West Africa
Spatial Analysis Prototype
Exploratory Analysis

The Effect of Aridity Zone on Child Nutritional Status

Demographic and Health Surveys
Macro International Inc.

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The Effect of Aridity Zone on Child Nutritional Status

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Introduction

In recent years there has been a large increase in the demand for data to monitor and evaluate government and international donor programs. A huge amount of data has been collected in West Africa but these data are typically not analyzed across sectors despite the fact that many sectors overlap and interact with each other. One reason for the lack of multi-sectoral analysis is that it is often difficult to combine data from different sources in a meaningful way. In recognition of the need to better utilize existing data, USAID's Regional Economic Development Services Office for West and Central Africa (REDSO/WCA) commissioned the development of the West Africa Spatial Analysis Prototype (WASAP). One of the objectives of WASAP was to develop a Geographic Information System (GIS) for West Africa that could be used to link data from different sources and that would permit analysis at the regional, national, and sub-national levels. WASAP was implemented jointly by the Bureau of the Census (BUCEN), World Resources Institute (WRI) and Macro International.

One area that would benefit from a multisectoral perspective is the analysis of child nutritional status. Data on the nutritional status of children are typically collected in household surveys such as the Demographic and Health Surveys (DHS) implemented by Macro International. These surveys generally also collect information on other health behaviors and on the socio-economic status of the child's household. Analyses of the factors associated with childhood nutritional status have, therefore, tended to focus on feeding patterns and socio-economic determinants. However, environmental factors such as climate and agricultural production are also likely to play a role in determining nutritional status. Environmental data are widely available for West Africa and can be linked to the household data using WASAP.

An earlier analysis using WASAP examined the relationship between agroclimatic aridity zone and four indicators of childhood nutritional status (stunting (low height-for-age), wasting (low weight-for-height), underweight (low weight-for age), and stunting and wasting) (WRI, 1996). That analysis found that the proportion of children stunted, underweight, and stunted and wasted peaked in the semi-arid zone and then decreased as humidity increased. The proportion of children wasted decreased as humidity increased. Sharma et al. (1996) also noted the high prevalence of malnutrition among children in semi-arid zones.

The analysis by WRI (1996) was primarily illustrative and was done at the aggregate level. Many other child-level and community-level factors influence nutritional status and it is possible that the apparent variation in nutritional status by aridity zone actually reflects variation in these other factors. In this paper we build on the earlier analysis and examine the association between aridity zone and childhood nutritional status net of other socio-economic and environmental factors that influence nutritional status. The analysis is primarily designed to illustrate the potential of WASAP to link data from different sources for multivariate analysis and to explore the issues involved in such analyses, but the results will also be of substantive interest.

Data and Methods

The WASAP GIS is based on a set of georeferenced databases for West Africa. In theory, any georeferenced database for West Africa can be added to the GIS. In this analysis, we use data from three sources; DHS surveys conducted in West Africa between 1988 and 1996, the West Africa Long Term Perspective Study database (WALTPS), and the Consultative Group on International Agricultural Research (CGIAR) International Center for Research in Agroforestry (ICRAF) in Nairobi.

Anthropometric data are available from the DHS surveys for children under three years of age. This analysis is restricted to children age 3-35 months because the nutritional status of children under 3 months of age is heavily influenced by their birthweight which in turn is influenced by prenatal factors. Data from 11 DHS surveys conducted in West Africa between 1988 and 1996 are used in this analysis. Table 1 lists the countries, year of survey, number of women age 15-49 interviewed, and the number of children age 3-35 months in the sample[1].

Table 1. Sample details for DHS Surveys in West Africa.

Country	Year of survey	Number of women age 15-49	Number of children age 3-35 months
Benin	1996	5,491	2,495
Burkina Faso	1992/93	6,354	2,797
Cameroon	1991	3,871	1,728
Central African Republic	1994/95	5,884	2,339
Côte d'Ivoire	1994	8,099	3,341
Ghana	1993	4,562	1,884
Mali	1995/96	9,704	4,761
Niger	1992	6,503	3,200
Nigeria	1990	8,781	3,823
Senegal	1992/93	6,310	2,796
Togo	1988	3,360	1,617
Total	1988-1996	68,919	30,781

Two child nutritional status outcomes are examined:

- Stunting = height-for-age below two standard deviations of the median height-for-age of the National Center for Health Statistics (NCHS) /Centers for Disease Control (CDC) /World Health Organization (WHO) reference population.
- Wasting = weight-for-height below two standard deviations of the median weight-for-height of the NCHS/CDC/WHO reference population.

