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Mapping Poverty in Sudan

August 2019

Poverty and Equity Global Practice

Africa Region

WORLD BANK GROUP
Poverty & Equity

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Abstract

This report aims to map poverty and inequality in Sudan and would be representative of the 18 states and 131 localities of Sudan. The poverty mapping technique is based on a small area estimation (SAE) technique developed by the World Bank to derive estimates of geographic poverty and inequality. It combines data from the 2014/15 National Household Budget and Poverty Survey (NHBPS) and the 2008 Population and Housing Census data to build spatially disaggregated poverty maps.

Although household surveys usually include measures of income and wealth, they are not representative beyond the state level. Yet, allowing lower levels of disaggregation is important for policy interventions, particularly for countries like Sudan that have state governments, which manage the activities of the state while reporting to the federal government. This study uses a model of household expenditure from a survey data set to estimate household welfare at the lower levels and apply it to the census data set which does not provide information on household income or expenditure. These maps illustrate the information gains provided by SAE, show there is a substantial spatial heterogeneity within the localities, and highlight the small areas most likely to exhibit the highest risk of poverty.

Abbreviations

AfDB	African Development Bank
AIC	Akaike Information Criteria
CBS	Central Bureau of Statistics
EB	Empirical Best
ELL	Model suggested by Elbers, Lanjouw, and Lanjouw
FE	Fixed-effects
FGT	Foster-Greer-Thorbecke
GDP	Gross Domestic Product
GLS	General Least Squares
HCI	Human Capital Index
HDI	Human Development Index
MDG	Millennium Development Goal
MSE	Mean Square Error
NHBPS	National Household Budget and Poverty Survey
OLS	Ordinary Least Squares
PSU	Primary Sampling Unit
SAE	Small Area Estimation
VIF	Variance Inflation Factor

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1. Introduction

Sudan is a country of considerable potential. Even after secession from South Sudan, it has abundant fertile land and livestock and a strategic market location. It has the potential to be a significant economic hub, lying as it does at the intersection of Sub-Saharan Africa and the Middle East. Moreover, Sudan is bordered by seven countries—the Arab Republic of Egypt, Eritrea, Ethiopia, South Sudan, the Central African Republic, Chad, and Libya—with four of them landlocked. The country's strategic geographical location makes its political and economic success critical to the region; its failure would have significant detrimental implications for north, east, and central Africa. Sudan has suffered from political instability and conflict for five of the six decades since its independence in 1956. The current situation is precarious, given ongoing internal and external challenges. Sudan is home to about 40.53 million people (UNFPA 2017) with about two-thirds living in rural areas and about 60 percent of the population below the age of 25 years.

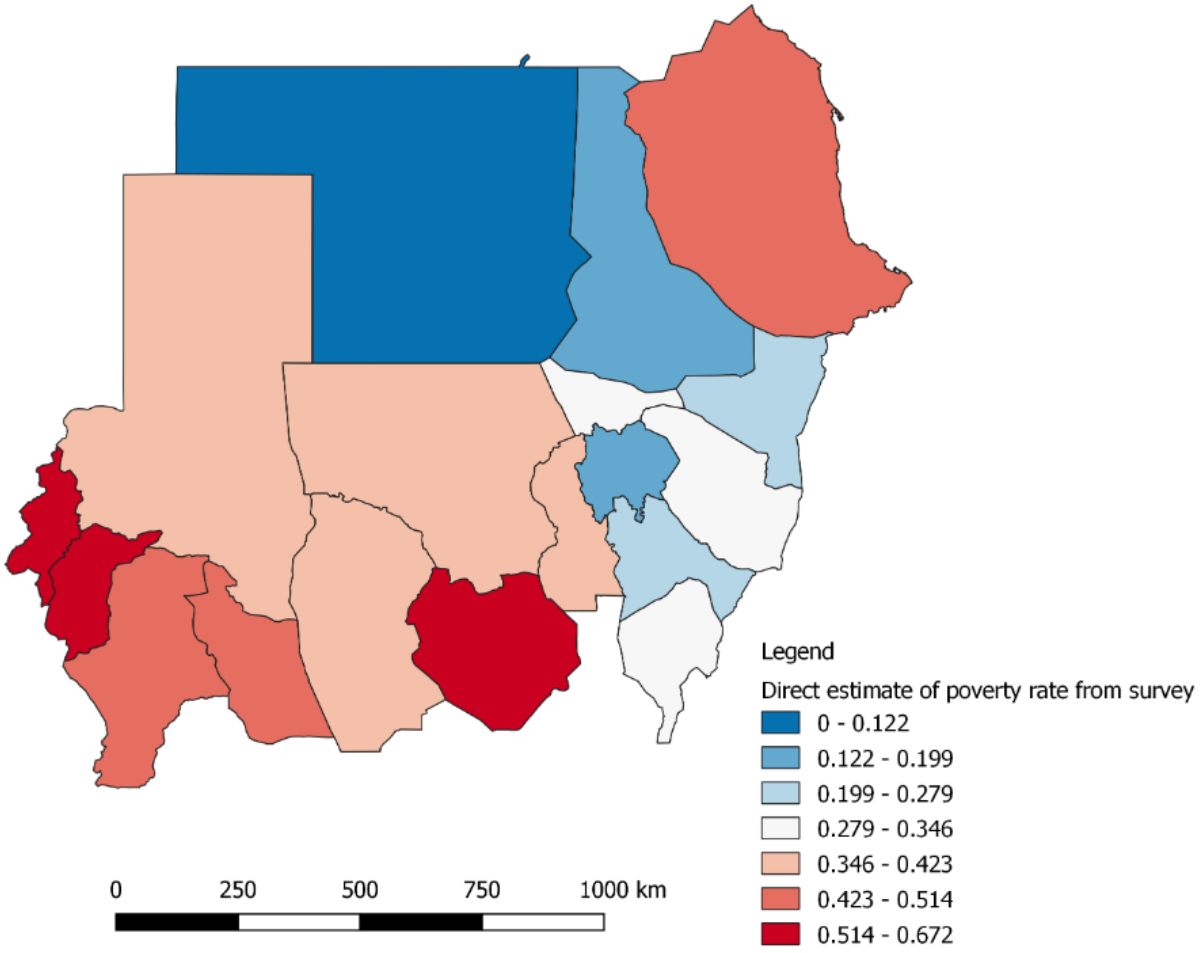
During 1999–2011, Sudan had a decade of high real economic growth rates, driven by oil production and exportation. After the discovery of oil in 1999, the size of Sudan's economy grew exponentially from US$12 billion in 1999 to US$65 billion in 2011—a 5.8 percent annual average growth. Over the same period, per capita income increased from US$934 to US$1,361 (constant 2010 U.S. dollar), raising Sudan to lower-middle-income status. Government revenue increased from 10 percent of gross domestic product (GDP) to 18 percent of GDP. The loss of oil production in 2011 brought about a deceleration of the economy but no recession. The economy continued to grow at a respectable 4.1 percent on average during 2012–17.

Sudan posts very poor human development indicators for its level of GDP. In 2018, it ranked 139 out of 157 countries according to the World Bank Human Capital Index (HCI)[1] and 167 out of 189 countries based on the Human Development Index (HDI).[2] It did not meet the 2015 Millennium Development Goals (MDGs) and its progress lags on many fronts compared to its neighbors and to the Sub-Saharan African average. Education and health indicators remain low and vary markedly across states, gender, and poverty levels. The gross primary school enrolment rate is only 70 percent (below the target of universal coverage), with substantial disparities across states, urban/rural areas, and gender. The under-5 mortality rate of 68 deaths per 1,000 births in 2014 is still higher than the 2015 MDG target of 41 per 1,000 births. This means that a lot of effort will be needed to achieve the 2030 Sustainable Development Goal target of 25 deaths per 1,000 births. Similarly, infant mortality rate and maternal mortality remain far higher than the Sustainable Development Goal targets.

[1] https://databank.worldbank.org/data/download/hci/HCI_2pager_SDN.pdf.
[2] http://www.hdr.undp.org/en/composite/HDI.

Because of the country's dire economic and financial situation, over one-third of Sudanese remain poor. In 2014/15, official estimates set the national poverty rate at 36.1 percent, indicating that some 13.4 million people were poor (CBS 2017). The official poverty rate is higher in urban areas (37.3 percent) than in rural areas (35.5 percent). There are marked spatial disparities in poverty incidence. Two-thirds of the population lives in rural areas. Disparities were also pronounced across states (Map 1). For instance, at about 67 percent, the incidence of poverty in either Central Darfur state or South Kordofan state was nearly five times higher than in the Northern state and double than in Khartoum state. The official Gini coefficient of 29.2 percent indicates that inequality was moderate compared to other Sub-Saharan African countries and in line with Middle East and North African countries.

Map 1: Direct Estimates at the State Level



Source: 2014/15 National Household Budget and Poverty Survey (NHBPS).

2. Methodology and Data

2.1. Methodology

The small area estimation (SAE) methodology has gained widespread popularity among development practitioners around the world. This methodology assigns consumption levels to census households based on a consumption model estimated from the household survey. The consumption model includes explanatory variables—for example, household and individual characteristics—that are statistically identical in both the census and the household survey. The consumption expenditures of the census households are imputed by applying the estimated coefficients to the variables common to the survey and the census data. Poverty and inequality statistics for small areas are then calculated based on the imputed consumption of census households.

Several poverty mapping methods have been used and documented by Bigman and Deichmann (2000). However, the selection of a specific poverty mapping methodology is a critical first step in deriving a poverty map. The SAE method developed by Elbers, Lanjouw, and Lanjouw (2003)—henceforth referred to as ELL—has acquired wide recognition among development practitioners around the world and is preferred within the World Bank when sufficient data are available (Mungai, Nguyen, and Pradhan 2018).

ELL has been chosen to estimate parameters in all maps in this report. As input, ELL uses household-level data from the 2008 Population and Housing Census and the NHBPS of Sudan. As a unit-level model, it uses detailed income or consumption information at the household level combined with observable characteristics of the household to estimate welfare. As the household survey helps estimate parameters given a set of observables in the model, the census will serve to implement the simulation. Given that Sudan has done the census in 2008 and the NHBPS in 2014, the World Bank has access to these data, which makes this method appropriate for the exercise. The model procedures can be described in the following manner. Once the model parameters are estimated in the household survey data, they are applied to the census data to predict the welfare for households that possess the same characteristics. Then, poverty rates are calculated for each locality presented in the census. Errors may occur in the poverty rates calculation, but literature and experience help us conclude that the results are still accurate for informing policy choices (Bedi, Coudouel, and Simler 2007).

The specificity of the ELL method is that the estimation of poverty incidence comes along with the estimation of the standard errors. This is not common for other poverty mapping methods. Notice that the standard errors estimate results from deriving the properties of the imputation errors obtained after using imputed consumption in the poverty estimates (Elbers, Lanjouw, and Lanjouw 2003).

The model formulation is as follows:

$$y_{ch} = X'_{ch}\boldsymbol{\beta} + u_{ch}\ (1),$$

where y_{ch} is the log per capita consumption of household *h* residing in area *c*, X_{ch} refers to household and area/location characteristics, and $u_{ch} = \mu_c + \varepsilon_{ch}$, representing the residual, which is composed of the area component μ_c and the household component ε_{ch}. μ_c and ε_{ch} have expected values of zero and are independent of each other. It is assumed that $E(u_c^2) = \sigma_\mu^2 + \sigma_\varepsilon^2$. The estimation of variance parameters is done through Henderson's method III, a commonly used estimator for the variance parameters of a nested error model (Henderson 1953; Searle, Casella, and McCulloch 1992).

A logistic transformation as a function of household and area characteristics $ln\left[\frac{e_{ch}^2}{A-e_{ch}^2}\right] = Z'_{ch}\alpha + r_{ch}$ is used for the estimation of other variances such as the residual ε_{ch}. However, heteroskedasticity is permitted so reestimation to get a general least squares (GLS) estimate of β and of the variance-covariance matrix would be needed.

As the main idea of SAE is the simulation, estimates are a means of that simulation. It can be written as:

$$\widehat{H} = \frac{1}{R}\sum_{r=1}^{R} h(\tilde{y}^r)\ (2),$$

where $h(y)$ is a function that converts the vector *y* with (log) incomes for all households into a poverty measure (such as the head count rate), $\tilde{y}^r$ denotes the *r*-th simulated vector with the elements:

$$\tilde{y}^r = X'\tilde{\beta}^r + \tilde{\mu}_c^r + \tilde{\varepsilon}_{ch}^r\ (3),$$

and R is the number of simulations. This simulation approach is well fitted because measures of poverty and inequalities are nonlinear functions.

According to Mungai, Nguyen, and Pradhan (2018), both the model parameters $\tilde{\beta}^r$ and the errors $\tilde{\mu}_c^r$ and $\tilde{\varepsilon}_{ch}^r$ are drawn from their estimated distributions for each simulation. $\tilde{\beta}^r$ is drawn by reestimating the model parameters using the *r*-th bootstrap version of the survey sample. Otherwise, $\tilde{\beta}^r$ may be drawn from its estimated asymptotic distribution, referred to as parametric drawing. The parametric drawing is computationally fast but the true distribution of the estimator for the model parameter vector may differ from the asymptotic distribution. The use of bootstrapping, albeit more computationally intensive, provides a means of identifying the finite-sample distribution and is thus expected to provide more accurate results when the sample size is small.

The sample size in the NHBPS we use is large enough for the asymptotic results to apply, and for this reason we expect to see little to no difference between estimates obtained with parametric drawing and bootstrapping.

Box 1: Step-by-step Summary of the Modelling Approach

(1) Bootstrap the survey, unless parametric drawing of the model parameters is used.

(2) Estimate β by means of ordinary least squares (OLS) and extract the residuals.

(3) Regress residuals from (2) on the area dummies (that is, estimate Fixed-effects [FE] model) and extract the residuals.

(4) Estimate the unconditional variance parameters of the nested error model (σ_μ^2 and σ_ε^2) by applying the Henderson method III (Henderson 1953), which uses the residuals from both (2) and (3).

(5) If heteroskedastic household errors are assumed, then (a) derive the estimates of the household errors by subtracting the area averages from the residuals (that is, deviations from the area mean residual), (b) apply a logistic transformation to the errors derived under (a) to obtain the left hand side (LFS) of the regression (also referred to as the alpha model) that will be used to predict the conditional variance of the household component ε_{ch}, denoted by $\sigma_{\varepsilon,ch}^2$, and (c) ensure that the unconditional variance is still equal to σ_ε^2, that is, $E[\sigma_{\varepsilon,ch}^2] = \sigma_\varepsilon^2$.

(6) Given the estimates of the unconditional variance σ_ε^2 and conditional variance $\sigma_{\varepsilon,ch}^2$, we may construct the covariance matrix Ω, which is used to obtain the GLS estimator for β.

(7) At this stage, we have the estimates for all the model parameters $\tilde{\beta}^r$. Next, we draw the area errors and the household idiosyncratic errors (5) from their respective normal distributions with variances

(8) We now have all we need to compute the round *r* simulated (log) household expenditure values for all households in the population census

(9) With the simulated household income data, we can now compute the poverty and inequality measures as if the population census came with household income data from the start.

(10) This yields a simulated poverty and inequality measure for each of the *R* simulation rounds. The average and standard deviation give us the poverty points estimate and the corresponding standard error, respectively.

Source: Mungai, Nguyen, and Pradhan 2018.

Another method that can be applied is the Empirical Best (EB) estimation. It assumes that for households sampled in area *c*, residuals $e_{ch} = y_{ch} - X'_{ch}\beta$ are informative of the latent area error μ_c. Thus, if we are conditioning on the residuals observed for sampled households, it should enable us to tighten the distributions from which to simulate μ_c (Mungai, Nguyen, and Pradhan 2018). The EB can only be applied for the drawing of the area errors which have been sampled in the survey. Other areas will use the unconditional distribution called ELL-EB and match with the standard ELL.

2.2. Main Sources of Data

2.2.1 Census and NHBPS

The poverty mapping exercise for Sudan combines data from the 2014/15 NHBPS and the 2008 household census. The 2008 Sudan Population and Housing Census was fielded during April 22 to May 6, 2008. The census provides comprehensive information on the household sociodemographic conditions, dwelling conditions, and individual characteristics of household members (for example, age, education, and marital and employment status), but it does not include information to construct consumption-based welfare measures.

Sudan's 2014/15 NHBPS consisted of three waves of data collection in November 2014, March 2015, and August 2015. The 2014/15 NHBPS collected consumption information used to calculate expenditure at the household level for all households. During the two 2015 waves, only consumption and expenditure data were collected, but the March 2015 round did not administer module five, which records nonfood consumption with a 12-month recall. The aim of this design was to explore and account for seasonality.

The national poverty analysis exercise relied on a sample of 11,953 households, with consumption averaged over the three waves. However, inspection of the item-level consumption and expenditure records showed that 13,733 households were initially interviewed.[3] The remaining 1,780 households, 13 percent of the initial sample, were dropped, mainly because they were not interviewed in either wave two or wave three (or both). Sampling weights were scaled up by the Central Bureau of Statistics (CBS), with different scaling factors applied across primary sampling units (PSUs). However, it is not clear exactly how this was done. Sudan's CBS implemented the 2014/15 NHBPS with funding support by African Development Bank (AfDB). The lowest level of representativeness in the 2014/15 NHBPS was the state. The sampling frame for the 2014/15 NHBPS was the 2008 Population and Housing Census.

2.2.2 Matching NHBPS and Census Data

The log per capita consumption forms the dependent variable of our models and is also used for the official measurement of poverty reported by the central statistical office. For constructing a unit-level model, the exercise relied on the NHBPS data on several household and personal characteristics—such as household composition, age, gender, and level of education—as well as dwelling characteristics, assets, and land ownership. The NHBPS data were combined with the data from the 2008 household census.

[3] In addition to detailed expenditure and consumption data, the data sets obtained included household and enumeration area identifiers as well as information about the locality (state of residence and rural/urban locality).

The census data similarly cover several key household and individual characteristics, including

(a) Demography: age/sex profiles, marital status, and household composition;

(b) Educational attainment;

(c) Information on dwellings: type of ownership, amenities, number and surface of rooms, type of sewerage facilities, and type of dwelling; and

(d) Assets and land ownership; see Appendix A' for the complete list of common variables.

