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GLOWA-Volta Common Sampling Frame –

Selection of Survey Sites

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1. Introduction

For several reasons constructing a common sampling frame (CSF), where different units of observation are hierarchically linked, provides advantages for interdisciplinary research teams. To give a short example: employing a CSF facilitates that the soil scientists collect soil samples from the plots of exactly those farmers who are interviewed by the agricultural economists and who are villagers in the communities being analyzed by the institutional analysts. Accordingly, a CSF ensures a maximum overlap of biophysical and socioeconomic field observations.

This paper describes the multivariate data analysis of the CSF that led to the selection of survey sites for GLOWA-Volta. Section 2 provides a list of broad research questions that motivated the CSF and joint field campaigns of social and natural scientists. Section 3 discusses the advantages and disadvantages of the CSF, and section 4 sketches the interdisciplinary discussion process about operational selection criteria. Section 5 provides more details about the statistical procedure in selecting the observation units. Section 6 provides an overview about the different survey activities and field measurements during the field campaign in 2001. Section 7 concludes with a few final remarks that relate the field observations to the planned multi-agent modeling approach of GLOWA-Volta.

It is important to note at the beginning of this documentation that from a socioeconomic point of view water and land use cannot be easily divided into two different research fields. Decision-making processes on water and land use are clearly interrelated at household, community, regional and national level. The CSF approach addresses this interrelatedness and therefore includes research activities both on water and land use.

2. Research questions and observation units

In GLOWA-Volta six broad socioeconomic research questions closely relate to the research activities undertaken by the natural scientists: 1) safe access of households to water; 2) determinants of household water demand; 3) household expenditures on water; 4) water-related health aspects; 5) possible causal relationship with migration; 6) possible changes in the use of land.

Evidently, all questions listed above require inputs from the natural sciences such as biophysical measurements and spatial data from remote-sensing techniques. In turn, the socioeconomic results will inform the natural scientists' research directly ("ground-truthing" of remote sensing images) or feed into the joint integrated modeling exercises (modeling of land use change, intersectoral water allocation).

For the economic subprojects, the main unit of observation is the individual household who takes decisions regarding the use of water and land resources. The research centers on understanding the households' choices among different feasible alternatives of action and in particular on their strategies for coping with water variability, climate and land cover changes. The institutional analysts, on the other hand, focus on decision-making processes at higher levels of social organization, for example on community, regional and national level. The unit of observation is accordingly not the single household but the village assembly, the water user association, etc.

The hydrologists, on the other hand, undertake their research in exemplary micro watersheds whereas the soil scientists plus geographers focus on landscape units that are grouped in different land use and land cover classes. In GLOWA-Volta, their main units of observation correspond roughly to the community and district level. A perfect hierarchy of observation units of all subprojects, however, cannot be constructed because administrative boundaries watersheds, and land cover polygons do not coincide. The socioeconomic and biophysical subprojects including those in the atmosphere cluster have therefore agreed on an appropriate spatial resolution for exchanging data among their models. In the course of the GLOWA-Volta project, a geo-referenced database will organize the data of all subprojects in 9 km^2 grid cells **(figure 1)**.

Figure 1: Observation units at different levels of aggregation ("scales")

Socio-economic	*biophysical*
Country	River Basin
|	|
Region	Sub-basin
|	|
District	Landscape
|	|
Community	Sub-catchment
|	|
Village	Hydrology/Nutrient Response Unit
|	|
Household	Farming systems
|	|
Technology Livestock Plot	Plot
	|
	Point sample (subplot)

Technically, the construction of the CSF consists of the following steps: 1) all subprojects identify their main observation units; 2) the interdisciplinary team then establishes a hierarchical structure of observation units; 3) the team agrees on a sampling frame and selection criteria that reflect the interests of all subprojects involved; 4) *a priori* information is employed to stratify the universe of observation units; 5) for each strata the team selects the observation and sub-observation units randomly if possible and calculates weighting factors; 6) the subproject finally gross up their results to the study region.

3. Advantages and disadvantages of common sampling frames

Employing a CSF provides several advantages for interdisciplinary research teams who plan to collect large amounts especially of primary data:

- The CSF yields certain "agglomeration" benefits particularly for the project logistics. Collecting information from hierarchically linked observation units usually implies a spatial concentration of field activities. As a consequence, transport and lodging costs for enumerators and technicians can be reduced, as well as training and interpreting costs since this concentration allows building larger teams of field assistants with knowledge of local languages. Additionally, costs of transforming and exchanging data between different scientific disciplines are usually lower.
- The CSF can make use of *a priori* information for stratification and therefore tends to increase precision and reliability as compared to a pure random sampling. Especially in the case of GLOWA-Volta, considerable amounts of socioeconomic data with high quality and large spatial extent are available. The *a priori* information additionally also helps developing research hypotheses and may guide the design of questionnaires or measurements.
- A hierarchical sampling frame permits the extrapolation ("grossing-up") of sample measurements to the universe. The research findings at different locations can be generalized and may then be used for deriving conclusions at national or basin level. This is potentially a large advantage over nonrandom and purposeful selections of observations units that allows only for comparisons of case studies or "anecdotal" evidence. In GLOWA-Volta this advantage might, however, be rather moderate because for budgetary reasons the sample fraction has to be very small and the sampling error will thus be relatively large.

A common sampling frame implies on the other hand the following disadvantages:

- Typically, interdisciplinary teams have to invest a lot of time to agree on a hierarchical structure of observation units and operational selection criteria for stratification. The discussion process is therefore costly and implies quite uncertain benefits. In spite of this disadvantage, the discussion process might help clarifying the different viewpoints of the disciplines involved and in the longer run lead to a shared terminology or even methodology. In the case of GLOWA-Volta, the construction of the CSF was the first interdisciplinary research activity where different subprojects of the land and water cluster started working together scientifically and thereby laid the basis for future integrative research.
- The common sampling might also be inapplicable for some disciplines that will then opt for their exclusion. This is particularly relevant when certain subprojects can undertake only very few and long-term measurements. A stratified random sampling implies for them a high risk of missing the observation units of their specific interest. Nevertheless, the CSF might also provide the chance in these cases of at least comparing the findings of these out-of-frame subprojects with other subprojects as long as information on the joint selection criteria will be collected.

4. Sampling frame and selection criteria

As the sampling frame for the Ghanaian part of the Volta basin, the research team agreed on a merged data set taken from the Ghana Living Standards Survey (GLSS4) and publicly available GIS maps. The GLSS, which was conducted by Ghana's Statistical Service with assistance from the World Bank and the European Union, provides data on various aspects of households' economic and social activities as well as community characteristics in Ghana. The survey was carried out on a probability sample of 6,000 households in 300 enumeration areas that were drawn from the Ghana population census of 1984. Of these 6,000 households sampled in the GLSS 2,240 lie within the Volta basin.[1] The remainder of this section explains the statistical procedure in selecting the GLOWA-Volta observation units on community level.

