KINGDOM OF CAMBODIA

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# SMALL-AREA ESTIMATION OF POVERTY AND MALNUTRITION IN CAMBODIA

NATIONAL INSTITUTE OF STATISTICS,
MINISTRY OF PLANNING, ROYAL GOVERNMENT OF CAMBODIA,
AND THE UNITED NATIONS WORLD FOOD PROGRAMME

APRIL 2013

Statistical analysis for and writing of this report has been undertaken by Professor Stephen Haslett, Associate Professor Geoffrey Jones and Alison Sefton of the Institute of Fundamental Sciences - Statistics, Massey University, New Zealand.

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The attached CD contains the full small-area estimates at the province, district and commune level as well as corresponding GIS maps.

# FOREWORD

It is our pleasure to share with you a copy of the report "Small-Area Estimation of Poverty and Malnutrition in Cambodia." The report is the product of close collaboration between the National Institute of Statistics of the Ministry of Planning, the United Nations World Food Programme, and Massey University.

The report presents the results of statistical analysis conducted by Professor Stephen Haslett, Associate Professor Geoffrey Jones and Alison Sefton of the Institute of Fundamental Sciences – Statistics, Massey University, New Zealand, in cooperation with the Poverty Mapping Group at the National Institute of Statistics of the Ministry of Planning and the Vulnerability Analysis and Mapping Unit of the United Nations World Food Programme. Small area estimation techniques were used to produce prevalence figures and maps for poverty incidence, gap and severity (determined on the basis of consumption expenditure) and child malnutrition (stunting and underweight) at the district and commune level. Data sources included the General Population Census of Cambodia 2008, Cambodia Anthropometric Survey 2008, Cambodia Socio-Economic Survey 2009, Cambodia Demographic and Health Survey 2010, and Geographical Information Systems (GIS) data 2008.

We hope that the information, which provides a clear picture of the geographic distribution and variation of poverty and child malnutrition throughout the country, will be useful to policy makers, analysts and programmers. By knowing where the poor and malnourished are we believe the Royal Government of Cambodia and development partners can more effectively and efficiently meet their specific needs through poverty reduction and development projects, public health nutrition interventions, and increasingly, through social protection measures to reach the poorest and most vulnerable Cambodians.

Furthermore, as 2015 approaches, we sincerely hope that results of this report will enable the Royal Government of Cambodia and development partners to identify and focus attention on communes and districts that lag behind the target for the three Cambodian Millennium Development Goal (CMDG) 1 indicators that are covered in this report. These include CMDG 1.1 proportion of people whose income is less than the national poverty line, CMDG 1.4 prevalence of underweight among children under five, and CMDG 1.6 prevalence of stunting among children under five.

The exercise would not have been possible without the involvement of and valuable inputs provided by various institutions and individuals. In particular, we would like to express our grateful thanks to the following partners and stakeholders for providing data, inputs, comments, and suggestions, and for assisting and facilitating the exercise: Statistics Sweden, United Nations Children's Fund (UNICEF), and World Bank.

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The completion of both this and the earlier 2008 and 2010 feasibility reports follows extensive consultation with the National Institute of Statistics (NIS), other staff from the Ministry of Planning (MoP), International Fund for Agricultural Development (IFAD), Statistics Sweden, UNICEF, World Bank, and the World Food Programme (WFP) - which commissioned this research.

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# SUMMARY

Small-area estimates (SAE) of poverty and malnutrition in Cambodia are produced at commune level by combining survey data with auxiliary data derived from the 2008 General Population Census of Cambodia (Census2008). A model for predicting log average per capita household expenditure is estimated from the 2009 Cambodia Socio-economic Survey (CSES2009) based on the Cambodia National Institute of Statistics calculation of expenditure in each of the households sampled in CSES. The model is applied to household-level census data to estimate poverty incidence, gap and severity. FAO and NIS have used CSES2009 to derive estimates of caloric intake in the form of kilocalories consumed per capita for each sampled household; and a survey based model for kilocalorie consumption is also applied to household-level census data to investigate the feasibility of predicting kilocalorie consumption per household; when compared with a kilocalorie cut-off norm this could potentially be used to estimate undernourishment at commune level. We find however that there remains considerable unmodellable uncertainty in the kilocalorie data, so that, since the small-area estimates of undernourishment at commune level are not sufficiently reliable, they have not been included in the report. Models for predicting standardized height-for age and weight-for-age are estimated from both the 2008 Cambodia Anthropometric Survey (CAS2008) and the 2010 Cambodia Demographic and Health Survey (CDHS2010), each being applied to child-level census data to estimate prevalence of stunting and underweight; the separate estimates from each source are combined using inverse-variance weighting to produce a single set of estimates for each of stunting and underweight. Estimates of wasting, though desirable, are not produced here because of the inadequacy of predictive models for weight-for-height from both CAS2008 and CDHS2010. The small-area estimation procedure used in this study does not produce direct measures of poverty, caloric intake or child malnutrition at the local level. Rather the procedure applied here is able to estimate welfare outcomes – based on a statistical model estimated in the relevant household survey. These estimates of wellbeing are measured with error, and the degree of imprecision will vary as a function of a wide variety of factors, most notably the degree of disaggregation at which indicators of wellbeing are being estimated. In this study it was found that estimates at the level of a commune– which comprises on average around 1700 households – are generally reasonably precise. Estimates at village or enumeration area level are far less precise. The precision of estimates varies with the specific indicator of wellbeing, and precision is generally better with consumption poverty estimates than with estimates of caloric intake and child malnutrition, because there are fewer survey variables that can be matched with the census in the latter models. Comparisons are made with the poverty estimates derived from the 2009 Commune Database (CDB2009), and with the earlier small-area estimates of poverty and malnutrition detailed in Fujji (2003). For Cambodia as a whole, an overriding consideration from the current study is the generally strong positive link between poverty and child malnutrition.

# 1

# INTRODUCTION

## 1.1 Background

Cambodia borders Thailand to the north and west, Laos to the northeast, and Vietnam to the east and southeast, with a 443-kilometre coastline along the Gulf of Thailand. It has an area of 181,035 square kilometres, including 4,520 square kilometres of lakes and inland waterways. The principal inland water bodies are the Mekong River, the Tonle Sap (Great Lake) and the Tonle-Bassac River which together form a network of river channels, levees and river basins stretching across the entire lowlands.

The population in 2008 was 13.4 million. Cambodia is one of the least developed countries, ranking 139 out of 187 countries on the Human Development Index (UNDP, 2011). Maps of population density, ecological zones, and the administrative units including commune boundaries are given in Appendix D.

Economic poverty is widespread. The lack of secure land tenure, remoteness from markets and services, lack of productive assets, low levels of education, and high dependency ratios are all factors contributing to the poor living conditions of the rural population. Analysis from the 2009 Cambodian Socio-economic Survey, using the National Institute of Statistics calculation of expenditure per household for the CSES sample, estimated poverty incidence at 22.9 percent (24.6 percent in rural areas) on the basis of an expenditure-based daily poverty line of 6347 Riel in Phnom Penh, 4352 Riel in other urban areas and 3503 Riel in rural areas (Ministry of Planning, 2013).

Small-area estimation is a mathematical and statistical method that models data collected from one or more data sources, to produce estimates, for example of poverty, that are more accurate at small area level than using only data collected from each small area. The additional accuracy is achieved in many such models by “borrowing strength” for the estimate for a particular small area by using information from areas to which it is similar. Some small-area estimation techniques combine data from different sources. For example, census and new survey information may be combined to update estimates from the original census. Alternatively, and this is more usually the case for malnutrition estimates, a statistical model is fitted to survey data collected around the same time as the census, and this model is used to predict a variable not collected in the census, based on variables that are collected in both survey and census.

The first study involving small-area estimation of malnutrition estimates in Cambodia is the *Micro-level Estimation of the Prevalence of Stunting and Underweight among Children in Cambodia* from the Ministry of Health, Cambodia / World Food Programme / Measure DHS+ - ORC Macro (2003). This study uses the World Bank method for small-area estimation to provide preliminary small-area estimates for stunting and underweight in children. The statistical models used are not given, and the detailed methodology is not discussed, but maps are provided at commune level and averages of estimated accuracy of the small-area estimates (as measured by their estimated standard errors given the fitted regression model is correct) are provided with discussion.

The World Bank method, popularly known as the Elbers Lanjouw and Lanjouw (ELL) method, has been commonly used in small-area estimation of poverty measures. In poverty studies, the most usual variable predicted is expenditure (or its logarithm) based on a model which includes education, age of household members, number of people in the household and type of house construction, among other variables. Poverty incidence, gap and severity are derived from the household level predictions of per capita expenditure. The poverty estimates are often mapped in detail, which is why this technique is sometimes given the generic title, “poverty mapping”. The maps can make interpretation simpler, but the central point is not the maps per se, but that poverty and relative poverty can be assessed at a much finer level at a much lower cost than by increasing the sample size sufficiently or rerunning the census. The statistical modelling has a cost, of course, but this is much lower than for a survey that is sufficiently large that it can produce estimates at this fine level. The cost of small-area estimation can be saved many times over by having better information at a finer level and maps for use in aid allocation.

The initial, national, small-area estimation of poverty in Cambodia was undertaken by Fujii (2002) for the World Food Programme, with support from the World Bank, using the 1998 population census and the 1997 Cambodia Socio-economic Survey (CSES). By fitting a set of separate statistical models for expenditure on the logarithmic scale to sample information within strata for the CSES, applying these multiple models to the census data to predict expenditure at household level for all households, and summing transformations of the predictions, small-area estimates of poverty incidence, gap and severity were derived, and mapped at commune level. The methodology used was a standard application of the World Bank method (Elbers, Lanjouw and Lanjouw, 2001, 2003), which is now available as free software (PovMap – Zhao, 2006) from the World Bank website. Variations of the Elbers, Lanjouw and Lanjouw (ELL) method have been implemented for the World Bank in a number of other countries including Thailand (Healy, 2003), South Africa (Alderman et al., 2002), Brazil (Elbers et al. 2001), the Philippines (Haslett and Jones, 2005), and for the World Food Programme in Bangladesh (Jones and Haslett, 2003) and Nepal (Jones and Haslett, 2006).

More recently, Pinney (2007) has undertaken a small-area estimation exercise in Cambodia to update Fujii’s estimates. Pinney has used the 2003/4 CSES and (rather than the population census, which as is common internationally is only conducted every ten years) has also used the commune database, also known as the Seila database or Seila commune database, or the National Committee for Decentralisation and Deconcentration (NCDD) database. The NCDD

database is an annual census of villages and provides household information on a limited number of variables, which restricts the strength or predictive capacity (as measured by the percentage of variance that can be explained, usually denoted $R^2$) for statistical modelling, or predictions based on it. Pinney fits a multiple regression to the CSES data based on the variables also in the NCDD database, but without including the random effects (which would allow estimates of standard error via modelling of an additional commune or village level random component, fitted for example using the bootstrap as in ELL). The methods used by Pinney are potentially useful for providing an update to the 1997/8 estimates of Fujii, but the limited number of variables available for modelling may limit utility. The lack of information about standard errors is also a restriction, because poverty estimates are consequently of uncertain accuracy, so that it must remain unknown whether the method can provide sound poverty estimates at commune or district level.

The April 2007 World Food Programme report, *Integrated Food Security and Humanitarian Phase Classification (IPC) Pilot in Cambodia*, provides a comprehensive food security and vulnerability analysis. It has a direct focus on food, reflecting WFP's mandate. It contains a series of useful maps in appendices, including expenditure poverty (from CSES 2003/4) and underweight, stunting, and wasting in children. See also map on page 44 – "Integrated Food security and Humanitarian Phase Classification (valid until 31.08.07) in Cambodia (as of 26.02.07)". None of these maps is however at commune level, so the need for small-area estimates of poverty remains. It has a useful reference list but no statistics, or relevant methodological details or content, although see Section 1.2 Methodology, which outlines a "meta analysis approach".

This report and the *Micro-level Estimation of the Prevalence of Stunting and Underweight among Children in Cambodia* mentioned above warrant general comment about the relationship between small-area estimation and mapping. Small-area estimation of poverty, especially if extended from poverty incidence, gap and severity, plus kilocalories, to stunting, underweight and wasting in children (as in Jones and Haslett, 2006), provides a detailed perspective on the spatial distribution of poverty. Other variables are also important however (e.g. health information, rainfall, and other Geographical Information Systems (GIS) data), even if these cannot be produced at such a fine level. For most users of this information, an atlas of maps is of much more general use than a detailed technical report on small-area estimation methodology, even if the technical report also contains finer level tabulated detail. The detailed small area report is however essential, as it provides a clear indication of the methodological foundation for small area maps (often called poverty maps) that are included in the atlas. Without sound use of small area methodology, and publication of the technical report that outlines that methodology, the accuracy and utility of a more generally-used atlas must remain in doubt.

In September 2007, the *Statistical Master Plan for Cambodia* was published by the National Institute of Statistics, Ministry of Planning. This document outlines the development of statistical functionality at NIS. Page 20, as part of section 6.3 "Censuses and surveys", contains detail on CSES as point 95, and Demographic and Health Surveys (DHS) as point 94. On page 21, there is Table 2, "Indicative Timetable for censuses and household surveys 2006-2015". Small areas, but not small-area estimation, are mentioned in item 89, page 19.

## 1.2 Geographic and administrative units

For administrative purposes, Cambodia is divided into a total of 24 provinces and municipality, which are sub-divided into 193 districts or *khan*. Within each district or *khan* there are a number of communes or *Sangkat,* each comprising several villages: the smallest administrative unit. For some purposes, such as census enumeration and sampling frames for surveys, the larger villages are split into enumeration areas (ea), but these are not in general well-defined administrative boundaries. Table 1.1 shows the total number of each of these units in Cambodia, and their approximate sizes in terms of average number of households.

**Table 1.1 Approximate number of administrative units at different levels**

| | Province | District | Commune | Village | ea |
|---|---|---|---|---|---|
| Number | 24 | 193 | 1621 | 14073 | 28455 |
| Mean no. households | 117000 | 15000 | 1700 | 200 | 100 |

Key: ea=census enumeration area

The communes in Cambodia are commonly classified as belonging to one of three regions: the capital Phnom Penh, Other Urban and Rural. The provinces are for some purposes grouped into five Ecological Zones: the capital Phnom Penh, the Coastal, Plains, Plateau / Mountain, and Tonle Sap zones. These ecological zones are characterized by differing economic conditions and activities.

Some knowledge exists on the general spatial pattern of poverty and malnutrition in Cambodia. Recent surveys (see Section 3) give estimates of economic and nutritional status for the whole country and for each province or group of provinces. However the accuracy of such estimates at a particular level depends crucially on the effective sample size at that level, so that at the district level and below the standard errors of survey-based estimates become too large to be useful because each is based on a small number of observations.

Effective targeting of development assistance, as advocated by the National Strategic Development Plan (NSDP), requires a nation-wide overview of poverty and nutrition status at sub-provincial level. Estimates need to be precise, i.e. with small standard errors, so that the areas with the greatest need are identified correctly. Our analysis includes an investigation using small-area estimation methods of how finely the estimates of poverty and malnutrition indicators may be disaggregated while still maintaining a reasonable level of precision.

## 1.3 Poverty maps

The statistical technique of small-area estimation (Ghosh and Rao, 1994, Rao, 1999; Rao, 2003) provides a way of improving survey estimates at small levels of aggregation, by combining the survey data with information derived from other sources, typically a population census. A variant of this methodology has been developed by a research team at the World Bank specifically for the

small-area estimation of poverty measures (Elbers, Lanjouw and Lanjouw, 2001, 2003). The ELL method has been implemented in a number of countries including Thailand (Healy, 2003), Cambodia (Fujii, 2004), South Africa (Alderman et al., 2002) and Brazil (Elbers et al. 2001), Bangladesh (Jones and Haslett, 2003) and the Philippines (Haslett and Jones, 2005a). The methodology is described in detail in the next section. Some additional general methodological issues are covered in Haslett and Jones (2005b; 2010) and Haslett, Isidro and Jones (2010). Outputs, in the form of estimates at local level together with their standard errors, can be combined with GIS location data to produce a "poverty map" for the whole country, giving a graphical summary of which areas are suffering relatively high deprivation.

Our main purpose in producing such maps is to aid the planning of development assistance programmes. They could in addition prove useful as a research tool, for example by overlaying geographic, social or economic indicators.

## 1.4 Measures of poverty, undernourishment and malnutrition

Poverty can be defined in a number of ways. The most common is the cost-of-basic-needs (CBN) approach, in which poverty lines are calculated to represent the level of per capita expenditure required to meet the basic needs of the members of a household, including an allowance for non-food consumption. First a food poverty line is established, being the amount necessary to meet basic food requirements. Then a non-food allowance is added, an amount equal to the typical non-food expenditure of households whose food expenditure is equal to the food poverty line. Because prices vary among geographical areas, poverty lines can be calculated separately for different regions for which price information is available. In Cambodia, these regions are Phnom Penh, Other Urban, and Rural. An important assumption in poverty mapping is that the prices faced by households are fairly homogenous within each region.

Thus in the CBN approach poverty measures are functions of household per capita expenditure. *Poverty incidence* for a given area is defined as the proportion of individuals living in that area who are in households with an average per capita expenditure below the poverty line. *Poverty gap* is the average distance below the poverty line, being zero for those individuals above the line. It thus represents the resources needed to bring all poor individuals up to a basic level. *Poverty severity* measures the average squared distance below the line, thereby giving more weight to the very poor. These three measures can be placed in a common mathematical framework, the so-called FGT measures (Foster, Greer and Thorbeck, 1984):

$$P_\alpha = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{z-E_i}{z}\right)^\alpha \cdot I(E_i < z) \qquad (1.1)$$

where N is the population size of the area, $E_i$ is the expenditure of the ith individual, z is the poverty line and $I(E_i < z)$ is an indicator function (equal to 1 when expenditure is below the poverty line, and 0 otherwise). Poverty incidence, gap and severity correspond to $\alpha$ = 0,1 and 2 respectively.

In our analysis we have produced estimates of all three measures down to commune level, using both the total poverty line and the food poverty line.

The term *poverty incidence* (also called the poverty headcount ratio) is used in this report to describe the percentage of poor people in a given administrative area in the reference date. In epidemiological terms this is, in fact, a prevalence figure rather than an incidence figure. Nevertheless, since the term *poverty incidence* is widely used in economics and development literature, we have used it in this report.

Three measures of malnutrition are considered, based on measurements of a child's height, weight and age. Stunting or low height-for-age is defined as having a height at least two standard deviations below the median height for a reference population. Underweight or low weight-for-age is similarly defined. Wasting is based on standardized weight-for-height, and low values can be a measure of acute malnutrition in some situations. The data used as a reference standard in these definitions was established in 1975 by the National Center for Health Statistics / Centers for Disease Control in the USA (Hamill, Dridz, Johnson, Reed et al., 1979). In 2005, the World Health Organization released new Child Growth Standards using data collected in the WHO Multicentre Growth Reference Study. Implicit in the use of a single international reference standard is the assumption that variations in height and weight for children below five years are caused largely by environmental rather than genetic factors, although even without this assumption it can provide a fixed reference point in international comparisons.

In this report we consider the nutrition status of children below the age of 60 months (i.e. five years). Within a particular region stunting is defined as the proportion of such children with a standardized height-for-age (HAZ) value below –2, and children below –3 are considered severely stunted. Similarly underweight is the proportion of children with a standardized weight-for-age (WAZ) value below –2, and severe underweight below –3. Stunting can be regarded as evidence of chronic malnutrition. Underweight reflects both chronic malnutrition and acute malnutrition. It is a current condition resulting from inadequate food intake, past episodes of under-nutrition or poor health conditions. Wasting is the proportion with a standardized weight-for-height (WHZ) value under –2, and severe wasting below –3. Wasting can be an indicator of acute malnutrition. Our original aim in this report was to construct commune-level maps for these three measures. However we were unable to find good predictive models for weight-for-height, so small area-estimates of wasting have not been produced.

Caloric intake is measured on the basis of kilocalorie consumption. The SAE methodology was also applied to predict kilocalorie consumption per person in the population census. This was then compared to the minimum dietary energy requirement (MDER) set for Cambodia which is 1770 kilocalories per person. All members of a household are considered undernourished if predicted kilocalorie intake per person for that household is below this norm.

# 2

# METHODOLOGY

We present in this section a brief overview of small-area estimation and the ELL method. Details of the implementation in Cambodia are given in Section 4.

## 2.1 Small-area estimation

Small-area estimation refers to a collection of statistical techniques designed for improving sample survey estimates through the use of auxiliary information (Ghosh and Rao, 1994; Rao, 1999; Rao, 2003). We begin with a target variable, denoted Y, for which we require estimates over a range of small subpopulations, usually corresponding to small geographical areas. (In this report Y is log-transformed per capita expenditure for poverty measures, and standardized height-for-age or weight-for-age for the malnutrition indicators, stunting and underweight.) Direct estimates of Y for each subpopulation are available from sample survey data, in which Y is measured directly on the sampled units (households or eligible children). Because the sample sizes within the subpopulations typically will be very small, these direct estimates will have large standard errors and hence not be reliable. Indeed, some subpopulations may not be sampled at all in the survey. Auxiliary information, denoted X, can be used under some circumstances to improve the estimates, giving lower standard errors.