As the ELL setup is based on estimating a welfare model on the NHBPS data and applying it to the population census data for prediction, one of the important parts of the model setup is the congruence between the variables in the NHBPS and the census. As part of building a welfare model, like for The Gambia, a two-step process was undertaken:

- **Step 1.** Compare the NHBPS and population census questionnaires to identify 'candidate variables' that exist both in the survey and the census and that are generated from identical or similar questions (see Appendix A'); and
- **Step 2.** Compare the distributions of the 'candidate variables' identified in Step 1 to examine whether they appear to capture the same underlying phenomena or whether, despite similar questions, their empirical distributions differ in any important ways.

Given that the goal of the model construction is to create a descriptive model which explains the variation in household consumption, the selection of candidate variables relies on a heuristic model of households' consumption. Thus, the consumption pattern of the household is assumed to be a function of

(a) The types of individuals in the household, for example, age of children, working-age adults, or elderly; and

(b) Income-earning characteristics of the household, for example, highest level of education of the household members.

In addition, while they are not determinants of income-earning capacity, the type of dwelling where the household resides or the types of assets the household possesses—for example, whether there is a bath or toilet in the dwelling—are also assumed to be able to describe or 'reflect' the income level of the household. Moreover, household income may also change across a given set of household characteristics or the location of the household, for example, rural versus urban, proximity to big cities, area with low or high employment rates, and so on. The above list is not unique or exhaustive, but the overlap between the survey and census questionnaires is the main constraint in the choice of the characteristics.

2.3. Modeling for Monetary Poverty

As described in the previous paragraph, the following variables were chosen since they are common to the survey and the census:

- **Demographic characteristics.** Gender; age; marital status; relationship to household head; household size; number of children, adults, and elderly in the household; and dependency ratio
- **Education.** Education level of the household head, literacy, and highest level of education of any household member
- **Occupation.** Employment status, occupation, and sector of employment of the household head.
- **Housing characteristics.** Type of housing unit, land and dwelling information, ownership and occupancy status of dwelling, type of energy used, source of drinking water and electricity, and type of toilet
- **Productive and durable assets.** Ownership of radio, television, personal computer, fan, air conditioner, refrigerator, motor vehicle, motorcycle, bicycle, canoe/boat, livestock, and poultry.

Depending on the data, single or multiple regression models can be fitted. The single regression model assumes that there is only one model that describes the poverty phenomenon in the whole country. The link between the income or consumption for all households and their characteristics are uniform for every single household, no matter the region they are in. All parameters are equal. This type of model is not realistic and is highly biased for a country like Sudan where spatial heterogeneity is mainly dominant. This can be in terms of climate, geography, security, returns in education, the capacity of each region to manage its natural resources, the availability of a formal job market, industry, and main economic activity. The multiple regression models are a more convenient way to surpass the single model.

Estimating a model for each region can be time consuming, but it offers good quality. First, the relationship between expenditure and the explanatory variables can differ throughout the country that induces more flexibility in the type of places where the unit is evolving. Second, it lessens the standard error of poverty prediction due to the error in modeling. Otherwise, introducing regional dummy variables in the regression can give similar results while having only one model.

Before an in-depth look at the modeling, let us describe the data. Table 1 displays the geographical distribution of the census[4] and survey.

Table 1: Geographic Distribution between the Census (2008) and the 2014/15 NHBPS

	Census[a]		Survey	
	Sample Size	**Weighted**	**Sample Size**	**Weighted**
Number of households	917,453	5,316,971	11,953	6,001,018
Number of individuals	5,049,590	30,248,885	69,828	34,574,848
Male	2,629,262	15,289,254	35,081	17,401,614
Female	2,420,328	14,959,631	34,747	17,173,234
Regions	6	—	6	—
States	15	—	18	—
Counties	131	—	134	—

Note: a. CBS provided a sample census data accounting for 16.6 percent of the total census population. So for any analysis one must weight the data to get the correct population size.

In this mapping, we chose to start from the national-level regression and go down to the region-level regression models to better determine the forms of regression to adopt. However, region in the census and region in the survey are not directly comparable due to changes in the government boundaries. Hence, one region may differ in states as well as one state may differ in counties components. Therefore, getting the regional-level regression model has implied aggregation of the data from the locality level. While multiple regression can offer flexibility to the parameter across the region, it also causes a loss in degrees of freedom and there is a risk of overfitting.[5] A solution that researchers recommended to avoid overfitting is that the sample size should be no smaller than 300 for each regression (Ahmed et al. 2014). To do this task, the means of candidate variables were manually compared between the two data sets. 'Acceptable' variables are included in the model selection, and the 'non-acceptable' variables are excluded. Criteria to define acceptable versus non-acceptable variables are based on the differences of means. Table 2 to Table 7 list the means of the variables evaluated at the household level by region and the significance of the test of mean equality (pvalue).

Table 2: Comparison of Household Characteristics between the Census (2008) and the 2014/15 NHBPS, Weighted Average, Variables Used in Model for Region 1

Variables	Description	mean1	mean2	p-value
depratio	Average dependency ratio (less than 18 + 65+ over adult pop)	1.164	1.132	0.376
dwelling1	Household having dwelling: Tent	0.098	0.037	0.000
head_age25t64	Household having head age of 25 to 64	0.774	0.782	0.573

[4] Sudan Census was done before the break-up.

[5] The models are forced to explain and justify the noise in the data in a small sample.

Variables	Description	mean1	mean2	p-value
head_edlevel3	Household whose head has education: Secondary	0.100	0.068	0.001
head_edlevel4	Household whose head has education: Tertiary	0.040	0.268	0.000
head_employer	Household whose head is employer	0.062	0.035	0.000
head_male	Household having male head	0.827	0.901	0.000
head_selfempl	Household whose head is self-employed	0.352	0.351	0.919
hhsize_2	Household with 2 members	0.113	0.078	0.001
hhsize_3	Household with 3 members	0.126	0.115	0.306
hhsize_4	Household with 4 members	0.134	0.168	0.002
hhsize_5	Household with 5 members	0.133	0.166	0.003
hhsize_6	Household with 6 members	0.117	0.145	0.006
nrooms	Average number of rooms	2.146	2.172	0.544
sector1_share	Share of member of household in agriculture	0.191	0.139	0.000
toilet1	Household having house toilet: Pit latrine private	0.505	0.864	0.000
toilet4	Household having house toilet: Flush toilet shared	0.005	0.072	0.000
urban	Share of urban population	0.215	0.226	0.374

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Table 3: Comparison of Household Characteristics between the Census (2008) and the 2014/15 NHBPS, Weighted Average, Variables Used in Model for Region 2

Variables	Description	mean1	mean2	p-value
charcoal	Household cooking with fuel: Charcoal	0.131	0.260	0.000
child_2	Household with two children	0.601	0.576	0.033
depratio	Average dependency ratio (less than 18 + 65+ over adult pop)	1.264	1.256	0.764
dwelling3	Household having dwelling: Tukul/gottiya of mud	0.108	0.306	0.000
elec	Household having access to electricity as source of lighting	0.341	0.462	0.000
elec_m_county	Household having access to electricity as source of lighting (county/locality mean)	0.357	0.406	0.000
gas	Household cooking with fuel: Gas	0.081	0.312	0.000
head_edlevel1	Household whose head has education: None	0.024	0.276	0.000
head_edlevel2	Household whose head has education: Primary	0.181	0.090	0.000
head_edlevel3	Household whose head has education: Secondary	0.029	0.044	0.000
head_employed	Household whose head is employed	0.781	0.895	0.000
head_employer	Household whose head is employer	0.091	0.087	0.530
head_unpaid	Household whose head is unpaid	0.076	0.004	0.000
hhsize_2	Household with 2 members	0.086	0.107	0.002
hhsize_3	Household with 3 members	0.116	0.136	0.008
hhsize_4	Household with 4 members	0.142	0.144	0.785
hhsize_5	Household with 5 members	0.154	0.150	0.682
hhsize_6	Household with 6 members	0.137	0.150	0.115

Variables	Description	mean1	mean2	p-value
nrooms	Average number of rooms	1.517	1.637	0.000
pri_abv_share	Share of member having completed primary education and above	0.048	0.625	0.000
sector1_share	Share of member of household in agriculture	0.277	0.179	0.000
sector3_share	Share of member of household in services	0.143	0.291	0.000
sum_age1t14_m_county	Average number of children of ages 1 to 15 years (county/locality mean)	2.260	2.198	0.000
sum_edlevel1_m_county	Average number of persons in a household with education level: None (county/locality mean)	0.137	1.643	0.000
sum_selfempl_m_county	Average number of persons in a household self-employed (county/locality mean)	0.611	0.551	0.000
sum_unpaid_m_county	Average number of persons in a household unpaid (county/locality mean)	0.210	0.165	0.000
toilet2	Household having house toilet: Pit latrine shared	0.026	0.081	0.000
urban	Share of urban population	0.172	0.373	0.000

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Table 4: Comparison of Household Characteristics between the Census (2008) and the 2014/15 NHBPS, Weighted Average, Variables Used in Model for Region 3

Variables	Description	mean1	mean2	p-value
child_2	Household with two children	0.537	0.547	0.516
depratio	Average dependency ratio (less than 18 + 65+ over adult pop)	1.003	1.096	0.007
dwelling4	Household having dwelling: Tukul/gottiya of sticks	0.009	0.030	0.000
dwelling5	Household having dwelling: Flat or apartment	0.014	0.020	0.122
everattend_share	Share of individuals of age 18 to 64 years having ever attended school	0.987	0.989	0.504
head_edlevel4	Household whose head has education: Tertiary	0.157	0.200	0.000
head_male	Household having male head	0.787	0.846	0.000
head_martial3	Household having marital status of the head: Widowed	0.050	0.075	0.000
head_selfempl	Household whose head is self-employed	0.223	0.145	0.000
hhsize_2	Household with 2 members	0.086	0.080	0.486
hhsize_3	Household with 3 members	0.098	0.113	0.133
hhsize_4	Household with 4 members	0.115	0.139	0.024
hhsize_5	Household with 5 members	0.122	0.175	0.000
hhsize_6	Household with 6 members	0.117	0.172	0.000
literacy_share	Share of member literate in a household	0.776	0.876	0.000
pri_abv_share	Share of member having completed primary education and above	0.386	0.590	0.000
sec_abv_share	Share of member having completed secondary education and above	0.158	0.364	0.000
sum_edlevel3_m_county	Average number of persons in a household with education level: Secondary (county/locality mean)	0.887	0.601	0.000
tenure2	Household having house tenure: Rented	0.250	0.230	0.162
toilet1	Household having house toilet: Pit latrine private	0.601	0.772	0.000

Variables	Description	mean1	mean2	p-value
urban	Share of urban population	0.807	0.795	0.345

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Table 5: Comparison of Household Characteristics between the Census (2008) and the 2014/15 NHBPS, Weighted Average, Variables Used in Model for Region 4

Variables	Description	mean1	mean2	p-value
charcoal_m_county	Household cooking with fuel: Charcoal (county/locality mean)	0.151	0.194	0.000
depratio	Average dependency ratio (less than 18 + 65+ over adult pop)	1.407	1.414	0.763
dwelling1	Household having dwelling: Tent	0.089	0.241	0.000
dwelling3_m_county	Household having dwelling: Tukul/gottiya of mud (county/locality mean)	0.121	0.647	0.000
head_edlevel4	Household whose head has education: Tertiary	0.034	0.367	0.000
head_employee	Household whose head is employee	0.256	0.439	0.000
head_employer	Household whose head is employer	0.059	0.070	0.015
head_martial2	Household having marital status of the head: Married	0.869	0.905	0.000
hhsize_2	Household with 2 members	0.086	0.067	0.000
hhsize_3	Household with 3 members	0.109	0.110	0.860
hhsize_4	Household with 4 members	0.128	0.146	0.005
hhsize_5	Household with 5 members	0.132	0.158	0.000
hhsize_6	Household with 6 members	0.125	0.142	0.007
literacy_share	Share of member literate in a household	0.507	0.630	0.000
nrooms	Average number of rooms	1.833	1.988	0.000
pri_abv_share	Share of member having completed primary education and above	0.141	0.539	0.000
sector1_share	Share of member of household in agriculture	0.164	0.187	0.000
toilet1	Household having house toilet: Pit latrine private	0.324	0.689	0.000
toilet2	Household having house toilet: Pit latrine shared	0.105	0.045	0.000
urban	Share of urban population	0.195	0.285	0.000
water_m_state	Household having access to drinking water (state mean)	0.485	0.370	0.000

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Table 6: Comparison of Household Characteristics between the Census (2008) and the 2014/15 NHBPS, Weighted Average, Variables Used in Model for Region 5

Variables	Description	mean1	mean2	p-value
bicycle	Household with bicycle	0.062	0.103	0.000
charcoal	Household cooking with fuel: Charcoal	0.065	0.165	0.000
child_1	Household with one child	0.807	0.811	0.644
child_3p	Household with three and more children	0.459	0.519	0.000
depratio	Average dependency ratio (less than 18 + 65+ over adult pop)	1.485	1.558	0.008

Variables	Description	mean1	mean2	p-value
dwelling3	Household having dwelling: Tukul/gottiya of mud	0.105	0.299	0.000
everattend_share	Share of individuals of age 18 to 64 years having ever attended school	0.972	0.983	0.002
fan	Household with fan	0.014	0.062	0.000
gas	Household cooking with fuel: Gas	0.022	0.069	0.000
head_edlevel1	Household whose head has education: None	0.048	0.274	0.000
head_edlevel3	Household whose head has education: Secondary	0.022	0.034	0.000
head_male	Household having male head	0.778	0.873	0.000
head_martial3	Household having marital status of the head: Widowed	0.050	0.058	0.099
head_selfempl	Household whose head is self-employed	0.428	0.533	0.000
hhsize_2	Household with 2 members	0.096	0.061	0.000
hhsize_3	Household with 3 members	0.130	0.099	0.000
hhsize_4	Household with 4 members	0.150	0.120	0.000
hhsize_5	Household with 5 members	0.152	0.144	0.350
hhsize_6	Household with 6 members	0.140	0.128	0.106
motor	Household with motor	0.016	0.028	0.000
phone	Household with phone	0.139	0.767	0.000
sector3_share	Share of member of household in services	0.144	0.176	0.000
sum_sector1_m_state	Average number of persons in a household in sector: Agriculture (state mean)	0.826	0.841	0.000
toilet4	Household having house toilet: Flush toilet shared	0.001	0.341	0.000
tv	Household with TV	0.051	0.187	0.000
urban	Share of urban population	0.083	0.222	0.000
water	Household having access to drinking water	0.231	0.148	0.000

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Table 7: Comparison of Household Characteristics between the Census (2008) and the 2014/15 NHBPS, Weighted Average, Variables Used in Model for Region 6

Variables	Description	mean1	mean2	p-value
child_1	Household with one child	0.832	0.869	0.000
child_2	Household with two children	0.664	0.727	0.000
computer	Household with computer	0.001	0.010	0.000
depratio	Average dependency ratio (less than 18 + 65+ over adult pop)	1.508	1.827	0.000
elec	Household having access to electricity as source of lighting	0.065	0.145	0.000
everattend_share	Share of individuals of age 18 to 64 years having ever attended school	0.974	0.971	0.200
firewood	Household cooking with fuel: Firewood	0.974	0.858	0.000
gas	Household cooking with fuel: Gas	0.002	0.008	0.000
head_literacy	Household whose head is able to read and write	0.229	0.561	0.000

Variables	Description	mean1	mean2	p-value
head_martial2	Household having marital status of the head: Married	0.878	0.846	0.000
hhsize_2	Household with 2 members	0.084	0.058	0.000
hhsize_3	Household with 3 members	0.128	0.101	0.000
hhsize_4	Household with 4 members	0.157	0.132	0.000
hhsize_5	Household with 5 members	0.159	0.141	0.004
hhsize_6	Household with 6 members	0.133	0.145	0.042
motor	Household with motor	0.007	0.017	0.000
motorcycle	Household with motorcycle	0.005	0.046	0.000
phone	Household with phone	0.070	0.638	0.000
pri_abv_share	Share of member having completed primary education and above	0.029	0.604	0.000
radio	Household with radio	0.482	0.256	0.000
refri	Household with refrigerator	0.005	0.031	0.000
sector3_share	Share of member of household in services	0.151	0.220	0.000
tenure2	Household having house tenure: Rented	0.014	0.071	0.000
toilet2	Household having house toilet: Pit latrine shared	0.032	0.044	0.000
tv	Household with TV	0.021	0.127	0.000
urban	Share of urban population	0.044	0.214	0.000
water_m_county	Household having access to drinking water (county/locality mean)	0.166	0.181	0.000

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

2.4. Technical Challenges

Evolving Administrative Boundaries and Classifications

Evolving administrative boundaries posed a technical challenge during this poverty mapping exercise. After the country split on July 2011, Sudan reviewed its administrative unit. The divisions, regions, states, and counties did not change but their composition did. For example, new states have been created in the Kordofan and Darfur regions. New states have been created such as in the Kordofan and Darfur regions. Kordofan, which earlier had two states, now has three. Darfur had three states, and now it has five.

Since the census was done before the split and the NHBPS after, it led to a change in the definition of the mapping. To tackle this issue, census localities were redefined according to the subdivision used in the NHBPS. It must be noted however that some of the localities in the census may not have any match in the survey, whether they are merged with other localities or replaced with a new one.

Only the localities having a match in the survey and those coming from the survey are used for the simulation; localities that were used in only the census are not needed. So even though completed in majority, simulated poverty data in this mapping are not exhaustive for Sudan.

Other technical issues that we needed to overcome were the differences between the census and survey classifications. This was especially true of the education and employment sections.

The education level section, 'currently attending' or 'was attending', has 17 categories but the content differs in the two questionnaires. It leads to confusion in determining the exact highest level to be taken in account. So, for more aggregated classification, only the four categories—None, Primary, Secondary, and Tertiary—are used. With regard to the employment section, the reference period for the variable asking 'Work' is different between the survey and the census; 10 days for the survey and 7 days for the census. The screening question was different as well. This may involve differences in comments that we need to be careful about. However, removing this variable would make the model weak as employment is a determinant for income and, consequently, for poverty.

3. Constructing the 2014/15 Sudan Poverty Maps

3.1. Model Selection

In addition to the manual selection of the variables to exclude at the first stage in the regression, the model selection borrowed the automated procedures performed in the poverty mapping for The Gambia (Mungai, Nguyen, and Pradhan 2018). The main advantages of this method are that it minimizes overfitting by incorporating the degrees of freedom into the evaluation.