Table 1: Example for tentative list of selection criteria, used during team discussions

Research Aspect	*Measure/Criterion*	*Data sets*
Household water use		
-drinking water	water charges	GLSS4-Sec9
	water sources	GLSS4-Sec7-D-1
-water for irrigation	irrigated crops	
	expenses for irrigation	GLSS4-Sec8-F-07
-water for livestock		
-fishing	HH members engaged in fishing	GLSS4-Sec6-3; Sec8-A-10
Coping with water variability/uncertainty		
-water harvesting		
-off-farm activities	wage labor, non-farm activities	GLSS4-Sec4-A,B,C; Sec10
-temporary migration		GLSS4-Sec5
-change of land use	abandonment of farms	GLSS4-Sec8-B-11
Sensitivity to price signals		
-market-orientation	cash crops, input purchase, processing and marketing	
Biophysical 'environment'		
-agro-ecological conditions		
-land suitability		GIS?
-intensity of land use change		GIS?
-geology, topography		GIS?
Health		
-health status		
-use of health services		

[1] Since administrative and watershed boundaries do not perfectly match, we had to define a decision rule for selecting the socio-economic observation units from the GLSS4 data set. To increase our sample size, we decided to consider all EAs in districts that drain their waters to the Volta basin—even though geographically a particular EA might lie outside the basin.

Table 1 gives an example of the major subject areas in the GLSS4 that were used for the derivation of the selection criteria. The 3rd column indicates the data sets from which data on the measure in column 2 were taken.

The team finally compiled a list of 22 operational selection criteria that captured the research interests of all subprojects involved (see table2 and table 3). The criteria range from variables measuring the agro-ecological potential to household water use and welfare, incidence of water-borne diseases, social capital and migration.

Table 2: Final list of selection criteria

Category	***Variable***	***Description***
Household water use	ImpWat	Percentage of HH with improved water supply [%]
	ImpWatDry	Percentage of HH with improved water supply also during dry season [%]
	FetchTimeH	average fetching time for water per month and head [hours]
	WatExpH	Total water expenditures per head and month [Cedis]
Agro-ecological conditions	AvTemp	Temperature (yearly average)
	AvRain	Rainfall (yearly average)
	PotEtr	Potential evapotranspiration
Agricultural intensity	AgricActiv	Frequency of agricultural activities among the 5 most important economic activities
	InvCropsL	HH crop investment costs per acre owned [Cedis]
	InvLivestH	HH livestock investment costs per head [Cedis]
Fishing	ModernFish	Percentage of HH with modern fishing inputs [%]
Market orientation	MarketDist	Market distance [km]
Welfare	IncomeH	HH income per head [Cedis]
	ExpenH	HH expenditures per head [Cedis]
	SavingsH	HH savings per head [Cedis]
	DAssetsH	Durable household assets per head [Cedis]
	OwnLand	Amount of land owned [acres]
	SharLand	Amount of land sharecropped [acres]
Health	HealthProb	Frequency of water-borne diseases among 5 most important health problems [%]
	HealthExpH	Total health expenditures per head and month [Cedis]
Social capital	Selfhelp	Contribution to Self-help projects [min per months]
Migration	Migrat	Migration Index [%]

Table 3: Selection criteria at community level (univariate statistics)

Variable	*N*	*Mean*	*StdDev*	*Minimum*	*Maximum*
Migrat	84	18.5248	15.2040	0.0000	75.0000
ImpWatDry	84	26.3449	28.5787	0.0000	95.0000
MarketDist	84	11.3871	55.4352	0.0000	480.0000
HealthProb	84	46.0927	17.5140	25.0000	75.0000
FetchTimeH	84	3.5528	2.0910	0.2488	12.9667
ImpWat	84	0.3894	0.4096	0.0000	1.0000
WatExpH	84	79.3391	317.8057	0.0000	2371.2500
HealthExpH	84	1625.0698	1867.1430	70.8333	13040.0000
InvCropsL	84	15450.1125	31613.8936	0.0000	115952.8140
InvLivestH	84	4498.3292	18292.6884	0.0000	152549.6830
DAssetsH	84	339891.3000	738541.8110	13275.5952	5420333.3300
SavingsH	84	18675.6233	72872.6958	0.0000	600000.0000
OwnLand	84	3.1524	4.7162	0.0000	26.4000
Selfhelp	84	4396.1158	7707.3922	0.0000	54900.0000
SharLand	84	0.2414	0.9182	0.0000	7.0000
IncomeH	84	416193.3310	292178.7260	70861.5057	1453540.0500
ExpenH	84	753422.8360	427463.1100	207564.5340	2667677.8700
AgricActiv	84	0.8154	0.2099	0.1429	1.0000
ModernFish	84	0.3342	0.4041	0.0000	1.0000
AvTemp	84	26.9035	1.1491	25.0000	28.5000
AvRain	84	1165.2608	207.2757	800.0000	1550.0000
PotEtr	84	1672.6965	196.1049	1425.0000	2025.0000

Note: 112 EAs of GLSS4 belong to the Volta basin of which 28 have missing data.

5. Multivariate data analysis

Initial correlation analysis revealed high interdependence among the selection criteria so we used principal correlation analysis (PCA) to derive a relatively small number of linear combinations of the original variables that retain as much information in the original variables as possible. The new variables, named as factors were later used for the cluster analysis.

5.1 Principal Component Analysis (PCA)

Based on the merged GLSS data set, the principal component analysis (PCA) detected high correlations among these variables and revealed 8 principal components that explain about 70% of the variance in the data (table 4).

The rotated correlations of the derived factors with the original variables are presented in table 5. For descriptive purposes each factor has to be explained by few original variables that score high on the factor. The explanation of the factors in table 4 used a cut-off point of 0.6 to choose the important variables that describe each of the eight factors. The cut-off point was based on the overall Kaiser's measure of sampling adequacy, which represents a summary of how small the partial correlations are relative to the ordinary correlations among the variables. Usually values recorded over 0.8 are considered good and those recorded below 0.5 point to a remedial action in the PCA (Kaiser, 1970; Kaiser and Rice, 1974).