In the situations examined in this report, X represents additional variables that have been measured for the whole population, either by a census or via a GIS database. A relationship between Y and X of the form

$$Y = X\beta + u$$

can be estimated using the survey data, for which both the target variable and the auxiliary variables are available. Here $\beta$ represents the estimated regression coefficients giving the effect of the X variables on Y, and u is a random error term representing that part of Y that cannot be explained using the auxiliary information. If we assume that this relationship holds in the population as a whole, we can use it to predict Y for those units for which we have measured X but not Y. Small-area estimates based on these predicted Y values will often have smaller standard errors than the direct estimates, even allowing for the uncertainty in the predicted values, because they are based on much larger samples. Thus the idea is to “borrow strength” from the much more detailed coverage of the census data to supplement the direct measurements of the survey.

## 2.2 Clustering

The units on which measurements have been made are often not independent, but are grouped naturally into clusters of similar units. Households tend to cluster together into villages or other small geographic or administrative units, which are themselves relatively homogenous. Put simply, households that are close together tend to be more similar than households far apart. When such structure exists in the population, the regression model above can be more explicitly written as

$$Y_{ij} = X_{ij}\beta + c_i + e_{ij} \qquad (2.1)$$

where $Y_{ij}$ represents the measurement on the *j*th unit in the *i*th cluster, $c_i$ the error term held in common by the ith cluster, and $e_{ij}$ the household-level error within the cluster. The relative importance of the two sources of error can be measured by their respective variances $\sigma_c^2$ and $\sigma_e^2$. Ghosh and Rao (1994) give an overview of how to obtain small-area estimates, together with standard errors, for this model. Where individual level data is available, as it is for stunting, underweight and wasting in children under five, an additional error term at child level within household is added. In the general explanation given below we focus on equation (2.1) in order to establish general principles useful for distinguishing the characteristics of variation at 'higher' and 'lower' levels. When there are three error terms rather than two, the three form a sequence in which the cluster remains the highest level of aggregation, household takes an intermediate status, and individual level variation is at the finest level. There is also the possibility of including a small area level error term at the greatest level of aggregation. Doing so does not affect the small-area estimates themselves, but does have the potential to increase standard error estimates, perhaps markedly. The small area models of Rao (2003) contain such an error term, but those of Elbers, Lanjouw and Lanjouw (2003) do not. Checking for the size of the small area-level error variance is strongly recommended, because if it is sufficiently large its omission leads to small-area estimates with understated standard errors and hence overstated accuracy. The issue is addressed for small-area estimation in Nepal in Jones and Haslett (2006), where the effect of the small area variance on the standard error estimates was found to be negligible. For Cambodia, see Section 5 below. Theoretical aspects of this question are discussed in detail in Haslett and Jones (2010).

We note that the auxiliary variables $X_{ij}$ may be useful primarily in explaining the cluster-level variation, or the household-level variation. The more variation that is explained at a particular level, the smaller the respective error variance, $\sigma_c^2$ or $\sigma_e^2$. The estimate for a particular small area will typically be the average of the predicted Ys in that area. Because the standard error of a mean gets smaller as the sample size gets bigger, the contribution to the overall standard error of the variation at each level, household and cluster, depends on the sample size at that level. The number of households in a small area will typically be much larger than the number of clusters, so to get small standard errors it is of particular importance that, at the higher level, the unexplained cluster-level variance $\sigma_c^2$ should be small. Two important diagnostics of the model-fitting stage, in which the relationship between Y and X is estimated for the survey data, are the $R^2$

measuring how much of the variability in Y is explained by X, and the ratio $\sigma_c^2 / (\sigma_c^2 + \sigma_e^2)$ measuring how much of the unexplained variation is at the cluster level. Note that although $\sigma_c^2$ and $\sigma_e^2$ are parameters they are different for different models with different regressors. GIS data and cluster-level means can be particularly useful in lowering this ratio. Some care is required when using $R^2$ as a diagnostic however, because it very much depends on the level of aggregation, and the level of aggregation in the fitted model is very much less than that of the small-area estimates. So, while high $R^2$ values are good, they are not essential, provided the variances at the finest level are sufficiently larger than those at more aggregated levels. This diminution of $R^2$ is especially apparent where individual-level data is being used (as for stunting, underweight and wasting), rather than household level data (as for kilocalories and expenditure modelling, where the variation within household, which may be large, is effectively omitted from the estimation of $R^2$ from the model due to data aggregation to household level).

Another important aspect of clustering is its effect on the estimation of the model. The survey data used for this estimation cannot be regarded as a simple random sample, because they have been obtained from a complex survey design which although it is random, nevertheless involves stratification and cluster sampling. To account properly for the complexity of the survey design requires the use of specialised statistical routines (Skinner et al., 1989; Chambers and Skinner, 2003, Lehtonen and Pakhinen, 2004, Longford, 2005) in order to get consistent estimates for the regression coefficient vector $\beta$ and its variance $V_\beta$.

## 2.3 The ELL method

The ELL methodology was designed specifically for the small-area estimation of poverty measures based on per capita household expenditure. Here the target variable Y is log-transformed expenditure, the logarithm being used to make more symmetrical the highly right-skewed distribution of untransformed expenditure. It is assumed that measurements on Y are available from a survey.

The first step is to identify a set of auxiliary variables X that are in the survey and are also available for the whole population. It is important that these should be defined and measured in a consistent way in both data sources. The model (2.1) is then estimated for the survey data, by incorporating aspects of the survey design for example through use of the "expansion factors" or inverse sampling probabilities. The residuals $\hat{u}_{ij}$ from this analysis are used to define cluster-level residuals $\hat{c}_i = \hat{u}_{i.}$, the dot denoting averaging over j, and household-level residuals $\hat{e}_{ij} = \hat{c}_i - \hat{u}_{ij}$.

It is usually assumed that the cluster-level effects $c_i$ all come from the same distribution, but that the household-level effects $e_{ij}$ may be heteroscedastic. This can be modelled by allowing the variance $\sigma_e^2$ to depend on a subset Z of the auxiliary variables:

$$g(\sigma_e^2) = Z\alpha + r$$

where g(.) is an appropriately chosen link function, $\alpha$ represents the effect of Z on the variance and r is a random error term. Fujii (2004) uses a version of the more general model of ELL involving a logistic-type link function, fitted using the squared household-level residuals. Fujii's model is:

$$\ln\left(\frac{\hat{e}_{ij}^2}{A-\hat{e}_{ij}^2}\right) = Z_{ij}\alpha + r_{ij} \qquad (2.2)$$

From this model the fitted variances $\hat{\sigma}^2_{e,ij}$ can be calculated and used to produce standardized household-level residuals $\hat{e}^*_{ij} = \hat{e}_{ij} / \hat{\sigma}_{e,ij}$. These can then be mean-corrected or mean-centred to sum to zero, either across the whole survey data set or separately within each cluster.

In standard applications of small-area estimation, the estimated model (2.1) is applied to the known X values in the population to produce predicted Y values, which are then averaged over each small area to produce a point estimate, the standard error of which is inferred from appropriate asymptotic theory. In the case of poverty mapping, our interest is not always directly in Y but in several non-linear functions of Y (see Section 1.4). The ELL method obtains unbiased estimates and standard errors for these by using a bootstrap procedure as described below.

## 2.4 Bootstrapping

Bootstrapping is the name given to a set of statistical procedures that use computer-generated random numbers to simulate the distribution of an estimator (Efron and Tibshirani, 1993). In the case of poverty mapping, we construct not just one predicted value

$$\hat{Y}_{ij} = X_{ij}\hat{\beta}$$

(where $\hat{\beta}$ represents the estimated coefficients from fitting the model) but a large number of alternative predicted values

$$Y^b_{ij} = X_{ij}\beta^b + c^b_i + e^b_{ij}\ , \quad b = 1,\ldots B$$

in such a way as to take account of their variability. The statistical analysis of the chosen model for Y yields information on how to appropriately insert variability into the calculation of the predicted values. We know for example that $\hat{\beta}$ is an unbiased estimator of $\beta$ with variance $V_\beta$, so we draw each $\beta^b$ independently from a multivariate normal distribution with mean $\hat{\beta}$ and variance matrix $V_\beta$. The cluster-level effects $c^b_i$ are taken from the empirical distribution of $c_i$, i.e. drawn randomly with replacement from the set of cluster-level residuals $\hat{c}_i$, since the appropriate cluster level residual is known only for the clusters in the sample not all the clusters in the census. To take account of unequal variances (heteroscedasticity) in the household-level residuals, we first draw $a^b$ from a multivariate normal distribution with mean $\hat{a}$ and variance matrix $V_a$ , combine it with $Z_{ij}$ to give a predicted variance and use this to adjust the household-level effect

$$e^b_{ij} = e^{*b}_{ij} \times \sigma^b_{e,ij}$$

where $e_{ij}^{*b}$ represents a random draw from the empirical distribution of $e_{ij}^{*}$, either for the whole data set or just within the cluster chosen for $c_i$ (consistently with the mean-centring of Section 2.3).

Each complete set of bootstrap values $Y_{ij}^{b}$, for a fixed value of b, will yield a set of small-area estimates. In the case of poverty estimates we exponentiate each Y to give predicted expenditure $E_{ij}=\exp(Y_{ij})$, then apply equation (1.1). This is not equivalent to totalling the $Y_{ij}$ in each small area and exponentiating, which is one reason that fitting the model at household (or individual level in the case of a three level model) is the better alternative. The mean and standard deviation of a particular small-area estimate, across all B values, then yields a point estimate and its standard error for that area.

## 2.5 Interpretation of standard errors

The standard error of a particular small-area estimate is intended to reflect the uncertainty in that estimate. A rough rule of thumb is to take two standard errors on each side of the point estimate as representing the range of values within which we expect the true value to lie. When two or more small-area estimates are being compared, for example when deciding on priority areas for receiving development assistance, the standard errors provide a guide for how accurate each individual estimate is and whether the observed differences in the estimates are indicative of real differences between the areas. They serve as a reminder to users of poverty maps that the information in them represents estimates, which may not always be very precise. A particular way of incorporating the standard errors into a poverty map is suggested in Section 4.

The size of the standard error depends on a number of factors. The poorer the fit of the model (2.1), in terms of small $R^2$, large $\sigma_c^2$ or $\sigma_e^2$ , or a large $\sigma_c^2/(\sigma_c^2+\sigma_e^2)$ ratio, the more variation in the target variable will be unexplained and the greater will be the standard errors of the small-area estimates. The population size, in terms of both the number of households and the number of clusters in the area, is also an important factor. Generally speaking, standard errors decrease proportionally as the square root of the population size. Standard errors will be acceptably small at higher geographic levels but not at lower levels. If we decide to create a poverty map at a level for which the standard errors are generally acceptable, there will be some, smaller, areas for which the standard errors are larger than we would like.

The sample size used in fitting the model is also important. The bootstrapping methodology incorporates the variability in the estimated regression coefficients $\hat{\alpha}$, $\hat{\beta}$. If the sample size is small these estimates will be very uncertain and the standard errors of the small-area estimates will be large. This problem is also affected by the number of explanatory variables included in the auxiliary information, X and Z. A large number of explanatory variables relative to the sample size increases the uncertainty in the regression coefficients. We can always increase the apparent explanatory power of the model (i.e. increase the $R^2$ from the survey data) by increasing the number of X

variables, or by dividing the population into distinct subpopulations and fitting separate models in each, but the increased uncertainty in the estimated coefficients may result in an overall loss of precision when the model is used to predict values for the census data. We must take care not to “over-fit” the model.

There will be some small uncertainty in the estimates, and indeed the standard errors, due to the bootstrapping methodology, which uses a finite sample of bootstrap estimates to approximate the distribution of the estimator. This could be decreased, at the expense of computing time, by increasing the number of bootstrap simulations B.

Finally, the integrity of the estimates and standard errors depends on the fitted model being correct, in that it applies to the census population in the same way that it applied to the sample. This relies on good matching of survey and census to provide valid auxiliary information. We must also take care to avoid, as much as possible, spurious relationships or artefacts which appear, statistically, to be true in the sample but do not hold in the population. This can be caused by fitting too many variables, but also by choosing variables indiscriminately from a very large set of possibilities. Such a situation could lead to estimates with apparently small, but spurious, standard errors. For this reason the final step in poverty mapping, field verification, is extremely important.

The requirement for variables to match in this way between survey and census is one reason that special care must be taken if survey and census are not from the same period. The changes between periods can be structural changes, i.e. the interpretation of a particular variables has changed, or simply a change in level. Both types of change have the potential to add to standard errors of estimates, and in some cases to produce bias.

## 2.6 Reference dates

The small-area estimates are derived from data sources from different years. While there is no easy answer regarding the exact reference date for small area estimates and maps, all the Cambodia survey dates are within two years of the census. Often data for surveys refer to the period over which data is collected rather than one fixed date, especially where surveys are intended to adjust for seasonality, which can further complicate setting exact reference dates. Note, however, that, in general, while the census and sample survey should be as close together in time as possible, the determinants of the poverty measures and of child malnutrition via stunting and underweight do not usually change rapidly. Even if they were to do so however, or as time passes, so that the absolute estimates become out of date, relative poverty and child malnutrition are rather less subject to change than absolute measures. So, for comparison purposes, the small-area information at commune level can be expected to remain useful for a number of years.

# 3

# DATA SOURCES

## 3.1 Cambodia Socio-economic Survey, 2009 (CSES2009)

The Cambodia Socio-economic Survey was carried out for the first time in 1993/94 by the National Institute of Statistics (NIS), and repeated in 1996, 1997, 1999, 2004, and annually since 2007. The 2007 and 2008 surveys were smaller interim surveys using a sub-sample of primary sampling units from the 2004 survey, designed to produce statistics only for the whole country and the Phnom Penh, Other Urban and Rural regions; the 2009 survey, like 2004, was designed to give reliable estimates down to province level.

The CSES broadly follows the methodology of the World Bank's Living Standard Measurement Survey. It contains an integrated household questionnaire designed to collect data at both household and individual level on socio-demographic characteristics in addition to detailed information about expenditure and food consumption patterns. Consumption is recorded using both recall and diary methods.

The sample design for CSES2009 used a stratified cluster sampling technique. The strata were the urban and rural parts of each province, giving a total of 48 strata. The Primary Sampling Units (PSUs) were villages, although the larger villages were subdivided based on enumeration areas from the 2008 census. In the first stage a total of 720 PSUs (240 urban and 480 rural) were chosen by stratified random sampling, using Probability Proportional to Size (PPS) sampling with the number of households as a measure of size. Then a systematic sample of either 10 (urban) or 20 (rural) households was taken within each sampled PSU. This gave a total sample size of 12000 households. Ultimately a total of 11971 households were enumerated.

In our analysis, we identified a few strata with only one PSU. We merged these with geographically adjacent strata in order to be able to calculate standard errors for estimated model parameters using standard survey regression techniques.

Because the sample size at a particular level has an important bearing on the precision of estimates at that level, we present in Table 3.1 a summary of the coverage of CSES2009 at various levels and the mean and minimum number of households and PSUs at each level. The number of provinces, districts and communes in CSES2009 can be compared with the numbers in Cambodia as a whole via Table 1.1. The coverage is adequate at provincial level, except for a few of the

smaller provinces where the sample sizes are small. Twenty-two of the 193 districts are not sampled, and at least one of the others has only one PSU. Thus we cannot expect to get precise estimates directly from CSES2009 at district or sub-district levels.

**Table 3.1 Structure of CSES2009 at various levels**

| | Province | District | Commune | Village |
|---|---|---|---|---|
| Contains | 24 | 171 | 621 | 715 |
| Mean households | 499 | 70 | 19.3 | 16.7 |
| Min households | 39 | 19 | 9 | 8 |
| Mean PSUs | 30 | 4.2 | 1.2 | 1.01 |
| Min PSUs | 3 | 1 | 1 | 1 |

Key: PSU=primary sampling unit

The target variable available in CSES2009 and used in this study is monthly per capita consumption expenditure, averaged at the household level. Calculation of total household-level consumption expenditure and the regional poverty lines was conducted by the NIS. Table 3.2 below gives the poverty lines.

**Table 3.2 Poverty lines (Riel per person per day)**

| | Province | District | Commune |
|---|---|---|---|
| Total poverty line | 6347 | 4352 | 3503 |
| Food poverty line | 3121 | 2607 | 2300 |

## 3.2 Cambodia Anthropometric Survey, 2008 (CAS2008)

The 2008 Cambodia Anthropometric Survey was carried out by NIS with technical and financial support from UNICEF. The main purpose of the survey was to provide policymakers and planners with updated information on nutrition in light of steep increases in the price of food. Anthropometric measures were taken on children aged 0-4 years to determine nutritional status as described in Section 1.4. In order to provide a comprehensive view on nutrition in the country, data on micronutrient deficiency, food consumption, disease, coping strategies, infant/young child feeding, and health services were included in the survey. The survey was designed to give data on the nutritional status of children in the country and in 19 domains defined as either single provinces or small groups of provinces.

CAS2008 sampled 7268 households with children aged 0-4 years from 760 PSUs, corresponding closely to enumeration areas from the 2008 national census, in 19 strata comprising the larger provinces and groups of smaller provinces. Most contributing households had only one eligible child, but 16% had two or more (see Table 3.3).

**Table 3.3 Eligible Children (0-4 years) per Household, CAS2008**

| No. of children | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| No. of households | 6046 | 1159 | 59 | 4 | 7268 |

The final dataset used consisted of 8537 children in 760 PSUs. The structure is shown in Table 3.4. Eight of the 193 districts are not included, and of those present some have very few PSUs, so direct estimates at district and sub-district are not possible.

**Table 3.4 Structure of CAS2008 dataset at various levels**

| | Province | District | Commune | PSU |
|---|---|---|---|---|
| Contains | 24 | 185 | 709 | 760 |
| Mean children | 356 | 46 | 12 | 11.2 |
| Min children | 21 | 9 | 5 | 5 |
| Mean PSUs | 31.7 | 4.1 | 1.1 | |
| Min PSUs | 2 | 1 | 1 | |

Key: PSU=primary sampling unit

The target variables for estimating stunting, underweight and wasting are height-for-age, weight-for-age, and weight-for-height (see Section 1.4). These were calculated from the raw height, weight and age measurements using a programme provided by the WHO.

The CAS2008 report (Ministry of Health, 2009) gave the national prevalence of underweight as 28.8%, not significantly different from the CDHS2005 figure. The estimated prevalence of stunting was reported as 39.5%, which represents an improvement over the CDHS2005 figure. Nutritional status was found to vary with the age and sex of the child, place of residence (urban/rural) and wealth status of the parents. However poor nutrition was found to be a national issue affecting every sector of society.

## 3.3 Cambodia Demographic and Health Survey, 2010 (CDHS2010)

The 2010 Cambodia Demographic and Health Survey, the third in a series of demographic and health surveys, was carried out by NIS and Directorate General for Health with technical support from ORC Macro and financial support from USAID, UNFPA, UNICEF, JICA, and the Second Health Sector Support Project (HSSP2). The survey was designed to provide up-to-date information on infant and child mortality, fertility preferences, family planning behaviour, maternal mortality, utilization of maternal and child health services, health expenditures, women's status, and knowledge and behaviour regarding HIV/AIDS and other sexually transmitted infections. Anthropometric measures were taken on selected children (aged 0-4 years) to determine nutritional status as described in Section 1.4, in addition to detailed information on household demographic characteristics, environmental conditions and child feeding and caring practices.

CDHS2010 sampled 16344 households from 611 PSUs, corresponding to enumeration areas from the 2008 census, in 38 strata formed from the urban and rural parts of 19 provinces or groups of provinces. Our interest is in the nutritional status of children below five years, so households with no eligible children were eliminated. Most contributing households had only one eligible child, but 24% had two or more (see Table 3.5).

**Table 3.5 Eligible Children (0-4 years) per Household, CDHS2010**

| No. of children | 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|
| No. of households | 2429 | 674 | 64 | 9 | 1 | 3177 |

The final dataset used consisted of 4010 children in 607 PSUs. The structure is shown in Table 3.6. Six of the 75 districts are not included, and of those present some have very few PSUs, so direct estimates at district and sub-district are not possible.

The target variables of height-for-age, weight-for-age, and weight-for-height (see Section 1.4) were calculated using the WHO's Stata programme. The CDHS 2010 report (NIS, 2011) gave the national prevalence of stunting as 39.9%, and underweight 28.3%.

**Table 3.6 Structure of CDHS2010 dataset at various levels**

| | Province | District | Commune | PSU |
|---|---|---|---|---|
| Contains | 24 | 187 | 526 | 607 |
| Mean children | 167 | 21.4 | 7.6 | 6.6 |
| Min children | 7 | 3 | 1 | 1 |
| Mean PSUs | 25.3 | 3.2 | 1.2 | |
| Min PSUs | 1 | 1 | 1 | |

Key: PSU=primary sampling unit

## 3.4 General Population Census of Cambodia, 2008 (Census 2008)

Since 1998, the Cambodian Government has committed to conducting a general population census every ten years. The 2008 census was carried out in early March, with a specified census date of 3 March 2008. Three types of forms were administered: Form A enumerated buildings, recording their purpose and construction materials; Form B enumerated households, recording ownership, utilities and appliances; Form C enumerated individual people, recording demographic variables. Since all three contained consistent codes for regional and household identifiers, data from the three forms could be merged to create a single household-level dataset in a format compatible with CSES2009, and a child-level dataset compatible with CAS2008 and CDHS2010.

The census collected information on all residents of Cambodia based on their usual place of residence, but excluding temporary visitors, tourists, resident foreign diplomats and refugees. Households were classified as residential or institutional type (e.g. hostels, hospitals, jails). Since the survey data only covered residential households, it was decided to restrict the census data to only residential households.