The modified stepwise procedure involves using the variance inflation factor (VIF), sequential removal of one variable at a time from GLS estimates, and rerunning it stepwise. The process is repeated until all variables in GLS estimate are significant. Technically, it first removes variables for which p-value is greater than 0.2 one by one, and then the variable with VIF more than 5. This last process prevents the multicollinearity between variables. Thompson (1995) can offer more detail on this procedure for modeling.

Stepwise Akaike Information Criteria (AIC) is then undertaken after the default model to limit overfitting. AIC is the information-based criteria that can be performed using 'vselect' in Stata. The score estimates the expected relative distance between the fitted model and the unknown true relationship. The purpose of this procedure is to minimize the AIC. Naming *r*, the number of parameters in the model, the score for AIC is formulated as

$$AIC = -2\log(likelihood) + 2r.$$

See Lindsey and Sheather (2010) for further details on information-based selection and the vselect package.

After using the implementation of the ELL methods in Stata 15 to build the model and following the validation process we just described, final models are specific for each region. The initial welfare models corresponding to equation (1) are presented in Tables 8 to 13, for each region. The adjusted R-squared for regional models is moderately high, ranging from 0.46 to 0.65. This means that the independent variables in the chosen model explain the variation on welfare moderately well.

Variable means at the region and district levels obtained from the census are introduced to the model to improve precision. It may moderate the unexplained variation in income due to location. With the inclusion of these variables, the ratios of the variance of η over regional models' Mean Square Error (MSE) are from 4 percent to 15 percent. The low ratio shows the key role the variables play in improving the precision of the estimates.

The estimated coefficients in the previous section serve as inputs to estimate the first part of the equation ($X'_{ch}\hat{\beta}$) by combining coefficients with the census variables. However, vectors of

disturbances for households are still unknown and so must be estimated. Thus, the error decomposition is done through Henderson's method III. The coefficients β are obtained by bootstrapped samples of the NHBPS data.

The final model chosen is where η and ε are drawn from a normal distribution with their respective variance structures. Finally, EB methods are chosen since these incorporate more information and are expected to provide a better fit. The model selection used was the stepwise with VIF using AIC criteria based on the comparison of poverty estimates from the survey and the census at the national and regional levels.

Tables 8 to 13 show the final regional model estimate (bGLS) that is preferred compared to the OLS model. Each also provides results of the disturbances selection process. All variables in final GLS estimate are significant.

Table 8: Model Estimates Based on the 2014/15 NHBPS - 'Northern' (Beta Model, Region 1)

	b_{OLS}		**b_{GLS}**	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
Depratio	−0.055***	0.011	−0.040***	0.010
dwelling1	−0.264***	0.065	−0.243***	0.077
head_age25t64	−0.113***	0.030	−0.107***	0.028
head_edlevel3	0.183***	0.045	0.203***	0.041
head_edlevel4	−0.121***	0.027	−0.100***	0.025
head_employer	0.167***	0.059	0.177***	0.052
head_male	−0.180***	0.038	−0.156***	0.036
head_selfempl	0.111***	0.024	0.129***	0.022
hhsize_2	0.844***	0.050	0.881***	0.048
hhsize_3	0.591***	0.042	0.655***	0.042
hhsize_4	0.419***	0.035	0.459***	0.030
hhsize_5	0.246***	0.034	0.289***	0.027
hhsize_6	0.161***	0.034	0.192***	0.029
Nrooms	0.054***	0.013	0.074***	0.011
sector1_share	−0.118**	0.053	−0.134***	0.043
toilet1	−0.192***	0.049	−0.149***	0.044
toilet4	−0.191***	0.068	−0.212***	0.062
Urban	−0.257***	0.029	−0.244***	0.025
_cons	9.220***	0.082	9.057***	0.078
Number of observations	1,002	Error decomposition		ELL
Adjusted R-squared	0.497	EB methods		No
Sigma ETA sq.	0.004	Beta drawing		Bootstrapped
Ratio of sigma eta sq over MSE	0.039	Eta drawing method		Normal
Variance of epsilon	0.099	Epsilon drawing method		Normal
Sampling variance of Sigma eta sq.	6E-06	Alpha model		Yes

Source: Authors' calculations based on the 2014/15 NHBPS.
Note: Model settings - Alpha model; Error decomposition - ELL; Bootstrapped with normal distribution; EB methods. ***p < 0.01; **p < 0.05; *p < 0.1.

Table 9: Model Estimates Based on the 2014/15 NHBPS - 'Eastern' (Beta Model, Region 2)

	b_{OLS}		b_{GLS}	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
Charcoal	0.073***	0.025	0.047**	0.022
child_2	−0.056**	0.027	−0.061**	0.024
Depratio	−0.026**	0.010	−0.032***	0.008
dwelling3	0.099***	0.023	0.109***	0.020
Elec	0.113***	0.026	0.106***	0.022
elec_m_county	0.259***	0.061	0.318***	0.118
Gas	0.167***	0.031	0.139***	0.026
head_edlevel1	0.070***	0.024	0.050**	0.020
head_edlevel2	0.098***	0.033	0.057**	0.025
head_edlevel3	0.155***	0.046	0.129***	0.034
head_employed	−0.076**	0.030	−0.066**	0.029
head_employer	0.093***	0.031	0.087***	0.028
head_unpaid	0.224*	0.127	0.178**	0.075
hhsize_2	0.882***	0.039	0.901***	0.032
hhsize_3	0.597***	0.036	0.609***	0.033
hhsize_4	0.442***	0.030	0.448***	0.025
hhsize_5	0.336***	0.028	0.345***	0.023
hhsize_6	0.200***	0.027	0.213***	0.024
Nrooms	0.057***	0.012	0.054***	0.009
pri_abv_share	−0.070***	0.027	−0.052**	0.023
sector1_share	0.094**	0.041	0.087**	0.035
sector3_share	0.147***	0.039	0.169***	0.034
sum_age1t14_m_county	0.361***	0.032	0.364***	0.064
sum_edlevel1_m_county	−0.098***	0.027	−0.117**	0.048
sum_selfempl_m_county	−0.443***	0.059	−0.345***	0.119
sum_unpaid_m_county	−0.336***	0.089	−0.435**	0.170
toilet2	0.153***	0.034	0.146***	0.033
Urban	−0.348***	0.027	−0.347***	0.027
_cons	8.027***	0.087	8.028***	0.162
Number of observations	1,633	Error decomposition		ELL
Adjusted R-squared	0.582	EB methods		No
Sigma ETA sq.	0.008	Beta drawing		Bootstrapped
Ratio of sigma eta sq over MSE	0.077	Eta drawing method		Normal
Variance of epsilon	0.094	Epsilon drawing method		Normal
Sampling variance of Sigma eta sq.	8.899e-06	Alpha model		Yes

Source: Authors' calculations based on the 2014/15 NHBPS.

Note: Model settings - Alpha model; Error decomposition - ELL; Bootstrapped with normal distribution; EB methods. ***p < 0.01; **p < 0.05; *p < 0.1.

Table 10: Model Estimates Based on the 2014/15 NHBPS - 'Khartoum' (Beta Model, Region 3)

	b_{OLS}		b_{GLS}	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
child_2	−0.127***	0.035	−0.105***	0.032
Depratio	−0.058***	0.017	−0.059***	0.016
dwelling4	0.402***	0.070	0.432***	0.052

	b_{OLS}		b_{GLS}	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
dwelling5	0.296***	0.084	0.324***	0.075
everattend_share	−0.776***	0.125	−0.784***	0.233
head_edlevel4	−0.141***	0.036	−0.105***	0.035
head_male	−0.078**	0.040	−0.075**	0.037
head_martial3	−0.125**	0.054	−0.124**	0.050
head_selfempl	0.100***	0.033	0.075**	0.030
hhsize_2	0.837***	0.050	0.868***	0.045
hhsize_3	0.622***	0.044	0.648***	0.040
hhsize_4	0.455***	0.038	0.472***	0.035
hhsize_5	0.324***	0.034	0.336***	0.032
hhsize_6	0.234***	0.034	0.238***	0.032
literacy_share	0.239***	0.058	0.255***	0.060
pri_abv_share	0.186***	0.043	0.151***	0.036
sec_abv_share	0.195***	0.048	0.228***	0.041
sum_edlevel3_m_county	0.354***	0.050	0.343**	0.144
tenure2	−0.055**	0.028	−0.078***	0.026
toilet1	−0.255***	0.033	−0.243***	0.029
Urban	−0.249***	0.029	−0.187***	0.029
_cons	9.460***	0.131	9.383***	0.253
Number of observations	930	Error decomposition		H3
Adjusted R-squared	0.652	EB methods		Yes
Sigma ETA sq.	0.009	Beta drawing		Bootstrapped
Ratio of sigma eta sq over MSE	0.079	Eta drawing method		Normal
Variance of epsilon	0.111	Epsilon drawing method		Normal
Alpha model	Yes			

Source: Authors' calculations based on the 2014/15 NHBPS.
Note: Model settings - Alpha model; Error decomposition - ELL; Bootstrapped with normal distribution; EB methods. ***p < 0.01; **p < 0.05; *p < 0.1.

Table 11: Model Estimates Based on the 2014/15 NHBPS - 'Central' (Beta Model, Region 4)

	b_{OLS}		b_{GLS}	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
charcoal_m_county	0.224***	0.061	0.282**	0.129
Depratio	−0.043**	0.007	−0.034**	0.007
dwelling1	−0.141**	0.022	−0.133***	0.023
dwelling3_m_county	−0.305***	0.038	−0.237***	0.071
head_edlevel4	−0.072***	0.022	−0.076***	0.020
head_employee	−0.060***	0.016	−0.066***	0.015
head_employer	0.128***	0.030	0.113***	0.029
head_martial2	0.085***	0.026	0.105**	0.024
hhsize_2	1.041***	0.035	1.078**	0.034
hhsize_3	0.689***	0.029	0.710***	0.028
hhsize_4	0.457**	0.025	0.472**	0.022
hhsize_5	0.288***	0.024	0.304***	0.023
hhsize_6	0.200*	0.024	0.216**	0.023
literacy_share	0.110***	0.028	0.098***	0.027

	b_{OLS}		b_{GLS}	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
Nrooms	0.054***	0.009	0.062***	0.008
pri_abv_share	0.150***	0.024	0.141***	0.022
sector1_share	−0.085***	0.031	−0.072***	0.029
toilet1	0.072***	0.019	0.066***	0.020
toilet2	0.223***	0.039	0.236***	0.042
Urban	−0.228***	0.019	−0.229**	0.019
water_m_state	0.508**	0.062	0.486**	0.125
_cons	8.384***	0.057	8.287***	0.074
Number of observations	2,708	Error decomposition		H3
Adjusted R-squared	0.566	EB methods		Yes
Sigma ETA sq.	0.004	Beta drawing		Bootstrapped
Ratio of sigma eta sq over MSE	0.039	Eta drawing method		Normal
Variance of epsilon	0.096	Epsilon drawing method		Normal
Alpha model	Yes			

Source: Authors' calculations based on the 2014/15 NHBPS.
Note: Model settings - Alpha model; Error decomposition - H3; Bootstrapped with normal distribution; EB methods. ***p < 0.01; **p < 0.05; *p < 0.1.

Table 12: Model Estimates Based on the 2014/15 NHBPS - 'Kordofan' (Beta Model, Region 5)

	b_{OLS}		b_{GLS}	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
Bicycle	−0.140***	0.029	−0.097***	0.030
Charcoal	0.174***	0.029	0.124***	0.028
child_1	−0.138***	0.029	−0.131***	0.027
child_3p	−0.108***	0.028	−0.121***	0.027
Depratio	−0.034***	0.009	−0.033***	0.009
dwelling3	0.068**	0.027	0.097***	0.027
everattend_share	−0.605***	0.075	−0.594***	0.071
Fan	0.077	0.047	0.128***	0.046
Gas	0.197***	0.042	0.139***	0.041
head_edlevel1	0.079***	0.021	0.068***	0.020
head_edlevel3	0.080	0.053	0.086*	0.050
head_male	−0.137***	0.032	−0.104***	0.030
head_martial3	−0.095**	0.047	−0.092**	0.044
head_selfempl	0.079***	0.019	0.041**	0.018
hhsize_2	0.685***	0.044	0.693***	0.042
hhsize_3	0.570***	0.036	0.562***	0.034
hhsize_4	0.307***	0.034	0.307***	0.032
hhsize_5	0.248***	0.028	0.246***	0.026
hhsize_6	0.120***	0.028	0.132***	0.027
Motor	0.314***	0.053	0.306***	0.050
Phone	0.061***	0.022	0.047**	0.021
sector3_share	0.106***	0.037	0.104***	0.035
sum_sector1_m_state	0.076*	0.044	0.256**	0.129
toilet4	−0.036*	0.021	−0.043**	0.020
Tv	0.099***	0.032	0.090***	0.031

	b_{OLS}		b_{GLS}	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
Urban	−0.309***	0.032	−0.259***	0.033
Water	0.094***	0.027	0.041	0.026
_cons	9.285***	0.092	9.124***	0.148
Number of observations	2,149	Error decomposition		ELL
Adjusted R-squared	0.511	EB methods		No
Sigma ETA sq.	0.014	Beta drawing		Parametric
Ratio of sigma eta sq over MSE	0.112	Eta drawing method		Normal
Variance of epsilon	0.114	Epsilon drawing method		Normal
Sampling variance of Sigma eta sq.	0.00008	Alpha model		No

Source: Authors' calculations based on the 2014/15 NHBPS.

Note: Model settings - Alpha model; Error decomposition - ELL; Parametric with normal distribution; EB methods. *** ***p < 0.01; **p < 0.05; *p < 0.1.

Table 13: Model Estimates Based on the 2014/15 NHBPS – 'Darfur' (Beta Model, Region 6)

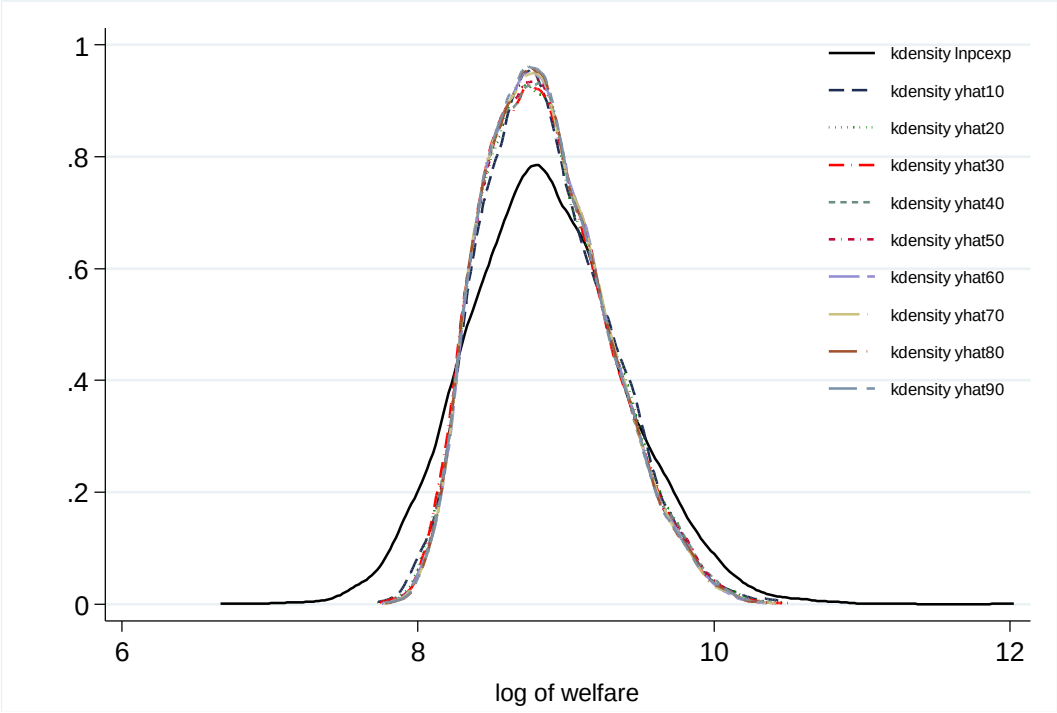
	b_{OLS}		b_{GLS}	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
child_1	−0.114***	0.035	−0.108***	0.032
child_2	−0.108***	0.031	−0.105***	0.029
Computer	0.231***	0.087	0.252***	0.081
Depratio	−0.017**	0.007	−0.022***	0.007
Elec	0.107***	0.039	0.146***	0.036
everattend_share	−0.307***	0.058	−0.281***	0.054
Firewood	−0.112***	0.032	−0.128***	0.030
Gas	0.254***	0.090	0.245***	0.084
head_literacy	0.080***	0.022	0.085***	0.020
head_martial2	−0.076***	0.026	−0.076***	0.024
hhsize_2	0.612***	0.045	0.641***	0.042
hhsize_3	0.492***	0.036	0.508***	0.033
hhsize_4	0.385***	0.028	0.403***	0.027
hhsize_5	0.243***	0.027	0.247***	0.025
hhsize_6	0.182***	0.026	0.177***	0.024
Motor	0.283***	0.066	0.230***	0.061
Motorcycle	0.110***	0.042	0.107***	0.039
Phone	0.119***	0.020	0.120***	0.019
pri_abv_share	0.051*	0.027	0.046*	0.025
Radio	0.135***	0.020	0.092***	0.019
Refri	0.075	0.056	0.093*	0.052
sector3_share	0.101***	0.030	0.081***	0.029
tenure2	0.087***	0.034	0.113***	0.031
toilet2	0.140***	0.046	0.133***	0.043
Tv	0.096**	0.040	0.078**	0.037
Urban	−0.228***	0.026	−0.245***	0.028
water_m_county	0.597***	0.043	0.555***	0.156
_cons	8.770***	0.065	8.800***	0.074
Number of observations	3,444	Error decomposition		H3
Adjusted R-squared	0.465	EB methods		Yes

	b_{OLS}		b_{GLS}	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
Sigma ETA sq.	0.023	Beta drawing		Bootstrapped
Ratio of sigma eta sq over MSE	0.155	Eta drawing method		Normal
Variance of epsilon	0.129	Epsilon drawing method		Normal
Alpha model	No			

Source: Authors' calculations based on the 2014/15 NHBPS.
Note: Model settings - Alpha model; Error decomposition - H3; Bootstrapped with normal distribution; EB methods. ***p < 0.01; **p < 0.05; *p < 0.1.