Table 4: Eigenvalues and explained variance

	Eigenvalue	*Difference*	*Proportion*	*Cumulative*
1	**4.38132**	**1.80535**	**0.1992**	**0.1992**
2	**2.57596**	**0.41168**	**0.1171**	**0.3162**
3	**2.16429**	**0.54133**	**0.0984**	**0.4146**
4	**1.62296**	**0.24134**	**0.0738**	**0.4884**
5	**1.38162**	**0.11325**	**0.0628**	**0.5512**
6	**1.26837**	**0.08722**	**0.0577**	**0.6088**
7	**1.18115**	**0.11789**	**0.0537**	**0.6625**
8	**1.06326**	**0.09904**	**0.0483**	**0.7109**
9	0.96421	0.08958	0.0438	0.7547
10	0.87463	0.07294	0.0398	0.7944
11	0.80169	0.07187	0.0364	0.8309
12	0.72983	0.13940	0.0332	0.8641
13	0.59043	0.02459	0.0268	0.8909
14	0.56584	0.08735	0.0257	0.9166
15	0.47850	0.09471	0.0217	0.9384
16	0.38379	0.05953	0.0174	0.9558
17	0.32426	0.12756	0.0147	0.9705
18	0.19670	0.04416	0.0089	0.9795
19	0.15254	0.01768	0.0069	0.9864
20	0.13486	0.03880	0.0061	0.9926
21	0.09606	0.02831	0.0044	0.9969
22	0.06775		0.0031	1.0000

Note: Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.607898

Table 5: Rotated correlations and descriptions of derived factors

Original variable	*Factor1*	*Factor2*	*Factor3*	*Factor4*	*Factor5*	*Factor6*	*Factor7*	*Factor8*
Migrat	-0.04946	-0.32477	0.03855	0.00558	-0.06070	0.11227	0.53792	-0.38608
ImpWatDry	-0.12211	-0.03484	0.17006	**0.88770**	0.07437	0.07524	-0.02768	-0.00497
MarketDist	-0.00731	-0.10877	0.03837	0.00151	-0.01669	-0.08510	-0.06858	**0.86540**
HealthProb	0.12346	0.09947	0.21077	-0.17741	-0.42661	0.08261	0.50042	0.05513
FetchTimeH	-0.18791	0.18853	-0.13878	-0.45678	-0.08806	0.28412	0.15733	0.47702
ImpWat	-0.04615	-0.02807	-0.00333	**0.74610**	-0.31105	0.13161	0.01904	-0.02103
WatExpH	-0.06872	**0.60069**	0.36239	0.28765	-0.19655	-0.04996	0.05489	-0.00928
HealthExpH	-0.22642	**0.70257**	-0.08297	-0.16195	-0.13060	0.05473	-0.08078	-0.16109
InvCropsL	-0.16160	0.05157	0.07426	-0.06921	**0.77336**	-0.13313	-0.16601	-0.17079
InvLivestH	0.05737	-0.01724	**0.92957**	0.13662	-0.04328	0.01861	0.07785	0.02755
DAssetsH	0.11128	**0.64627**	0.06096	-0.06809	0.31544	0.22991	-0.12485	0.02083
SavingsH	0.15327	-0.01010	-0.01743	0.07789	0.02863	-0.09025	**0.60004**	-0.01911
OwnLand	-0.11717	0.01625	0.19892	-0.04550	-0.07869	**0.85241**	-0.12510	-0.07260
Selfhelp	-0.12322	0.21451	**0.88803**	0.03678	0.05059	0.07837	-0.03053	-0.03293
SharLand	-0.12887	0.18276	-0.10987	0.25290	0.06575	**0.70966**	0.15546	0.01222
IncomeH	-0.12967	0.33808	-0.01476	-0.22289	0.37348	0.10337	0.53838	0.15093
ExpenH	-0.32901	**0.73400**	0.18599	-0.11171	0.24245	0.11186	0.26076	0.14088
AgricActiv	0.51710	-0.40965	-0.27648	-0.25707	-0.03585	0.21387	-0.11587	-0.04028
ModernFish	-0.14069	0.05077	-0.04499	-0.10994	**0.69330**	0.11147	0.23205	0.12916
AvTemp	**0.87782**	-0.10157	0.00292	-0.04140	-0.18203	-0.25546	0.11223	0.03697
AvRain	**-0.92880**	-0.04202	-0.06434	0.00591	0.02421	0.01087	-0.04655	0.01947
PotEtr	**0.85838**	-0.28217	-0.10389	-0.05919	-0.19185	-0.12717	0.09621	-0.06478

Note: Description of factors on next page

Factor Descriptions

Factor 1:	Agro-ecological conditions ("aridity")
Factor 2:	Expenditures
Factor 3:	Livestock and social capital
Factor 4:	Improved water supply
Factor 5:	Investments
Factor 6:	Farm size
Factor 7:	Savings
Factor 8:	Market distance

5.2 Cluster Analysis (CA)

Based on the results of the PCA, finally10 clusters (or strata) were identified in a subsequent cluster analysis. In this case the analysis employed a disjoint cluster method in which GLSS4 enumeration areas that are grouped into one cluster tend to be similar to each other in some sense and others in different clusters tend to be dissimilar. Using the k-means method under FASTCLUS procedure in SAS (SAS, 1999), each GLSS4 enumeration area in the Volta basin was placed in one and only one cluster.

Table 6: Selected villages/communities

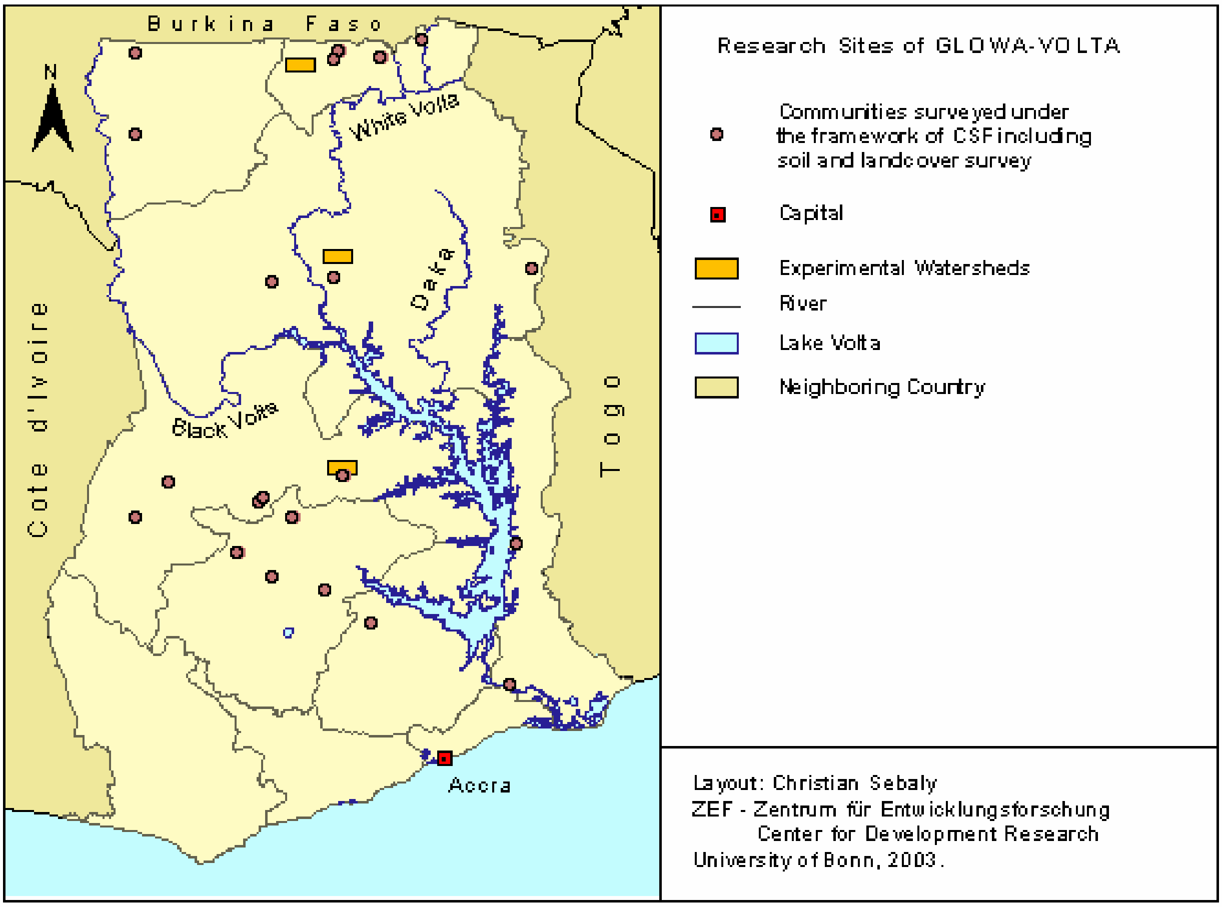
Note: weighting factors extracted from GLSS4 dataset: **pov_gh.sas7bdat)**

