion from the conference. – In: Cohen, M. N., Armelagos, G. J. (Eds.) Paleopathology at the Origins of Agriculture, Academic Press, Orlando.
[27] Ruhlen, M. (1991): A guide to the world's languages; Vol.1: Classification. - Edward Arnold, London.
[28] Silberbauer, G.B. (1981): Hunter and habitat in the central Kalahari Desert. - Cambridge University Press, Cambridge, UK.
[29] Tanaka, J. (1976): Subsistence ecology of the central Kalahari San. – In: Lee, R. B., De Vore, I. (Eds.) Kalahari hunter-gatherers: studies of the !Kung San and their neighbours, 98-119, Harvard University Press, Cambridge, USA.
[30] Tabachnick, B.G., Fidell, L.S. (1996): Using multivariate statistics. - Harper Collins College Publishers, New York.
[31] The Times (1997): Atlas of the World. - Times Books, London.
[32] U.S. Census Bureau – World POPClock Projection". July 2012–July 2013 data. http://www.census.gov/popclock/
[33] Wild, A. (1994): Soils and the environment: an introduction. - Cambridge University Press, New York.
[34] Winterhalder, B. (2001): The behavioral ecology of hunter-gatherers. – In: Panter-Brick C, Layton, R.H., Rowley-Conwy, P. (Eds) Hunter-Gatherers: an interdisciplinary perspective, Cambridge University Press, Cambridge.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: 10.15666/aeer/1303_849862