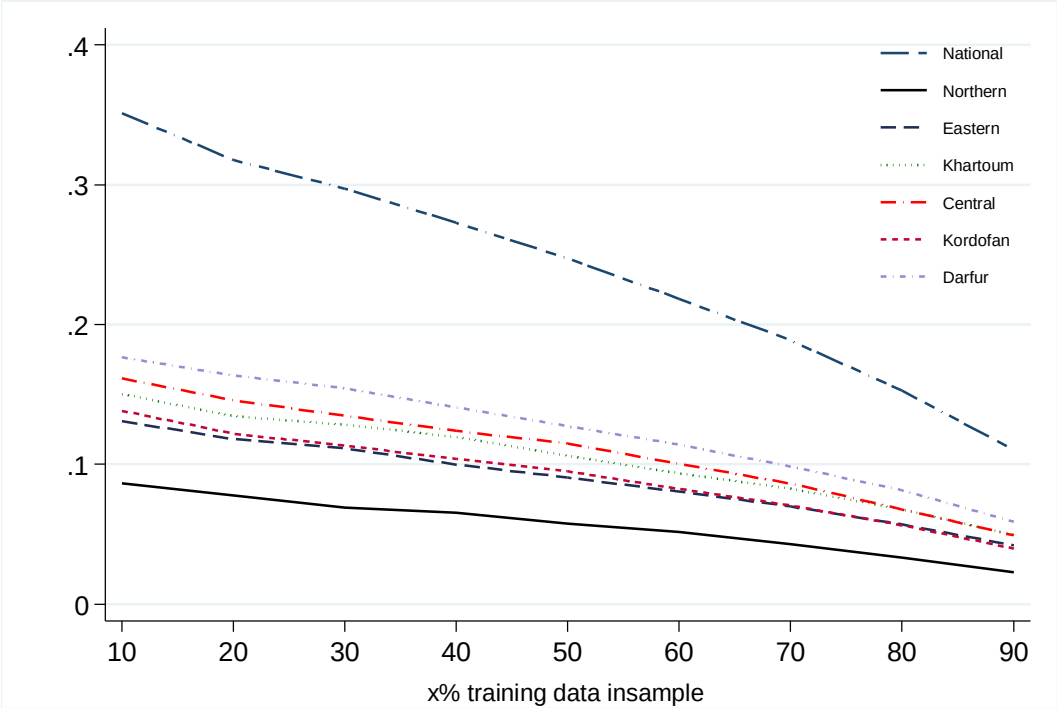
A visual assessment was conducted to compare the predicted and simulated consumption distributions as displayed in Figures 1 and 2. The results are based on various training samples—beginning with 10 percent of the sample and continuing up to 90 percent—at each region to ensure the robustness of the approach and the resulting distributions. This demonstrates a high level of statistical precision. However, this precision level declines as the degree of spatial disaggregation increases. This approach should be supplemented with complementary sources of information if further lower-level disaggregation is envisaged, but this should be done with a lot of caution.

Figure 1: Distributions with Actual and Imputed Testing Sample



Source: Authors' calculations based on the 2014/15 NHBPS.

Figure 2: Weighted Ratio Mean Square Error of Out sample for Sudan and its Regions



Source: Authors' calculations based on the 2014/15 NHBPS.

3.2. Level of Disaggregation

The clustering used for estimations is at the PSU level and the poverty mapping results are based on survey direct estimates. To measure the share of the poor, the poverty line of SDG 5,109.78 per year per capita is used. Table 14 displays the poverty head count for direct and poverty mapping at the national level and across the region. One may notice that the World Bank's poverty rate[6] is different from these numbers. The reason is that the World Bank poverty rate of 46.5 per cent was estimated on the basis of Survey 2009 with the poverty line at SDG 114 per month per capita. However, the poverty rate in this report considers the national poverty rate estimated by the CBS through the 2014/15 NHBPS.

The results of the mapping are similar to the estimates obtained from the NHBPS. At the national level, direct and small area estimates provide a good match because they differ at about +1 percentage point. Furthermore, the differences between the survey and small area estimates across regions are significantly low.

[6] https://data.worldbank.org/indicator/si.pov.nahc

Table 14: Poverty Estimates from Survey (Observed) and the Census (SAE)

	Survey				Census			
	Head Count	Standard Error	95% Confidence Interval		No. of Households	No. of Individuals	Head Count	Standard Error
Sudan	**36.14**	**0.44**	**35.28**	**37.00**	**917,453**	**29,757,647**	**37.47**	**0.81**
Northern	17.14	1.19	14.80	19.47	38,895	1,730,571	18.45	1.83
Eastern	35.24	1.16	32.96	37.52	146,841	4,364,809	35.83	2.28
Khartoum	29.90	1.50	26.95	32.85	80,521	5,230,708	33.79	1.47
Central	27.05	0.85	25.39	28.72	129,942	7,295,131	29.10	1.08
Kordofan	44.23	1.07	42.13	46.33	164,120	4,229,456	43.66	3.95
Darfur	51.59	0.85	49.92	53.26	357,134	6,906,972	51.09	1.08

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Looking at Table 14 and taking every step into account, one may infer that the methodology adopted to compute monetary poverty indicators at a lower level of spatial disaggregation is fully consistent with the poverty profile figures resulting from direct estimation from the survey. Therefore, standard errors of the poverty indicators can be computed, and the poverty maps are compatible with the poverty profile. It is probably a natural extension to the poverty profiles.

4. Poverty Mapping Results

This section presents the results of the poverty mapping, tables and maps, in descending order. Poverty rate and Gini at national and regional levels are reported in Table 15. For the visualization, poverty by region is drawn in Map 1 while the number of poor by state is drawn in Map 2. Recall that the poverty mapping applies the results from the 2014/15 NHBPS to the census, the tables and maps below refer to these simulations, and the results are close to the survey.

Table 15: Census SAE of Poverty and Gini at the National and Regional Levels

	Number		Poverty		No. of Poor	Gini	
	Households	Individuals	Head Count	Standard. Error		Estimate	Standard Error
Sudan	**917,453**	**29,757,647**	**37.47**	**0.81**	**11,148,985**	**0.30**	**0.00**
Northern	38,895	1,730,571	18.45	1.83	319,214	0.25	0.01
Eastern	146,841	4,364,809	35.83	2.28	1,563,727	0.27	0.02
Khartoum	80,521	5,230,708	33.79	1.47	1,767,652	0.30	0.01
Central	129,942	7,295,131	29.10	1.08	2,123,153	0.25	0.01
Kordofan	164,120	4,229,456	43.66	3.95	1,846,471	0.28	0.01
Darfur	357,134	6,906,972	51.09	1.08	3,528,766	0.38	0.00

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Results in Table 16 show that poverty rates within a region are not the same as for the region itself. They may exceed or be inferior; some regions may have lower poverty rates but states included in them may have higher poverty rates, or the opposite may hold true. The maximum difference noticed for all is about 10 percent. This is the case for the Central and Darfur regions. In the Central region, the poverty rate ranges from 21.24 percent in Al-Gezira state to 40.78 percent in White Nile state whereas the rate at the regional level is 29.10 percent. In the Darfur region, where at 51.09 percent, poverty rates are the highest, they range between 46.02 percent in East Darfur and 61.05 percent in Central Darfur. In addition to having the highest poverty rates, Darfur has the highest inequality (0.38). Consistently, its states' inequality ranges from 0.365 to 0.388 while others do not exceed 0.304. Map 2 and Map 3 show the poverty rate at the state level and the number of poor for each state, respectively. Inequality statistics of Gini per state are shown in Map 4.

At the lower level for each region, poverty rates results and Gini at the locality level are displayed in Table 17. It shows that poverty is a heterogenous phenomenon across counties. For instance, poverty rate in the Northern region is 18.45 percent with a standard error of 1.83 percent. However, at the locality level, the poverty rates range from 4.99 percent to 27.71 percent. Once again, this result justifies the choice of the disaggregated model. Another finding is that the regions that have the highest poverty rates at the regional and state levels tend to have lower poverty rates in the localities within them and vice versa. For example, Darfur with a poverty rate of 51.09 percent has a locality with a 33.02 percent poverty rate while Khartoum with a poverty rate of 33.79 percent has a locality with a 61.25 percent poverty rate. So poverty at the locality level is heterogenous and is not influenced by the poverty rate at the regional level. Map 5 displays the relative share of poor, Map 6 the number of poor, and Map 7 the Gini statistics by locality.

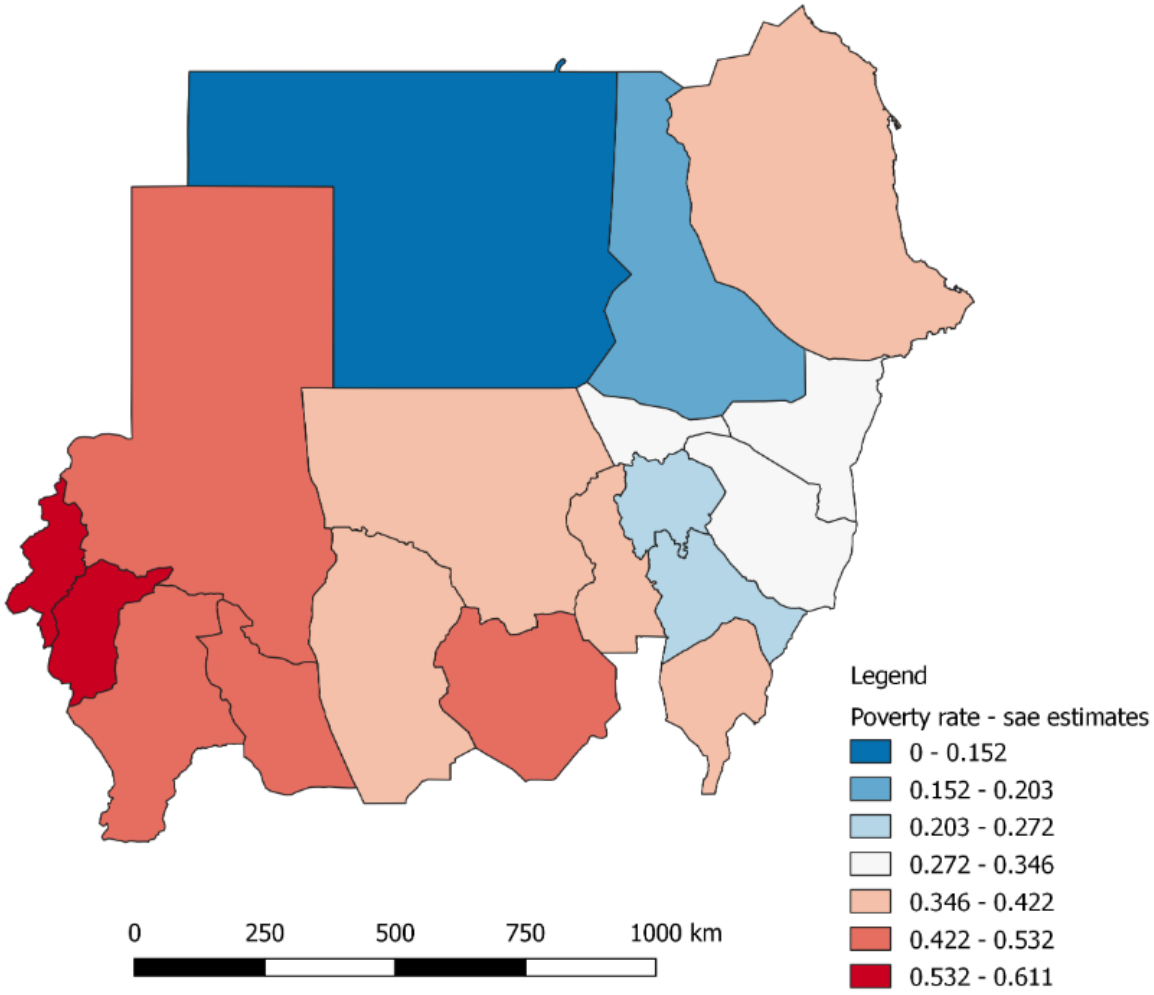
Table 16: Census SAE of Poverty and Gini at the State Level

Region	State	Number		Poverty		No. of Poor	Gini	
		Households	Individuals	Head Count	Standard Error		Estimate	Standard Error
Northern	Northern	13,852	635,755	15.20	2.15	96,641	0.251	0.010
	River Nile	25,043	1,094,816	20.33	2.41	222,574	0.255	0.009
Eastern	Red Sea	62,682	1364398	42.16	4.21	575,229	0.259	0.015
	Kassala	56,734	1683786	34.60	2.98	582,560	0.269	0.022
	Al-Gedarif	27,425	1316625	30.83	3.30	405,938	0.262	0.017
Khartoum	Khartoum	80,521	5,230,708	33.79	1.47	1,767,652	0.304	0.007
Central	Al-Gezira	56,679	3,490,560	21.24	1.47	741,532	0.234	0.007
	White Nile	31,623	1,727,955	40.78	1.76	704,637	0.262	0.008

Region	State	Number		Poverty		No. of Poor	Gini	
		Households	Individuals	Head Count	Standard Error		Estimate	Standard Error
	Sinnar	25,504	1,249,265	27.22	1.78	340,023	0.241	0.006
	Blue Nile	16,136	827,349	40.73	2.39	336,961	0.249	0.008
Kordofan	North Kordofan	100,913	2,061,612	41.89	5.85	863,688	0.274	0.009
	South Kordofan	23,025	866,698	53.19	5.89	461,006	0.275	0.009
	West Kordofan	40,182	1,301,145	40.10	4.93	521,776	0.271	0.006
Darfur	North Darfur	88,597	2,118,507	50.54	2.12	1,070,630	0.378	0.005
	West Darfur	26,942	790,383	58.99	1.15	466,258	0.388	0.005
	South Darfur	144,580	2,541,122	49.64	1.39	1,261,450	0.374	0.004
	Central Darfur	31,712	398,518	61.05	1.63	243,302	0.368	0.004
	East Darfur	65,303	1,058,440	46.02	1.51	487,124	0.365	0.004

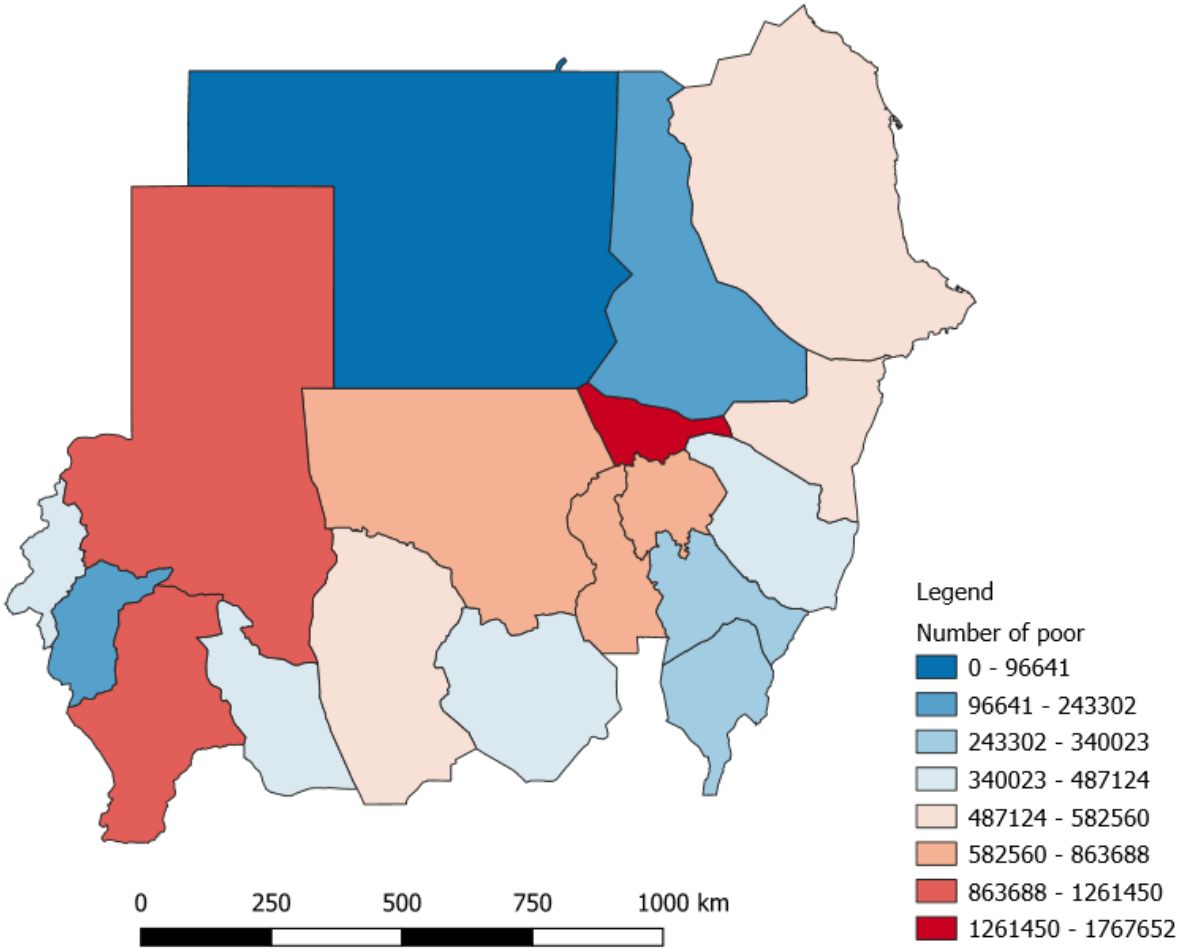
Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Map 2: Census SAE of Poverty at the State Level