Enumeration area	*Weighting Factor*	*Cluster*	*Distance to centroid*	*Selected villages/communities*
4855	**1.23069**	**1**	**0.7311556**	**selected**
4952	3.9538314	1	0.80081622	
4081	1.350802	1	0.926765696	
4862	1.9489863	1	1.056283932	
4809	0.1980463	1	1.2375826	
4842	2.3334835	1	1.298926042	
4849	0.3747658	1	1.396623336	
4852	1.4238349	1	1.522639364	
4875	2.2255975	2	0.709795975	
4959	**0.55822**	**2**	**0.9439383**	**selected**
4872	0.7932936	2	1.023704995	
4879	0.5391588	2	1.208742628	
4869	1.2335665	2	1.353152969	
4882	0.3399563	2	1.906696238	
4439	**0.64743**	**3**	**0.5904444**	**selected**
4932	0.8451679	3	1.095875629	
4435	0.6629002	3	1.112957517	
4452	0.9028367	3	1.936359238	
4929	0.4127935	3	2.51324488	
4599	0.7650227	3	2.978524092	
4059	0.9357703	3	8.15977188	
4949	**1.36321**	**4**	**1.0550278**	**selected**
4839	2.2086466	4	1.189082913	
4944	0.4645665	4	1.202749315	
4815	1.7013727	4	1.313824275	
4812	1.130248	4	1.601932592	
4795	0.888745	4	1.956736053	
4835	1.1741033	4	1.995778834	

4935	0.8845575	4	2.578401342	
4145	0.6135949	4	3.52015565	
4829	1.1036854	4	3.862323819	
4865	1.2368067	4	6.555642731	
4845	1.1126936	4	8.601943025	
4512	1.3796871	5	1.130928724	
4805	0.8610602	5	1.330206938	
4522	**0.54814**	**5**	**1.5028483**	**selected**
4635	0.8714852	5	1.595813919	
4792	1.182172	5	2.448236843	
4785	0.5303202	5	2.576930208	
4545	**0.76117**	**6**	**1.158275**	**selected**
4822	0.8072152	6	1.372684341	
4515	**0.63299**	**6**	**1.4467904**	**selected**
4652	1.0820618	6	1.53288766	
4605	0.8551784	6	1.676670993	
4069	1.0396889	6	1.831306117	
4802	0.7021603	6	2.071677251	
4075	2.648333	6	2.58116985	
4832	1.1117498	6	2.757605589	
4542	5.3152923	6	3.177825566	
4062	0.5824247	6	5.102020158	
4939	0.8911097	6	7.013889955	
4079	1.1207234	6	8.376996022	
4825	**0.99969**	**7**	**0.976665**	**selected**
4782	0.6989096	7	1.248031244	
4552	0.6065537	7	1.608706208	
4889	**0.3597**	**8**	**0.501228**	**selected**
4919	0.907	8	0.6737383	inaccessible by road
4905	**1.4395**	**8**	**0.6850719**	**selected**
4915	0.7140645	8	0.7304728	
4859	1.2805022	8	1.058823253	
4922	1.2376146	8	1.067730417	
4885	0.5581136	8	1.087473518	
4892	0.9220505	8	1.209055991	
4909	1.1941895	8	1.259853435	
4955	1.2316991	8	1.397193017	
4899	0.8605219	8	1.616485058	
4902	0.4813918	8	1.676925038	
4895	0.4373496	8	1.897406304	
4912	1.2852042	8	2.728380741	
4819	**1.16783**	**9**	**0.8759715**	**selected**
4639	0.7803615	9	1.485499459	
4790	0.8454444	9	1.564863405	
4942	0.5205671	9	3.404793771	
4509	0.89687	9	3.496221305	
4602	**0.79711**	**10**	**1.0179195**	**selected**
4629	**0.81056**	**10**	**1.1255763**	**selected**
4449	1.1262035	10	1.346197199	
4632	1.0931764	10	1.561588623	
4925	0.9942409	10	1.574429677	
4642	0.2650359	10	1.785045694	
4799	0.4731979	10	1.935980793	
4445	0.5131902	10	3.015816954	
4595	1.3949167	10	4.311247489	
4152	1.1736567	10	12.18329193	

The procedures revealed Euclidean distances from the centriod of each cluster to its respective enumeration areas. The enumeration areas closest to the cluster centroid were then selected as representative communities according to the proportional-to-size rule (i.e. "large" clusters with many enumeration areas are represented with more survey sites)[2]. To ensure an overlap with other GLOWA-Volta subprojects researching at locations, which are not contained in the original GLSS sampling frame, additional sites were added to the sample. As a result of the sampling procedure, a list of 20 survey communities was compiled **(**see **table 6** and **figure 2)**.

Figure 2: Survey communities of GLOWA Volta



[2] In four cases, this selection rule could not be applied strictly because of data problems, and in one case because of road problems. The next closest EA was then selected. The sum of distances of all selected EAs, however, only increases by 5%, that is, the 'selection error' is rather moderate.

7. Descriptions of clusters

This section describes the clusters of GLSS4 enumeration areas from which the representative villages/communities were selected. To make the cluster descriptions more clear, we have normalized the rotated factors' scores for the EAs closest to the centroid on a scale of 0 to 1 and then introduced 4 classes of very low, low, high and very high factor scores (see **table 7**).