The enumerated population on census night was declared to be 13,395,682 in 2,841,897 households, with 19.5% living in urban areas. The structure of each of the two derived census datasets (household- and child-level) is shown in Tables 3.7 and 3.8, in terms of number of households and number of enumeration areas.

**Table 3.7 Structure of Census household dataset at various levels**

| | Province | District | Commune | Village | ea |
|---|---|---|---|---|---|
| Contains | 24 | 193 | 1621 | 14073 | 28455 |
| Mean households | 117228 | 14578 | 1736 | 200 | 99 |
| Min households | 7193 | 850 | 60 | 3 | 3 |
| Mean ea | 1186 | 147 | 17.6 | 2 | |
| Min ea | 66 | 10 | 2 | 1 | |

Key: ea=enumeration area

**Table 3.8 Structure of Census child (0-4 years) dataset at various levels**

| | Province | District | Commune | Village | ea |
|---|---|---|---|---|---|
| Contains | 24 | 193 | 1621 | 14073 | 28448 |
| Mean children | 56890 | 7074 | 842 | 97 | 48 |
| Min children | 3800 | 518 | 48 | 2 | 1 |
| Mean households | 45757 | 5690 | 677 | 78 | 39 |
| Min households | 3019 | 400 | 32 | 2 | 1 |
| Mean ea | 1186 | 147 | 17.5 | 2 | |
| Min ea | 66 | 10 | 2 | 1 | |

Key: ea=enumeration area

## 3.5 Commune Database, 2009 (CDB2009)

The commune database (CDB), also known as the Seila database or Seila commune database, or the National Committee for Decentralisation and Deconcentration (NCDD) database, collects information on the demographic, socio-economic and physical assets of each village and commune in Cambodia. Starting in 2002, the CDB is maintained by the Ministry of Planning, with data collection taking place at the end of the year. Data are collected by Village Chiefs and Commune Chiefs, giving some village-level and some commune-level variables.

The data are used by communes for preparation of socio-economic profiles at commune, district and provincial levels, as part of the annual planning exercises. The CDB is also used by the Ministry of Planning to produce a poverty index for the allocation of investment funds for communes.

The CDB was not designed for measuring economic poverty as defined in section 1.4 since it does not directly measure household consumption expenditure. However, it does contain variables that may be useful proxies for village- and commune-level economic poverty incidence. Pinney (2007) and Hou, Ny and Karim (2010) both use commune level (rather than household level data as for small-area estimation) to develop estimates of poverty incidence at commune level. Hou, Ny and Karim is particularly interesting. Their results will be discussed in Section 5.3 and compared with the small-area estimates via ELL. Hou, Ny and Karim use the IDPoor database (see Section 3.6 below) that in 2009 contained only a limited number of communes to set up a model predicting poverty incidence, and then they apply their regression model to the commune database which contains information for most of the communes in Cambodia. In concept then, the idea is similar to ELL, requiring matching of predictor variables in two different data sources. The sample available for IDPoor for 2009 is not random and the model can only be fitted at aggregate commune level so, unlike ELL, their technique is not able to provide particularly sound estimates of accuracy, nor can it be extended (as ELL can) to providing poverty gap or severity. However, Hou, Ny and Karim (2010) does have the major advantage over ELL that it can provide annual updates, rather than only being implementable following a near coincident survey and population census. (c.f. Isidro, Haslett and Jones, 2010a & 2010b).

The CDB2009 contained information on 13983 villages, slightly less than the total number in Census2008. Moreover there were some inconsistencies in the area codes, not all of which could be resolved. Ultimately about 200 villages in Census2008 remained unmatched with CDB2009 information.

## 3.6 Identification of Poor Households (IDPoor)

The Identification of Poor Households (IDPoor) Programme was established in 2006 within the Ministry of Planning with funding and technical assistance from the Australian Agency for International Development (AusAID), the European Union, the Federal Republic of Germany (technical assistance implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit, GIZ) and UNICEF. IDPoor's objective is to "develop an improved procedure for identifying poor households, reach official consensus on the common use of a harmonised procedure, and put it into practice in selected provinces".

The intention is that this “process will in the medium term assist various sector programmes to reach the poor more effectively. It will also be possible to reduce the overall administrative costs of selecting target groups and allow scarce public resources to be redistributed in a way that benefits the poorest target groups. Already-identified potential areas for application of a harmonised procedure are the provision of medical services through Health Equity Funds, improving access of the poor to education through targeted financial support, the provision of services related to rural development, and allocation of land to the poor” (Cambodia German Cooperation, 2006). The project consists of a national-level and a sub-national-level component.

In 2010 and 2011 combined, IDPoor has been further extended to cover all rural villages in Cambodia. IDPoor is nevertheless not intended to be a formal, statistically based methodology for measuring poverty incidence, but is particularly useful as a basis for targeting poor households within communes and villages.

# 4

# IMPLEMENTATION

## 4.1 Selection of auxiliary data

The auxiliary data X used to predict the target variable Y can be classified into two types: the survey variables, obtainable or derivable from the survey at household or individual level, and area-level variables applying to particular geographic units that can be merged from other sources into the survey data using area codes (e.g. province-district-commune-village-ea codes). The latter includes means of census variables calculated at enumeration area level from the census data.

As noted earlier, it is important that any auxiliary variables used in modelling and predicting should be comparable in the estimation (survey) dataset and the prediction (census) dataset. In the case of survey variables, we begin by examining the survey and census questionnaires to find out which questions in each elicit equivalent information. In some cases equivalence may be achieved by collapsing some categories of answers. For example, in the 2008 census questionnaire there are eight categories for Roof Material, whereas in CSES2009 there are ten such categories, some of which appear to correspond exactly to the census categories and others which do not: a new categorization needs to be defined into which the Census2008 and CSES2009 categories can be mapped. A preliminary identification and matching of common survey and census variables, in consultation with NIS staff, was reported by Haslett et al (2010) for CSES2009 and CAS2008. This process was repeated with CDHS2010, and all three sets of common variables were then subjected to statistical checks to ensure that the corresponding survey and census variables matched statistically as well as conceptually. In the case of categorical data we compare proportions in each category; for numerical data, such as household proportion of females, we compare the means and standard deviations. For this purpose confidence intervals can be calculated for the relevant statistics in the survey dataset, taking account of the stratification and clustering in the sample design. The equivalent statistic for the census data should be within the confidence interval for the survey. Failures in statistical matching can sometimes be resolved by further collapsing categorical variables. A list of matching variables for each of the survey datasets is given in Appendices A.1 to A.3.

For modelling purposes the first level of each categorical variable was dropped so that the first category becomes the reference category with which others are compared. We also created some new variables from this basic list, for example mean-corrected squared household size defined as $hhsizesq=(hhsize-4.77)^2$, and interactions between basic variables such as region×hhsize

which modifies the effect of household size according to whether the household is in the Phnom Penh, Other Urban or Rural region. The variable ezone was added to allow for differences between Ecological Zones as defined in Section 1.2.

For the CAS2008 dataset we faced the difficulty that some of the variables expected to be useful in predicting nutrition status of individual children, for example, educational attainment of the mother, were not directly available in the census because there was no explicit link between children in the census dataset and their birth mother. We attempted to circumvent this problem by creating these variables at household level, averaging over potential mothers in the household. This inevitably introduces some measurement error into these variables.

Generally, variables which are in either the census dataset, but are either not in the survey or do not match properly, can still be used by forming regional averages and merging them with the survey data using regional indicators. The inclusion of these census means should be straightforward since they can be merged with the survey and census data using indicators for the geographical unit to which each household or individual belongs. This can be problematic in practice however, because of changing boundaries and the creation of new units or codes. Most of these problems were solved in collaboration with NIS, and the few remaining unmatched households should have negligible influence on the final estimates. Appendix A.4 gives a list of all the census means considered in the modelling process. These variables have all been averaged at enumeration-area level. Since the CDHS2010 dataset did not have enumeration-area codes, the census means were recalculated at village level for merging with the CDHS2010.

Poverty estimates from the CDB2009 via IDPoor were not included in the small area modelling, because keeping them out of the small-area estimation modelling enabled later direct comparison at commune level of the CDB based poverty incidence estimates with those from the small-area estimation. These two sets of poverty incidence estimates at commune level are independent, because one uses IDPoor and CDB, and the other the Census2008 and CSES2009, so any links between them provide evidence of the veracity of both. In Appendix A.5 is a list of CDB variables considered by the Cambodia National Committee for Sub-National Democratic Development (NCDD) in their modelling.

## 4.2 First stage regressions

The selection of an appropriate model for (2.1) is a difficult problem. We have a large number of possible predictor variables (36 + 52 = 98 for CSES2009: see Appendix A) to choose from, with inevitably a good deal of interrelationship between them in the form of multicollinearity. If we also include two-way interactions there are well over a thousand. (A “two-way interaction” is the product of two basic or “main-effect” variables). Squares or other transformations of numerical variables could also be considered. As noted in Section 2.5, we must be careful not to over-fit, so the number of predictors included in the model should be small compared to the number of observations in the survey, but there is also the problem of selecting a few variables from the large number available

which appear to be useful, only to find (or even worse, not find) an apparently strong statistical relationship in the survey data, which does not hold for the population as a whole.

The search for significant relationships over such a large collection of variables must inevitably be automated to a certain extent, but we have chosen not to rely entirely on automatic variable selection methods such as stepwise or best-subsets regression. See Miller (2002) for a general discussion of subset selection. We have generally adopted the principle of hierarchical modelling in which higher-order terms such as two-way interactions are included in the model only if their corresponding main-effects are also included. Thus we begin with main-effects only, and add interaction and nonlinear terms carefully and judiciously. However due to the failure of statistical matching for several demographic variables in Phnom Penh, interactions with region were included as this allowed omission of the variables which had inadequate statistical matching in Phnom Penh, while still allowing these variables to be included for the remaining regions. We look not just for statistical significance but also for a plausible relationship. For example, the effect of household size (hhsize) on log expenditure was initially investigated by fitting hhsize as a categorical variable and choosing a parsimonious functional form that produces the correct approximate shape. This is shown in Figure 4.1.

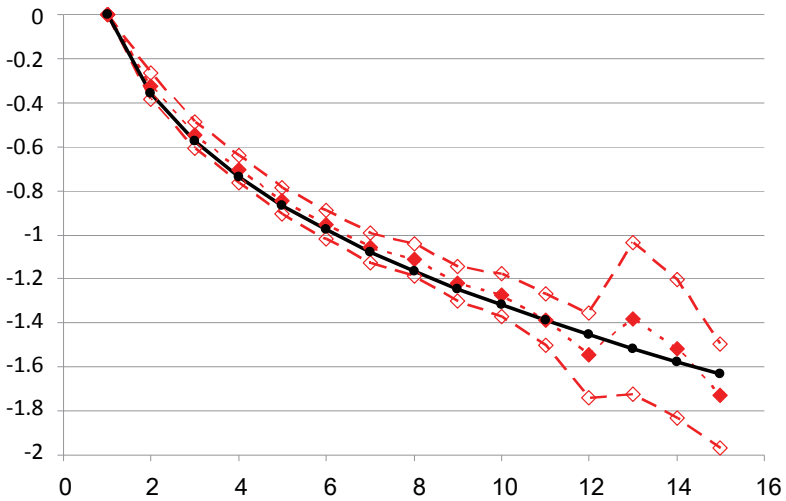



*Figure 4.1 Coefficients for effect of hhsize on log expenditure, fitted as categorical with 95% confidence limits (dashed lines), and fitted linear model β0+β1hhsize+β2ln(hhsize).*

This process was repeated for all numerical variables (number of rooms, number of cellphones etc.) to give in each case a parsimonious functional representation of the effect of each numerical auxiliary variable on the target variable. For example, the effect of increasing number of rooms on log expenditure in CSES2009 seems to attenuate after numroom=4, so larger values were set to four. Following the initial fit, some categorical variables were collapsed further to give smaller numbers of distinct categories when there was no significant difference between the estimated effects of similar categories. For example, the eight categories of wall in CSES2009 were eventually collapsed to two: “bamboo” and “other”.

Other implementations of ELL methodology have fitted separate models for each stratum defined by the survey design. This has the advantage of tailoring the model to account for the different characteristics of each stratum, but it can increase the problem of over-fitting if some strata are small. We chose initially to try for one model across the whole country, and then to use regional interaction terms as necessary to allow for modelling differences between regions. This has the advantage of more stable parameter estimates and a better chance of finding genuine relationships that apply outside of the estimation data. Following this approach for modelling log expenditure in CSES2009, we obtained an $R^2$ value of 49.3% (see Appendix B.1).

We were less successful at finding good predictive models based on $R^2$ for the other target variables (height-for-age, weight-for-age, weight-for-height and log per capita kilocalorie consumption). For modelling height-for-age and weight-for-age in CAS2008 and CDHS2010 achieved $R^2$ values were in the range 15-20%. The resulting models are given in Appendices B.2, B.3, B.4, and B.5. Although the $R^2$ for each was 20% or less, it is interesting to note that the major component of unexplained variation for each appears to be between children in the same household. This is discussed further in the next Section. We were unable to find predictive models for weight-for-height, so do not provide small-area estimates for this variable. Regarding log per capita kilocalorie consumption, we achieved an $R^2$ value of only about 13%. Here there was still significant unexplained variability at cluster level, suggesting that small-area estimation for communes may not have sufficient precision. Hence, neither models nor maps for weight-for-height / wasting or kilocalories per capita have been included in this report.

We departed from the usual ELL implementation in our use of a single-stage, robust regression procedure for estimating model (2.1). This has the advantages of accounting for the survey design and obtaining consistent estimates of the covariance matrices in a single step. These covariance matrices were saved, along with the parameter estimates and both household- and cluster-level residuals (as defined in Section 2.3), for implementation of the prediction step.

## 4.3 Variance modelling

Like Healy et al (2003) we amended the regression model (2.2) for the household-level variance to prevent very small residuals from becoming too influential. We used a slightly different amendment:

$$L_{ij} = \ln\left(\frac{\hat{e}_{ij}^2 + \delta}{A - \hat{e}_{ij}^2}\right) = Z_{ij}\alpha + r_{ij}$$

where $\delta$ is a small positive constant and A is chosen to be just larger than the largest $\hat{e}^2_{ij}$ (e.g. $\delta$=0.0001, $A$=1.05 x max $\hat{e}^2_{ij}$). These choices can be justified empirically by graphical examination of the $L_{ij}$, which should show neither abrupt truncation nor extreme outliers. The predicted value of the household-specific variance, using the delta method, then becomes:

$$\sigma^2_{e,ij} = \left[\frac{AB_{ij} - \delta}{1 + B_{ij}}\right] + \frac{1}{2}\hat{\sigma}^2_r \left[\frac{(A+\delta)B_{ij}(1 - B_{ij})}{(1 + B_{ij})^3}\right]$$

where B = $e^{z^{\alpha}}$

There was however very little heteroscedasticity in any of our models. For example the heteroscedasticity regressions for log expenditure gave an $R^2$ value of below 1%. These models for variance essentially control for outliers, by adjusting or shrinking large residuals toward zero. They form an explicit part of the ELL methodology. Other forms are possible. Even skipping this step would have been acceptable given the low $R^2$ values. However, in keeping with the need to maintain international comparison, for example with Cambodia, South Africa, Bangladesh, and the Philippines, heteroscedasticity modelling has been used here for log expenditure, using Region as the only covariate. Despite the negligible $R^2$, the coefficients for region 2 (other urban) and region 3 (other rural) were statistically significant in the regression, and there is a priori expectation of structural differences between regions.

For modelling height-for-age and weight-for-age we found it necessary to depart from the usual methodology, in order to account for the expected correlation in these measures between children in the same household. We now have a three-level model, in which the regression residuals can be decomposed into three components

$$u_{ijk} = c_i + h_{ij} + e_{ijk} \qquad (4.1)$$

for child k in household j of cluster (PSU) i. The variances $\sigma^2_c$, $\sigma^2_h$, $\sigma^2_e$ of the respective components can be estimated by maximum likelihood (ML) or restricted maximum likelihood (REML), and the cluster- and household-level residuals (or random effects) derived as empirical best linear unbiased predictors (EBLUPs). For methodological details see Laird and Ware (1982) and Robinson (1991). The alternative of defining household-level residuals to be the average of the regression residuals for each respective household is not appropriate here, as most households had only one child. Our previous implementation of this method in Nepal (Jones and Haslett, 2006) adjusted the three sets of residuals for shrinkage and used these in a nonparametric bootstrap procedure, as described in the next section. Here we use the much simpler parametric bootstrap approach, sampling from normal distributions with variances set to the estimated variance components. There should be little difference in practice as estimation with this many levels tends to encourage approximate normality in the residuals.

## 4.4 Simulation of predicted values

Simulated values for the model parameters $\alpha$ and $\beta$ were obtained by parametric bootstrap, i.e. drawn from their respective sampling distributions as estimated by the survey regressions. Simulation of the cluster-and standardized household-level effects $c_i$ and $e^*_{ij}$ presents several possible choices. A parametric bootstrap could be used by fitting suitable distributions (e.g. Normal, t) to the residuals and drawing randomly from these. For simulating log per capita expenditure, and hence poverty incidence, we chose a non-parametric bootstrap in which we sample with replacement from the residuals, i.e. from the empirical distributions. One can either resample the $e^*_{ij}$ from the full set or only from those within the cluster corresponding to the chosen $c_i$. We chose the latter, which links the household effects estimated via the bootstrap to households in the same cluster, so when mean-correcting the standardized residuals (see Section 2.3) we used

$$\hat{e}^*_{ij} = \hat{e}_{ij} / \hat{\sigma}_{e,ij} - \frac{1}{n_i} \sum_{j=1}^{n_i} \hat{e}_{ij} / \hat{\sigma}_{e,ij}$$

Note that mean correction when needed can be an indication of the extent of any bias in the bootstrap and hence of an incorrect regression model, so it is encouraging that mean corrections here were small in relative terms.

A total of 100 bootstrap predicted values $Y^b_{ij}$ were produced for each unit in the census and for each target variable, as described in Section 2.4. For the three-level models, height-for-age and weight-for-age, this was amended slightly to:

$$Y^b_{ijk} = X_{ijk}\beta^b + c^b_i + h^b_{ij} + e^b_{ijk} \ , \quad b = 1, \ldots B$$

with the residuals at each level $c^b_i$, $h^b_{ij}$, $e^b_{ijk}$ drawn independently from normal distributions with mean zero and variances equal to the estimated variance components from the regression analysis.

## 4.5 Production of final estimates

Since a log transform was applied in modelling expenditure, we first reverse this transformation by exponentiating, i.e. predicted expenditure $E^b_{ij} = e^{Y^b_{ij}}$. The predicted values can then be grouped at the appropriate geographic level. Our main target is commune-level small-area estimates, but we have also considered higher levels of aggregation (region, ecological zone, and province) for comparison with the direct survey estimates. Once the predicted values have been produced and stored it is easy to investigate alternative levels of aggregation, using the standard errors as a guide to what is an appropriate level.

For expenditure the census units are households and the target variables are household average values, so the aggregation needs to be weighted by household size. Thus for example the formula for $P_R^b$ the bth bootstrap estimate of poverty incidence ($\alpha$=0 in equation 1.1) in region R is amended to:

$$P_R^b = \sum_{ij \in R} n_{ij} \cdot I(E_{ij}^b < z) \Big/ \sum_{ij \in R} n_{ij}$$

where $n_{ij}$ is the size of household ij in R. The census units for height-for-age and weight-for-age are individual children, so no weighting is required. For example the estimated incidence of stunting for region R is:

$$S_R^b = \sum_{ij \in R} I(HAZ_{ij}^b < -2.00) / N_R$$

where $N_R$ is the number of eligible children in R.

The 100 bootstrap estimates for each region, e.g. $P_R^1 \ldots P_R^{100}$ were summarized by their mean and standard deviation, giving a point estimate and a standard error for each region. For expenditure we have produced commune-level averages in addition to incidence, gap and severity below each of the total poverty line and the food poverty line. For height-for-age and weight-for-age we only give two measures: incidence below two standard deviations and incidence below three standard deviations.

5

# RESULTS FOR POVERTY MEASURES

## 5.1 Comparison with CSES2009 Estimates

The results for poverty incidence were first accumulated to high levels of aggregation for comparison with the direct estimates available from the CSES2009 survey. Table 5.1 shows both sets of estimates (P0) together with their standard errors (se). These estimates are all based on the expenditure data and poverty lines, so are for comparison purposes only. The standard errors for the direct survey estimates have been calculated using a robust variance technique which controls for the survey design. The standard errors for the small-area estimates (SAE) are the standard deviations of the 100 bootstrap estimates. We have added a standardized difference between the two sets of estimates, defined as

$$Z = \frac{\text{Small area estimate - direct estimate}}{\sqrt{(\text{small area se})^2 + (\text{direct estimate se})^2}}$$

If both methods are correctly estimating the same quantities, then Z should approximate a standard normal distribution.

**Table 5.1 Comparison of estimates of poverty incidence**

| | CSES | | SAE | | Standard Difference |
|---|---|---|---|---|---|
| | P0 | se | P0 | se | |
| Cambodia | 0.229 | 0.008 | 0.227 | 0.005 | -0.256 |
| Phnom Penh | 0.129 | 0.017 | 0.116 | 0.011 | -0.631 |
| Other Urban | 0.193 | 0.021 | 0.212 | 0.010 | 0.820 |
| Rural | 0.246 | 0.009 | 0.242 | 0.006 | -0.418 |
| Phnom Penh | 0.128 | 0.017 | 0.116 | 0.011 | -0.615 |
| Plains | 0.204 | 0.011 | 0.196 | 0.007 | -0.612 |
| Tonle Sap | 0.274 | 0.016 | 0.275 | 0.010 | 0.097 |
| Plateau/Mountain | 0.299 | 0.025 | 0.293 | 0.016 | -0.234 |
| Coastal | 0.188 | 0.024 | 0.213 | 0.008 | 0.986 |

Key: SAE=Small-Area Estimation, se=standard error

These Z scores suggest that the small-area estimates are all within two standard errors of the direct estimates, indicating a reasonable level of agreement between the two, especially since there are eight tests of significance, so that it could be expected that one Z score would exceed two even if none were really statistically significant.