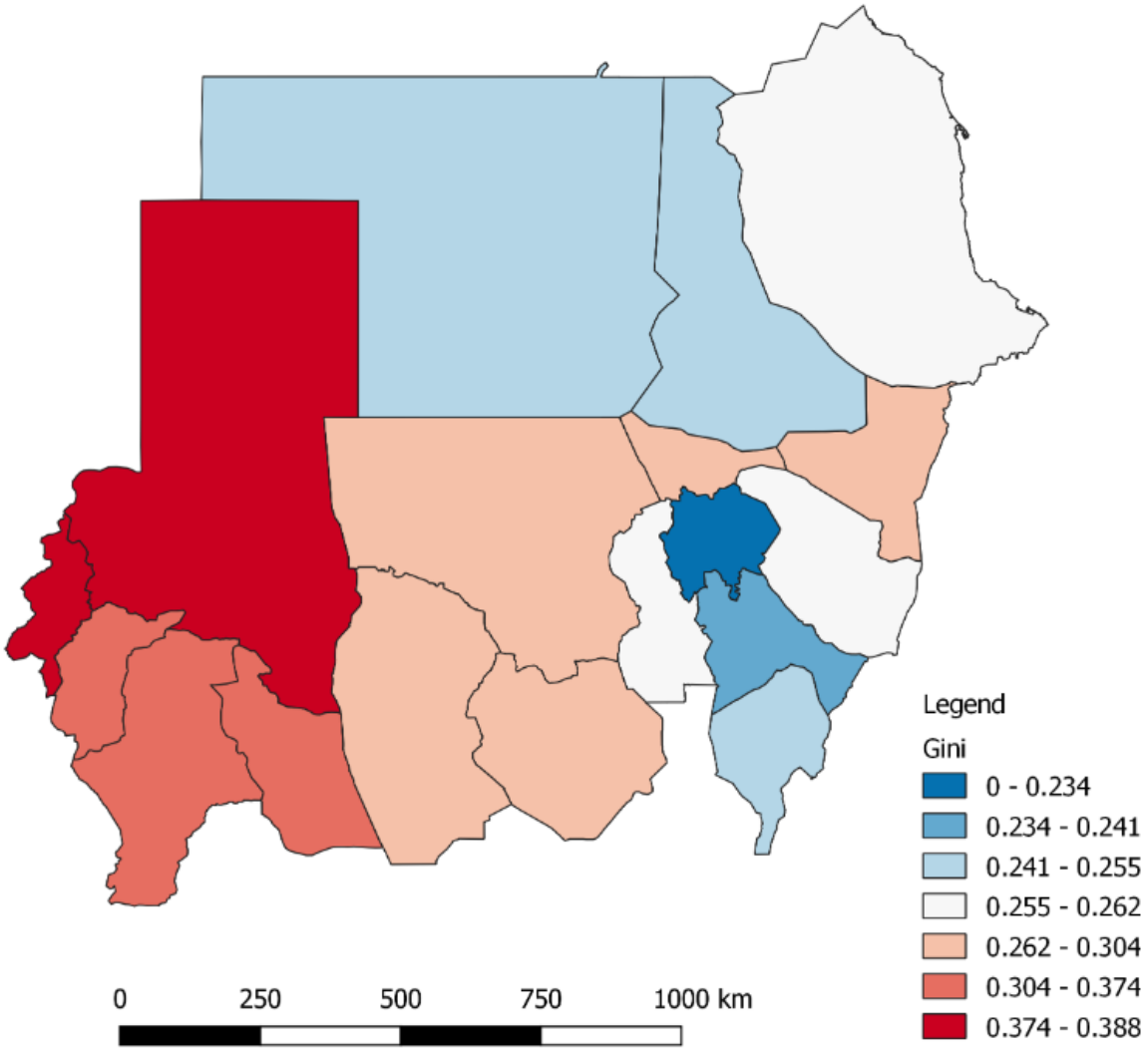
Source: Based on the 2008 Population and Housing Census.

Map 3: Census SAE of Number of Poor at the State Level



Source: Based on the 2008 Population and Housing Census.

Map 4: Census SAE of Gini at the State Level



Source: Based on the 2008 Population and Housing Census.

Table 17: Census SAE of Poverty and Gini at the Locality Level

Region	State	Locality Code	Number		Poverty		No. of Poor	Gini	
			Households	Individuals	Head Count	Standard Error		Estimate	Standard Error
Northern	Northern	1111101	583	27,349	12.30	4.92	3,363	0.229	0.011
	Northern	1111102	1,015	45,003	4.99	2.40	2,246	0.250	0.014
	Northern	1111103	1,140	76,247	11.54	3.71	8,799	0.225	0.008
	Northern	1111104	2,589	145,185	16.68	4.42	24,215	0.247	0.009
	Northern	1111105	1,999	96,396	16.98	4.74	16,367	0.243	0.009
	Northern	1111106	2,460	88,388	22.01	5.12	19,451	0.249	0.008
	Northern	1111107	4,066	157,184	14.12	4.40	22,201	0.245	0.008
	River Nile	1121201	3,388	139,950	13.07	3.93	18,298	0.253	0.009
	River Nile	1121202	2,728	148,938	20.41	4.77	30,395	0.244	0.008
	River Nile	1121203	2,305	107,939	24.28	4.61	26,205	0.248	0.009
	River Nile	1121204	8,461	272,756	27.71	6.22	75,575	0.262	0.010
	River Nile	1121205	5,059	250,880	16.45	4.07	41,280	0.243	0.009
	River Nile	1121206	3,102	174,351	17.68	4.31	30,820	0.241	0.008
Eastern	Red Sea	2212101	5,940	91,773	37.71	11.07	34,604	0.234	0.014
	Red Sea	2212102	4,581	172,700	36.86	9.41	63,650	0.239	0.039
	Red Sea	2212103	7,673	409,912	44.62	9.05	182,899	0.272	0.012
	Red Sea	2212104	6,121	93,366	32.11	8.69	29,981	0.268	0.024
	Red Sea	2212105	11,813	112,928	49.91	9.31	56,363	0.255	0.019
	Red Sea	2212106	9,339	249,351	41.93	9.89	104,542	0.239	0.013
	Red Sea	2212107	10,649	146,469	35.12	9.25	51,435	0.233	0.014
	Red Sea	2212108	6,566	87,895	58.88	11.25	51,753	0.224	0.023
	Kassala	2222201	5,301	76,177	51.15	7.63	38,967	0.280	0.033
	Kassala	2222202	6,703	178,316	37.48	11.15	66,829	0.205	0.019
	Kassala	2222203	7,968	219,963	34.41	8.10	75,689	0.234	0.032
	Kassala	2222204	3,454	94,410	30.69	8.19	28,972	0.258	0.019
	Kassala	2222205	8,200	82,275	12.34	5.83	10,156	0.248	0.020

Region	State	Locality Code	Number		Poverty		No. of Poor	Gini	
			Households	Individuals	Head Count	Standard Error		Estimate	Standard Error
	Kassala	2222206	4,424	236,888	38.15	8.19	90,377	0.290	0.019
	Kassala	2222207	8,426	147,832	41.64	9.34	61,554	0.247	0.018
	Kassala	2222208	4,394	259,418	33.48	8.18	86,841	0.276	0.012
	Kassala	2222209	4,500	191,272	25.63	8.31	49,024	0.251	0.042
	Kassala	2222210	1,842	108,916	38.18	8.23	41,588	0.271	0.033
	Kassala	2222211	1,522	88,315	36.87	8.77	32,561	0.263	0.037
	Al-Gedarif	2232301	1,320	54,883	20.74	7.61	11,382	0.219	0.025
	Al-Gedarif	2232302	3,332	133,859	20.93	7.65	28,018	0.240	0.016
	Al-Gedarif	2232303	2,243	116,144	19.80	8.07	22,997	0.251	0.044
	Al-Gedarif	2232304	4,368	259,148	47.66	10.07	123,511	0.255	0.013
	Al-Gedarif	2232305	2,928	165,427	17.60	6.76	29,119	0.256	0.018
	Al-Gedarif	2232306	4,530	215,084	23.88	7.46	51,368	0.239	0.019
	Al-Gedarif	2232307	1,414	68,141	42.12	9.64	28,701	0.236	0.013
	Al-Gedarif	2232308	2,439	90,673	33.25	8.57	30,148	0.252	0.020
	Al-Gedarif	2232309	1,480	68,289	31.85	9.72	21,751	0.236	0.011
	Al-Gedarif	2232310	3,371	144,973	40.66	9.04	58,940	0.249	0.021
Khartoum	Khartoum	3313101	11,084	720,130	38.58	3.19	277,853	0.275	0.006
	Khartoum	3313102	16,763	1,117,428	61.25	2.94	684,444	0.268	0.008
	Khartoum	3313103	6,599	418,831	20.95	3.53	87,763	0.291	0.008
	Khartoum	3313104	9,184	586,762	18.80	2.35	110,307	0.295	0.007
	Khartoum	3313105	13,614	885,800	27.04	2.58	239,492	0.277	0.007
	Khartoum	3313106	9,677	618,773	12.35	2.23	76,397	0.288	0.008
	Khartoum	3313107	13,600	882,980	33.00	3.34	291,394	0.267	0.007
Central	Al-Gezira	4414101	7,796	467,042	19.52	2.63	91,182	0.234	0.007
	Al-Gezira	4414102	6,816	418,471	17.26	3.18	72,233	0.231	0.007
	Al-Gezira	4414103	9,654	589,382	24.52	2.68	144,504	0.232	0.007
	Al-Gezira	4414104	3,801	240,626	29.73	4.26	71,543	0.229	0.007

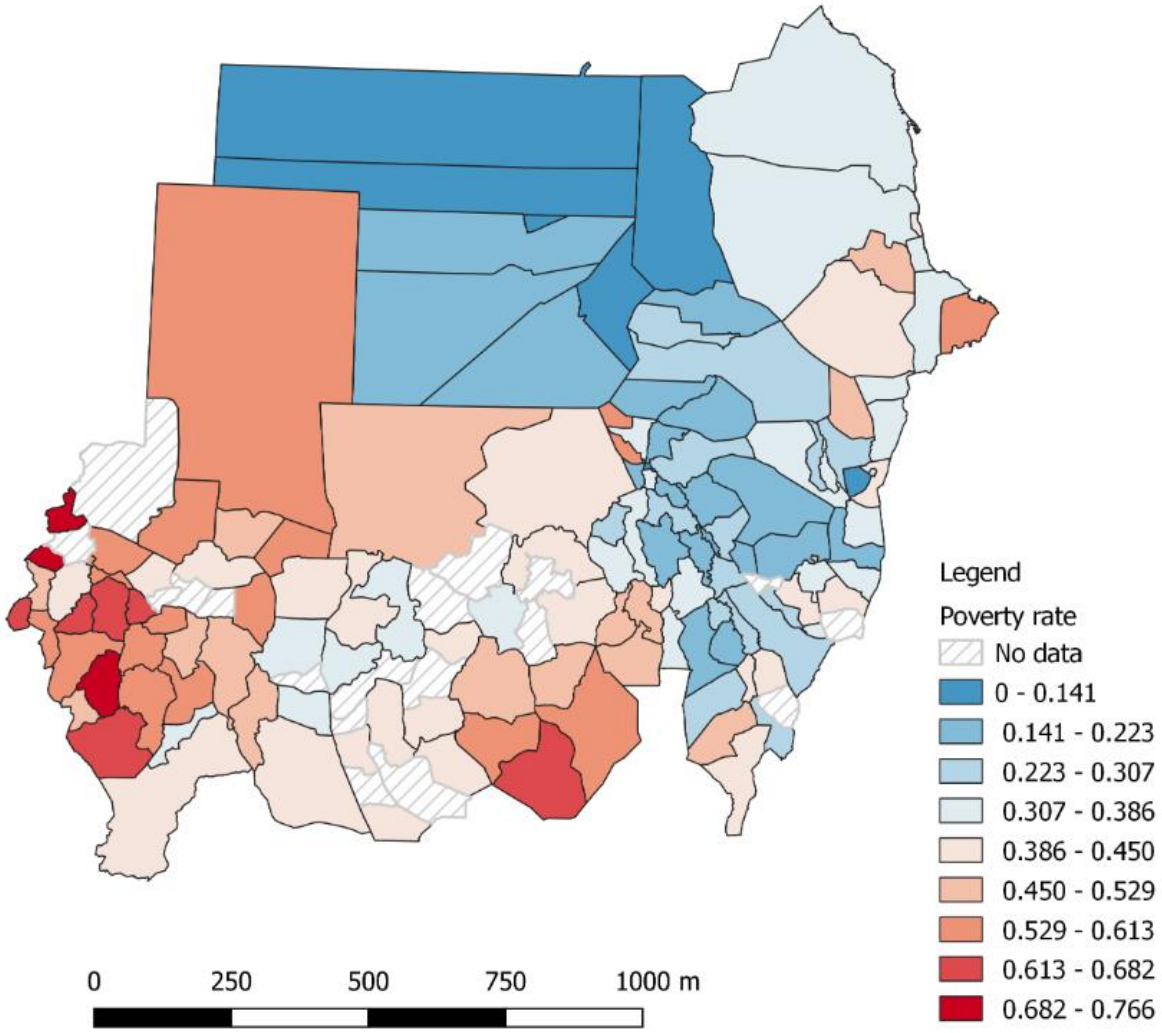
Region	State	Locality Code	Number		Poverty		No. of Poor	Gini	
			Households	Individuals	Head Count	Standard Error		Estimate	Standard Error
	Al-Gezira	4414105	6,305	381,603	22.08	3.13	84,272	0.251	0.011
	Al-Gezira	4414106	8,901	564,915	20.16	3.40	113,863	0.223	0.006
	Al-Gezira	4414107	13,406	828,516	19.79	2.59	163,933	0.231	0.007
	White Nile	4424201	4,427	280,111	34.07	4.03	95,422	0.262	0.010
	White Nile	4424202	1,518	91,756	28.20	3.28	25,878	0.255	0.007
	White Nile	4424203	4,213	265,367	34.90	3.67	92,619	0.262	0.010
	White Nile	4424204	3,337	239,867	39.07	4.47	93,709	0.260	0.010
	White Nile	4424205	3,536	141,470	32.31	4.12	45,715	0.245	0.007
	White Nile	4424206	6,751	422,600	47.82	3.61	202,070	0.258	0.010
	White Nile	4424207	4,611	92,369	50.15	5.64	46,327	0.242	0.009
	White Nile	4424208	3,230	194,413	52.93	4.90	102,897	0.246	0.008
	Sinnar	4434301	3,337	200,056	25.86	4.08	51,732	0.241	0.007
	Sinnar	4434302	5,095	289,581	31.76	3.56	91,984	0.251	0.007
	Sinnar	4434303	5,199	167,890	28.39	3.51	47,660	0.229	0.009
	Sinnar	4434304	3,891	245,534	29.45	3.23	72,299	0.233	0.006
	Sinnar	4434305	2,430	147,961	24.31	4.47	35,970	0.249	0.009
	Sinnar	4434306	2,426	122,156	19.16	4.26	23,410	0.223	0.009
	Sinnar	4434307	3,126	76,084	22.30	5.75	16,968	0.233	0.011
	Blue Nile	4444401	4,496	237,687	44.48	2.84	105,714	0.247	0.009
	Blue Nile	4444402	3,378	212,765	42.08	2.80	89,525	0.257	0.009
	Blue Nile	4444403	1,164	64,235	25.89	3.53	16,627	0.229	0.010
	Blue Nile	4444404	2,872	132,062	48.78	8.51	64,423	0.223	0.010
	Blue Nile	4444405	2,417	94,419	23.73	4.93	22,405	0.241	0.010
	Blue Nile	4444406	1,809	86,178	44.40	8.00	38,266	0.240	0.012
Kordofan	North Kordofan	5515101	31,709	209,773	42.81	10.65	89,810	0.255	0.003
	North Kordofan	5515102	34,984	324,477	47.20	10.79	153,142	0.255	0.003
	North Kordofan	5515103	8,115	387,736	42.71	10.23	165,599	0.274	0.004

Region	State	Locality Code	Number		Poverty		No. of Poor	Gini	
			Households	Individuals	Head Count	Standard Error		Estimate	Standard Error
	North Kordofan	5515104	13,612	612,660	41.56	12.24	254,600	0.271	0.004
	North Kordofan	5515106	12,493	526,964	38.05	10.09	200,536	0.268	0.004
	South Kordofan	5525201	5,857	204,056	48.54	10.05	99,058	0.270	0.005
	South Kordofan	5525202	4,780	196,087	57.11	12.38	111,979	0.260	0.005
	South Kordofan	5525203	5,462	271,372	48.64	10.59	131,992	0.271	0.005
	South Kordofan	5525204	3,270	93,272	56.64	10.03	52,834	0.265	0.006
	South Kordofan	5525206	3,656	101,908	63.92	10.13	65,141	0.255	0.005
	West Kordofan	5535302	4,715	249,095	37.79	9.96	94,141	0.264	0.004
	West Kordofan	5535303	2,655	126,062	39.01	10.63	49,173	0.263	0.005
	West Kordofan	5535304	3,294	136,878	42.02	11.12	57,513	0.266	0.005
	West Kordofan	5535307	6,537	284,177	36.78	10.20	104,533	0.265	0.004
	West Kordofan	5535308	6,638	148,177	44.61	11.39	66,101	0.266	0.005
	West Kordofan	5535309	3,906	128,074	40.68	11.09	52,099	0.266	0.005
	West Kordofan	5535311	10,705	171,668	42.93	10.30	73,695	0.259	0.004
	West Kordofan	5535312	1,732	57,010	43.01	9.92	24,519	0.265	0.007
Darfur	North Darfur	6616101	6,878	166,801	60.37	3.88	100,698	0.349	0.008
	North Darfur	6616102	1,058	162,038	48.98	5.70	79,359	0.356	0.008
	North Darfur	6616104	1,396	224,876	59.63	8.86	134,083	0.357	0.006
	North Darfur	6616105	10,680	201,532	57.85	9.68	116,580	0.363	0.007
	North Darfur	6616106	9,800	139,054	44.98	3.55	62,553	0.367	0.007
	North Darfur	6616107	1,079	100,743	56.87	4.15	57,289	0.358	0.009
	North Darfur	6616108	4,325	101,450	55.12	7.11	55,924	0.341	0.012
	North Darfur	6616109	3,461	300,105	44.69	2.74	134,114	0.398	0.009
	North Darfur	6616110	1,813	166,843	38.88	4.13	64,870	0.358	0.008
	North Darfur	6616111	819	118,086	59.34	6.28	70,072	0.359	0.011
	North Darfur	6616112	1,596	203,375	33.02	4.93	67,148	0.360	0.007
	North Darfur	6616114	45,692	233,598	54.77	10.55	127,937	0.362	0.003