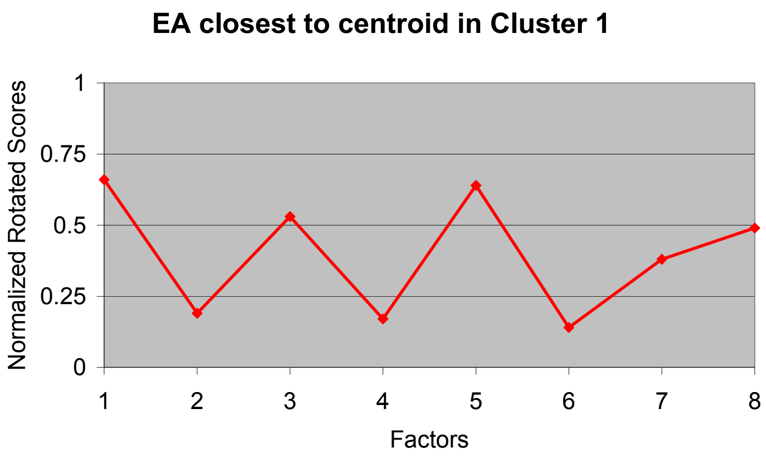
Table 7: Normalized rotated factor scores of EAs closest to the cluster centroid

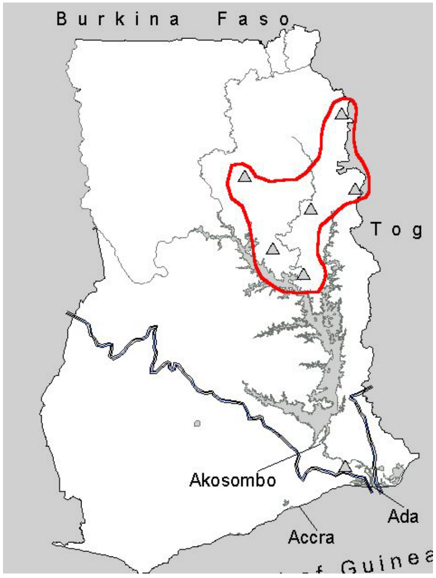
Cluster	*Factor1*	*Factor2*	*Factor3*	*Factor4*	*Factor5*	*Factor6*	*Factor7*	*Factor8*
	Aridity	Expenditure	Livestock; social capital	Improved water supply	Investments	Farm size	Savings	Market distance
1	0,66	0,19	0,53	0,17	0,64	0,14	0,38	0,49
2	0,70	0,25	0,72	0,88	0,16	0,07	0,10	0,58
3	0,00	1,00	0,35	0,18	0,42	0,00	0,35	0,00
4	0,56	0,58	0,70	0,12	0,87	0,14	1,00	0,76
5	0,16	0,56	0,00	0,63	0,39	0,72	0,48	1,00
6	0,09	0,32	1,00	0,50	0,00	0,31	0,62	0,95
7	0,26	0,00	0,77	0,13	0,77	0,87	0,87	0,72
8	1,00	0,30	0,36	0,35	0,43	0,27	0,36	0,44
9	0,28	0,22	0,42	0,00	1,00	1,00	0,00	0,36
10	0,27	0,79	0,18	1,00	0,22	0,16	0,53	0,42

Very low	0.0-0.25
Low	0.26-0.50
High	0.51-0.75
Very high	>0.75

Cluster1

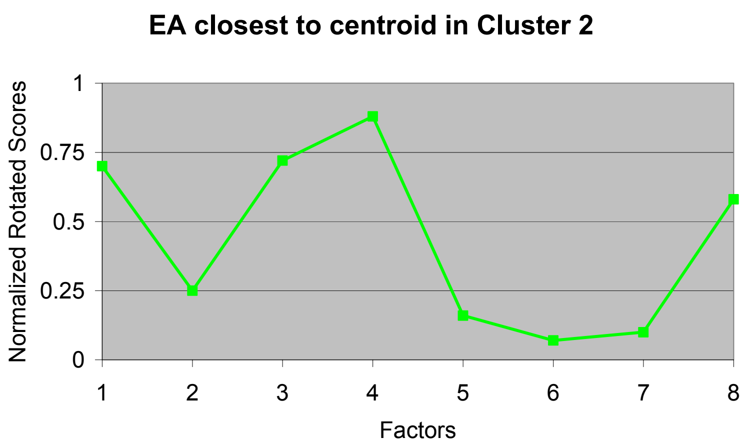
The enumeration areas in Cluster 1 are located in the middle to the eastern part of the Northern Region of Ghana. Households face arid conditions, have only poor water supply, and operate on small farms.

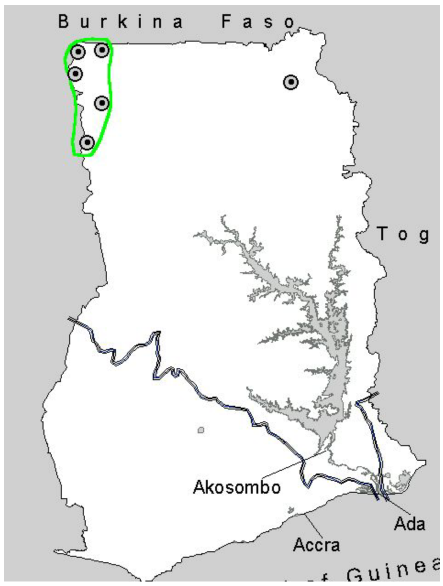




Cluster 2

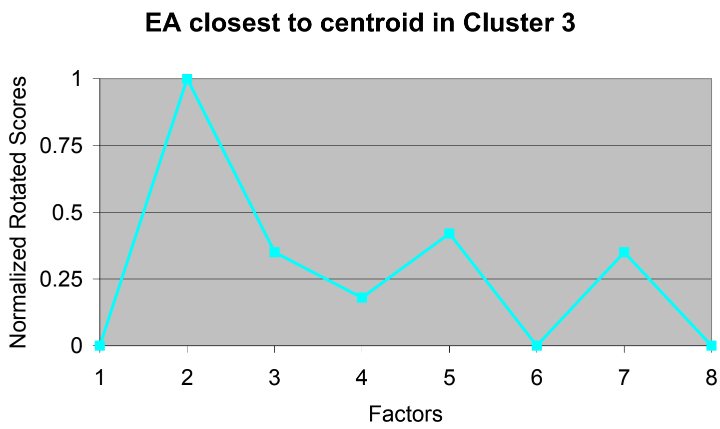
Cluster 2 is located in the north western corner of Ghana. Similar to cluster 1, arid conditions and small farm sizes prevail; however, households can count on highly improved water supply.