We note from Table 5.1 that, although in all cases the SAEs are more precise (i.e. smaller standard errors) than the direct estimates, there is little reduction in standard error from the small-area methodology at the largest levels of aggregation. This is because the uncertainty in the direct estimates due to sampling variability is replaced by uncertainty in the estimated model for the SAEs. At the lower levels however the improvement in precision is much more dramatic.

## 5.2 Poverty at District and Commune levels

**Table 5.2 Summary of district-level poverty measures**

| | Incidence | | Gap | | Severity | |
|---|---|---|---|---|---|---|
| | P0 | se0 | P1 | se1 | P2 | se2 |
| Mean | 0.2480 | 0.0218 | 0.0690 | 0.0078 | 0.0249 | 0.0036 |
| Standard deviation | 0.0787 | 0.0099 | 0.0268 | 0.0043 | 0.0118 | 0.0023 |
| Minimum | 0.0646 | 0.0085 | 0.0125 | 0.0024 | 0.0036 | 0.0008 |
| Maximum | 0.5095 | 0.0571 | 0.1763 | 0.0264 | 0.0761 | 0.0148 |

Table 5.2 gives a statistical summary of the estimates for the 193 districts. A complete listing of the estimates at the district and provincial level is given in Appendix C. Poverty incidence at district level ranges from 6.5% (Chamkar Mon in Phnom Penh) to 50.9% (Ta Veaeng in Ratanak Kiri), with a standard deviation of 7.87%. The standard errors of these estimates are acceptably small, being in all cases less than 5.8% and with a mean of 2.18% (about 28% of the variability between districts). The small area level variance component mentioned in Section 2.2 while difficult to estimate, was essentially zero, in models for log expenditure reflecting both the adequacy and complexity of the fitted models at this level. The conclusion for height-for-age and for weight-for-age were similar.

The general pattern of the poverty estimates in Cambodia is that poverty is comparatively low in Phnom Penh, slightly higher in the plains, river valleys, around the shores of the Tonle Sap and on the sea coast, but rises to higher levels in the northeast and in the internal area away from the shore to the southwest of the Tonle Sap.

Table 5.3 gives a statistical summary of the estimates for the 1621 communes. The standard errors of the incidence estimates have a mean of 4.8%, and most standard errors (1050 out of 1621) are below 5%. Figure 5.1 shows that, as expected, the larger standard errors occur in the smaller communes in terms of population size. For the most part, then, these estimates would seem to be useful in making poverty comparisons at commune level.

**Table 5.3 Summary of commune-level poverty measures**

| | Incidence | | Gap | | Severity | |
|---|---|---|---|---|---|---|
| | P0 | se0 | P1 | se1 | P2 | se2 |
| Mean | 0.2418 | 0.0482 | 0.0667 | 0.0170 | 0.0238 | 0.0077 |
| Standard deviation | 0.0875 | 0.0195 | 0.0291 | 0.0084 | 0.0119 | 0.0044 |
| Minimum | 0.0382 | 0.0135 | 0.0070 | 0.0036 | 0.0019 | 0.0013 |
| Maximum | 0.6188 | 0.1482 | 0.2247 | 0.0643 | 0.0997 | 0.0372 |

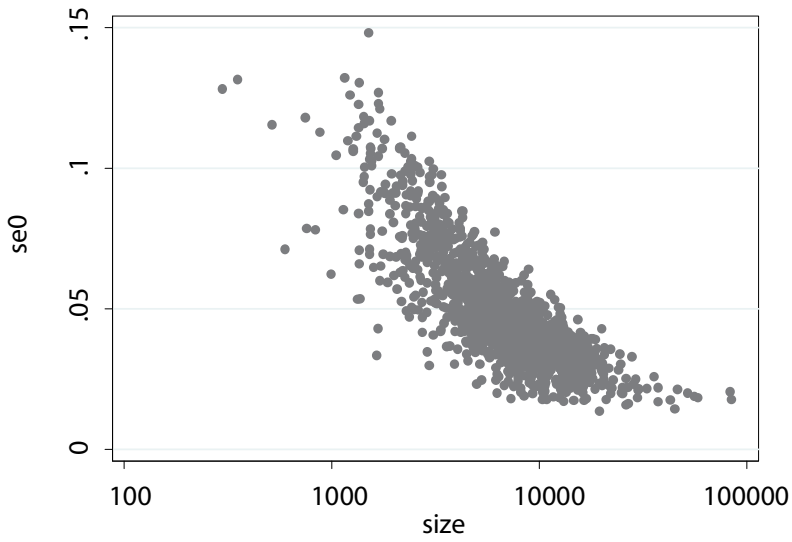



*Figure 5.1 Standard error of poverty incidence estimate versus commune size*

## 5.3 Comparison with Commune Database Estimates of Poverty Incidence

A comparison at commune level of our provisional small-area estimates with those obtained via the Commune Database shows that, although derived in very different ways using different data and methodologies, they correlate reasonably well (Pearson correlation coefficient 0.782). One noticeable difference is the group of communes estimated to have zero poverty incidence from the CDB. These are almost all within Phnom Penh province; most have been estimated by SAE as having low but non-zero levels of poverty, although a few (particularly in Dangkao and Ruessi Kaev districts) are estimated to have levels of over 20%.

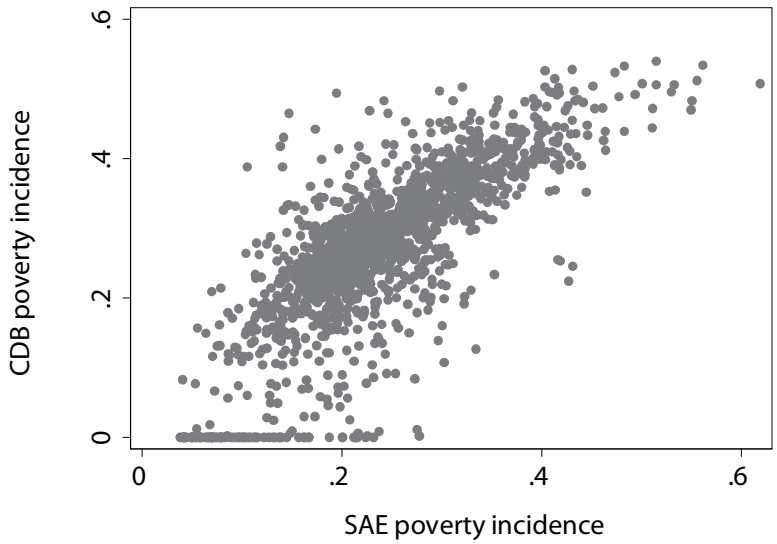
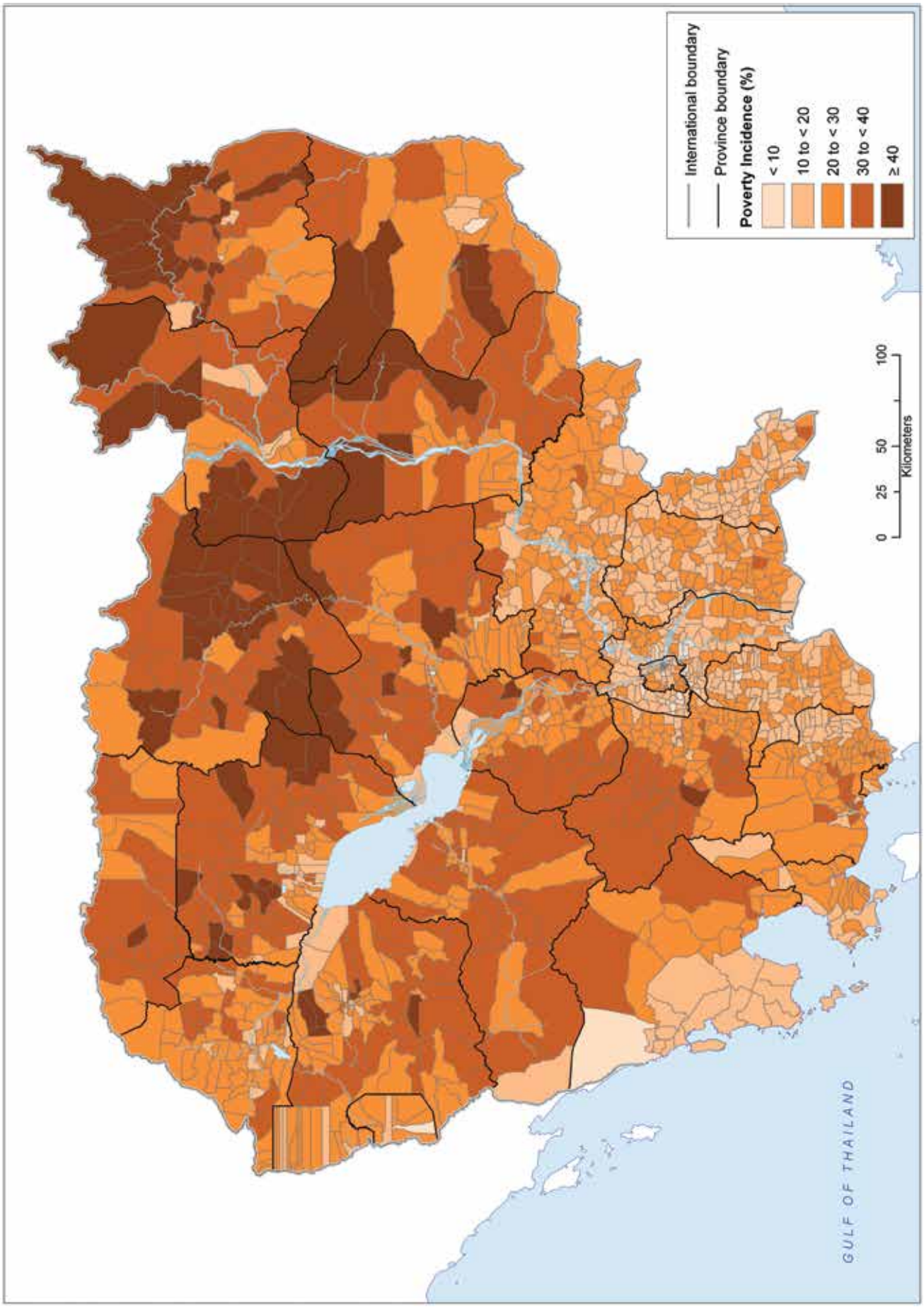



*Figure 5.2 CDB versus SAE estimates of poverty incidence at commune level*

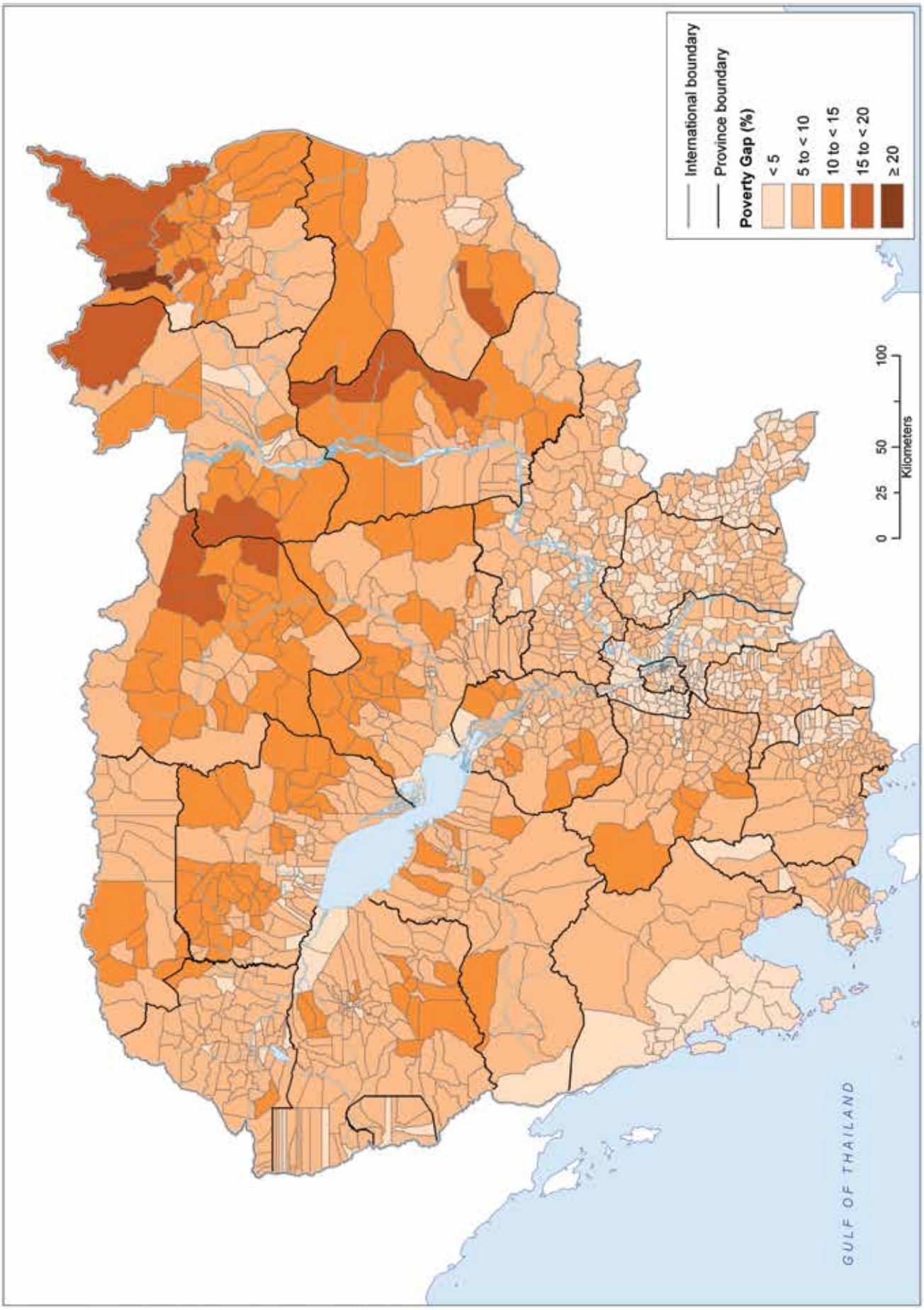
## 5.4 Poverty Maps

Maps of these poverty estimates, including incidence (P0), gap (P1) and severity (P2) at the commune level, are provided here.

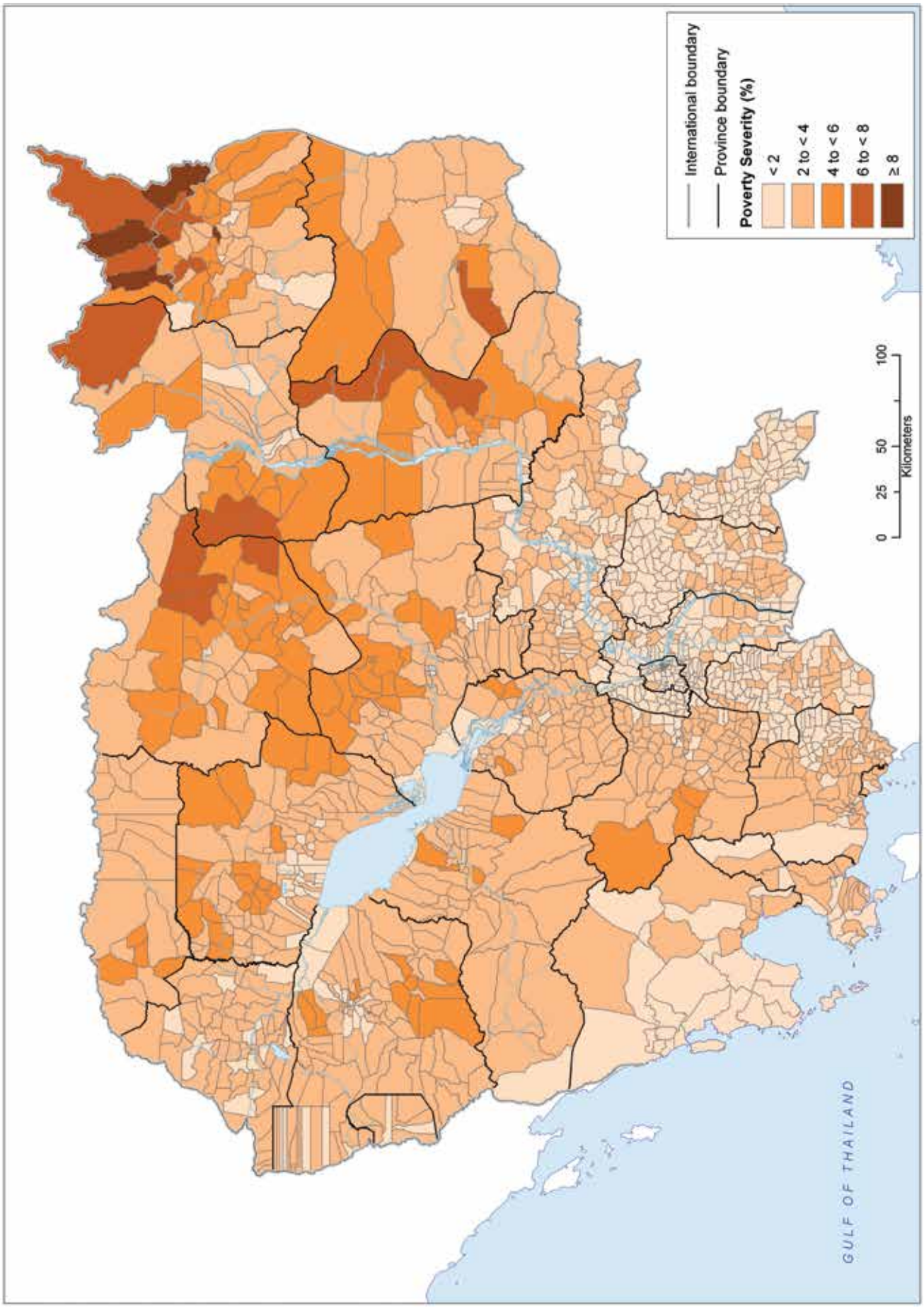
**Map 5.1 Poverty Incidence (P0)**



**Map 5.2 Poverty Gap (P1)**



**Map 5.3 Poverty Severity (P2)**



6

# RESULTS FOR MALNUTRITION MEASURES

## 6.1 Results for stunting

**Table 6.1 Comparison of estimates of stunting prevalence (S2) from CAS2008**

| | CAS | | SAE | | Standard Difference |
|---|---|---|---|---|---|
| | S2 | se | S2 | se | |
| Cambodia | 0.372 | 0.007 | 0.414 | 0.006 | 4.494 |
| Phnom Penh | 0.293 | 0.035 | 0.316 | 0.027 | 0.505 |
| Other Urban | 0.296 | 0.020 | 0.348 | 0.015 | 2.133 |
| Rural | 0.389 | 0.008 | 0.429 | 0.006 | 3.932 |
| Phnom Penh | 0.293 | 0.035 | 0.316 | 0.027 | 0.505 |
| Plains | 0.359 | 0.013 | 0.410 | 0.006 | 3.472 |
| Tonle Sap | 0.400 | 0.012 | 0.426 | 0.007 | 1.857 |
| Plateau / Mountain | 0.406 | 0.013 | 0.446 | 0.008 | 2.640 |
| Coastal | 0.357 | 0.018 | 0.408 | 0.007 | 2.652 |

Key: SAE=Small-Area Estimation, se=standard error

**Table 6.2 Comparison of estimates of stunting prevalence (S2) from CDHS2010**

| | CDHS | | SAE | | Standard Difference |
|---|---|---|---|---|---|
| | S2 | se | S2 | se | |
| Cambodia | 0.399 | 0.011 | 0.409 | 0.007 | 0.800 |
| Phnom Penh | 0.260 | 0.032 | 0.309 | 0.025 | 1.217 |
| Other Urban | 0.313 | 0.022 | 0.325 | 0.012 | 0.471 |
| Rural | 0.419 | 0.013 | 0.426 | 0.008 | 0.464 |
| Phnom Penh | 0.260 | 0.032 | 0.309 | 0.025 | 1.217 |
| Plains | 0.386 | 0.021 | 0.406 | 0.009 | 0.886 |
| Tonle Sap | 0.416 | 0.018 | 0.417 | 0.007 | 0.079 |
| Plateau / Mountain | 0.453 | 0.024 | 0.448 | 0.009 | -0.220 |
| Coastal | 0.426 | 0.034 | 0.404 | 0.010 | -0.630 |

Key: SAE=Small-Area Estimation, se=standard error

Initially, separate small-area estimates of stunting (S2) were prepared from the CAS2008 and CDHS2010 surveys. Tables 6.1 and 6.2 compare the SAEs with the direct survey estimates from each source. The CDHS-based small-area estimates match reasonably well with the direct estimates, whereas the CAS-based estimates seem to be too high, particularly in the rural areas. As noted earlier, the first stage regression models for height-for-age were poor in terms of predictive power, with $R^2$ values of 20%, 17% respectively (see Appendices B.2, B.3). Despite this, it appears from Tables 6.1, 6.2 that the small-area estimates of stunting at high aggregation levels still have smaller standard errors than the direct estimates from the surveys. This is perhaps due to the fact that very little of the residual variation from the model is at PSU-level, so that this unexplained variation, though considerable, is mostly averaged over a large number of individuals.