The two outcome variables are defined as binary variables taking the value one if the child is stunted (or wasted) and zero if the child is not stunted (or wasted). Stunting is accepted as an indicator of long-term malnutrition while wasting is an indicator of short-term malnutrition.

Table 2 defines the independent DHS variables included in the child-based data file. These variables are included in the analysis because they have been shown to be associated with childhood nutritional status in other studies (e.g. Haggerty et al., 1998).

[1] There was a DHS survey in Liberia in 1986 but that survey did not include any anthropometric data so it is not included in this analysis.

Table 2. Independent variables from the DHS.

Variable	Definition
Age	Age of child in months. Fitted as a quadratic effect in the regression models.
Birth order	Birth order of child: 1, 2-3, 4-6, 7+
Sex	Sex of child: male, female
Breastfeeding	Current breastfeeding status. Defined as not breastfeeding, breastfeeding and receiving solids (partial, solids), breastfeeding and receiving liquids other than plain water but no solids (partial, liquids), and breastfeeding and receiving no supplements or plain water only (full breastfeeding).
Diarrhea	Child had diarrhea in the last two weeks: no, yes.
Sanitation	Index based on the sum of the following scores: 1 if the child's household has piped drinking water or uses bottled drinking water; 1 if household has a flush toilet.
Socio-economic status	Index based on the sum of the following scores: 1 if the child's household has a bicycle, motorcycle, or car; 1 if the child's dwelling has a non-dirt floor; 1 if the child's mother's partner works in a non-agricultural occupation or works in agriculture on his own land (scores 0 if the child's mother doesn't have a partner).
Mother's education	No schooling, has attended school.
Area of residence	Urban, rural

The main independent variable of interest is agroclimatic aridity zone. Arididty zone is defined using the aridity index ranges given in the World Atlas of Desertification (UNEP, 1992) (Table 3). The aridity index is the ratio of precipitation (PPT) to potential evaporation (PET). The aridity zones for West Africa are based on PPT and PET surfaces from ICRAF in Nairobi and are available in WASAP. Aridity zones one and two are combined in this analysis because few children live in the hyper-arid zone.

Additional environmental and economic independent variables are obtained from WALTPS. WALTPS was a long term assessment of the economic geography of West Africa conducted by the Club du Sahel and the African Development Bank in 1992-94 (Brunner et al., 1995). One by-product of the study is the WALTPS database which includes lots of information that was put together to answer the questions addressed by WALTPS. Table 4 describes the variables from the WALTPS database that are used in this analysis. All the variables refer to 1990 which is within the period covered by the DHS surveys. A full description of the contents of the WALTPS database is given in Brunner et al. (1995).

Table 3. Definition of Aridity Zones for West Africa.

Aridity zone	Name	Aridity index range
1	Hyper-arid	< 0.05
2	Arid	0.05-0.20
3	Semi-arid	0.20-0.50
4	Dry sub-humid	0.5-0.65
5	Moist sub-humid	0.65-1
6	Humid	> 1

Source: WRI (1996).

Table 4. Independent variables from WALTPS.

Variable	Description
Population density	Population per km^2 in 1990 for the agricultural census unit in which the child lives. Based on census data.
Non-food crop production	1990 per capita production in tonnes of non-food crops (coffee, cotton, rubber and tobacco) for the agricultural census unit in which the child lives.
Food crop production	1990 per capita production in tonnes for food crops (millet, sorghum, maize, rice, wheat, other cereal, soybean, yam, cassava, plantain, banana, taro, cocoa, peanut, palm oil, hevea, legumes, sweet potatoes, fonio, berbere, sugar cane, coconut, cocoyam, tomatoes, sesame, peppers, pulses, and other fruits) for the agricultural census unit in which the child lives.
Market tension	Theoretical measure of the opportunity to market agricultural products. Measured on a scale from 1=low tension to 8=high tension. Grouped as: low (0-2), medium (3-5), and high (6-8). Refers to 1990.

Population density is included in the analysis because high population density may lead to increased exposure to disease and increased competition for food which may lead to reduced nutritional status. However, a high population density area may be able to import food to meet its needs more easily than a low population density area and may, therefore, have access to a wider range of foods. Food crop production is included to indicate the ability of an area to provide food for its population. Children living in areas of high food crop production are expected to be better off nutritionally because they are expected to have access to more food and because excess food can be sold at market providing cash income for other goods and services (including health services). To the extent that non-food crop production displaces food production, areas of high non-food crop production could be worse of nutritionally than areas of low non-food crop production. However, non-food crop production may lead to higher incomes which can be used to purchase food and health services.