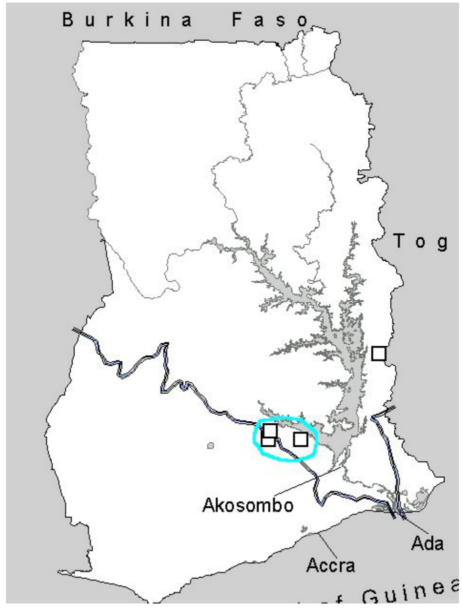




Cluster 3

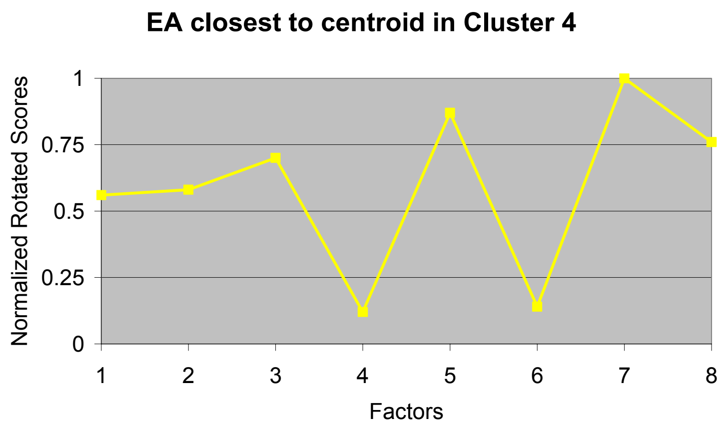
The communities/villages belonging to Cluster 3 are located near the basin boundary in the Eastern Region. Households have very high levels of expenditures, but only poor water supply, and small farm sizes. Markets are very close, and agro-ecological conditions are very humid.

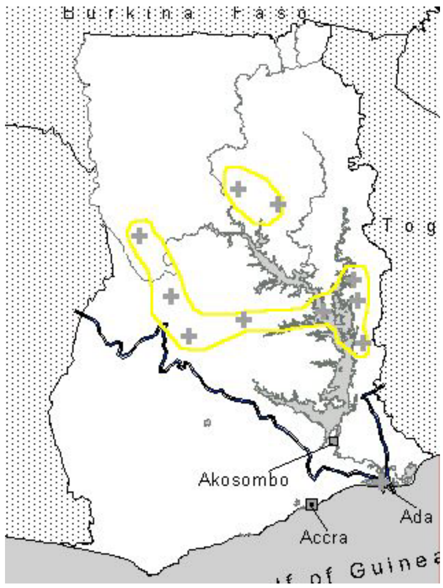




Cluster 4

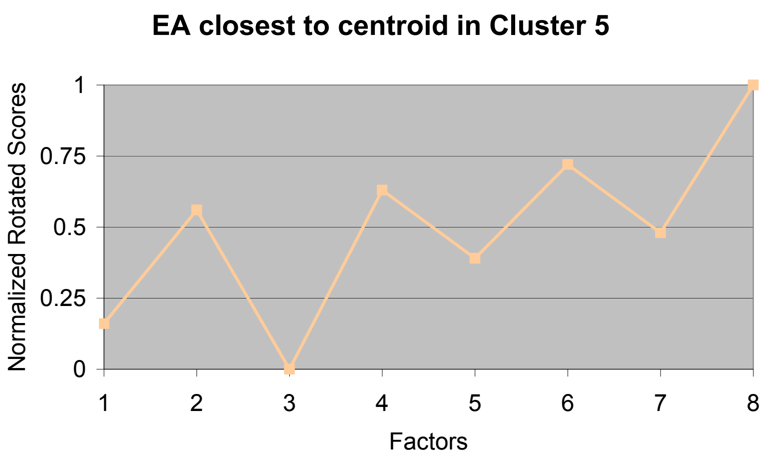
The communities/villages of Cluster 4 are mainly located in the north, west and eastern part of Lake Volta. They are characterized by very high levels of investments and savings, poor water supply, and small farm sizes

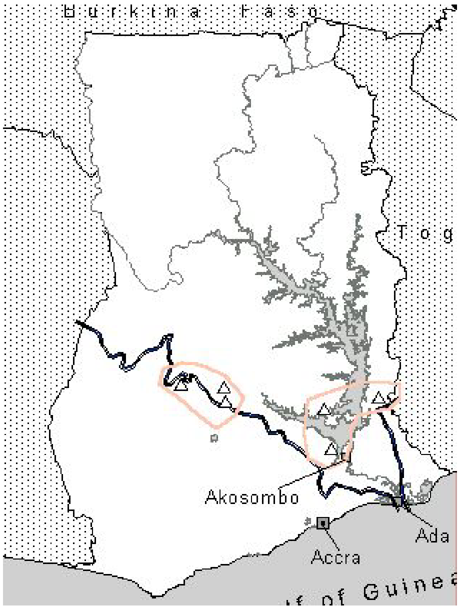




Cluster 5

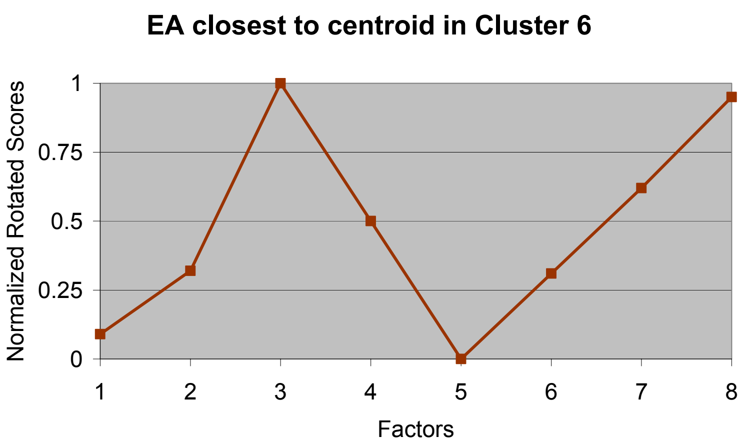
As can be seen on the map, the communities/villages of Cluster 5 are located around the basin boundary as well as next to Lake Volta. There is very little livestock/social capital, and markets are very remote. Agro-ecological conditions are very humid.