Region	State	Locality Code	Number		Poverty		No. of Poor	Gini	
			Households	Individuals	Head Count	Standard Error		Estimate	Standard Error
	West Darfur	6626201	5,314	90,416	73.60	2.54	66,543	0.354	0.009
	West Darfur	6626202	4,231	114,074	75.27	2.14	85,868	0.364	0.007
	West Darfur	6626203	4,266	97,936	44.23	3.34	43,320	0.362	0.007
	West Darfur	6626204	3,364	245,568	49.01	2.37	120,349	0.388	0.007
	West Darfur	6626205	4,179	91,438	68.17	2.93	62,333	0.364	0.007
	West Darfur	6626206	5,588	150,947	58.19	2.94	87,842	0.364	0.006
	South Darfur	6636302	11,539	428,808	46.69	2.68	200,196	0.391	0.006
	South Darfur	6636303	2,251	11,994	60.47	9.30	7,253	0.358	0.005
	South Darfur	6636304	10,110	156,341	56.08	3.45	87,681	0.364	0.005
	South Darfur	6636305	48,384	709,985	54.33	2.95	385,748	0.359	0.003
	South Darfur	6636306	8,456	243,551	56.13	3.90	136,717	0.364	0.005
	South Darfur	6636309	37,243	400,784	34.25	3.60	137,287	0.354	0.004
	South Darfur	6636310	16,075	274,755	64.62	3.37	177,553	0.360	0.004
	South Darfur	6636311	10,522	314,900	40.97	3.22	129,014	0.350	0.004
	Central Darfur	6646407	5,280	119,475	62.94	3.22	75,202	0.363	0.006
	Central Darfur	6646408	5,887	32,245	66.31	2.17	21,381	0.365	0.006
	Central Darfur	6646409	2,046	11,265	67.68	3.89	7,624	0.362	0.006
	Central Darfur	6646411	10,289	175,870	57.56	2.49	101,227	0.361	0.005
	Central Darfur	6646412	4,877	32,119	76.58	2.08	24,597	0.364	0.008
	Central Darfur	6646413	3,333	27,540	48.18	3.18	13,268	0.362	0.011
	East Darfur	6656501	11,481	182,629	50.92	3.07	92,998	0.368	0.005
	East Darfur	6656507	18,355	447,965	50.49	1.99	226,199	0.364	0.005
	East Darfur	6656508	4,594	202,180	36.33	3.17	73,448	0.354	0.007
	East Darfur	6656512	30,873	225,664	41.87	3.33	94,478	0.358	0.004

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

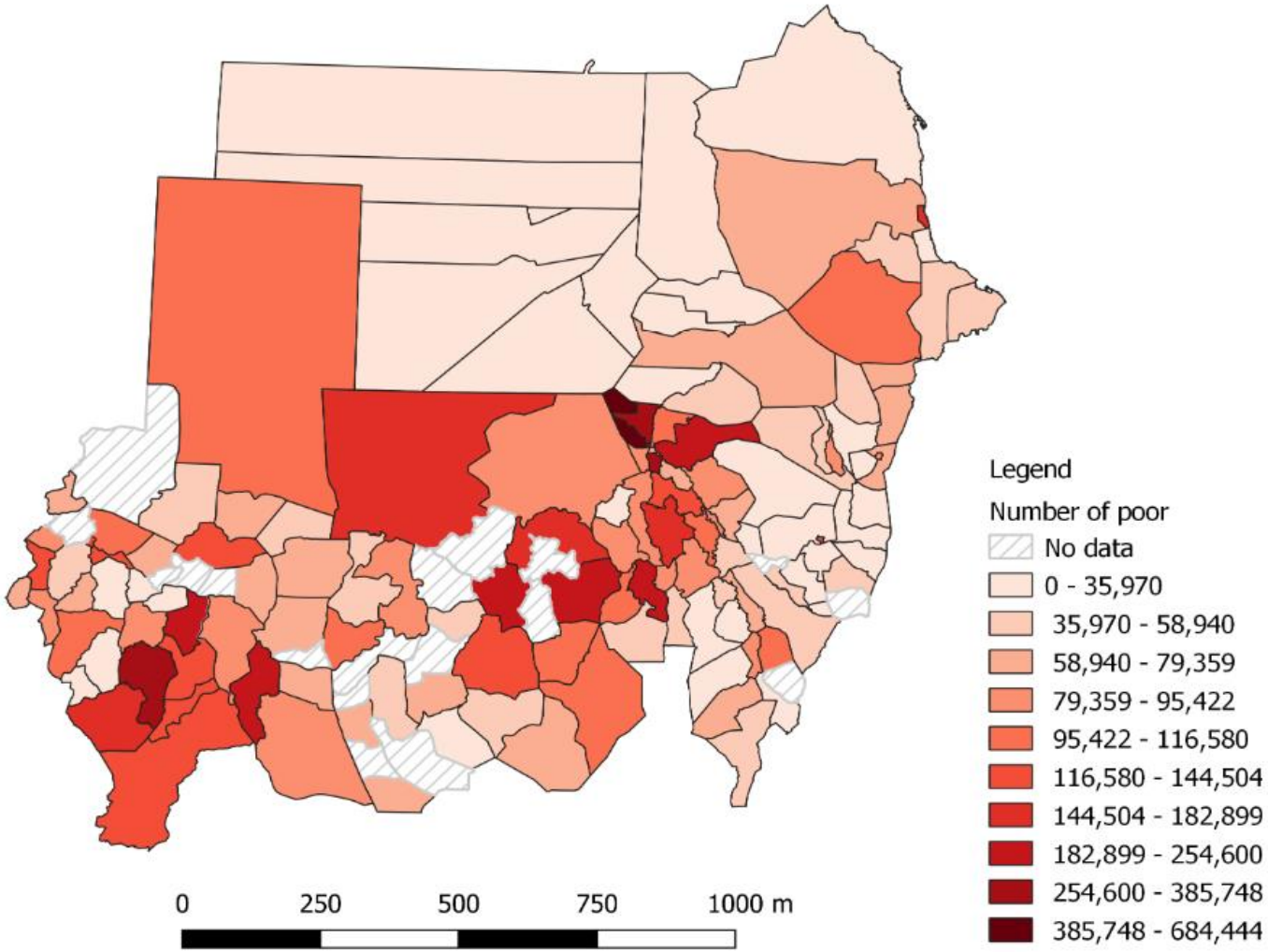
Map 5: Census SAE of Poverty at the Locality Level



Source: Based on the 2008 Population and Housing Census.

Note: No data imply that the locality was not in the Sample Census 2008.

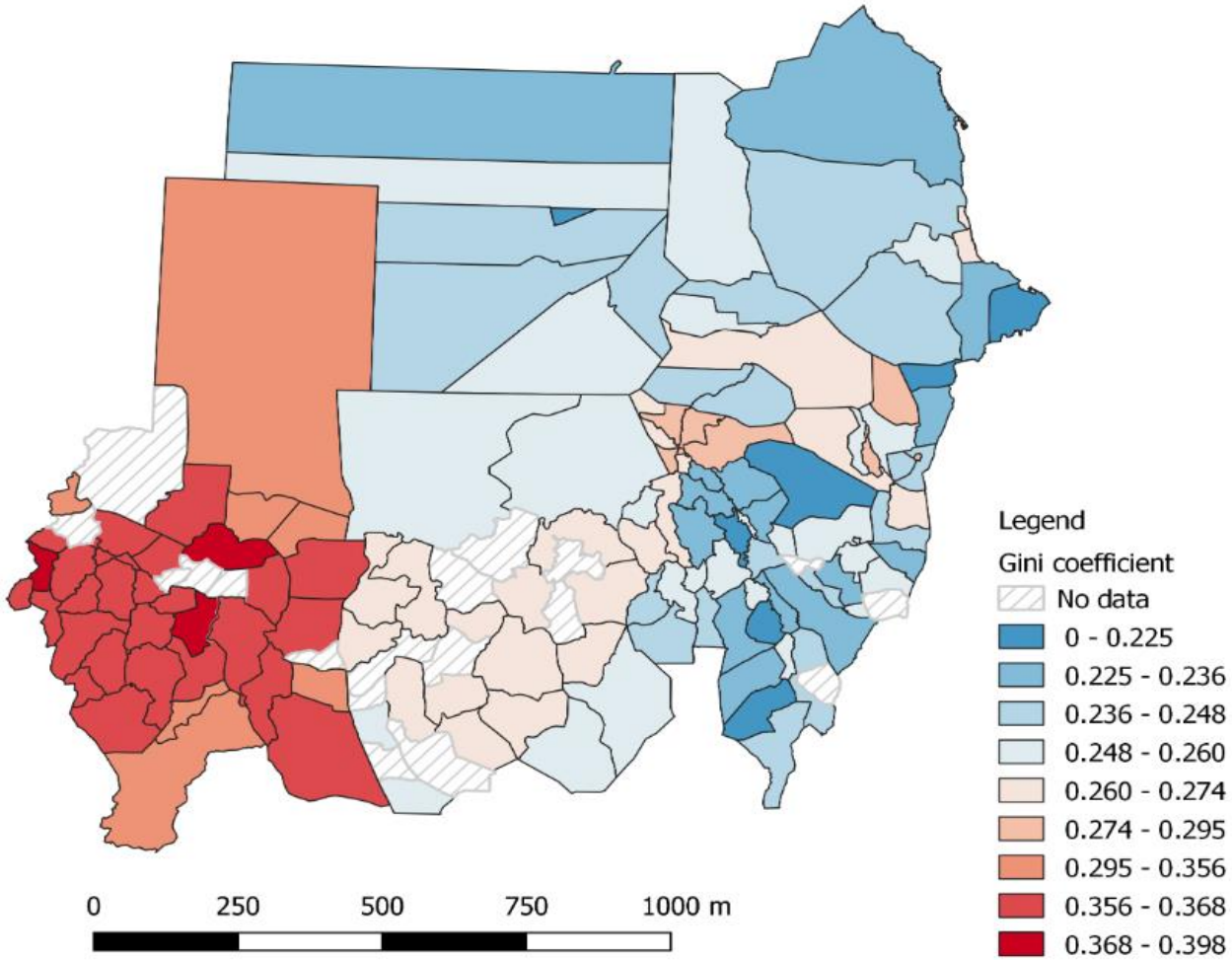
Map 6: Census SAE of Number of Poor at the Locality Level



Source: Based on the 2008 Population and Housing Census.

Note: No data imply that the locality was not in the Sample Census 2008.

Map 7: Census SAE Gini at the Locality Level



Source: Based on the 2008 Population and Housing Census.

Note: No data imply that the locality was not in the Sample Census 2008.

5. Conclusions

Poverty maps, unlike household surveys, allow for a greater focus on the spatial distribution of poverty and inequality at lower levels. This analysis highlights the potential gains from a more aggregate level to a lower-level geographical targeting. This may offer an effective approach for reaching the poor where there are substantial disparities in living standards within and across geographical areas. Although it is beyond the scope of this note, this methodology can be complemented with other indicators of well-being, opportunity, and access for regional patterns.

This report describes the methodology of the small area poverty and inequality estimation presenting the results for the 131 localities of Sudan using the 2014/15 NHBPS and the 2008 Population and Housing Census. Variables such as demographics characteristics, education, occupation, housing characteristics, and productive and durable assets are used in the modeling. Since the Sudan poverty phenomenon is heterogenous, the disaggregated model is seen as a better fit compared to the national model.

Estimates of poverty head count at the national and state levels are found to be in line with the poverty levels observed in the 2014/15 NHBPS. Northern region has the lowest poverty head count and Darfur region has the highest poverty head count as well as inequality. Overall inequality is moderate. Poverty rates at state or locality level do not always correspond with data at regional levels. These differences are induced by the heterogenous character of the poverty phenomenon. The poverty and inequality maps presented in this report may find use for other future analysis. Poverty estimates for localities may be used as inputs to conduct the analysis at the district level or to look at specific non-geographical factors associated with poverty and inequality. These results may also provide decision-makers with a starting point for improving the targeting of poverty reduction strategies.

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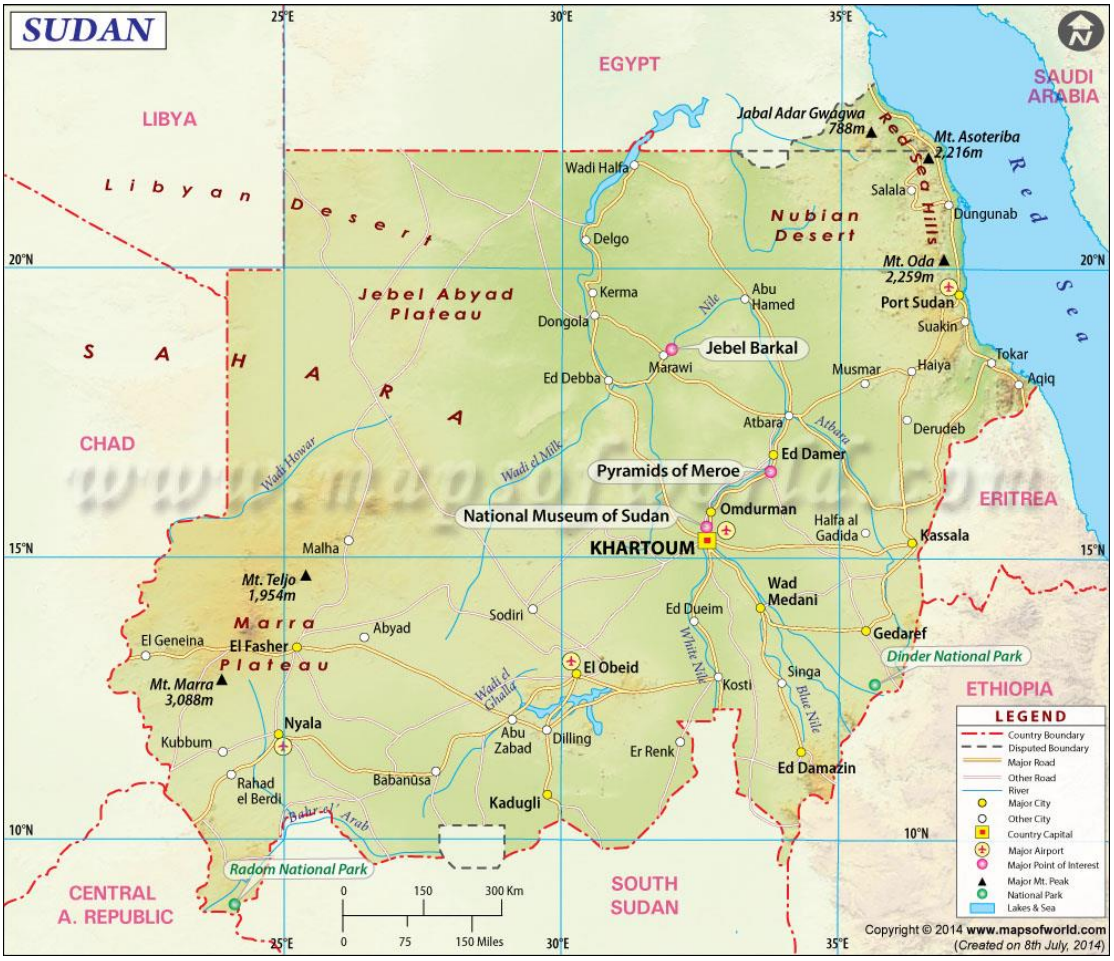
Appendix A: Sudan Administrative Boundaries



Source: www.mapsofworld.com/July 2014.

Appendix B: Common Variables between the Census and 2014/15 NHBPS

Individual Information	
Age	
Gender	
0	Female
1	Male
Relationship to the head of HH	
1	Head
2	Spouse
3	Child
4	Parents
5	Other relative
6	Non-relative
Marital status	
1	Never married
2	Married
3	Widowed
4	Divorced
Able to read or write	
0	Illiterate
1	Literate
Has ever attended school	
0	not attended
1	Attended
Is currently attending school	
0	not attending
1	Attending
Highest education level attainted	
1	None
2	Incomplete primary
3	Primary
4	Secondary
5	Tertiary
Level of schooling currently attending	
1	Primary
2	Secondary
3	Tertiary
Employed	
0	No
1	Yes

Individual Information	
why not in labor force	
1	No hope to find job
2	Full time student
3	Income recipient
4	Too old
5	Disabled/too sick
6	Full time homemaker/housewife
7	Pensioner/retired
type of employment	
1	Paid employee
2	Employer
3	Own account worker
4	Unpaid family worker
5	Unpaid working for others
Industry (Main industry)	
Sector of work	
1	Agr
2	Mnf
3	Services
Any disability?	
Difficulty in seeing	
0	No
1	Yes
Blindness	
0	No
1	Yes
Difficulty in hearing	
0	No
1	Yes
Deafness	
0	No
1	Yes
Difficulty in speaking	
0	No
1	Yes
Mutism	
0	No
1	Yes
Disability in other part of the body	
0	No

Individual Information	
1	Yes
Mental retardation	
0	No
1	Yes
Other disability type	
0	No
1	Yes
Father alive?	
1	Dead
2	Alive
3	Not know
Mother alive?	
1	Dead
2	Alive
3	Not know

Household Information	
Household size	
Age (head)	
Number of rooms used for sleeping	
Number of livestock and poultry	
1	Cattle
2	Horses
3	Donkeys
4	Sheep
5	Goats
6	Poultry
7	Camels
Region	
1	Northern
2	Eastern
3	Khartoum
4	Central
5	Kordofan
6	Darfur
Rural or Urban	
0	Rural
1	Urban
Type of dwelling	
1	Tent
2	Dwelling of straw mats
3	Gottiya-mud
4	Gottiya-sticks
5	Apartment
6	Villa
7	House of one floor-mud
8	House of one floor-brick/concrete
9	House constructed of wood
10	Multi-storey house
11	Incomplete
Ownership of dwelling	
1	Owned
2	Rented
3	Housing provided as part of work
4	Free
Access to drinking water	

Household Information	
0	No
1	Yes
Access to electricity	
0	No
1	Yes
Energy used for cooking	
1	Firewood
2	Charcoal
3	Gas
4	Electricity
5	Paraffin
6	Cow dung
7	Grass
8	Biogas
9	No cooking
Type of toilet	
1	Pit latrine private
2	Shared pit latrine
3	Private flush toilet
4	Shate flush toilet
5	Bucket toilet
6	No toilet facility
Assets	
tv	
0	No
1	Yes
Radio	
0	No
1	Yes
Phone	
0	No
1	Yes
computer	
0	No
1	Yes
refrigerator	
0	No
1	Yes
Fan	
0	No