Market tension is a theoretical measure of the "pull" of local urban and international markets on the rural hinterland. It is based on soils, climate, and the ability to reach markets which in turn depends on the distance to those markets and the quality of the road system to reach the market. It is designed to indicate the attractiveness of a rural area for farming. Areas with high quality soils, a favorable climate and good access to markets have high market tension whereas areas without these qualities have lower market tension. Further explanation of market tension is given in Brunner et al. (1995). Children living in areas with high market tension are expected to be better of nutritionally than those living in areas of low market tension because their households are expected to have higher cash incomes and because areas of high market tension are expected to be better off economically generally.

The different data sources were linked spatially through WASAP using ArcView (ESRI, 1996). First, a West Africa child-based file was constructed from the DHS women's recode data files for each country. This file contained only the DHS variables plus identification information including the sample cluster identification number. This file was not part of WASAP per se but all the DHS clusters have been georeferenced and are included in WASAP along with cluster-level data from the DHS (DHS, 1997). The ICRAF and WALTPS data were then linked spatially to the DHS clusters in WASAP to produce a cluster-level data file. Each cluster was assigned the value of the aridity zone in which it lay. Similarly, each cluster was assigned the value of population density, food crop production, and non-food crop production corresponding to the agricultural census unit it lay in. Market tension appears spatially as a series of contours so the clusters were assigned the value of market tension according to which contour they lay in. The cluster-level file was then linked to the child-based DHS file based on the cluster identification number to produce the final analysis file. Table 5 presents the unweighted distributions of the categorical independent variables and Table 6 presents the mean, standard deviation, minimum, and maximum of the continuous independent variables in the final linked data file.

Logistic regression models are fitted for each outcome (stunting and wasting) using STATA (Statacorp, 1997). Three models are presented. The first model includes only aridity zone to estimate the gross effect of aridity zone on each nutritional status outcome. Second, all the other variables are added to the model to see what effect controlling for them has on the effect of aridity zone. Finally two interactions are tested: aridity zone by area of residence and breastfeeding status by child's age. The influence of aridity zone may vary between urban and rural areas because rural areas may be more sensitive to climatic factors. The effect of breastfeeding status on nutritional status is expected to vary by age because appropriate feeding patterns vary substantially with age from 3-35 months. Both interactions are tested using a likelihood ratio test and are included in Model 3 if they are significant at the five percent level. Cases with missing values on any of the dependent or independent variables are excluded from the logistic regression analysis. The final number of cases for the models of stunting is 26,333 and for the models of wasting is 27,943.

The DHS surveys are conducted using a cluster sample design. Observations within a cluster are expected to be more alike than observations in different clusters. To allow for correlation between observations within clusters, the standard errors of the parameter estimates in the logistic regression models were adjusted using the Huber-White correction (Huber, 1967; White 1980,1982). Country was also included in Models 2 and 3 to allow for unobserved country effects (e.g. effects due to a country's health policy and infrastructure). The country variable also absorbs the effect of differential timing of surveys both in terms of the year of the survey and the season in which the survey was conducted.

Table 5. Unweighted percent distributions of the categorical independent variables.

Variable	Percent	Number
Aridity zone		
Hyper-arid/arid	7.9	2,433
Semi-arid	35.2	10,847
Dry sub-humid	9.5	2,932
Moist sub-humid	25.1	7,730
Humid	22.2	6,839
Birth order		
1	18.2	5,586
2-3	30.6	9,427
4-6	32.3	9,937
7+	18.9	5,831
Sex		
Male	50.4	15,500
Female	49.6	15,281
Current breastfeeding status		
None	38.0	11,701
Partial/solids	43.3	13,330
Partial/liquids	6.5	1,999
Full	12.2	3,751
Diarrhea in last 2 weeks		
Yes	27.2	8,246
No	72.8	22,099
Sanitation index		
0	70.8	21,781
1	25.1	7,737
2	4.1	1,263
Socio-economic index		
0	2.6	797
1	20.6	6,350
2	29.5	9,089
3	31.4	9,661
4	15.9	4,884
Mother's education		
No schooling	68.7	21,154
Some schooling	31.3	9,627
Urban/rural residence		
Urban	35.4	10,888
Rural	64.6	19,893
Market tension		
Low (0-2)	9.4	2,885
Medium (3-5)	51.2	15,755
High (6-8)	39.4	12,141
Total	100.0	30,781