Although the CAS-based small-area estimates do not match particularly well with the direct estimates, they do match quite well with the DHS-based SAEs. When comparisons are made at province level there is a good degree of correlation between the SAEs and direct estimates for both surveys, with a few anomalous small provinces where the direct estimates are not reliable. We have decided therefore that, despite some reservations about the quality of the CAS-based estimates, that there is still some value in them. We have therefore decided, for our final estimates, to use a weighted average of the CAS- and DHS-based SAEs, the weights being the inverse of the variance of each individual estimate, i.e.

$$S2_{Final} = \frac{w_1 S2_{CAS} + w_2 S2_{CDHS}}{w_1 + w_2}$$

where $w_1 = [\mathrm{se}(S2_{CAS})]^{-2}$ and $w_2 = [\mathrm{se}(S2_{CDHS})]^{-2}$. This gives an optimal weighting of the two estimates assuming independence (which is a reasonable assumption because the two surveys were undertaken separately), resulting in smaller standard errors than either of the individual estimates. A similar approach was used for severe stunting (S3) – the proportion of children at least three standard deviations below average height-for-age.

Turning to the district-level estimates, summarized in Table 6.3, we find that the standard errors are quite small, with an average of only 1.2%. One out of 193 is a little over 3%. The estimates of stunting prevalence range from 23% (Prampir Meakkakra) to 54% (Andoung Meas). The standard errors for severe stunting are also quite small, averaging 0.9% in comparison with the standard deviation of 3.6%, so should provide a reasonably accurate comparisons of severe stunting between areas. A complete listing of the estimates at the district and provincial level is given in Appendix C.

**Table 6.3 Summary of district-level estimates of stunting prevalence (S2, S3)**

| | Stunting | | Severe stunting | |
|---|---|---|---|---|
| | S2 | se2 | S3 | se3 |
| Mean | 0.4207 | 0.0121 | 0.1893 | 0.0088 |
| Standard deviation | 0.0544 | 0.0046 | 0.0364 | 0.0036 |
| Minimum | 0.2347 | 0.0065 | 0.0802 | 0.0047 |
| Maximum | 0.5428 | 0.0324 | 0.2823 | 0.0267 |

Key: se2=standard error of S2, se3=standard error of S3

Even at commune level, as shown in Table 6.4, the estimates of both S2 and S3 have reasonably small standard errors in comparison with the variability between the communes. Stunting incidence S2 has an average standard error of 2.3%, and only six out of 1621 have standard errors of over 5%. Estimates at commune level range from 18% (Boeng Keng Kay Muong in Phnom Penh) to 62% (Kaoh Pang in Ratanak Kiri). Standard errors for severe stunting S3 average 1.7%, in comparison with the standard deviation of 4% between the communes. Thus, although the models used to derive the estimates have low predictive power for individual children, they seem to be capturing a considerable amount of variability in malnutrition between communes.

**Table 6.4 Summary of commune-level estimates of stunting prevalence (S2, S3)**

| | Stunting | | Severe stunting | |
|---|---|---|---|---|
| | S2 | se2 | S3 | se3 |
| Mean | 0.4176 | 0.0233 | 0.1860 | 0.0172 |
| Standard deviation | 0.0614 | 0.0067 | 0.0404 | 0.0057 |
| Minimum | 0.1847 | 0.0115 | 0.0543 | 0.0081 |
| Maximum | 0.6183 | 0.0637 | 0.3307 | 0.0492 |

Key: se2=standard error of S2, se3=standard error of S3

## 6.2 Results for underweight

As with stunting, two separate sets of estimates of underweight (U2) were originally prepared, one based on CAS2008 and the other on CDHS2010. Comparison between these and the direct survey-only estimates are presented in Tables 6.5, 6.6. Again the CAS-based estimates seem significantly too high, largely because of over-estimation in the rural areas. The CDHS-based estimates are also a little too high overall, but reproduce quite well the pattern of the direct estimates at ecozone level, with all differences being less than two standard errors. Both sets of SAEs correlate quite well with their respective direct estimates at province level, except for a few anomalies for smaller provinces. We therefore conclude again that both are capturing regional variation in prevalence of underweight, so for our final estimates have use a weighted average of the CAS- and DHS-based SAEs, with inverse-variance weights, i.e.

$$U2_{Final} = \frac{w_1 U2_{CAS} + w_2 U2_{CDHS}}{w_1 + w_2}$$

where $w_1 = [\mathrm{se}(U2_{CAS})]^{-2}$ and $w_2 = [\mathrm{se}(U2_{CDHS})]^{-2}$, with similar approach taken for severe underweight (U3).

**Table 6.5 Comparison of estimates of prevalence of underweight (U2) from CAS2008**

| | CAS | | SAE | | Standard Difference |
|---|---|---|---|---|---|
| | U2 | se | U2 | se | |
| Cambodia | 0.274 | 0.007 | 0.308 | 0.005 | 4.038 |
| Phnom Penh | 0.160 | 0.022 | 0.190 | 0.018 | 1.072 |
| Other Urban | 0.219 | 0.017 | 0.234 | 0.012 | 0.706 |
| Rural | 0.292 | 0.008 | 0.325 | 0.006 | 3.474 |
| Phnom Penh | 0.160 | 0.022 | 0.190 | 0.018 | 1.072 |
| Plains | 0.287 | 0.013 | 0.317 | 0.007 | 2.049 |
| Tonle Sap | 0.298 | 0.010 | 0.323 | 0.006 | 2.053 |
| Plateau / Mountain | 0.260 | 0.013 | 0.303 | 0.010 | 2.672 |
| Coastal | 0.262 | 0.017 | 0.316 | 0.007 | 3.002 |

Key: SAE=Small-Area Estimation, se=standard error

**Table 6.6 Comparison of estimates of prevalence of underweight (U2) from CDHS2010**

| | CDHS | | SAE | | Standard Difference |
|---|---|---|---|---|---|
| | U2 | se | U2 | se | |
| Cambodia | 0.284 | 0.010 | 0.314 | 0.007 | 2.485 |
| Phnom Penh | 0.182 | 0.030 | 0.174 | 0.023 | -0.197 |
| Other Urban | 0.204 | 0.013 | 0.228 | 0.010 | 1.410 |
| Rural | 0.300 | 0.011 | 0.334 | 0.008 | 2.422 |
| Phnom Penh | 0.182 | 0.030 | 0.174 | 0.023 | -0.197 |
| Plains | 0.282 | 0.018 | 0.318 | 0.008 | 1.810 |
| Tonle Sap | 0.289 | 0.015 | 0.320 | 0.008 | 1.845 |
| Plateau / Mountain | 0.332 | 0.021 | 0.349 | 0.010 | 0.723 |
| Coastal | 0.271 | 0.030 | 0.314 | 0.007 | 1.391 |

Key: SAE=Small-Area Estimation, se=standard error

The district-level estimates for underweight, described in Table 6.7, have standard errors similar to those for stunting, having an average of only 1.1%, with the largest just over 3%. The underweight estimates themselves range from 14% (Prampir Meakkakra) to 43% (Siem Pang). The standard errors for severe underweight are also quite small, with a standard error of 0.5% in contrast to the district-level standard deviation of 2%. The estimates of underweight and severe underweight are very strongly correlated (r = 0.991) so would give very similar results if used to discriminate between districts. A complete listing of the estimates at the district and provincial level is given in Appendix C.

**Table 6.7 Summary of district-level estimates of underweight prevalence (U2, U3)**

| | Underweight | | Severe Underweight | |
|---|---|---|---|---|
| | U2 | se2 | U3 | se3 |
| Mean | 0.3134 | 0.0112 | 0.0828 | 0.0053 |
| Standard deviation | 0.0518 | 0.0045 | 0.0207 | 0.0024 |
| Minimum | 0.1387 | 0.0064 | 0.0198 | 0.0024 |
| Maximum | 0.4308 | 0.0301 | 0.1398 | 0.0157 |

Key: se2=standard error of U2, se3=standard error of U3

Again at commune level the standard errors for underweight incidence are reasonably small, as shown in Table 6.8. Only 4 out of 1621 are above 5%, with an average of 2.1%. Estimated incidence of underweight ranges from 10% (Tuol Svay Prey Ti Pir in Phnom Penh) to 50% (Anlong Phe in Stung Treng). Thus the models for weight-for-age, although similarly low in predictive power to those of height-for-age, seem to be capturing a considerable amount of variability in incidence of underweight between communes.

**Table 6.8 Summary of commune-level estimates of underweight prevalence**

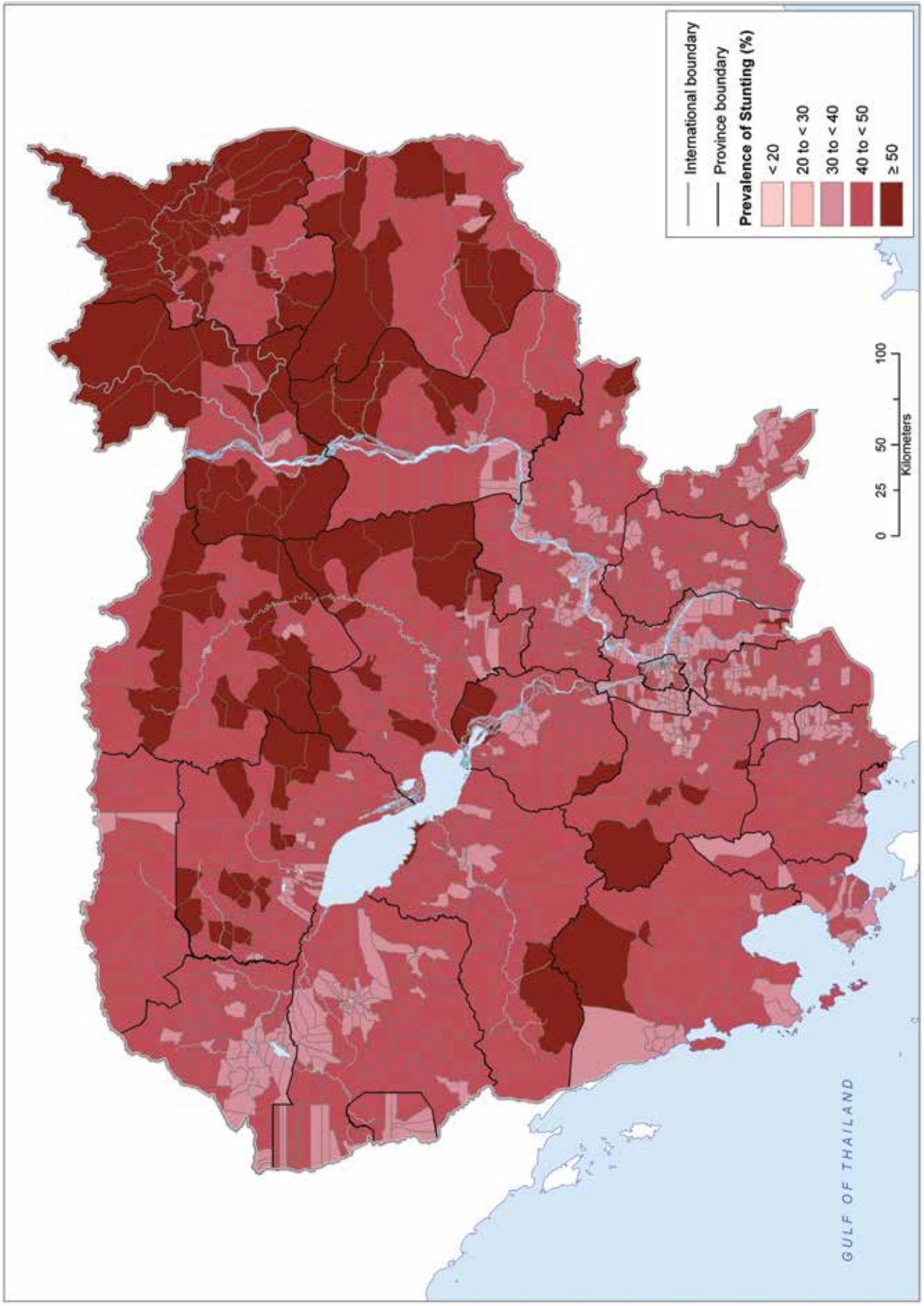
| | Underweight | | Severe Underweight | |
|---|---|---|---|---|
| | U2 | se2 | U3 | se3 |
| Mean | 0.3174 | 0.0207 | 0.0835 | 0.0106 |
| Standard deviation | 0.0583 | 0.0062 | 0.0232 | 0.0038 |
| Minimum | 0.1015 | 0.0103 | 0.0124 | 0.0037 |
| Maximum | 0.5035 | 0.0554 | 0.1797 | 0.0425 |

Key: se2=standard error of U2, se3=standard error of U3

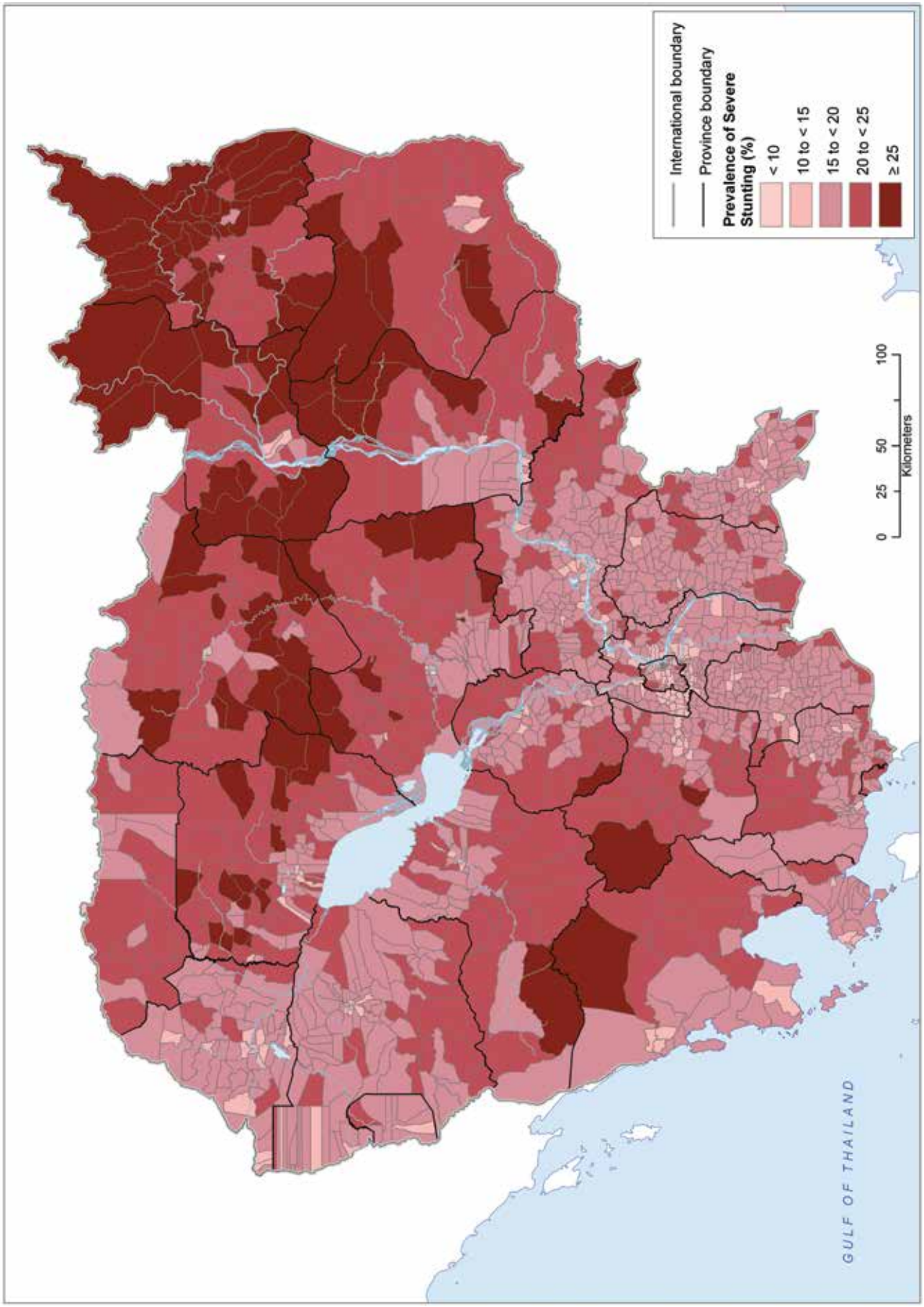
## 6.3 Malnutrition Maps

Maps of these malnutrition estimates, including stunting (S2), severe stunting (S3), underweight (U2) and severe underweight (U3), at the commune level are provided here.