Household Information	
1	Yes
Ac	
0	No
1	Yes
motor	
0	No
1	Yes
motorcycle	
0	No
1	Yes
bicycle	
0	No
1	Yes
boat	
0	No
1	Yes
anitran	
0	No
1	Yes
agriland	
0	No
1	Yes
Land ownership	
1	Owned
2	Rented
3	Partially owned
4	Communal
Forms of livelihood	
1	Crop farming
2	Animal husbandry
3	Wages and salaries
4	Owned business enterprise
5	Property income
6	Remittances
7	Pension
8	Aid
9	Others

Appendix C: Region Alpha Model Estimates

Table C.1: Northern (Alpha Model, Region 1)

	Coefficient	Standard Error	P >|z|
head_age25t64	−135.941	68.789	0.048
head_edlevel4	9.496	4.281	0.027
hhsize_5	−12.953	10.308	0.209
dwelling1_yhat	0.115	0.046	0.013
head_age25t64_yhat	29.175	15.094	0.053
head_edlevel4_yhat	−1.029	0.474	0.030
hhsize_4_yhat	−0.059	0.026	0.022
hhsize_5_yhat	1.358	1.145	0.236
hhsize_6_yhat	−0.037	0.027	0.170
nrooms_yhat	−0.028	0.010	0.003
sector1_share_yhat	−0.094	0.040	0.018
head_age25t64_yhat2	−1.566	0.827	0.058
Constant	−4.033	0.317	0.000

Table C.2: Eastern (Alpha Model, Region 2)

	Coefficient	Standard Error	P >|z|
charcoal	165.980	78.269	0.034
child_2	66.230	90.890	0.466
dwelling3	−105.706	63.141	0.094
elec_m_county	−285.426	138.722	0.040
Gas	232.837	93.291	0.013
head_edlevel2	−170.842	92.598	0.065
head_edlevel3	489.506	227.036	0.031
head_unpaid	519.549	462.419	0.261
hhsize_2	−447.455	251.435	0.075
nrooms	3.756	1.860	0.043
sum_age1t14_m_county	−5.807	37.175	0.876
charcoal_yhat	−37.844	17.725	0.033
child_2_yhat	−15.245	20.412	0.455
dwelling3_yhat	23.313	14.110	0.098
elec_m_county_yhat	63.621	31.328	0.042
gas_yhat	−53.392	20.950	0.011
head_edlevel2_yhat	37.034	20.539	0.071
head_edlevel3_yhat	−106.442	49.409	0.031
head_employed_yhat	-0.056	0.022	0.011
head_employer_yhat	0.041	0.024	0.096

	Coefficient	Standard Error	P >|z|
head_unpaid_yhat	−115.306	101.985	0.258
hhsize_2_yhat	97.062	53.554	0.070
hhsize_6_yhat	0.040	0.019	0.041
nrooms_yhat	−0.428	0.209	0.040
sum_age1t14_m_county_yhat	1.542	8.309	0.853
charcoal_yhat2	2.154	1.003	0.032
child_2_yhat2	0.872	1.146	0.447
dwelling3_yhat2	−1.285	0.787	0.103
elec_m_county_yhat2	−3.524	1.767	0.046
gas_yhat2	3.052	1.175	0.009
head_edlevel2_yhat2	−2.001	1.138	0.079
head_edlevel3_yhat2	5.774	2.685	0.032
head_unpaid_yhat2	6.381	5.614	0.256
hhsize_2_yhat2	−5.259	2.852	0.065
sector3_share_yhat2	0.005	0.003	0.058
sum_age1t14_m_county_yhat2	−0.097	0.464	0.834
toilet2_yhat2	0.007	0.003	0.025
Constant	−4.988	0.548	0.000

Table C.3: Khartoum (Alpha model, Region 3)

	Coefficient	Standard Error	P >|z|
hhsize_6	9.247	4.794	0.054
everattend_share_yhat	−0.185	0.080	0.020
hhsize_6_yhat	−1.035	0.540	0.055
pri_abv_share_yhat	−0.073	0.032	0.024
sec_abv_share_yhat	0.105	0.032	0.001
Constant	−3.234	0.683	0.000

Table C.4: Central (Alpha model, Region 4)

	Coefficient	Standard Error	P >|z|
dwelling3_m_county	6.706	3.326	0.044
head_employee	84.187	39.203	0.032
hhsize_4	−0.470	0.158	0.003
nrooms	−2.621	1.247	0.036
toilet1	−0.366	0.117	0.002
urban	0.231	0.117	0.048
water_m_state	−1.381	0.435	0.001
dwelling3_m_county_yhat	−0.678	0.376	0.071
head_employee_yhat	−18.761	8.757	0.032

	Coefficient	Standard Error	P >|z|
nrooms_yhat	0.294	0.140	0.035
head_employee_yhat2	1.041	0.489	0.033
pri_abv_share_yhat2	−0.004	0.002	0.037
Constant	-4.549	0.212	0.000

Appendix D: Poverty Measures

This section provides the mathematical expressions for the poverty measures used in the paper and for the World Bank. Three poverty measures of the Foster-Greer-Thorbecke (FGT) class (Foster, Greer, and Thorbecke 1984) are used—the head count, the poverty gap, and the squared poverty gap. For a simple introduction to poverty measurement and profiles, see Coudouel Hentschel, and Wodon (2002). The poverty head count is the share of the population which is poor, that is, the proportion of the population for whom consumption per equivalent adult y is less than the poverty line z. If we consider a population of size n in which q people are poor, then the head count index is defined as

$$H = \frac{q}{n}.$$

The poverty gap, which is often considered as representing the depth of poverty, is the mean distance separating the population from the poverty line, with the nonpoor being given a distance of zero. Arranging consumption in ascending order y_1,...., $y_q < z < y_q+1$, ..., y_n with the poorest household's consumption denoted by y_1, the next poorest y_2, and so on, and the richest household's consumption by y_n, the poverty gap is defined as follows:

$$PG = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{z - y_i}{z}\right],$$

where y_i is the income of individual i, and the sum is taken only on those individuals who are poor, although in practice, we often work with household consumption rather than individual consumption. The poverty gap is thus a measure of the poverty deficit of the entire population where the notion of 'poverty deficit' captures resources that would be needed—as a proportion of the poverty line—to lift all the poor out of poverty through perfectly targeted cash transfers.

The squared poverty gap is often described as a measure of the severity of poverty. While the poverty gap considers the distance separating the poor from the poverty line, the squared poverty gap takes the square of that distance into account. When using the squared poverty gap, the poverty gap is weighted by itself, so as to give more weight to the very poor. In other words, the squared poverty gap takes into account the inequality among the poor. It is defined as follows:

$$SPG = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{z - y_i}{z}\right]^2.$$

The head count, the poverty gap, and the squared poverty gap are the first three measures of the FGT class of poverty measures and a common structure is evident that suggests a generic class of additive measures. It must be noted that the additive measures are such that aggregate poverty is equal to the population-weighted sum of poverty in various subgroups of society. The general formula for the class of poverty measures depends on a parameter α which takes a value of 0 for the head count, 1 for the poverty gap, and 2 for the squared poverty gap in the following expression:

$$P_{\alpha} = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z - y_i}{z}\right)^{\alpha} \quad (\alpha \geq 0)$$

.

The discussion that follows focuses on the head count index of poverty. Higher-order poverty measures—poverty gap and squared poverty gap—are provided in Appendix E.

Appendix E: Census Poverty Measures by Administrative Units

Table E.1: Poverty Measures by Region and State

Region	State	Head Count	Poverty Gap	Severity of Poverty	Population Share	Contribution of Poverty			Population Size	Number of Poor
						Head Count	Poverty Gap	Severity of Poverty		
SUDAN		**37.47**	**10.58**	**4.37**	**100**	**100**	**100**	**100**	**29,757,647**	**11,148,985**
Northern		**18.45**	**3.72**	**1.19**	**5.82**	**2.86**	**2.04**	**1.58**	**1,730,571**	**319,214**
	Northern	15.20	2.85	0.86	2.14	0.87	0.58	0.42	635,755	96,641
	River Nile	20.33	4.22	1.38	3.68	2.00	1.47	1.16	1,094,816	222,574
Eastern		**35.83**	**8.27**	**2.80**	**14.67**	**14.03**	**11.47**	**9.39**	**4,364,809**	**1,563,727**
	Red Sea	42.16	10.03	3.45	4.59	5.16	4.35	3.62	1,364,398	575,229
	Kassala	34.60	7.90	2.65	5.66	5.23	4.23	3.43	1,683,786	582,560
	Al-Gedarif	30.83	6.91	2.31	4.42	3.64	2.89	2.34	1,316,625	405,938
Khartoum	Khartoum	**33.79**	**8.51**	**3.07**	**17.58**	**15.85**	**14.14**	**12.37**	**5,230,708**	**1,767,652**
Central		**29.10**	**6.34**	**2.09**	24.52	**19.04**	14.70	11.71	**7,295,131**	**2,123,153**
	Al-Gezira	21.24	3.95	1.15	11.73	6.65	4.38	3.07	3,490,560	741,532
	White Nile	40.78	10.31	3.75	5.81	6.32	5.66	4.98	1,727,955	704,637
	Sinnar	27.22	5.54	1.73	4.20	3.05	2.20	1.66	1,249,265	340,023
	Blue Nile	40.73	9.37	3.13	2.78	3.02	2.46	1.99	827,349	336,961
Kordofan		**43.66**	**11.39**	**4.16**	**14.21**	**16.56**	**15.30**	**13.54**	**4,229,456**	**1,846,471**
	North Kordofan	**41.89**	**10.76**	**3.89**	6.93	7.75	7.05	6.16	2,061,612	863,688
	South Kordofan	53.19	15.25	5.95	2.91	4.13	4.20	3.96	866,698	461,006
	West Kordofan	40.10	9.82	3.41	4.37	4.68	4.06	3.41	1,301,145	521,776
Darfur		**51.09**	**19.30**	**9.68**	**23.21**	**31.65**	**42.35**	**51.41**	**6,906,972**	**3,528,766**
	North Darfur	50.54	18.94	9.43	7.12	9.60	12.75	15.37	2,118,507	1,070,630
	West Darfur	58.99	24.30	12.94	2.66	4.18	6.10	7.86	790,383	466,258
	South Darfur	49.64	18.43	9.12	8.54	11.31	14.88	17.83	2,541,122	1,261,450
	Central Darfur	61.05	24.86	13.08	1.34	2.18	3.15	4.01	398,518	243,302
	East Darfur	46.02	16.29	7.80	3.56	4.37	5.48	6.34	1,058,440	487,124

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Table E.2: Poverty Measures by Locality

Level			Head Count	Poverty Gap	Severity of Poverty	Population Share	Contribution of Poverty			Population Size	Number of Poor
Region	State	Locality Code					Head Count	Poverty Gap	Severity of Poverty		
SUDAN			**37.47**	**10.58**	**4.37**	**100**	**100**	**100**	**100**	**29,757,647.00**	**11,148,985.00**
Northern			**18.45**	**3.72**	**1.19**	**5.82**	**2.86**	**2.04**	**1.58**	**1,730,571.00**	**319,214.00**
	Northern	1111101	**12.30**	**1.84**	**0.44**	0.09	0.03	0.02	0.01	27,349.00	3,363.00
	Northern	1111102	4.99	0.75	0.19	0.15	0.02	0.01	0.01	45,003.00	2,245.89
	Northern	1111103	11.54	1.91	0.51	0.26	0.08	0.05	0.03	76,247.00	8,798.65
	Northern	1111104	16.68	3.06	0.89	0.49	0.22	0.14	0.10	145,185.00	24,214.59
	Northern	1111105	16.98	3.21	0.98	0.32	0.15	0.10	0.07	96,396.00	16,367.13
	Northern	1111106	22.01	4.62	1.52	0.30	0.17	0.13	0.10	88,388.00	19,450.83
	Northern	1111107	14.12	2.69	0.83	0.53	0.20	0.13	0.10	157,184.00	22,200.59
	River Nile	1121201	13.07	2.45	0.75	0.47	0.16	0.11	0.08	139,950.00	18,297.63
	River Nile	1121202	20.41	4.16	1.36	0.50	0.27	0.20	0.16	148,938.00	30,395.48
	River Nile	1121203	24.28	4.87	1.52	0.36	0.24	0.17	0.13	107,939.00	26,205.36
	River Nile	1121204	27.71	6.37	2.25	0.92	0.68	0.55	0.47	272,756.00	75,574.92
	River Nile	1121205	16.45	3.13	0.95	0.84	0.37	0.25	0.18	250,880.00	41,280.11
	River Nile	1121206	17.68	3.49	1.09	0.59	0.28	0.19	0.15	174,351.00	30,819.64
Eastern			**35.83**	**8.27**	**2.80**	**14.67**	**14.03**	**11.47**	**9.39**	**4,364,809.00**	**1,563,727.00**
	Red Sea	2212101	37.71	8.06	2.55	0.31	0.31	0.23	0.18	91,773.00	34,604.00
	Red Sea	2212102	36.86	8.34	2.84	0.58	0.57	0.46	0.38	172,700.00	63,650.00
	Red Sea	2212103	44.62	11.00	3.88	1.38	1.64	1.43	1.22	409,912.00	182,899.00
	Red Sea	2212104	32.11	7.29	2.44	0.31	0.27	0.22	0.18	93,366.00	29,981.21
	Red Sea	2212105	49.91	13.33	5.02	0.38	0.51	0.48	0.44	112,928.00	56,362.58
	Red Sea	2212106	41.93	9.38	3.02	0.84	0.94	0.74	0.58	249,351.00	104,541.86
	Red Sea	2212107	35.12	7.77	2.53	0.49	0.46	0.36	0.29	146,469.00	51,434.85
	Red Sea	2212108	58.88	15.22	5.41	0.30	0.46	0.42	0.37	87,895.00	51,752.72
	Kassala	2222201	51.15	13.65	5.06	0.26	0.35	0.33	0.30	76,177.00	38,967.39

Level			Head Count	Poverty Gap	Severity of Poverty	Population Share	Contribution of Poverty			Population Size	Number of Poor
Region	State	Locality Code					Head Count	Poverty Gap	Severity of Poverty		
	Kassala	2222202	37.48	7.82	2.42	0.60	0.60	0.44	0.33	178,316.00	66,829.37
	Kassala	2222203	34.41	7.55	2.49	0.74	0.68	0.53	0.42	219,963.00	75,688.67
	Kassala	2222204	30.69	6.76	2.21	0.32	0.26	0.20	0.16	94,410.00	28,972.09
	Kassala	2222205	12.34	2.10	0.57	0.28	0.09	0.06	0.04	82,275.00	10,155.94
	Kassala	2222206	38.15	9.33	3.28	0.80	0.81	0.70	0.60	236,888.00	90,376.99
	Kassala	2222207	41.64	9.79	3.29	0.50	0.55	0.46	0.37	147,832.00	61,553.76
	Kassala	2222208	33.48	7.64	2.52	0.87	0.78	0.63	0.50	259,418.00	86,841.17
	Kassala	2222209	25.63	5.12	1.57	0.64	0.44	0.31	0.23	191,272.00	49,023.64
	Kassala	2222210	38.18	9.28	3.27	0.37	0.37	0.32	0.27	108,916.00	41,587.89
	Kassala	2222211	36.87	8.75	3.03	0.30	0.29	0.25	0.21	88,315.00	32,560.81
	Al-Gedarif	2232301	20.74	3.54	0.95	0.18	0.10	0.06	0.04	54,883.00	11,382.49
	Al-Gedarif	2232302	20.93	3.81	1.08	0.45	0.25	0.16	0.11	133,859.00	28,017.71
	Al-Gedarif	2232303	19.80	4.02	1.28	0.39	0.21	0.15	0.11	116,144.00	22,997.06
	Al-Gedarif	2232304	47.66	12.34	4.50	0.87	1.11	1.02	0.90	259,148.00	123,511.50
	Al-Gedarif	2232305	17.60	3.38	1.01	0.56	0.26	0.18	0.13	165,427.00	29,119.06
	Al-Gedarif	2232306	23.88	4.61	1.38	0.72	0.46	0.32	0.23	215,084.00	51,367.86
	Al-Gedarif	2232307	42.12	9.82	3.34	0.23	0.26	0.21	0.17	68,141.00	28,700.73
	Al-Gedarif	2232308	33.25	7.31	2.37	0.30	0.27	0.21	0.17	90,673.00	30,148.35
	Al-Gedarif	2232309	31.85	6.32	1.87	0.23	0.20	0.14	0.10	68,289.00	21,750.81
	Al-Gedarif	2232310	40.66	9.73	3.40	0.49	0.53	0.45	0.38	144,973.00	58,939.97
Khartoum			**33.79**	**8.51**	**3.07**	**17.58**	**15.85**	**14.14**	**12.37**	**5,230,708**	**1,767,652**
	Khartoum	3313101	38.58	9.25	3.18	2.42	2.49	2.12	1.76	720,130.00	277,852.98
	Khartoum	3313102	61.25	18.53	7.46	3.76	6.14	6.58	6.41	1,117,428.00	684,444.43
	Khartoum	3313103	20.95	4.23	1.29	1.41	0.79	0.56	0.41	418,831.00	87,763.41
	Khartoum	3313104	18.80	3.75	1.13	1.97	0.99	0.70	0.51	586,762.00	110,306.51
	Khartoum	3313105	27.04	5.76	1.83	2.98	2.15	1.62	1.24	885,800.00	239,492.09
	Khartoum	3313106	12.35	2.25	0.64	2.08	0.69	0.44	0.30	618,773.00	76,397.22