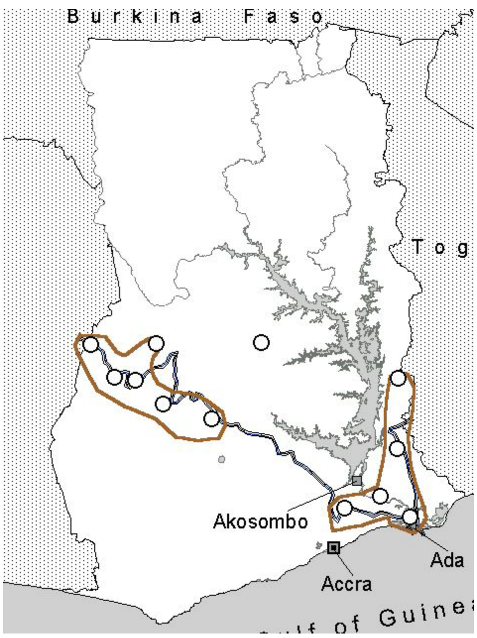




Cluster 6

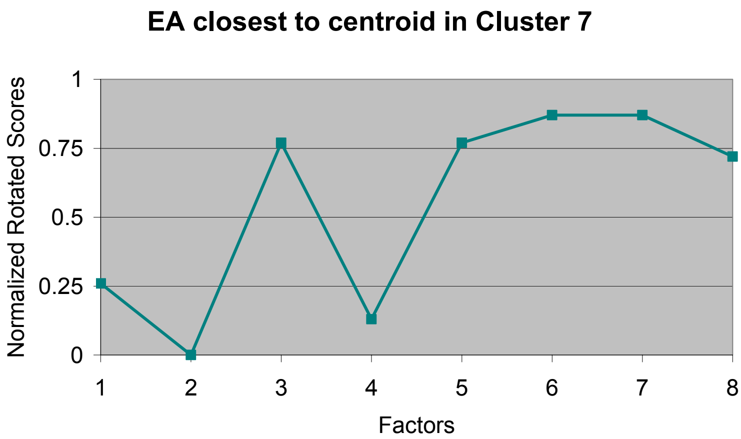
Communities of Cluster 6 are located in the western part of Ghana around the basin-boundary and in the south-eastern part of the country. Like in Cluster 5, markets are very remote and agro-ecological conditions are very humid. But there is very high intensity of livestock/social capital.

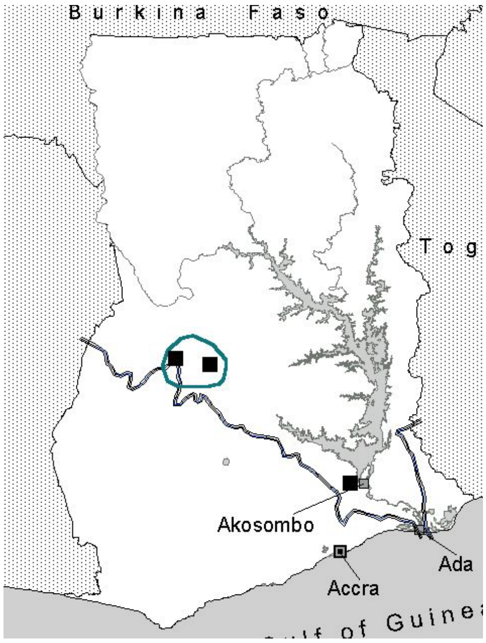




Cluster 7

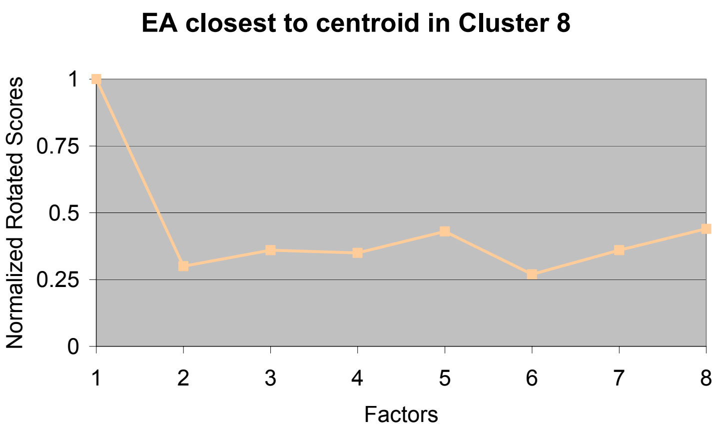
Communities in Cluster 7 are characterized by very high intensity of livestock/social capital, large farm sizes, as well as high levels of investments and savings. Markets, however, are rather remote.

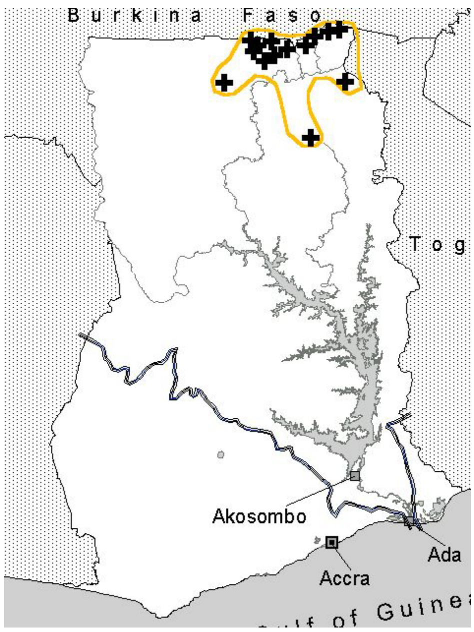




Cluster 8

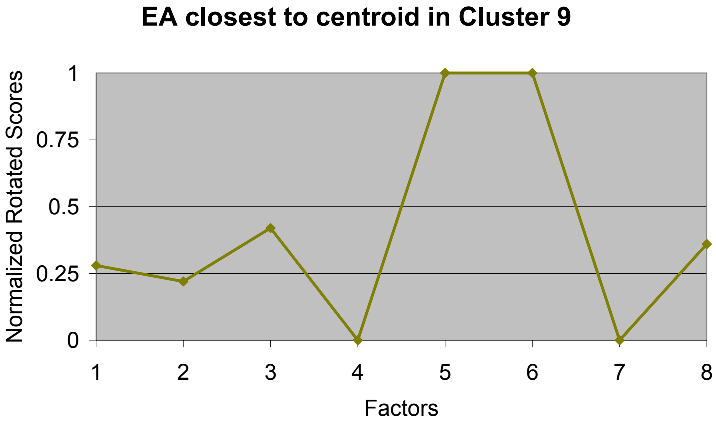
The communities/villages of Cluster 8 are located in the north eastern corner of Ghana, mainly at the border with Burkina Faso. Agro-ecological conditions are highly arid, and households have only low levels of expenditures, investments, and savings. Market distance is medium.