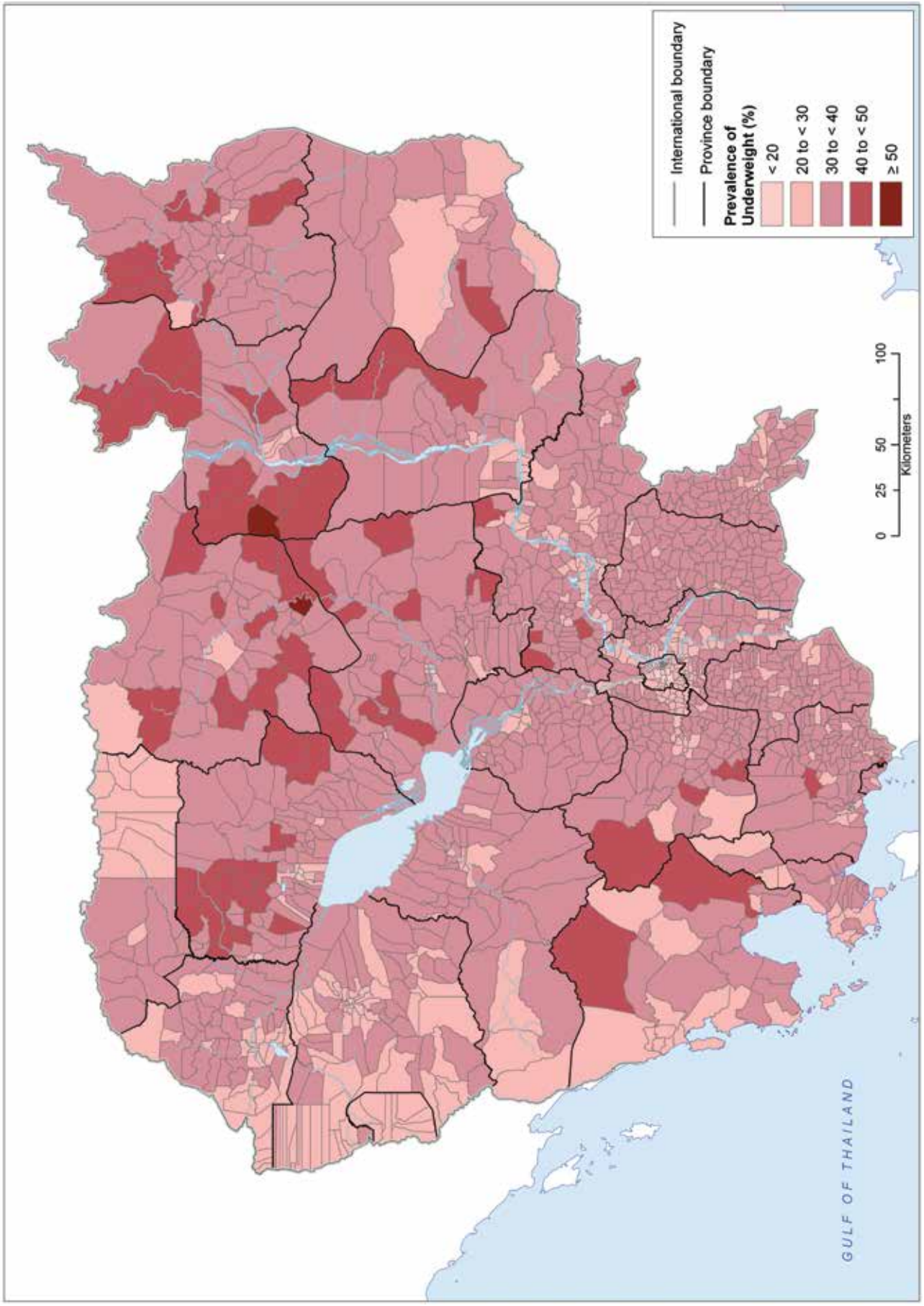
**Map 6.1 Stunting (S2)**



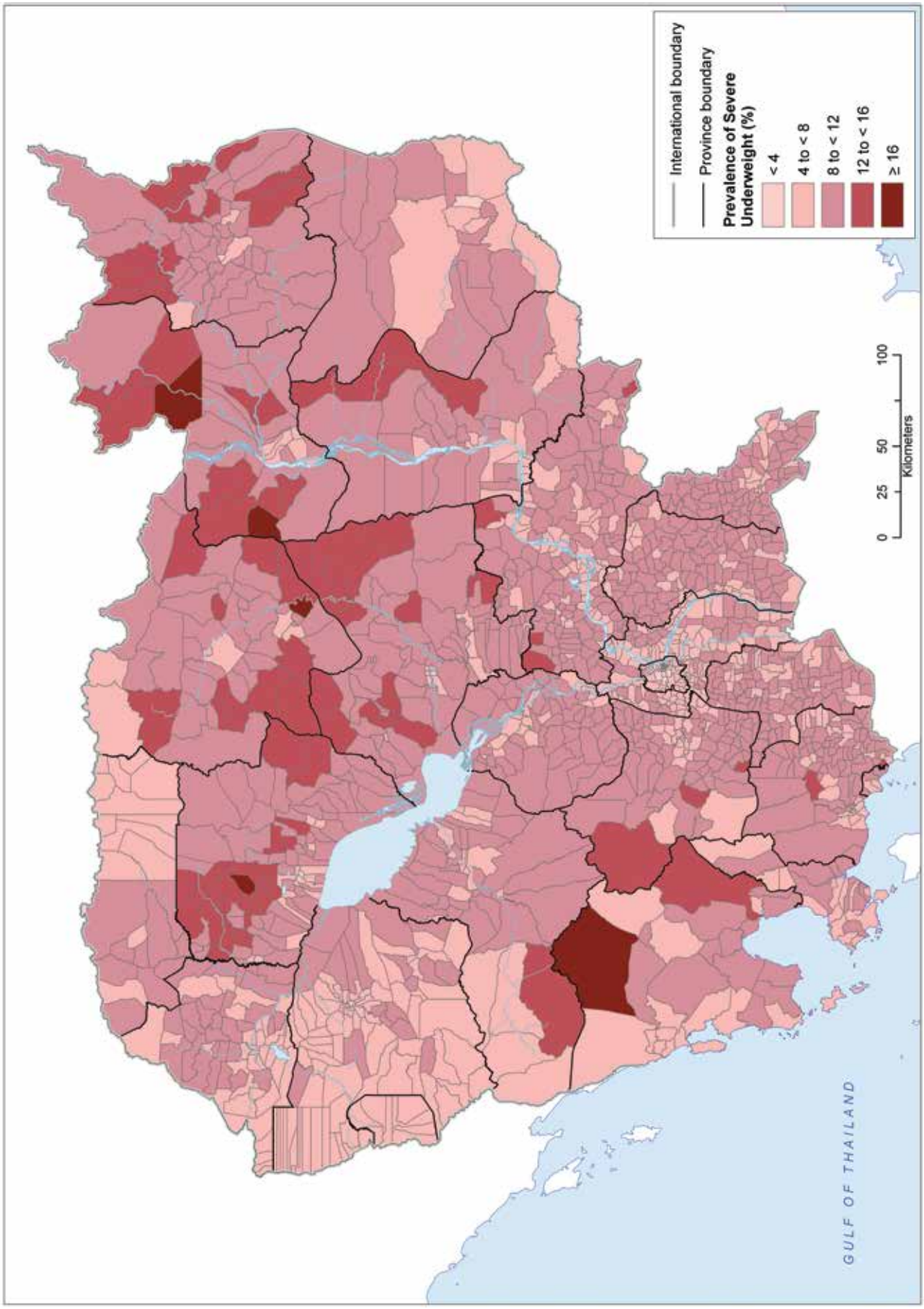
**Map 6.2 Severe Stunting (S3)**



**Map 6.3 Underweight (U2)**



**Map 6.4 Severe Underweight (U3)**



# 7

# MULTIVARIATE ANALYSIS

## 7.1 Correlations

**Table 7.1 Pairwise correlations for all three measures, commune level**

| | P0 | S2 | U2 |
|---|---|---|---|
| P0 | 1 | | |
| S2 | 0.7882 | 1 | |
| U2 | 0.6921 | 0.8999 | 1 |

Here we investigate the relationships between the three measures of deprivation estimated in this report, namely: poverty (P0), stunting (S2), and underweight (U2). Table 7.1 shows the correlations between the commune-level estimates of these measures. All show strong positive correlation, which suggests that those areas showing high levels of deprivation on one measure tend also to be high on the other measures.

## 7.2 Principal Components

**Table 7.2 Principal component analysis for poverty, stunting and underweight**

| Component | Eigenvalue | Difference | Proportion | Cumulative |
|---|---|---|---|---|
| Component 1 | 2.5898 | 2.2649 | 0.8633 | 0.8633 |
| Component 2 | 0.3249 | 0.2396 | 0.1083 | 0.9716 |
| Component 3 | 0.0853 | | 0.0284 | 1 |

| Variable | Component 1 | Component 2 | Component 3 | Unexplained |
|---|---|---|---|---|
| P0 | 0.5503 | 0.8077 | 0.2118 | 0 |
| S2 | 0.6009 | -0.2069 | -0.7720 | 0 |
| U2 | 0.5797 | -0.5522 | 0.5992 | 0 |

Here we consider the possibility of combining all three indicators into a single measure using principal components analysis. The results at commune level, presented in Table 7.2, show that the first principal component, representing the combination giving maximum overall variation, gives approximately equal weighting to all three measures, and so is close to a simple average of poverty, stunting and underweight prevalences. This first component represents 86% of the overall variation in the three indicators and could be useful if a single measure (a composite index) is required for targeting more generic types of development assistance (See 7.3 below). The second component contrasts poverty with underweight. These two components together account for 97% of the variation.

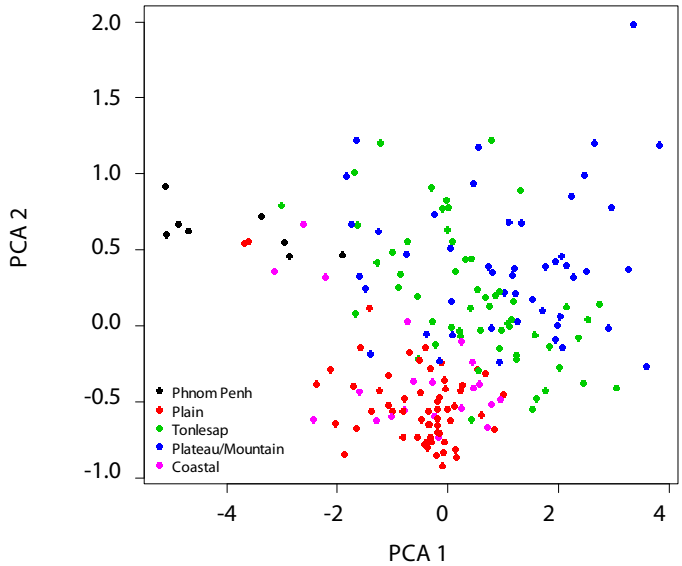



*Figure 7.1 Plot of first two principal components for districts*

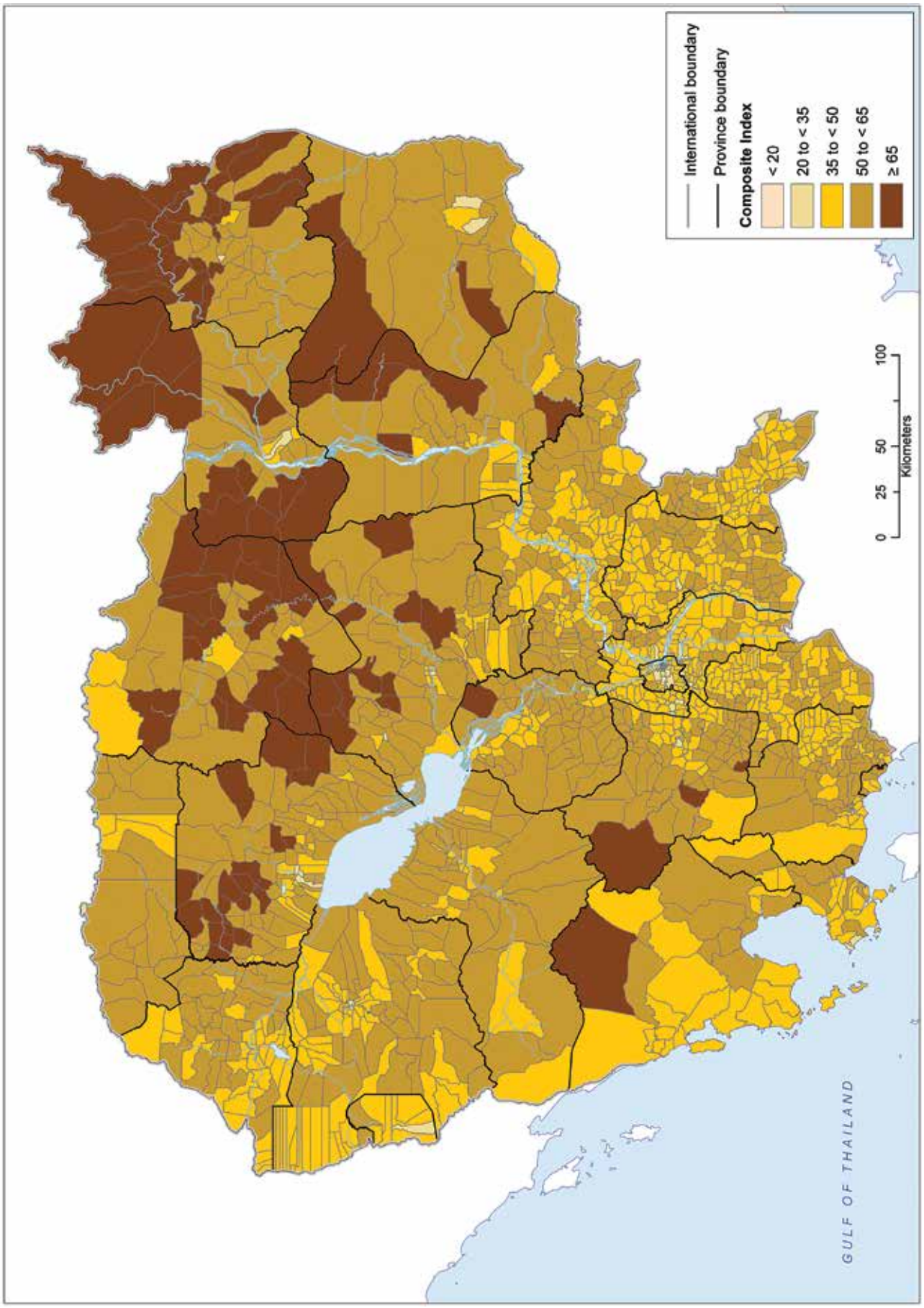
The first principal component has positive coeffiocients for P0, S2 and U2, which is the reason it can provide a general measure of poverty. The second principal component contrasts P0 with U2 (and to a lesser extent with S2), so that it separates districts that have relatively higher poverty levels but lower underweight from those that have lower poverty but higher underweight. Interestingly, when the values for each district are then plotted, as in Figure 7.1, the districts within ecozones tend to clump together. This indicates that districts within ecozones have similar (though not identical patterns) of poverty and underweight. For example, Phnom Penh tends to have low poverty but mid-range underweight, the Plains has mid-range poverty but low relative underweight, and the Plateau/Mountain has relatively high values of both poverty and underweight.

The effect of contrasting poverty and underweight, while important, is not however marked. After all, the second principal component explains only 10.8% of the total variance, while the first principal component explains 86.3%, so the overriding consideration for Cambodia as a whole is the positive link between poverty and underweight.

## 7.3 Composite Index Map

A map of a composite index of poverty (P0), stunting (S2) and underweight (U2) at the commune level is provided here. It should be noted that the composite index is not, and should not be interpreted as, a percentage. It is an index number that represents a linear combination of the three measures – poverty (P0), stunting (S2), and underweight (U2) – that aligns best with all three. It has been scaled arbitrarily to have a mean of 50 and a standard deviation of 10. When this index is high, then poverty and malnutrition rates will tend to be high, and vice versa. The principal component, and hence the composite index, is particular to Cambodia, so direct comparison of this index for different countries is not possible. It is suitable for Cambodia because the first principal component explains so much of the overall variation (86%). This reflects the high correlation, in Cambodia, between the three measures: poverty, stunting and underweight.

**Map 7.1 Composite Index**



# 8

# CONCLUSIONS AND DISCUSSION

We have produced small-area estimates of poverty and malnutrition in Cambodia at district and commune levels by combining survey data with auxiliary data derived from the 2008 census. A single model was found to be adequate for predicting log average per capita household consumption expenditure and the poverty measures derived from it. The commune-level estimates obtained have acceptably low standard errors.

It is interesting to note that the estimates derived from height-for-age, weight-for-age (but not weight-for-height or calorie intake) also had acceptably small standard errors down to commune level, even though our predictive models for these variables had lower $R^2$ values than for log average per capita household consumption expenditure. The lower $R^2$ values for these regression models in part reflect the additional level of variation (children within households) in comparison with the model for log average per capita household consumption expenditure. Smaller $R^2$ is also more acceptable if the large unexplained variation is truly random across households or individuals, with little or no cluster-level variation. Since the methodology incorporates in the standard errors any remaining cluster-level variation, this would appear to be the case. It is nevertheless likely that some of this variation represents missing variables in the model which would give better prediction if they were available. If important factors are missing then the small-area estimates obtained will not reflect the true variability in these malnutrition indicators, and will tend to have larger standard errors than would otherwise be the case. Calorie intake is inevitably imprecisely measured, so a large part of its unexplained variation (and the main reason it could not be modelled adequately) is due to measurement error. However, this argument does not apply to height-for-age, weight-for-age, or weight-for-height which are measured quite accurately. This suggests that the problems modelling weight-for-height reflect comparatively small differences between parts of Cambodia for this measure. There are other factors, particularly health-related ones, that would be useful predictors of malnutrition, but these variables were not available for the population from the census data and so could not be included in the small-area models.

Geographic Information Systems (GIS) variables were not used directly in the regression and heteroscedasticity models. GIS variables are necessarily at aggregate level and, as for census means, because they are aggregated are not able to provide household level information. Like all regressor variables, they are to be included in models only where they explain variation in addition to that *explained* by the other variables in the model. GIS and other variables, even when they are not included directly in the model, can nevertheless be important in their own right.

As a consequence, although maps of small-area estimates of the various poverty measures are important, so are various complementary maps of GIS and other variables. What is important is whether such variables have high correlation with the small-area estimates (even if they are not in the regression model itself).

As noted earlier, we have departed from previous implementations of ELL methodology in a few important ways. More detailed discussion can be found in Haslett and Jones (2005b, 2010). For example, the strategy for choosing appropriate regression models for the target variable is not usually made explicit, but Miller (2002) sounds a number of cautions. Using separate survey based models for subgroups such as geographical strata, especially where there are a large number of such subgroups, and selecting variables have from a very large pool of possibilities including all interaction terms cannot be recommended. Model-fitting criteria such as adjusted $R^2$ or *AIC* will penalize for fitting too many variables, but do not account for the number of variables that are being selected from. Cross-validation (i.e. dividing the sample, fitting a model to one part, and testing its utility on the other) might be useful here. We have tried where possible to fit a single model for the whole population, including interaction terms only when the corresponding main effects are also included and looking carefully at the interpretability of the estimated effects, i.e. whether the model makes sense. This is a time-consuming procedure but can lead to more stable parameter estimation and more reliable prediction. This does not preclude fitting subgroup or area effects in models when required, or combining area based models into an essentially equivalent single model containing appropriate interactions to improve stability of regression parameter estimates. When the effects of most factors on the target variable are similar in all areas, with modulation only between rural and non-rural areas, an urban/rural possibly with some interactions with other variables will suffice. Even a single model can produce very different area based estimates when appropriate as the results in Appendix C attest. Furthermore if there is prior knowledge on which factors are likely to affect the target variable, this can be incorporated into the model selection. A more formal way of doing this would be through a Bayesian analysis, but this is beyond the scope of the present work.

The use of specialised survey regression routines, such as those available in Stata, Sudaan and WesVar, in the initial model fitting to the survey data has distinct advantages, since it incorporates the entire survey design and gives a consistent estimate of the covariance matrix. These specialized routines use a robust estimation methodology, essentially collapsing the covariance matrix within clusters, and such methods are consequently more stable than ones which estimate a covariance within each cluster. A perceived disadvantage is that such robust methods may give poor estimates if used for small subpopulations with few clusters. However this is a real effect, not an artefact of the fitting procedure. Note that such routines require all survey data to be included in any analysis (even of a subpopulation) in order to give unbiased standard errors, so that analysis of sub-setted survey data is not recommended, even if different models are being fitted to different subgroups. The weighting of the survey observations is complex not only because of the survey design but also because the target variable is often a per capita average. Alternatively, if individual data are used, these will be correlated when from the same family, although the robust variance estimate is still valid even there because it only assumes independence between clusters, not of observations within clusters.

To allow for non-independence between children in the same household at the prediction stage, we have extended the ELL approach to incorporate three levels of variation. Whilst the estimation of variance components in such a hierarchical model is now well-understood, the use of estimated random effects in a non-parametric bootstrap raises some theoretical issues, such as adjustment for degrees of freedom, which might provide fruitful areas for further research. We have also tested, to the extent possible given many sampled communes contain only one sampled primary sampling unit (PSU), that small area (i.e. commune) level random effects are negligible when estimating standard errors.

The benefits of the ELL methodology accrue when interest is in several nonlinear functions of the same target variable, as in the case here of three poverty measures defined on household per capita expenditure, or in distributional properties. If only a single measure were of interest it might be worthwhile to consider direct modelling of this. For example small-area estimates of poverty incidence could be derived by estimating a logistic regression model for incidence in the survey data. Ghosh and Rao (1994) consider this situation within the framework of generalized linear models. If on the other hand there are several target variables which might be expected to be highly correlated, it might increase efficiency to use a multivariate model rather than separate univariate regressions. The discussion in Section 7.2 does however raise some interesting issues about the utility of such multivariate models, since such techniques tend to shrink estimates of each component toward one another, and it is sometimes the contrast rather than the combination of variables such as height-for age, weight-for-age, and weight-for-height that is important.

From a theoretical perspective, the best (i.e. most efficient) small-area estimator uses the actual observed Y when these values are known, i.e. for the units sampled in the survey, and the predicted Y values otherwise. The resulting estimator can be thought of as a weighted mean of the direct estimator, from the survey only, and an indirect estimator derived from the auxiliary data, the weights being related to the standard errors of the two estimates. In practice it may be impossible for confidentiality reasons to identify individual households in the survey and match them to the census, but there is a theoretical basis for using a weighted mean of the two estimates and thereby increasing precision. Further it is not necessary to resample unconditionally from the empirical distribution of the cluster-level residuals for those clusters which are present in the survey. An alternative would be to resample each of these parametrically from an estimated conditional distribution, i.e. for clusters present in the survey we would calculate the bootstrap predictions using the known value rather than a draw from a random distribution. This would however not have a major effect where the number of clusters in the sample is small relative to the number of clusters defined over the whole population. See also Valliant, Dorfman and Royall (2000).

The provision of standard errors with the small-area estimates is important because it gives the user an indication of how much accuracy is being claimed, conditional on the model being correct. Ultimately decisions are to be made on which areas should receive the most development assistance, so it is important that this information be given to users in a way that is most useful for this purpose. It is not clear exactly how the standard error information should be incorporated, but this is at least in part because the answer will depend on the parameters of the decision problem.

We have explored a possible way of incorporating the standard errors into a poverty map, first calculating standardized departures from a pre-specified incidence level, say 40%, as

$$Z = \frac{\text{estimate} - 0.40}{\text{standard error}}$$

and then transforming this into a probability assuming a normal distribution. This value can then be mapped and interpreted as the probability that the corresponding area has a poverty incidence at least as high as the pre-chosen level. Thus when targeting assistance we could focus on those areas which we believe have the greatest chance of exceeding a threshold poverty incidence, although as with any single map some caution is required if the population sizes in the areas differ markedly. The probabilities here are calculated on the assumption that the sampling distributions of the small-area estimates of incidence are approximately normal. A nonparametric alternative would be to take the proportion of bootstrap estimates above the cut-off value.

From a technical perspective, the statistical methods used would benefit from further theoretical development and justification. The range of models possible using small-area estimation is very broad, and while the ELL methodology has a number of theoretical and practical advantages, sensitivity of estimates to different small-area estimation models remains an only partially explored issue. This question relates both to the choice of the ELL method, vis-à-vis others, and to the choice of explanatory variables within models (e.g. submodels for different areas, cross-validation of variables selected from a large pool including higher level interactions, consistency of sign and magnitude of parameter estimates with likely influence on poverty in the presence of correlated variables). These questions need theoretical work and extend beyond the present study.

Ground truthing or validation of small-area estimates by visits to selected small areas after models have been fitted and small-area estimates derived from them can be a useful exercise. Some cautions are however warranted. The first is that small-area estimation is a technique that works best in aggregate - not every small-area estimate can be expected to give precise information, so that choosing areas to visit on the basis of possible anomalies can give a biased picture of the utility of the estimates as a whole. It is also difficult to ask participants in a validation exercise to differentiate various types of poverty or not to include aspects (such as health or water quality) which because they are not included in the census variables cannot be part of the small-area estimates themselves. Validation exercises are also usually limited by funds, so that formal testing of the accuracy of the small-area estimates is not possible by this method. Nevertheless, validation can provide useful qualitative insights and even more importantly a forum for discussion of results of poverty mapping with local communities.

Small-area models are not perfect, and standard errors derived from them depend on the model being at least approximately correct, or at least correct enough to make sound predictions. Despite these caveats, from a practical point of view the Cambodia small-area poverty and malnutrition estimates presented in this report are at a much finer geographical level than has previously been possible and consequently should be of considerable benefit when a mechanism for allocation of development assistance is required.