Level			Head Count	Poverty Gap	Severity of Poverty	Population Share	Contribution of Poverty			Population Size	Number of Poor
Region	State	Locality Code					Head Count	Poverty Gap	Severity of Poverty		
	Khartoum	3313107	33.00	7.56	2.53	2.97	2.61	2.12	1.72	882,980.00	291,394.14
Central			**29.10**	**6.34**	**2.09**	24.52	**19.04**	**14.70**	**11.71**	**7,295,131**	**2,123,153**
	Al-Gezira	4414101	19.52	3.44	0.95	1.57	0.82	0.51	0.34	467,042.00	91,181.58
	Al-Gezira	4414102	17.26	3.02	0.84	1.41	0.65	0.40	0.27	418,471.00	72,232.90
	Al-Gezira	4414103	24.52	4.69	1.39	1.98	1.30	0.88	0.63	589,382.00	144,504.41
	Al-Gezira	4414104	29.73	5.97	1.82	0.81	0.64	0.46	0.34	240,626.00	71,542.93
	Al-Gezira	4414105	22.08	4.45	1.40	1.28	0.76	0.54	0.41	381,603.00	84,272.13
	Al-Gezira	4414106	20.16	3.60	1.00	1.90	1.02	0.65	0.44	564,915.00	113,863.49
	Al-Gezira	4414107	19.79	3.58	1.02	2.78	1.47	0.94	0.65	828,516.00	163,933.41
	White Nile	4424201	34.07	8.17	2.89	0.94	0.86	0.73	0.62	280,111.00	95,421.59
	White Nile	4424202	28.20	6.18	2.03	0.31	0.23	0.18	0.14	91,756.00	25,878.10
	White Nile	4424203	34.90	8.44	2.98	0.89	0.83	0.71	0.61	265,367.00	92,618.52
	White Nile	4424204	39.07	9.86	3.63	0.81	0.84	0.75	0.67	239,867.00	93,708.59
	White Nile	4424205	32.31	7.04	2.27	0.48	0.41	0.32	0.25	141,470.00	45,714.96
	White Nile	4424206	47.82	13.00	5.01	1.42	1.81	1.75	1.63	422,600.00	202,069.84
	White Nile	4424207	50.15	12.69	4.47	0.31	0.42	0.37	0.32	92,369.00	46,327.17
	White Nile	4424208	52.93	13.84	5.01	0.65	0.92	0.85	0.75	194,413.00	102,897.14
	Sinnar	4434301	25.86	5.26	1.63	0.67	0.46	0.33	0.25	200,056.00	51,731.72
	Sinnar	4434302	31.76	7.17	2.42	0.97	0.83	0.66	0.54	289,581.00	91,983.68
	Sinnar	4434303	28.39	5.40	1.56	0.56	0.43	0.29	0.20	167,890.00	47,660.37
	Sinnar	4434304	29.45	5.98	1.86	0.83	0.65	0.47	0.35	245,534.00	72,299.39
	Sinnar	4434305	24.31	5.01	1.58	0.50	0.32	0.24	0.18	147,961.00	35,969.68
	Sinnar	4434306	19.16	3.24	0.86	0.41	0.21	0.13	0.08	122,156.00	23,409.58
	Sinnar	4434307	22.30	3.75	0.98	0.26	0.15	0.09	0.06	76,084.00	16,967.56
	Blue Nile	4444401	44.48	10.57	3.62	0.80	0.95	0.80	0.66	237,687.00	105,713.60
	Blue Nile	4444402	42.08	10.40	3.71	0.71	0.80	0.70	0.61	212,765.00	89,524.89
	Blue Nile	4444403	25.89	4.65	1.28	0.22	0.15	0.09	0.06	64,235.00	16,627.25

Level			Head Count	Poverty Gap	Severity of Poverty	Population Share	Contribution of Poverty			Population Size	Number of Poor
Region	State	Locality Code					Head Count	Poverty Gap	Severity of Poverty		
	Blue Nile	4444404	48.78	10.84	3.43	0.44	0.58	0.45	0.35	132,062.00	64,423.37
	Blue Nile	4444405	23.73	4.31	1.20	0.32	0.20	0.13	0.09	94,419.00	22,405.14
	Blue Nile	4444406	44.40	10.27	3.42	0.29	0.34	0.28	0.23	86,178.00	38,265.99
Kordofan			**43.66**	**11.39**	**4.16**	**14.21**	**16.56**	**15.30**	**13.54**	**4,229,456**	**1,846,471**
	North Kordofan	5515101	42.81	10.79	3.84	0.70	0.81	0.72	0.62	209,773.00	89,810.06
	North Kordofan	5515102	47.20	12.33	4.48	1.09	1.37	1.27	1.12	324,477.00	153,141.93
	North Kordofan	5515103	42.71	11.13	4.06	1.30	1.49	1.37	1.21	387,736.00	165,599.35
	North Kordofan	5515104	41.56	10.79	3.93	2.06	2.28	2.10	1.85	612,660.00	254,600.24
	North Kordofan	5515106	38.05	9.47	3.36	1.77	1.80	1.59	1.36	526,964.00	200,535.93
	South Kordofan	5525201	48.54	13.18	4.94	0.69	0.89	0.85	0.77	204,056.00	99,058.21
	South Kordofan	5525202	57.11	16.84	6.69	0.66	1.00	1.05	1.01	196,087.00	111,979.26
	South Kordofan	5525203	48.64	13.33	5.04	0.91	1.18	1.15	1.05	271,372.00	131,992.36
	South Kordofan	5525204	56.64	16.88	6.75	0.31	0.47	0.50	0.48	93,272.00	52,833.82
	South Kordofan	5525206	63.92	19.96	8.23	0.34	0.58	0.65	0.65	101,908.00	65,140.54
	West Kordofan	5535302	37.79	8.99	3.06	0.84	0.84	0.71	0.59	249,095.00	94,141.01
	West Kordofan	5535303	39.01	9.45	3.25	0.42	0.44	0.38	0.32	126,062.00	49,173.42
	West Kordofan	5535304	42.02	10.61	3.79	0.46	0.52	0.46	0.40	136,878.00	57,512.76
	West Kordofan	5535307	36.78	8.64	2.91	0.95	0.94	0.78	0.64	284,177.00	104,533.45
	West Kordofan	5535308	44.61	11.38	4.06	0.50	0.59	0.54	0.46	148,177.00	66,101.22
	West Kordofan	5535309	40.68	10.20	3.62	0.43	0.47	0.42	0.36	128,074.00	52,099.23
	West Kordofan	5535311	42.93	10.64	3.72	0.58	0.66	0.58	0.49	171,668.00	73,694.57
	West Kordofan	5535312	43.01	10.82	3.82	0.19	0.22	0.20	0.17	57,010.00	24,518.72
Darfur			**51.09**	**19.30**	**9.68**	**23.21**	**31.65**	**42.35**	**51.41**	**6,906,972**	**3,528,766**
	North Darfur	6616101	60.37	23.47	11.88	0.56	0.90	1.24	1.52	166,801.00	100,697.81
	North Darfur	6616102	48.98	17.46	8.37	0.54	0.71	0.90	1.04	162,038.00	79,359.32
	North Darfur	6616104	59.63	23.70	12.25	0.76	1.20	1.69	2.12	224,876.00	134,083.15

Level			Head Count	Poverty Gap	Severity of Poverty	Population Share	Contribution of Poverty			Population Size	Number of Poor
Region	State	Locality Code					Head Count	Poverty Gap	Severity of Poverty		
	North Darfur	6616105	57.85	23.10	12.01	0.68	1.05	1.48	1.86	201,532.00	116,579.51
	North Darfur	6616106	44.98	15.95	7.65	0.47	0.56	0.70	0.82	139,054.00	62,552.82
	North Darfur	6616107	56.87	22.05	11.21	0.34	0.51	0.71	0.87	100,743.00	57,289.42
	North Darfur	6616108	55.12	20.44	10.02	0.34	0.50	0.66	0.78	101,450.00	55,923.73
	North Darfur	6616109	44.69	16.38	8.05	1.01	1.20	1.56	1.86	300,105.00	134,114.45
	North Darfur	6616110	38.88	12.70	5.74	0.56	0.58	0.67	0.74	166,843.00	64,869.86
	North Darfur	6616111	59.34	23.41	12.00	0.40	0.63	0.88	1.09	118,086.00	70,071.94
	North Darfur	6616112	33.02	10.35	4.53	0.68	0.60	0.67	0.71	203,375.00	67,148.26
	North Darfur	6616114	54.77	21.33	10.91	0.79	1.15	1.58	1.96	233,598.00	127,936.96
	West Darfur	6626201	73.60	33.21	18.61	0.30	0.60	0.95	1.29	90,416.00	66,543.45
	West Darfur	6626202	75.27	35.23	20.28	0.38	0.77	1.28	1.78	114,074.00	85,867.87
	West Darfur	6626203	44.23	15.37	7.26	0.33	0.39	0.48	0.55	97,936.00	43,320.21
	West Darfur	6626204	49.01	18.39	9.18	0.83	1.08	1.43	1.73	245,568.00	120,348.92
	West Darfur	6626205	68.17	29.66	16.29	0.31	0.56	0.86	1.15	91,438.00	62,333.05
	West Darfur	6626206	58.19	22.88	11.75	0.51	0.79	1.10	1.36	150,947.00	87,842.02
	South Darfur	6636302	46.69	17.23	8.51	1.44	1.80	2.35	2.80	428,808.00	200,195.64
	South Darfur	6636303	60.47	24.56	12.89	0.04	0.07	0.09	0.12	11,994.00	7,253.17
	South Darfur	6636304	56.08	21.72	11.03	0.53	0.79	1.08	1.33	156,341.00	87,681.48
	South Darfur	6636305	54.33	20.50	10.21	2.39	3.46	4.62	5.58	709,985.00	385,747.55
	South Darfur	6636306	56.13	21.62	10.95	0.82	1.23	1.67	2.05	243,551.00	136,716.84
	South Darfur	6636309	34.25	10.73	4.70	1.35	1.23	1.37	1.45	400,784.00	137,286.68
	South Darfur	6636310	64.62	26.82	14.24	0.92	1.59	2.34	3.01	274,755.00	177,553.03
	South Darfur	6636311	40.97	13.55	6.17	1.06	1.16	1.36	1.49	314,900.00	129,013.89
	Central Darfur	6646407	62.94	25.94	13.71	0.40	0.67	0.98	1.26	119,475.00	75,201.97
	Central Darfur	6646408	66.31	28.20	15.25	0.11	0.19	0.29	0.38	32,245.00	21,380.81
	Central Darfur	6646409	67.68	29.06	15.78	0.04	0.07	0.10	0.14	11,265.00	7,624.09
	Central Darfur	6646411	57.56	22.36	11.37	0.59	0.91	1.25	1.54	175,870.00	101,227.21

Level			Head Count	Poverty Gap	Severity of Poverty	Population Share	Contribution of Poverty			Population Size	Number of Poor
Region	State	Locality Code					Head Count	Poverty Gap	Severity of Poverty		
	Central Darfur	6646412	76.58	36.29	21.06	0.11	0.22	0.37	0.52	32,119.00	24,597.46
	Central Darfur	6646413	48.18	17.16	8.25	0.09	0.12	0.15	0.17	27,540.00	13,268.22
	East Darfur	6656501	50.92	18.96	9.40	0.61	0.83	1.10	1.32	182,629.00	92,998.18
	East Darfur	6656507	50.49	18.45	9.00	1.51	2.03	2.63	3.10	447,965.00	226,199.43
	East Darfur	6656508	36.33	11.49	5.07	0.68	0.66	0.74	0.79	202,180.00	73,448.15
	East Darfur	6656512	41.87	14.14	6.55	0.76	0.85	1.01	1.14	225,664.00	94,477.75

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Appendix F: Census Non-monetary Indicators by Administrative Units

Table F.1: Population Characteristics by Region and State

		Sex		Population Structure			Literacy		Education Level				
		Male	Female	0–14 Years	15–64 Years	65+ Years	Adult (15+ Years)	Youth (15–24 Years)	None	Primary	Secondary	Tertiary	Not Applicable/Do Not Know
SUDAN		**49.57**	**50.43**	**42.57**	**53.78**	**3.65**	**32.61**	**13.48**	**4.54**	**40.16**	**7.97**	**4.09**	**43.25**
Northern		**49.18**	**50.82**	**36.29**	**58.11**	**5.60**	**44.97**	**16.43**	**10.02**	**45.28**	**11.91**	**4.93**	**27.86**
	Northern	48.88	51.12	34.51	59.56	5.93	47.62	17.29	8.98	47.23	13.54	5.24	25.01
	River Nile	49.35	50.65	37.33	57.27	5.40	43.43	15.92	10.64	44.11	10.93	4.74	29.58
Eastern		**52.12**	**47.88**	**42.05**	**54.73**	**3.22**	**26.52**	**10.98**	**3.47**	**36.64**	**4.87**	**1.81**	**53.20**
	Red Sea	**55.86**	**44.14**	**37.98**	**59.50**	**2.52**	**26.16**	**10.01**	**4.41**	**29.61**	**6.19**	**2.26**	**57.53**
	Kassala	51.55	48.45	42.07	54.60	3.32	24.24	10.38	2.32	35.53	4.01	1.51	56.65
	Al-Gedarif	48.99	51.01	46.23	49.97	3.80	29.81	12.76	3.97	45.93	4.56	1.73	43.82
Khartoum	Khartoum	**51.67**	**48.33**	**34.91**	**61.76**	**3.33**	**52.69**	**20.43**	**4.20**	**46.93**	**17.39**	**11.67**	**19.82**
Central		**47.58**	**52.42**	**42.28**	**53.47**	**4.26**	**35.66**	**14.98**	**5.71**	**45.28**	**8.16**	**3.41**	**37.44**
	Al-Gezira	47.34	52.66	40.58	**55**.05	4.37	41.41	16.90	5.83	49.05	10.70	4.58	29.84
	White Nile	47.60	52.40	42.44	53.26	4.30	32.77	14.27	4.75	43.69	7.29	3.12	41.15
	Sinnar	47.37	52.63	43.22	52.48	4.31	32.63	13.88	7.02	44.15	5.65	1.94	41.24
	Blue Nile	48.90	51.10	47.66	48.71	3.63	22.00	10.03	5.21	33.67	2.68	1.13	57.30
Kordofan		**47.50**	**52.50**	**46.92**	**49.18**	**3.89**	**21.98**	**9.93**	**5.24**	**33.73**	**3.96**	**1.54**	**55.53**
	North Kordofan	47.23	52.77	45.71	50.14	4.15	21.91	10.01	6.69	32.70	4.06	1.56	54.99
	South Kordofan	47.95	52.05	47.85	48.44	3.71	24.69	10.66	3.50	38.70	4.50	2.22	51.07
	West Kordofan	47.65	52.35	48.23	48.16	3.60	20.30	9.32	4.05	32.08	3.44	1.04	59.39
Darfur		**49.83**	**50.17**	**47.93**	**49.19**	**2.88**	**21.41**	**9.65**	**2.36**	**34.02**	**3.56**	**1.50**	**58.56**
	North Darfur	50.08	49.92	47.53	49.35	3.12	25.20	11.89	3.09	39.60	5.02	2.26	50.02
	West Darfur	47.50	52.50	47.33	49.04	3.63	23.11	10.13	1.36	38.64	2.87	1.31	55.83
	South Darfur	50.44	49.56	48.48	48.85	2.67	20.47	9.00	2.48	32.14	3.32	1.32	60.76
	Central Darfur	46.94	53.06	49.99	46.99	3.02	11.14	4.65	1.30	21.87	0.51	0.20	76.12
	East Darfur	50.73	49.27	47.07	50.65	2.29	18.66	8.26	1.75	28.31	2.86	1.00	66.08

Table F.2: Households Characteristics by Region and State

		Sanitation					Water					Own House		
		Toilet Shared			Bucket/No Toilet		Improved*			With Network		Own	Rent	Free
		Yes	No		Yes	No	Yes	No		Yes	No			
SUDAN		**54.66**	**45.34**		**43.11**	**56.89**	**74.01**	**25.99**		**37.06**	**62.94**	**87.30**	**7.90**	**4.79**
Northern		**31.06**	**68.94**		**20.19**	**79.81**	**79.05**	**20.95**		**67.58**	**32.42**	**89.51**	**6.14**	**4.35**
	Northern	19.52	80.48		14.16	85.84	92.22	7.78		78.23	21.77	88.01	5.72	6.27
	River Nile	37.77	62.23		23.69	76.31	71.40	28.60		61.40	38.60	90.39	6.38	3.23
Eastern		**66.80**	**33.20**		**61.48**	**38.52**	**55.07**	**44.93**		**26.80**	**73.20**	**90.80**	**5.88**	**3.32**
	Red Sea	72.15	27.85		68.41	31.59	58.58	41.42		18.71	81.29	88.22	8.32	3.46
	Kassala	65.65	34.35		60.65	39.35	55.57	44.43		29.44	70.56	91.74	5.26	3.01
	Al-Gedarif	62.71	37.29		55.37	44.63	50.81	49.19		31.80	68.20	92.27	4.15	3.58
Khartoum	Khartoum	**24.54**	**75.46**		**7.76**	**92.24**	**84.82**	**15.18**		**78.77**	**21.23**	**69.35**	**22.30**	**8.34**
Central		**58.73**	**41.27**		**45.79**	**54.21**	**69.54**	**30.46**		**50.05**	**49.95**	**89.49**	**4.73**	**5.78**
	Al-Gezira	56.55	43.45		43.12	56.88	80.92	19.08		72.03	27.97	87.25	5.23	7.52
	White Nile	66.56	33.44		50.66	49.34	54.93	45.07		31.68	68.32	89.09	5.65	5.26
	Sinnar	60.52	39.48		47.82	52.18	73.69	26.31		40.39	59.61	93.11	3.04	3.85
	Blue Nile	48.84	51.16		43.80	56.20	45.79	54.21		10.29	89.71	94.29	3.26	2.45
Kordofan		**62.46**	**37.54**		**51.87**	**48.13**	**69.84**	**30.16**		**9.94**	**90.06**	**92.99**	**3.76**	**3.25**
	North Kordofan	69.34	30.66		61.50	38.50	73.77	26.23		16.16	83.84	93.55	3.58	2.87
	South Kordofan	63.99	36.01		57.95	42.05	77.98	22.02		3.60	96.40	91.65	4.01	4.34
	West Kordofan	50.55	49.45		32.57	67.43	58.20	41.80		4.33	95.67	92.99	3.89	3.12
Darfur		**66.64**	**33.36**		**55.83**	**44.17**	**83.79**	**16.21**		**7.20**	**92.80**	**92.35**	**4.60**	**3.05**
	North Darfur	55.61	44.39		48.97	51.03	83.14	16.86		4.47	95.53	94.49	3.92	1.59
	West Darfur	58.94	41.06		47.32	52.68	87.51	12.49		11.57	88.43	89.26	6.42	4.32
	South Darfur	73.22	26.78		58.81	41.19	81.86	18.14		8.73	91.27	90.90	5.56	3.54
	Central Darfur	90.32	9.68		85.81	14.19	90.26	9.74		2.23	97.77	96.59	1.02	2.39
	East Darfur	69.76	30.24		57.44	42.56	84.54	15.46		7.61	92.39	92.25	3.64	4.11

Source: Authors' calculations based on the 2014/15 NHBPS and the 2008 Population and Housing Census.

Note: * Improved water sources refer to water filtering, boreholes, hand pump, sand filter, and dug well but not in modalities.