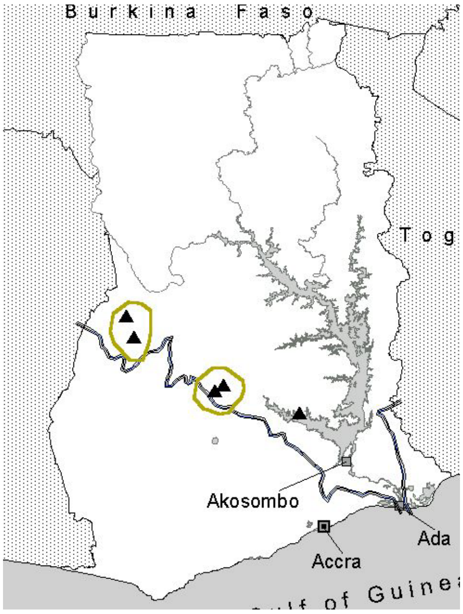




Cluster 9

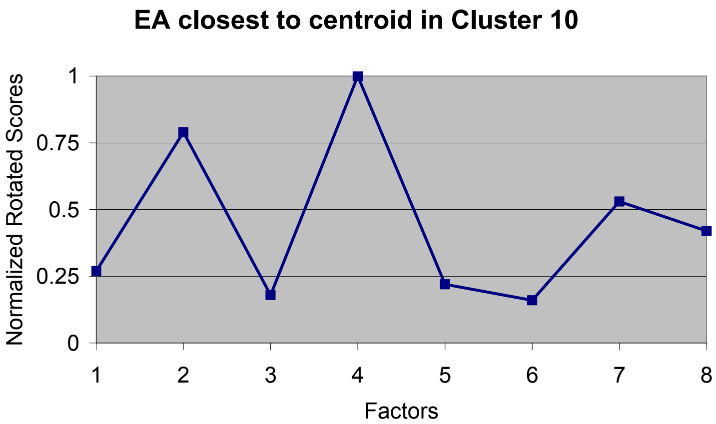
The communities/villages in Cluster 9 are located in the western and middle part of Ghana near the basin boundary. Investment levels are very high, while saving levels are very low. Farm sizes are very large, but water supply is very poor.

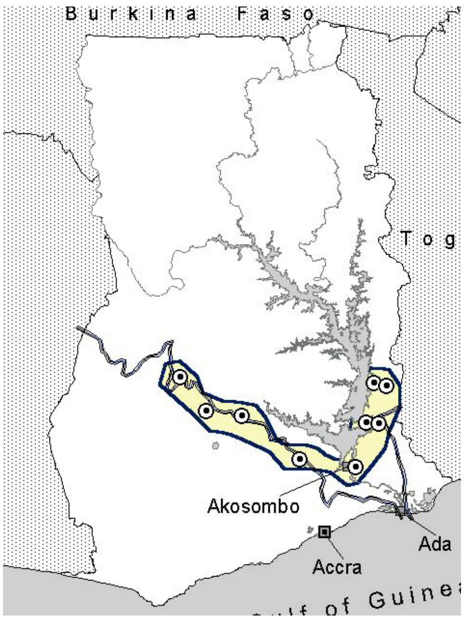




Cluster 10

Cluster 10 has its communities/villages located in a U shape around the basin boundary and the south of the Lake Volta (see map). Households have high levels of expenditures and highly improved water supply. There is only little livestock & social capital.





8. Surveys and field measurements

The various sub-observation units such as sample households, plots and water sources were then randomly drawn from each survey community. The interdisciplinary research team conducted jointly the following survey activities and field measurements during 2001:

Discipline	*Sub-project*	*Research activity and observation unit*	*Purpose*
Geography	L1	Land cover recording chart of community landscape	Ground-truthing
Political sciences, anthropology	W5	In-depth interviews with village elders; household interviews	Institutional analysis
Economics	W4 L2	Household interviews	Household water demand; Migration behavior
Agricultural Economics	L3	Household interviews	Water and land-use decisions
Soil sciences	L5	Plot survey	Soil quality analysis
Health	W3	Bacteriological analysis of water	Water quality analysis

8.1 Sample frame and weighting coefficients

Even though the GLSS4 dataset is considered to be nationally representative of households in Ghana, the survey could not be designed as a free-weighting one. This is because of the quite old sampling frame used and the remarkable errors observed during the listing of the households (GSS, 2000).

In the GLSS4, a two-stage sample was selected for the survey. At the first stage, 300 enumeration areas (EAs) were selected using systematic sampling with probability proportional to size method (PPS) where the size measure is the 1984 number of households in the EA. It was observed that some of the selected EAs had grown in size over time and therefore needed segmentation. This was done to achieve a modified list of EAs, which consisted of 200 households each. However, results from the 2000 Population and Housing Census revealed that the segmentation was not properly done because the number of households in the various EAs had grown at different rates and some of the selected EAs were not listed completely.

In order to get the true contribution of each selected EA in the sample, weights were computed based on the true sizes of the EAs since 1984, using the household listing from the 2000 Population and Housing Census. The weighting coefficient for the i^{th} EA, W_i, is given by the reciprocal of the overall probability of selecting that EA, which was derived as follows:

$$W_i = 407.5 * \frac{M_i^*}{M_i}$$

Where M_i = Number of 1984 population census households in the i^{th} selected EA
M_i^* = Number of 2000 population households in the i^{th} selected EA

The respective weighting coefficients for the selected clusters for the GLOWA-Volta common sampling frame are reproduced in **table 6**. These weights had to be applied for the statistical analyses described above.

8.2 Grossing up estimates

To obtain estimates for the entire GLOWA-Volta region, the field measurements will have to be grossed up by an appropriate weighting factor, taking into account the different cluster sizes. The computation of these grossing up multiplier will be done at a later stage of research.

9. Outlook for future research

The common sampling frame in GLOWA-Volta has yielded a consistent and interrelated data set that meets the data requirements of the various scientific disciplines involved. Since all field observations were geo-referenced with GPS measurements, the next step consists in building an integrated spatially explicit database by means of a geographical information system (GIS).

The joint data base is also a fundamental input to develop an integrated water and land use model as proposed in the Land Use and Land Cover Change project (LUCC) of IGBP and (IHDP). As LAMBIN ET AL. (1999) argue, an integrated LUCC model should include a rich specification of human decision making in order to produce meaningful forecasts and policy scenarios. The common sampling frame completes the first milestone in direction to this research goal as it captures the decision-making processes of economic actors and their biophysical environment on multiple scales. GLOWA-Volta is an endorsed project of the LUCC project and contributed significantly to the new LUCC report on agent-based modeling (PARKER ET AL., 2002).

Acknowledgment

The construction of the common sampling frame was a group effort to which many team members of GLOWA-Volta contributed. In particular, we would like to mention Yaw Bonsu Osei-Asare, who compiled the GLSS4 data set for this analysis, and Christian Sebaly, who provided all maps used in this paper.

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