# BIBLIOGRAPHY


Alderman H., Babita M., Demombynes G., Makhata N. and Ozler B., 2002. "How low can you go? Combining census and survey data for mapping poverty in South Africa", *Journal of African Economics, 11, 169-200.*

Cambodian-German Cooperation, 2006. *Identification of Poor Households Project (IDPoor): Project Outline,* April 2006

Chambers R.L and Skinner C.J. (eds.), 2003. *Analysis of Survey Data.* Wiley.

Conway, T. and Goh, C., 2006. *Cambodia: Halving poverty by 2015? Poverty Assessment 2006*, World Bank, xviii+198pages+appended tables, February 2006.

Council for Social Development, Cambodia, 2002. *National Poverty Reduction Strategy 2003-2005*, Council for Social Development, Royal Cambodian Government, xiv+238 pages, December 2002.

Dalén, J., 2005a. *Measurement problems in poverty estimation in Cambodia*, Statistics Sweden International Consulting Office, Camstat Report 2005:12.

Dalén, J., 2005b. *Some comments on price index estimates in the draft Cambodia 2004 poverty report by James C Knowles*, Statistics Sweden International Consulting Office, Camstat Report 2005:13.

Dalén, J., 2006. *Sampling issues in a continuous Cambodia Socio-economic Survey*, Statistics Sweden International Consulting Office, Camstat Report 2006:08.

Davidsson, G. and Pettersson, H., 2003. *Survey design for the Cambodian Socio-economic Survey 2003-4*, Statistics Sweden International Consulting Office, Camstat Report 2003:03.

Efron B. and Tibshirani R.J., 1993. *An Introduction to the Bootstrap*. Chapman and Hall.

Elbers C., Lanjouw J.O. and Lanjouw P., 2001. *Welfare in villages and towns: micro-level estimation of poverty and inequality*, unpublished manuscript, World Bank.

Elbers C., Lanjouw J.O., Lanjouw P. and Leite P.G., 2001. *Poverty and inequality in Brazil: new estimates from combined PPV-PNAD* data, unpublished manuscript, World Bank.

Elbers C., Lanjouw J. and Lanjouw P., 2003. "Micro-level estimation of poverty and inequality", *Econometrica*, 71, 355-364.

Food and Agriculture Organization/ World Health Organization / United Nations University, 1985. *Energy and Protein Requirements*, WHO Technical Report Series 724. Geneva, WHO.

Foster J., Greer J. and Thorbeck E., 1984. “A class of decomposable poverty measures”, *Econometrica*, 52, 761-766.

Fujii T., 2004. “Commune-level estimation of poverty measures and its application in Cambodia”, In *Spatial Disparities in Human Development:* Perspectives from Asia, edited by Kanbur R., Venables A.J., & G. Wan, United Nations University Press.

Fujii, T., 2002. *Estimation of Poverty Rates at Commune-Level in Cambodia – using Small-Area Estimation Technique to Obtain Reliable Estimates*, Ministry of Planning and the United Nations World Food Programme, October 2002, vi+62 pages+CD of estimates.

Fujii T., Lanjouw P., Alayou S. and Montana L., 2004. *Micro-level estimation of prevalence of child malnutrition in Cambodia*, World Bank.

Food and Agriculture Organization / World Health Organization / United Nations University, 1985. *Energy and Protein Requirements*, WHO Technical Report Series 724. Geneva, WHO.

German Technical Co-operation, 2006a. *Identification of Poor Households Project (IDPoor)*, Cambodian – German Co-operation, German Technical Co-operation (GTZ).

German Technical Co-operation, 2006b. *Procedures for identification of Poor Households in Cambodia, Version 1 for 2007 Rounds 1a and 1b*, German Technical Co-operation (GTZ) / Cambodia Ministry of Planning.

Ghosh M. and Rao J.N.K., 1994. “Small area estimation: an appraisal”, *Statistical Science*, 9, 55-93.

Hamill P.V.V., Dridz T.A., Johnson C.Z., Reed R.B. et al., 1979. “Physical growth: National Center for Health Statistics percentile”. *American Journal of Clinical Nutrition*, 32, 607-621.

Haslett, S., 2008 *Potential for Small-area estimation and Poverty Mapping at District and Commune Level in Cambodia: Interim Feasibility Report*, Massey University report prepared for the World Food Programme, Cambodia, May 2008.

Haslett, S. Isidro, M. and Jones, G. 2010. “Comparison of survey regression techniques in the context of small-area estimation of poverty”, *Survey Methodology*, 36, 2, 157-170.

Haslett, S. and Jones, G., 2005a. *Estimation of Local Poverty in the Philippines*, Philippines National Statistics Co-ordination Board / World Bank, November 2005.

Haslett, S. and Jones, G., 2005b. “Small-area estimation using surveys and censuses: some practical and statistical issues”, *Statistics in Transition*, 7 (3), 541-555

Haslett. S. and Jones, G., 2008. *Potential for Small-area estimation and Poverty Mapping at District and Commune Level in Cambodia*, report to UN World Food Programme, December 2008.

Haslett, S. and Jones, G., 2010. “Small-area estimation of poverty: the aid industry standard and its alternatives”, *Australian and New Zealand Journal of Statistics*, 52(4), 341-362.

Haslett, S., Jones, G. and Isidro, M., 2010. *Potential for Small-area estimation of Malnutrition at District and Commune Level in Cambodia: Feasibility Report Phases 1 and 2*, Report for the UN World Food Programme.

Healy A.J., Jitsuchon S. and Vajaragupta, Y., 2003. *Spatially disaggregated estimation of poverty and inequality in Thailand*, World Bank.

Hou, T. E, Ny, B. and Karim, R., 2010. *Poverty and Select CMDGs Maps and Charts 2003-2009: Preliminary Results of CDB-based Research and Analysis Project*, 2010 updated edition, Kingdom of Cambodia Ministry of Planning & UNDP.

Isaksson, A., 2007. *Inference from the Cambodian Socio-economic survey*, Statistics Sweden International Consulting Office, Camstat Report 2007:05.

Isidro, M., 2010. *Intercensal updating of small-area estimates*, Thesis in partial fulfilment of PhD degree requirements, Massey University, New Zealand.

Isidro, M., Haslett, S. and Jones, G., 2010a. "Comparison of intercensal updating techniques for local level poverty statistics", *Proceedings of Statistics Canada Symposium* 2010, 10B-4, http://www.statcan.gc.ca/conferences/symposium2010/abs-res-eng.htm

Isidro, M, Haslett, S. and Jones, G., 2010b. "Extended Structure-Preserving Estimation Method for Updating Small-Area Estimates of Poverty", *Joint Statistical Meetings, Proceedings of the American Statistical Association 2010*, Vancouver, Canada, http://www.amstat.org/meetings/jsm/2010/onlineprogram

Johansson, S., 2005. *Recall and diary estimates of food consumption. Understanding the differences in CSES 2004*, Statistics Sweden International Consulting Office, Camstat Report 2005:14.

Johansson, S., 2006. *Designing the continuous Cambodia Socio-economic survey (1-3)*, Statistics Sweden International Consulting Office, Camstat Report 2006:02.

Jones, G. and Haslett, S., 2003. *Local Estimation of Poverty and Malnutrition in Bangladesh*. Bangladesh Bureau of Statistics and UN World Food Programme.

Jones G., and Haslett, S., 2006. *Small-area estimation of poverty, caloric intake and malnutrition in Nepal*, Published: Nepal Central Bureau of Statistics / UN World Food Programme / World Bank, September 2006, 184pp, ISBN 999337018-5.

Knowles, J C., 2006. *A new set of poverty indicators for Cambodia, 1993/4 to 2004*, Report to the EAS Country Units of the World Bank, Washington DC. Original report 2005; revised version 28 November 2006.

Laird, N.M. and Ware, J.H., 1982. "Random-Effects Models for Longitudinal Data," *Biometrics*, 38, 963 - 974.

Lehtonen, R. and Pakhinen, E., 2004. *Practical Methods for Design and Analysis of Complex Sample Surveys*, 2nd Edition, Wiley.

Longford, N. T., 2005. *Missing Data and Small-area estimation*, Springer Verlag.

Miller, A., 2002. *Subset Selection in Regression*, 2nd edition, Chapman and Hall / CRC

Ministry of Planning, Cambodia, 2005. *National Strategic Development Plan, 2006-2010*, Royal Government of Cambodia, Ministry of Planning, xviii+121pages+appendices, December 2005

Ministry of Planning, Cambodia, 2013. *Poverty in Cambodia - A New Approach. Redefining the Poverty Line*, Royal Government of Cambodia, Ministry of Planning, April 2013.

National Institute of Statistics, Cambodia, 2004. *A Poverty Mapping Profile of Cambodia, 2004*, National Institute of Statistics, Ministry of Planning, xiv+122pages, February 2006.

National Institute of Statistics, Cambodia, 2007. *Statistical Master Plan for Cambodia*, National Institute of Statistics, Ministry of Planning, v+40pages, September 2007.

National Institute of Statistics, Cambodia / FAO, 2007. *Summary Report on the Food Insecurity Assessment in Cambodia: 2003/04 Cambodia Socio-economic Survey*, National Institute of Statistics, Ministry of Planning; EC-FAO Food Security "Information for Action Programme", September 2007.

National Institute of Statistics, Ministry of Planning and UNICEF Cambodia, 2009. *Cambodia anthropometrics survey 2008*. Phnom Penh, Cambodia: National Institute of Statistics, Ministry of Planning and UNICEF Cambodia.

National Institute of Statistics (Cambodia), Ministry of Health (Cambodia) and ICF Macro, 2011. *Cambodia Demographic and Health Survey 2010-2011*. ICF Macro, Calverton, United States.

Neupert, R., 2005. *New demographic estimates and updated projections for Cambodia*, Statistics Sweden International Consulting Office, Camstat Report 2005:04.

Pettersson, H., 2004. *Calibration of sampling weights for Cambodian Socio-economic surveys*, Statistics Sweden International Consulting Office, Camstat Report 2004:03.

Pettersson, H., 2005. *Calibration of sampling weights for Cambodian Socio-economic surveys (2)*, Statistics Sweden International Consulting Office, Camstat Report 2005:01.

Pinney, A., 2007. *Initial calculation of small-area estimates of poverty using CSES 2003/04 and Commune Database 2002-2006*, draft report: UNDP / National Institute of Statistics. July 2008.

Rao J.N.K., 1999. "Some recent advances in model-based small-area estimation", *Survey Methodology*, 23, 175-186.

Rao, J.N.K., 2003. *Small-area estimation*. Wiley.

Robinson, G.K., 1991. "That BLUP is a Good Thing: The Estimation of Random Effects," *Statistical Science*, 6, 15 - 51.

Sandqvist, A., 2007a. *Development of expenditure statistics in Cambodia*, Statistics Sweden International Consulting Office, Camstat Report 2007:03.

Sandqvist, A., 2007b. *Development of expenditure statistics in Cambodia, II*, Statistics Sweden International Consulting Office, Camstat Report 2007:09.

Skinner, C. J., Holt, D. and Smith T.M.F. (eds), 1989. *Analysis of Complex Survey Data*. Wiley.

Swindale A. and Ohri-Vachaspati, P., 2004. *Measuring Household Food Consumption: A Technical Guide. Washington DC: Food and Nutrition Technical Assistance (FANTA) Project*, Academy for Educational Development (AED).

UNDP, 2011. *Human development report, 2011*, United Nations Development Programme, New York.

UNICEF-Cambodia, 2008. *Cambodia Anthropometric Survey: English Supplement*, UNICEF, Cambodia.

Valliant, R., Dorfman, A. H., and Royall, R. M., 2000. *Finite Population Sampling and Inference: A Prediction Approach*, John Wiley, New York.

WHO Multicentre Growth Reference Study Group, 2006. *WHO Child Growth Standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development*. Geneva: World Health Organization; pp 312.: http://www.who.int/childgrowth/publications/en/

World Bank / IMF, 1999. *Poverty Reduction Strategy papers – Status and Next Steps* (SM/99/267, Rev. 1, (11/19/99), http://www.imf.org/external/np/pdr/prsp/status.htm

World Bank and Cambodia Development Forum 2007. *Cambodia - Sharing Growth: Equity and Development Report 2007*, World Bank and Cambodia Development Forum, xv+201pages+ appended tables, June 2007.

World Food Programme, 2007. *Integrated Food Security and Humanitarian Phase Classification (IPC) Pilot in Cambodia*, Final Report, World Food Programme, 57 pages, April 2007.

You, Y., Rao, J. N. K. and Kovacevic, M., 2003. "Estimating fixed effects and variance components in a random intercept model using survey data", *Statistics Canada International Symposium Series - Proceedings*.

Zhao, Q., 2006. *User Manual for PovMap*, World Bank. http://siteresources.worldbank.org/INTPGI/Resources/342674-1092157888460/Zhao_ManualPovMap.pdf

# APPENDICES

## Appendix A. Auxiliary variables

### A.1 Obtainable or derivable from CSES2009.

| variable name | variable label |
|---|---|
| region | phnom penh, o. urban & o. rural |
| rural | house in rural area |
| hhsize | household size |
| numroom | number of rooms |
| rfree | dwelling is rent free |
| electric | main source of lighting is electricity |
| charcoal | charcoal for cooking |
| lpge | lpg / electric for cooking |
| wall | wall material |
| roof | roof material |
| floor | floor material |
| notoilet | no toilet within premises |
| radio | number of radios owned |
| tv | number of tvs owned |
| phone | number of phones owned |
| cellphone | number of cellphones owned |
| computer | number of computers owned |
| bicycle | number of bicycles owned |
| motorbike | number of motorbikes owned |
| car | number of cars owned |
| boat | number of boats owned |
| tractor | number of tractors owned |
| koyaon | number of koyaons owned |
| bikeonly | household has bicycle(s) but no car/motorbikes |
| h_school | head of household attended school |
| h_senior | head of household over 65 years |
| h_divsep | head of household divorced/separated |
| h_lit | head of household literate |
| h_seced | head of household has some secondary education |
| h_subag | head of household engaged in subsistence agriculture |
| pkids06 | prop of hh aged 0-6 |
| pkids714 | prop of hh aged 7-14 |
| psenior | prop of hh aged 65+ |
| plit | prop of hh literate |
| pseced | prop of hh with secondary education |
| pemp | prop of hh employed |

## A.2 Obtainable or derivable from CAS2008.

| variable name | variable label |
|---|---|
| nch | number of eligible children (0-4 years) in household |
| tmom | number of eligible mothers in household |
| age | age in completed years |
| female | female |
| sub_ag | at least one adult involved in subsistence agriculture |
| educ_primary | proportion of eligible mothers with highest educational attainment primary |
| educ_low_second | proportion of eligible mothers with highest educational attainment low_second |
| educ_uper_sec~d | proportion of eligible mothers with highest educational attainment upper_second |
| educ_higher | proportion of eligible mothers with higher education |
| dsw_spouse | proportion of eligible mothers divorced, widowed or separated |
| school | proportion of eligible mothers attended school |
| electric | household has electricity |
| radio | household has radio |
| tv | household has tv |
| cellphone | household has cellphone |
| bicycle | household has bicycle |
| motorbike | household has motorbike |
| car | household has car |
| boat | household has boat |
| bikeonly | household has bicycle(s) but no car/motorbikes |
| roof_natural | household has natural roof |
| roof_finished | household has finished roof |
| roof_rudim | household has rudimentary roof |

## A.3 Obtainable or derivable from CDHS2010.

| variable name | variable label |
|---|---|
| rel_head | Relationship to head |
| age | Age of household members |
| female | Female |
| nch | Number of eligible children (0-4 years) |
| hhsize | Number of household members |
| electric | Household has electricity |
| radio | Household has radio |
| tv | Household has television |
| bicycle | Household has bicycle/cyclo |
| motorbike | Household has motorcycle/scooter |
| cell | Household has a mobile telephone |
| boat | Household has a boat |
| h_fem | female head of household |
| pkids06 | prop of hh aged 0-6 |
| pkids714 | prop of hh aged 7-14 |
| psenior | prop of hh aged 65+ |
| pwamale | prop of hh males 15-64 |
| pseced | prop of hh with secondary education |
| ck_fwood | Cook with firewood |
| ck_charc | Cook with charcoal |
| notoilet | No toilet |
| dr_public | Drinking water from pipe of public tap |
| dr_tubed | Drinking water from pipe of tube well or borehole |
| h_noschool | Head of household never attended school |
| h_seced | Head of household attended secondary school |
| floor | Main floor material |
| wall | Main wall material |
| roof | Main roof material |
| h_age | age of head of household |
| h_marital | marital status of head of household |

## A.4 Census means (enumeration-area level) from Census2008

| variable name | variable label |
|---|---|
| rural_e | mean rurality |
| radio_e | mean number of radios owned |
| phone_e | mean number of phones owned |
| cellphone_e | mean number of cellphones owned |
| computer_e | mean number of computers owned |
| bicycle_e | mean number of bicycles owned |
| motorbike_e | mean number of motorbikes owned |
| car_e | mean number of cars owned |
| boat_e | mean number of boats owned |
| koyaon_e | mean number of koyaons owned |
| nethome_e | propn with internet at home |
| netout_e | propn accessing internet outside home |
| deaths_e | death rate |
| rfree_e | propn rent free |
| elec_e | propn with electricity |
| charc_e | propn using charcoal for cooking |
| lpge_e | pron using lpg/electric for cooking |
| notoilet_e | propn with no toilet within premises |
| pipew_e | propn piped/tubed water |
| withinw_e | propn with water within premises |
| onerm_e | propn with only one room |
| bikeonly_e | propn with bicycle(s) but no car/motorbikes |
| nhh_e | number of households |
| wallrud_e | propn with rudimentary wall |
| roofrud_e | propn with rudimentary roof |
| floorrud_e | propn with rudimentary floor |
| resplus_e | propn residential+shop/business |
| mtnonkh_e | propn mother-tongue non-khmer |
| regnonb_e | propn religion non-buddhist |
| bovill_e | propn born outside current village |
| hmfovill_e | propn hhead moved from outside current village |
| hmov2_e | propn hhead less 2yrs in current village |
| hmovins_e | propn hhead moved for insecurity/calamity/unemployment |
| hlitfe_e | propn hhead literate in French or English |
| disabled_e | propn disabled |
| hunemp_e | propn hhead unemployed |
| hemp06_e | propn hhead employed 6 months or less in past year |
| subag_e | propn hhead in subsistence agriculture/hunting |
| hownacc_e | propn hhead own-account workers |
| wkabroad_e | propn employed working abroad |
| h_school_e | propn head of household attended school |
| h_senior_e | propn head of household over 65 years |
| h_divsep_e | propn head of household divorced/separated |
| h_lit_e | propn head of household literate |
| h_seced_e | propn head of household has some secondary education |
| h_subag_e | propn head of household engaged in subsistence agriculture |
| pkids06_e | prop of ea aged 0-6 |
| pkids714_e | prop of ea aged 7-14 |
| psenior_e | prop of ea aged 65+ |
| plit_e | prop of ea literate |
| pseced_e | prop of ea with secondary education |
| pemp_e | prop of ea employed |

## A.5 Village (_v) and commune (_c) variables from CDB2009

| variable name | variable label |
|---|---|
| totfam_v | number of families in village |
| totpop_v | population of village |
| kmpsch_v | distance (km) to primary school |
| kmjsch_v | distance (km) to junior sec. school |
| kmssch_v | distance (km) to senior sec. school |
| kmmkt_v | distance (km) to nearest market |
| kmroad_v | distance (km) to year-round road |
| hrsroad_v | time to year-round road by motor vehicle |
| hfem_v | propn hh with female head |
| hfu5_v | % hh headed by mother w/ u5s |
| rland1_v | % hh w/ less than 1ha rice land |
| fland1_v | % hh w/ less than 1ha farm land |
| dispoll_v | % hh suffering disaster/pollution |
| toilet_v | % hh with toilet |
| publand_v | % hh living on public land |
| ucjob_v | % aged 18-60 with uncertain/irregular jobs |
| fucjob_v | % females aged 18-60 with uncertain/irregular jobs |
| immigrant_v | % immigrants |
| emigrant_v | % emigrants |
| hmless_v | % homeless |
| totpop_c | population of commune |
| totfam_c | number of families in commune |
| psch100_c | primary schools per 100 people |
| pcrm100_c | primary school classrooms per 100 people |
| pcls100_c | primary school classes per 100 people |
| lscls100_c | lower secondary school classes per 100 people |
| uscrm100_c | upper secondary school classrooms per 100 people |
| ptch100_c | primary school teachers per 100 people |
| ricepc_c | per capita rice production |
| ricepha_c | rice production per hectare |
| mkt1000_c | markets per 1000 people |
| clin1000_c | health clinics per 1000 people |
| rural_c | rurality of commune |
| flood_c | prone to flooding |
| drought_c | prone to drought |