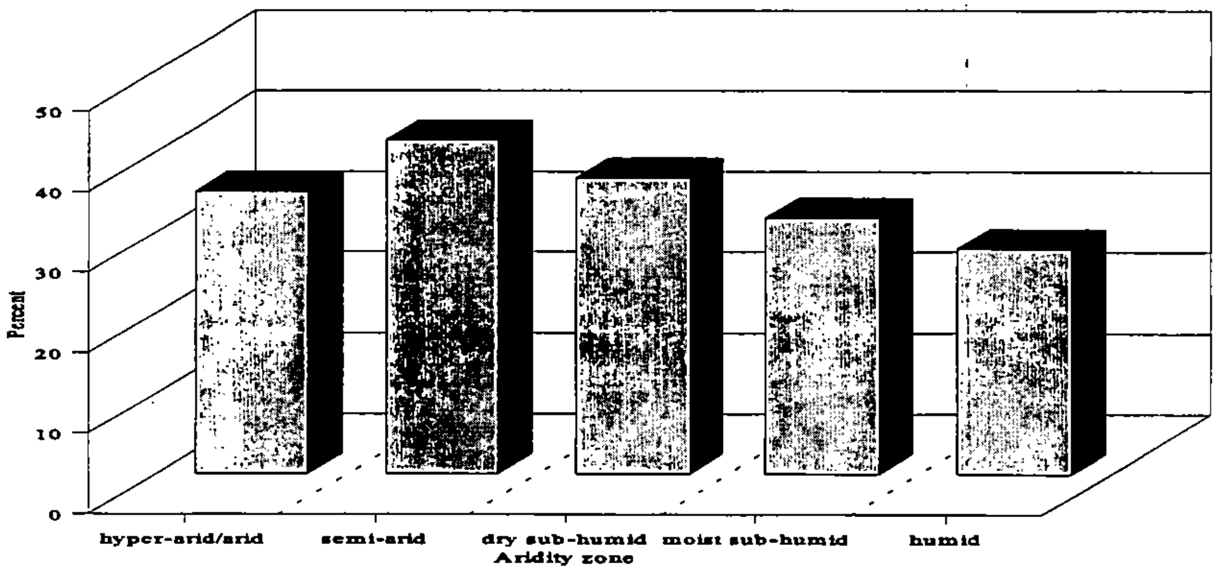
Table 6. Unweighted summary statistics for continuous independent variables.

Variable	Mean	Standard Deviation	Minimum	Maximum	Number
Age	18.2	9.7	3	35	30,781
Population density	615.4	1,874.8	0	14,904	30,781
Non-food crop production	131.7	388.7	0	4,546.9	30,653
Food crop production	4,788.3	8,403.8	20.8	108,490.3	30,653

Results

Figures 1 and 2 present the proportion of children stunted and wasted respectively, by agroecological aridity zone.

Figure 1. Percentage of children age 3-35 months who are stunted by aridity zone. West Africa, 1988-96.



The percentage of children who are stunted is highest in the semi-arid zone (41 percent) and then decreases to 28 percent in the humid zone. The percentage of children who are wasted decreases from 21 percent in the hyper-arid/arid zone to 8 percent in the humid zone. These patterns match those seen in the earlier study (WRI, 1996) as expected.

Figure 2. Percentage of children age 3-35 months who are wasted by aridity zone. West Africa, 1988-96.

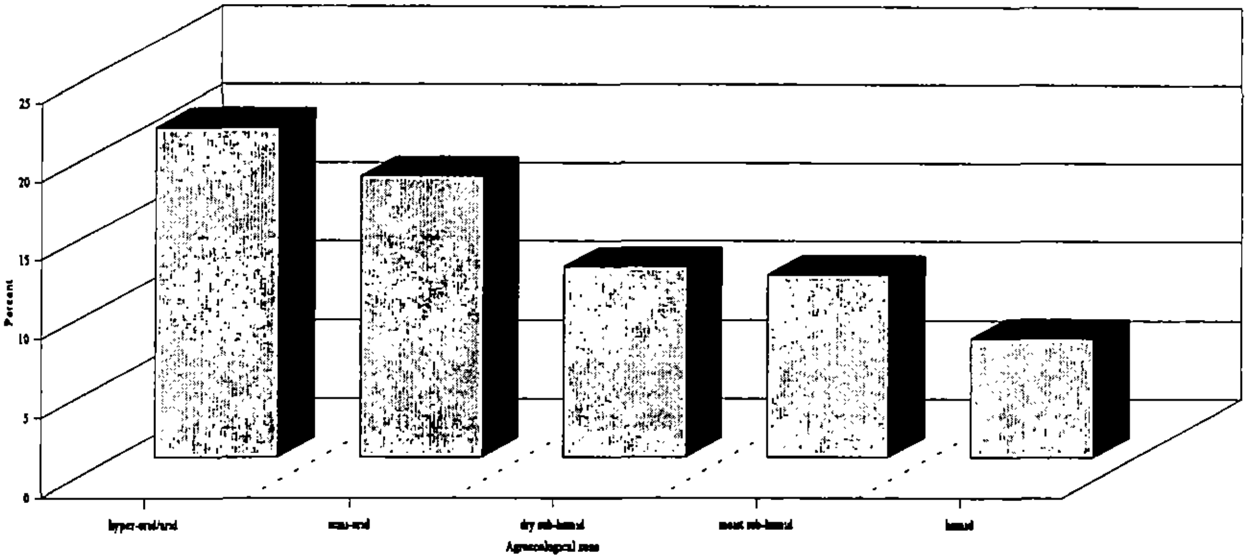


Table 7 presents odds ratios for the three models of stunting described above. The gross effect of aridity zone on the odds of a child being stunted is significant (Model 1). There are no significant differences between the odds of stunting in the hyper-arid/arid, semi-arid, and dry sub-humid zones, but children in the moist sub-humid and humid zones are significantly less likely to be stunted than their counterparts in dryer areas. However, when other variables are included in the model (Model 2), the effect of aridity zone becomes insignificant.

Two interactions are added in Model 3. The interaction between aridity zone and area of residence was found to be significant at the five percent level according to the likelihood ratio test, although the individual parameter estimates are not significant. Figure 3 presents the predicted percentage of children stunted from Model 3 by aridity zone and area of residence[2]. In urban areas the predicted percentage of children stunted, controlling for other characteristics in the model, ranges from 31 percent in the dry sub-humid zone to 27 percent in the moist sub-humid zone. In rural areas it ranges from 34 percent in the dry sub-humid zone to 29 percent in the moist sub-humid zone. It appears that the effect of aridity zone on the risk of stunting is relatively weak after controlling for other factors that affect nutritional status[3].

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[2] The predicted percentages are obtained by setting the value of area of residence and aridity zone to the desired values for all children and leaving the values of the other variables unchanged. Predicted probabilities were calculated using STATA and then converted to percentages.

[3] The percentages presented in Figures 1 and 2 are weighted by the survey sample weights and a combined country weight and inflation factor that inflates the figures to the national populations. The logistic regression was done unweighted (which is appropriate when studying relationships). A weighted version of Model 3 was also fitted. The parameter estimates from the weighted model were less stable and had larger standard errors. The broad substantive conclusions regarding the effect of aridity zone and stunting were similar to those from the unweighted model but there were some differences and the magnitude of the odds ratios differed. The weighted model is

Table 7. Odds ratios for three logistic models of stunting.

Variable	Model 1	Model 2	Model 3
Aridity zone			
Hyper-arid/arid (ref)	1.00	1.00	1.00
Semi-arid	0.95	1.14	0.94
Dry sub-humid	0.97	1.00	1.03
Moist sub-humid	0.85 *	0.89	0.81
Humid	0.77 ***	0.88	0.85
Age		1.31 ***	1.10 ***
Age²		0.996 ***	0.999 *
Birth order			
1 (ref)		1.00	1.00
2-3		0.85 ***	0.85 ***
4-6		0.88 **	0.88 **
7+		0.91	0.91 *
Sex			
Male (ref)		1.00	1.00
Female		0.87 ***	0.87 ***
Current breastfeeding status			
None (ref)		1.00	1.00
Partial/solids		2.11 ***	0.21 ***
Partial/liquids		3.10 ***	0.32 **
Full		2.74 ***	0.27 ***
Diarrhea in last 2 weeks			
Yes		1.20 ***	1.19 ***
No (ref)		1.00	1.00
Sanitation index			
0 (ref)		1.00	1.00
1		0.93	0.93
2		0.51 ***	0.49 ***
Socio-economic index			
0 (ref)		1.00	1.00
1		1.19	1.19
2		1.03	1.03
3		0.95	0.95
4		0.86	0.87
Mother's education			
No schooling (ref)		1.00	1.00
Some schooling		0.76 ***	0.76 ***

heavily influenced by Nigeria because of its large population. Further investigation is needed to reconcile the differences between the weighted and unweighted models. However, such an investigation is beyond the scope of this illustrative analysis.

Table 7 Continued.

Urban/rural residence		
Urban (ref)	1.00	1.00
Rural	1.38 ***	1.16
Population density	1.00	1.00
Non-food crop production	1.00	1.00
Food crop production	1.00	1.00
Market tension		
Low (0-2) (ref)	1.00	1.00
Medium (3-5)	0.95	0.94
High (6-8)	0.79 ***	0.79 ***
Country		
Benin (ref)	1.00	1.00
Burkina Faso	0.74 **	0.73 **
Cameroon	1.04	1.02
Central African Republic	1.52 ***	1.54 ***
Côte d'Ivoire	0.99	0.99
Ghana	1.01	1.03
Mali	0.94	0.93
Niger	1.20	1.26
Nigeria	1.94 ***	1.91 ***
Senegal	0.70 ***	0.72 **
Togo	1.09	1.09
Interactions		
Rural/hyper arid/arid		1.00
Rural/semi-arid		1.37
Rural/dry sub-humid		1.01
Rural/moist sub-humid		1.19
Rural/humid		1.10
Age/ no breastfeeding		1.00
Age^2/ no breastfeeding		1.00
Age/ partial,solids		1.17 ***
Age^2/ partial, solids		0.997 ***
Age/ partial, liquids		1.19 ***
Age^2/ partial, liquids		0.997 *
Age/ full breastfeeding		1.19 ***
Age^2/ full breastfeeding		0.997 **

*** $p<0.001$ ** $p<0.01$ * $p<0.05$.
Ref = reference category

The effect of other variables on the risk of stunting are generally as anticipated and will not be discussed in detail. One interesting point to note is that the WALTPS variables are generally not significant. Population density, food crop production and non-food crop production do not appear to affect the risk of stunting. However, the risk of stunting does decrease as market tension increases. Thus areas that have good access to markets and favorable soil conditions experience lower levels of stunting than areas which do not have good market access or soil fertility.

Figure 3. Predicted percentage of children age 3-35 months who are stunted by aridity zone and area of residence. West Africa, 1988-96.

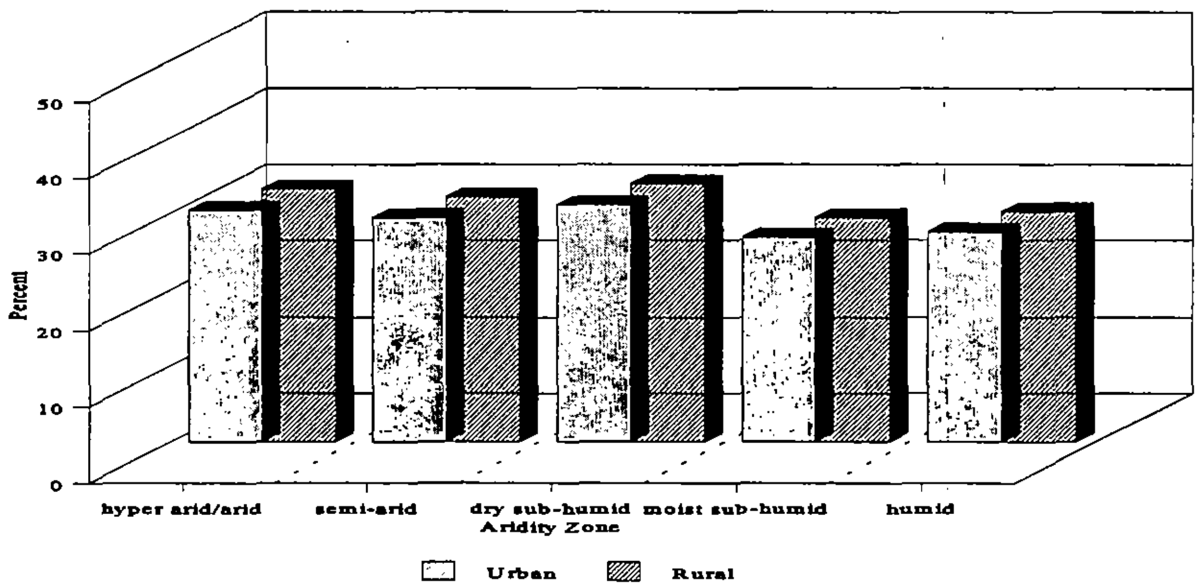


Table 8 presents odds ratios for the three models of wasting. The gross effect of aridity zone on the risk of a child being wasted is highly significant (Model 1). The odds of a child being wasted decrease systematically as humidity increases so that the odds of wasting in the humid zone are only 0.24 times the odds of wasting in the hyper-arid/arid zone. When the other variables are added into the model, the effect of aridity zone is attenuated but remains highly significant (Model 2). The interaction between aridity zone and area of residence was not found to be significant for wasting so Model 3 includes only the interaction between breastfeeding and age which is highly significant. Adding this interaction to the model makes virtually no difference to the effect of aridity zone on the risk of wasting. The predicted percentage of children wasted (from Model 3) decreases from 18.4 percent in the hyper-arid/arid zone to 9.4 percent in the humid zone (Figure 4).

Again, the effect of the socio-economic and demographic variables in the model are generally as anticipated and will not be discussed. Population density, food crop production, and market tension do not significantly affect the risk of wasting. However, increases in per capita non-food crop production are associated with significantly increased risk of wasting. This is an interesting and potentially important finding. As mentioned earlier, it is possible that non-food crop production competes with food production and therefore has a detrimental effect on nutritional status. However, further investigation is needed to fully understand this effect.

Table 8 . Odds ratios for three logistic models of wasting.

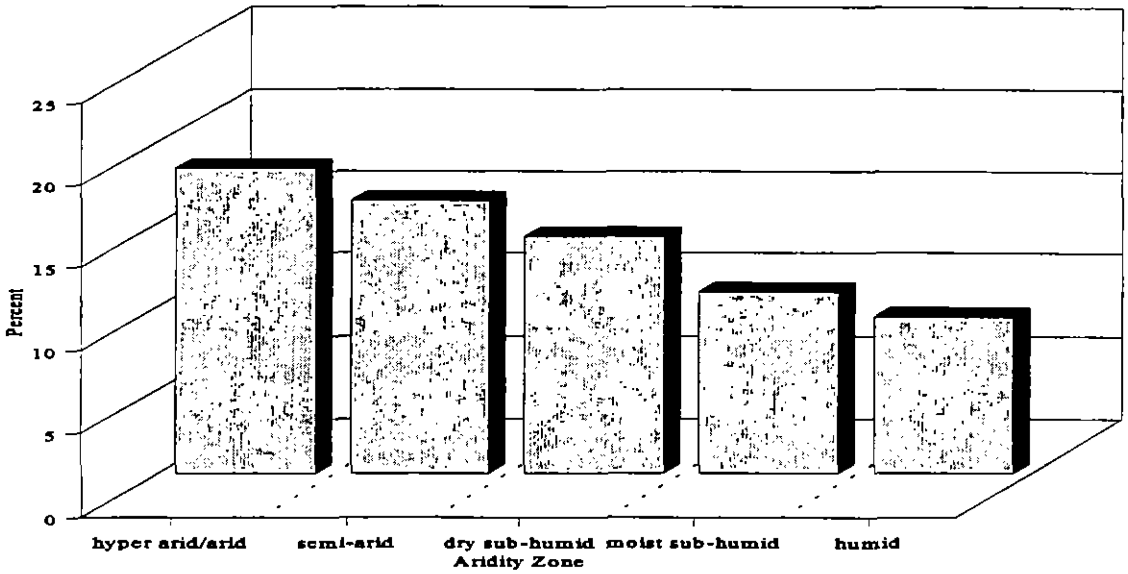
Variable	Model 1	Model 2	Model 3
Aridity zone			
Hyper-arid/arid (ref)	1.00	1.00	1.00
Semi-arid	0.75 ***	0.86 *	0.86 *
Dry sub-humid	0.64 ***	0.72 **	0.71 **
Moist sub-humid	0.40 ***	0.52 ***	0.52 ***
Humid	0.24 ***	0.44 ***	0.44 ***
Age		1.20 ***	0.97
Age²		0.995 ***	0.999
Birth order			
1 (ref)		1.00	1.00
2-3		1.02	1.03
4-6		1.10	1.11
7+		1.14 *	1.15 *
Sex			
Male (ref)		1.00	1.00
Female		0.85 ***	0.85 ***
Current breastfeeding status			
None (ref)		1.00	1.00
Partial/solids		1.67 ***	0.19 ***
Partial/liquids		1.62 ***	0.06 ***
Full		1.49 ***	0.07 ***
Diarrhea in last 2 weeks			
Yes		1.48 ***	1.46 ***
No (ref)		1.00	1.00
Sanitation index			
0 (ref)		1.00	1.00
1		1.08	1.08
2		1.11	1.08
Socio-economic index			
0 (ref)		1.00	1.00
1		1.10	1.09
2		0.99	0.98
3		0.91	0.90
4		0.79	0.78
Mother's education			
No schooling (ref)		1.00	1.00
Some schooling		0.85 **	0.85 **
Urban/rural residence			
Urban (ref)		1.00	1.00
Rural		1.06	1.06

Table 8 Continued.

Population density	1.000	1.000
Non-food crop production	1.002 **	1.002 **
Food crop production	1.000	1.000
Market tension		
Low (0-2) (ref)	1.00	1.00
Medium (3-5)	1.13	1.13
High (6-8)	1.01	1.02
Country		
Benin (ref)	1.00	1.00
Burkina Faso	0.74 *	0.75 *
Cameroon	0.33 ***	0.32 ***
Central African Republic	0.54 ***	0.54 ***
Côte d'Ivoire	0.66 ***	0.66 ***
Ghana	0.95	0.95
Mali	1.19	1.22
Niger	0.75 *	0.75 *
Nigeria	0.70 **	0.67 **
Senegal	0.48 ***	0.48 ***
Togo	0.34 ***	0.33 ***
Interactions		
Age/ no breastfeeding		1.00
Age²/ no breastfeeding		1.00
Age/ partial,solids		1.18 ***
Age²/ partial, solids		0.997 ***
Age/ partial, liquids		1.38 ***
Age²/ partial, liquids		0.993 ***
Age/ full breastfeeding		1.34 ***
Age²/ full breastfeeding		0.994 ***

*** $p<0.001$ ** $p<0.01$ * $p<0.05$
Ref = reference category

Figure 4. Predicted percentage of children age 3-35 months who are wasted by aridity zone. West Africa, 1988-96.



Discussion

The objective of this paper was to illustrate how the WASAP GIS could be used to link data from different sources for multivariate analysis. Linking the geocoded DHS, WALTPS, and ICRAF aridity zone data in WASAP was easy. The ease of linking the data is largely due to the preparatory work that was done under the WASAP Project. All these datasets had been geocoded, checked, and put into ARC/VIEW format so relatively little work was needed to create the variables needed for the analysis and link them together. In principle, any geocoded datasets could be linked in this way, but it is likely that more work would be needed to link datasets that have not undergone the standardization and cleaning that was done under WASAP. In particular, linking data collected at different points in time, or linking data from surveys conducted in different clusters may be problematic.

The ability to link datasets using a GIS expands the potential for analysis and provides opportunities to examine new relationships. In this analysis, the ability to link environmental and agricultural data to the DHS provided an excellent opportunity to add a new dimension to the analysis of the determinants of nutritional status. The potential of linking datasets to expand analysis will largely depend on the availability of suitable datasets for linking. We would encourage anybody collecting data to include GPS coordinates to facilitate spatial linking of datasets. The more widely used geocoding becomes, the greater the analysis potential will be. However, it is important that the introduction of new variables from an external source be done on a sound theoretical basis. The relationship between aridity zone and nutritional status provides a particularly good example of linking datasets because there is a strong theoretical basis for expecting environmental factors to be linked to nutritional status. Yet the relationship between environmental factors and nutritional status has not been widely studied because of the difficulties in linking environmental and health data. In contrast, very few non-DHS variables are available in WASAP that are relevant for the analysis of fertility or contraceptive use so the potential for linking datasets to the DHS to expand these analyses is low at present. As more georeferenced datasets that include variables relevant to fertility analysis become available (e.g. economic variables such as income and expenditure) the potential for linking datasets to the DHS to expand fertility analysis will increase.

One of the aims of the WASAP project was to allow analysis to be undertaken at the regional level. The analysis in this paper benefits from a regional perspective because the West Africa region covers all five aridity zones and therefore provides greater variability in the independent variable of primary interest than would a country-level analysis. One disadvantage of conducting analysis at the regional level is that the researcher is constrained to using variables that are available across all countries (or at least most of them) in a standardized format. Additional opportunities for linking datasets may be provided at the country level or at the regional level within countries which would broaden the scope of analysis. For example, a project in Niger developed a GIS that included census data, environmental data, and health infrastructure data (Wane et al., 1995). In principle, these data could be linked to the WASAP data for Niger to provide a rich database. Similarly, data from the Famine Early Warning System (FEWS) Project are available in geocoded format for Burkina Faso, Mali, and Niger. The WASAP has been used to link the FEWS data to the DHS data for these countries (McGuire, 1998).

From a substantive perspective, our analysis shows that the relationship between aridity zone and stunting is relatively weak once other variables that affect nutritional status are controlled. However, there is a strong negative relationship between aridity zone and wasting that persists after controlling for other variables. Although these results are illustrative and should be viewed as preliminary, they do suggest a genuine association between aridity and wasting. The causal nature of this relationship is unclear and should be examined further.

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