# Appendix B. Regression results

## B.1 Model for $\log_e$(expenditure) in CSES2009

| n | p | $R^2$ | $\sigma^2_u$ | $\sigma^2_c / \sigma^2_u$ |
|---|---|---|---|---|
| 11949 | 32 | 0.4934 | 0.173 | 0.245 |

where n = sample size, p = number of variables, $R^2$ = coefficient of determination
$\sigma^2_u$ = residual variance, $\sigma^2_c / \sigma^2_u$ = ratio of cluster to total residual variation

| Variable | Coef. | Std. Err. | t | P>t | Label |
|---|---|---|---|---|---|
| pkids06 | -0.1092 | 0.0288 | -3.79 | 0.000 | prop of hh aged 0-6 |
| plit | 0.1036 | 0.0215 | 4.82 | 0.000 | prop of hh literate |
| pseced | 0.0961 | 0.0228 | 4.22 | 0.000 | prop of hh with secondary education |
| car | 0.1928 | 0.0262 | 7.36 | 0.000 | number of cars owned |
| computer | 0.0698 | 0.0282 | 2.47 | 0.014 | number of computers owned |
| electric | 0.0513 | 0.0246 | 2.08 | 0.038 | main source of lighting is electricity |
| phone | 0.1620 | 0.0636 | 2.55 | 0.011 | number of phones owned |
| tv | 0.0516 | 0.0105 | 4.90 | 0.000 | number of tvs owned |
| floor_t | 0.0761 | 0.0295 | 2.58 | 0.010 | floor of tiles |
| floor_c | 0.0224 | 0.0072 | 3.14 | 0.002 | floor of cement,parquet |
| roof_t | 0.0617 | 0.0188 | 3.29 | 0.001 | roof of tiles |
| roof_m | 0.0369 | 0.0152 | 2.43 | 0.015 | roof of metal |
| wall_b | -0.0519 | 0.0134 | -3.86 | 0.000 | walls of bamboo / mixed type |
| boat_e | 0.1439 | 0.0426 | 3.38 | 0.001 | mean number of boats owned |
| cellphone_e | 0.1067 | 0.0292 | 3.65 | 0.000 | mean number of cellphones owned |
| h_lit_e | 0.2889 | 0.1236 | 2.34 | 0.020 | propn hhead literate |
| plit_e | -0.4268 | 0.1445 | -2.95 | 0.003 | prop of ea literate |
| resplus_e | 0.3287 | 0.0977 | 3.37 | 0.001 | propn hh residential+shop/business |
| reg3 | 0.1898 | 0.0411 | 4.62 | 0.000 | rural (outside Phnom Penh) |
| tonlesap | -0.0570 | 0.0191 | -2.98 | 0.003 | Tonlesap ecological zone |
| plnmount | -0.0722 | 0.0260 | -2.77 | 0.006 | Plains/Mountains ecological zone |
| hhsizeXs23 | -0.0441 | 0.0088 | -4.99 | 0.000 | interaction of household size and regions excluding Phnom Penh |
| lnhhszXs23 | -0.2881 | 0.0430 | -6.69 | 0.000 | interaction of log household size and regions excluding Phnom Penh |

| | | | | | |
|---|---|---|---|---|---|
| notolietXs23 | -0.0321 | 0.0154 | -2.08 | 0.038 | interaction of no toilet within premises and regions excluding Phnom Penh |
| cellphone~23 | 0.1389 | 0.0090 | 15.47 | 0.000 | interaction of cellphone and regions excluding Phnom Penh |
| rfreeXs23 | -0.0709 | 0.0293 | -2.42 | 0.016 | interaction of rfree and regions excluding Phnom Penh |
| floor_sXs23 | 0.3363 | 0.1032 | 3.26 | 0.001 | interaction of floor made out of stone and regions excluding Phnom Penh |
| roof_cXS3 | 0.2328 | 0.0432 | 5.38 | 0.000 | interaction of roof made out of concrete, other and regions excluding Phnom Penh |
| num-rooomXS2 | 0.1412 | 0.0157 | 9.00 | 0.000 | interaction of number of rooms and rural |
| num-roomXS3 | 0.0561 | 0.0114 | 4.94 | 0.000 | interaction of number of rooms and rural |
| motor-bikeXS2 | 0.0920 | 0.0180 | 5.11 | 0.000 | interaction of motorbike and urban |
| motor-bikeXS3 | 0.1067 | 0.0102 | 10.46 | 0.000 | interaction of motorbike and rural |
| _cons | 8.7825 | 0.0666 | 131.96 | 0.000 | constant term |

## B.2 Model for height-for-age (stunting) in CAS2008

| n | p | $R^2$ | $\sigma_c^2$ | $\sigma_h^2$ | $\sigma_e^2$ |
|---|---|---|---|---|---|
| 7965 | 26 | 0.203 | 0.0691 | 0.3937 | 1.3937 |

where n = sample size, p = number of variables, $R^2$ = coefficient of determination
$\sigma_c^2$ = cluster-level variance, $\sigma_h^2$ = household-level variance, $\sigma_e^2$ = residual variance

| Variable | Coef. | Std. Err. | t | P>t | Label |
|---|---|---|---|---|---|
| age_1 | -0.9881 | 0.0590 | -16.74 | 0.000 | aged 1 year |
| age_2 | -1.3365 | 0.0556 | -24.03 | 0.000 | aged 2 years |
| age_3 | -1.4311 | 0.0649 | -22.06 | 0.000 | aged 3 years |
| age_4 | -1.5346 | 0.0595 | -25.77 | 0.000 | aged 4 years |
| female | 0.1330 | 0.0368 | 3.62 | 0.000 | female |
| cellphone | 0.2026 | 0.0503 | 4.03 | 0.000 | household has cellphone |
| radio | 0.3471 | 0.0909 | 3.82 | 0.000 | household has radio |
| motorbike | 0.1792 | 0.0476 | 3.77 | 0.000 | household has motorbike |
| roof_natural | -0.1155 | 0.0498 | -2.32 | 0.021 | household has natural roof |
| school | 0.3447 | 0.1235 | 2.79 | 0.005 | prop of eligible mothers attended school |
| educ_primary | -0.2995 | 0.1209 | -2.48 | 0.014 | prop of eligible mothers with highest educ attainment primary |
| educ_low_sec | -0.1724 | 0.1166 | -1.48 | 0.140 | prop of eligible mothers with highest educ attainment low_second |
| dsw_spouse | 0.2033 | 0.0939 | 2.17 | 0.031 | prop of eligible mothers divorced, widowed or separated |
| pkids06_e | -2.2573 | 0.8483 | -2.66 | 0.008 | prop of ea aged 0-6 |
| cellphone_e | 0.3099 | 0.1000 | 3.1 | 0.002 | mean number of cellphones owned |
| motorbike_e | -0.3922 | 0.1703 | -2.3 | 0.022 | mean number of motorbikes owned |
| boat_e | -0.2721 | 0.1106 | -2.46 | 0.014 | mean number of boats owned |
| psenior_e | 3.3011 | 1.3265 | 2.49 | 0.013 | prop of ea aged 65+ |
| bovill_e | 0.2024 | 0.1290 | 1.57 | 0.117 | propn born outside current village |
| region_3 | 0.3734 | 0.1536 | 2.43 | 0.015 | rural (outside Phnom Penh) |
| schoolXS2 | 0.4859 | 0.1600 | 3.04 | 0.002 | interaction of school and other urban |
| cellphoneXS2 | -0.2850 | 0.1304 | -2.19 | 0.029 | interaction of cellphone and other urban |
| radioXS3 | -0.2584 | 0.1009 | -2.56 | 0.011 | interaction of radio and rural |
| _cons | -1.0001 | 0.2049 | -4.88 | 0.000 | constant term |

## B.3 Model for height-for-age (stunting) in CDHS2010

| n | p | $R^2$ | $\sigma_c^2$ | $\sigma_h^2$ | $\sigma_e^2$ |
|---|---|---|---|---|---|
| 3986 | 15 | 0.1680 | 0.0562 | 0.4177 | 1.2527 |

where n = sample size, p = number of variables, $R^2$ = coefficient of determination
$\sigma_c^2$ = cluster-level variance, $\sigma_h^2$ = household-level variance, $\sigma_e^2$ = residual variance

| Variable | Coef. | Std. Err. | t | P>t | Label |
|---|---|---|---|---|---|
| age_1 | -0.9009 | 0.0832 | -10.83 | 0.000 | aged 1 year |
| age_2 | -1.1973 | 0.0795 | -15.06 | 0.000 | aged 2 years |
| age_3 | -1.1971 | 0.0731 | -16.37 | 0.000 | aged 3 years |
| age_4 | -1.2412 | 0.0695 | -17.86 | 0.000 | aged 4 years |
| hhsize | -0.0426 | 0.0136 | -3.12 | 0.002 | number of household members |
| radio | 0.1179 | 0.0525 | 2.25 | 0.025 | household has a radio |
| cell | 0.1248 | 0.0544 | 2.29 | 0.022 | household has a mobile telephone |
| h_seced | 0.1484 | 0.0532 | 2.79 | 0.005 | head of household attended secondary school |
| floor_t | 0.3162 | 0.1113 | 2.84 | 0.005 | tiled floor |
| plit_v | 0.9045 | 0.2690 | 3.36 | 0.001 | prop of village literate |
| regnonb_v | 0.5208 | 0.2602 | 2.00 | 0.046 | propn in village non-buddhist |
| boat_v | 0.2738 | 0.0836 | 3.27 | 0.001 | mean number of boats per hh in village |
| koyaon_v | 0.7981 | 0.3855 | 2.07 | 0.039 | mean number of koyaons per hh in village |
| phone_v | 3.3405 | 1.5933 | 2.10 | 0.036 | mean number of phones per hh in village |
| pseced_v | 0.5252 | 0.3153 | 1.67 | 0.096 | prop of village with secondary education |
| _cons | -1.5334 | 0.1884 | -8.14 | 0.000 | constant tern |

## B.4 Model for weight-for-age (underweight) in CAS2008

| n | p | $R^2$ | $\sigma_c^2$ | $\sigma_h^2$ | $\sigma_e^2$ |
|---|---|---|---|---|---|
| 7965 | 16 | 0.155 | 0.0642 | 0.2791 | 0.8101 |

where n = sample size, p = number of variables, $R^2$ = coefficient of determination
$\sigma_c^2$ = cluster-level variance, $\sigma_h^2$ = household-level variance, $\sigma_e^2$ = residual variance

| Variable | Coef. | Std. Err. | t | P>t | Label |
|---|---|---|---|---|---|
| age1 | -0.6095 | 0.0442 | -13.80 | 0.000 | aged 1 year |
| age2 | -0.8022 | 0.0385 | -20.81 | 0.000 | aged 2 years |
| age3 | -0.8960 | 0.0504 | -17.79 | 0.000 | aged 3 years |
| age4 | -1.0083 | 0.0444 | -22.69 | 0.000 | aged 4 years |
| motorbike | 0.1350 | 0.0373 | 3.62 | 0.000 | household has motorbike |
| radio | 0.0874 | 0.0355 | 2.46 | 0.014 | household has radio |
| cellphone | 0.0804 | 0.0359 | 2.24 | 0.026 | household has cellphone |
| educ_usec | 0.2399 | 0.0943 | 2.54 | 0.011 | prop of eligible mothers with upper sec education |
| school | 0.0797 | 0.0393 | 2.03 | 0.043 | prop of eligible mothers attended school |
| car | 0.1628 | 0.0888 | 1.83 | 0.067 | household has car |
| pkids06_e | -1.1856 | 0.5711 | -2.08 | 0.038 | prop of ea aged 0-6 |
| hmovins_e | 0.2029 | 0.0643 | 3.15 | 0.002 | prop hhead moved for insecurity/ calamity/unemployment |
| mtnonkh_e | 0.2739 | 0.0955 | 2.87 | 0.004 | prop mother-tongue non-khmer |
| h_lit_e | 0.2860 | 0.1194 | 2.40 | 0.017 | propn head of household literate |
| motorbike_e | -0.2871 | 0.1289 | -2.23 | 0.026 | mean number of motorbikes owned |
| cellphone_e | 0.2699 | 0.0632 | 4.27 | 0.000 | mean number of cellphones owned |
| _cons | -0.9870 | 0.1577 | -6.26 | 0.000 | constant term |

## B.5 Model for weight-for-age (underweight) in CDHS2010

| n | p | $R^2$ | $\sigma_c^2$ | $\sigma_h^2$ | $\sigma_e^2$ |
|---|---|---|---|---|---|
| 3985 | 20 | 0.1410 | 0.0111 | 0.2760 | 0.7413 |

where n = sample size, p = number of variables, $R^2$ = coefficient of determination
$\sigma_c^2$ = cluster-level variance, $\sigma_h^2$ = household-level variance, $\sigma_e^2$ = residual variance

| Variable | Coef. | Std. Err. | t | P>t | Label |
|---|---|---|---|---|---|
| age_1 | -0.4360 | 0.0622 | -7.01 | 0.000 | aged 1 year |
| age_2 | -0.5939 | 0.0560 | -10.61 | 0.000 | aged 2 years |
| age_3 | -0.6767 | 0.0598 | -11.32 | 0.000 | aged 3 years |
| age_4 | -0.7799 | 0.0577 | -13.51 | 0.000 | aged 4 years |
| hhsize | -0.0193 | 0.0096 | -2.01 | 0.045 | number of household members |
| h_seced | 0.1513 | 0.0447 | 3.39 | 0.001 | head of household attended secondary school |
| boat | 0.1855 | 0.0725 | 2.56 | 0.011 | household has a boat |
| cell | 0.1387 | 0.0455 | 3.05 | 0.002 | household has a mobile telephone |
| dr_public | 0.2008 | 0.0820 | 2.45 | 0.015 | drinking water from pipe or public tap |
| ck_charc | 0.1465 | 0.0757 | 1.94 | 0.053 | cook with charcoal |
| floor_t | 0.2537 | 0.0876 | 2.90 | 0.004 | floor type tile |
| floor_o | -0.8250 | 0.2520 | -3.27 | 0.001 | floor type other |
| roof_4 | 0.3647 | 0.1594 | 2.29 | 0.023 | roof type concrete |
| region_2 | 0.1565 | 0.1053 | 1.49 | 0.138 | urban (outside Phnom Penh) |
| region_3 | 0.1686 | 0.1142 | 1.48 | 0.141 | rural (outside Phnom Penh) |
| plit_v | 0.6242 | 0.1586 | 3.94 | 0.000 | prop of village literate |
| koyaon_v | 0.9078 | 0.3286 | 2.76 | 0.006 | mean number of koyaons per hh in village |
| bovill_v | 0.3944 | 0.0958 | 4.11 | 0.000 | prop born outside current village |
| h_senior_v | 1.4560 | 0.5040 | 2.89 | 0.004 | prop head of hh in village over 65 years |
| regnonb_v | 0.2574 | 0.1439 | 1.79 | 0.074 | propn in village non-buddhist |
| _cons | -1.8614 | 0.1994 | -9.34 | 0.000 | constant term |

# Appendix C. Small-area estimates

P0 = poverty incidence, se0 = standard error of P0, P1 = poverty gap, se1 = standard error of P1, P2 = poverty severity, se2 = standard error of P2
S2 = prevalence of stunting, seS2 = standard error of S2, S3 = prevalence of severe stunting, seS3 = standard error of S3
U2 = prevalence of underweight, seU2 = standard error of U2, U3 = prevalence of severe underweight, seU3 = standard error of U3

## Province-level measures of poverty, stunting and underweight

| | | Poverty measures | | | | | | | Stunting measures | | | | | Underweight measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| province code | province | population (whole) | P0 | se0 | P1 | se1 | P2 | se2 | population (children under five) | S2 | seS2 | S3 | seS3 | U2 | seU2 | U3 | seU3 |
| 1 | Banteay Meanchey | 663519 | 0.2578 | 0.0106 | 0.0707 | 0.0037 | 0.0254 | 0.0016 | 69812 | 0.3968 | 0.0061 | 0.1738 | 0.0041 | 0.2952 | 0.0059 | 0.0769 | 0.0025 |
| 2 | Battambang | 1005369 | 0.2679 | 0.0097 | 0.0757 | 0.0035 | 0.0277 | 0.0015 | 105428 | 0.4023 | 0.0051 | 0.1764 | 0.0037 | 0.2895 | 0.0057 | 0.0726 | 0.0025 |
| 3 | Kampong Cham | 1656067 | 0.2178 | 0.0073 | 0.0581 | 0.0025 | 0.0201 | 0.0010 | 175511 | 0.4206 | 0.0053 | 0.1888 | 0.0039 | 0.3241 | 0.0054 | 0.0867 | 0.0025 |
| 4 | Kampong Chhnang | 464914 | 0.2785 | 0.0141 | 0.0777 | 0.0050 | 0.0280 | 0.0022 | 50841 | 0.4228 | 0.0064 | 0.1862 | 0.0048 | 0.3317 | 0.0055 | 0.0888 | 0.0026 |
| 5 | Kampong Speu | 708091 | 0.2612 | 0.0159 | 0.0721 | 0.0054 | 0.0257 | 0.0023 | 77162 | 0.4235 | 0.0057 | 0.1905 | 0.0042 | 0.3274 | 0.0065 | 0.0872 | 0.0030 |
| 6 | Kampong Thom | 622533 | 0.2903 | 0.0124 | 0.0822 | 0.0046 | 0.0299 | 0.0021 | 70880 | 0.4487 | 0.0061 | 0.2095 | 0.0047 | 0.3555 | 0.0064 | 0.1018 | 0.0033 |
| 7 | Kampot | 580099 | 0.2303 | 0.0089 | 0.0618 | 0.0030 | 0.0215 | 0.0012 | 59053 | 0.4169 | 0.0054 | 0.1859 | 0.0039 | 0.3314 | 0.0056 | 0.0899 | 0.0027 |
| 8 | Kandal | 1233036 | 0.1637 | 0.0068 | 0.0421 | 0.0021 | 0.0142 | 0.0008 | 120975 | 0.3799 | 0.0061 | 0.1624 | 0.0041 | 0.2881 | 0.0049 | 0.0713 | 0.0021 |
| 9 | Koh Kong | 114600 | 0.1908 | 0.0132 | 0.0506 | 0.0044 | 0.0177 | 0.0019 | 12977 | 0.4044 | 0.0105 | 0.1793 | 0.0069 | 0.3004 | 0.0072 | 0.0791 | 0.0033 |
| 10 | Kratie | 312964 | 0.3077 | 0.0172 | 0.0895 | 0.0065 | 0.0335 | 0.0030 | 38224 | 0.4437 | 0.0061 | 0.2073 | 0.0048 | 0.3297 | 0.0069 | 0.0876 | 0.0033 |
| 11 | Mondul Kiri | 59432 | 0.2865 | 0.0247 | 0.0830 | 0.0097 | 0.0309 | 0.0046 | 8428 | 0.4770 | 0.0141 | 0.2292 | 0.0114 | 0.3058 | 0.0156 | 0.0797 | 0.0073 |
| 12 | Phnom Penh | 1246589 | 0.1159 | 0.0111 | 0.0240 | 0.0029 | 0.0073 | 0.0010 | 91152 | 0.3119 | 0.0182 | 0.1212 | 0.0106 | 0.1838 | 0.0141 | 0.0375 | 0.0049 |
| 13 | Preah Vihear | 166552 | 0.3552 | 0.0203 | 0.1052 | 0.0079 | 0.0398 | 0.0037 | 21846 | 0.4739 | 0.0090 | 0.2293 | 0.0073 | 0.3404 | 0.0104 | 0.0968 | 0.0053 |
| 14 | Prey Veng | 936021 | 0.2072 | 0.0080 | 0.0539 | 0.0025 | 0.0182 | 0.0010 | 97005 | 0.4223 | 0.0050 | 0.1876 | 0.0036 | 0.3295 | 0.0061 | 0.0885 | 0.0029 |
| 15 | Pursat | 391959 | 0.2890 | 0.0125 | 0.0819 | 0.0047 | 0.0299 | 0.0021 | 42659 | 0.4295 | 0.0057 | 0.1946 | 0.0042 | 0.3257 | 0.0058 | 0.0873 | 0.0028 |
| 16 | Ratanak Kiri | 147120 | 0.3329 | 0.0215 | 0.1018 | 0.0089 | 0.0399 | 0.0044 | 19889 | 0.4994 | 0.0138 | 0.2485 | 0.0114 | 0.3345 | 0.0177 | 0.0910 | 0.0087 |
| 17 | Siem Reap | 874711 | 0.2789 | 0.0120 | 0.0794 | 0.0045 | 0.0292 | 0.0020 | 102644 | 0.4416 | 0.0066 | 0.2048 | 0.0051 | 0.3484 | 0.0066 | 0.1002 | 0.0035 |
| 18 | Preah Sihanouk | 215432 | 0.1734 | 0.0099 | 0.0453 | 0.0033 | 0.0157 | 0.0014 | 21261 | 0.3735 | 0.0091 | 0.1582 | 0.0059 | 0.2730 | 0.0062 | 0.0657 | 0.0026 |
| 19 | Stung Treng | 107046 | 0.3144 | 0.0203 | 0.0916 | 0.0078 | 0.0342 | 0.0036 | 14074 | 0.4819 | 0.0103 | 0.2361 | 0.0084 | 0.3616 | 0.0099 | 0.1057 | 0.0050 |
| 20 | Svay Rieng | 476759 | 0.1843 | 0.0082 | 0.0472 | 0.0025 | 0.0157 | 0.0010 | 47581 | 0.4117 | 0.0070 | 0.1789 | 0.0048 | 0.3310 | 0.0065 | 0.0886 | 0.0031 |
| 21 | Takeo | 836980 | 0.1931 | 0.0076 | 0.0502 | 0.0024 | 0.0169 | 0.0010 | 83705 | 0.4103 | 0.0057 | 0.1807 | 0.0040 | 0.3246 | 0.0055 | 0.0860 | 0.0025 |
| 22 | Oddar Meanchey | 180958 | 0.3171 | 0.0177 | 0.0917 | 0.0064 | 0.0342 | 0.0029 | 21302 | 0.4440 | 0.0092 | 0.2067 | 0.0068 | 0.2958 | 0.0104 | 0.0759 | 0.0044 |
| 23 | Kep | 35317 | 0.2450 | 0.0250 | 0.0668 | 0.0085 | 0.0237 | 0.0036 | 3800 | 0.4365 | 0.0111 | 0.1985 | 0.0083 | 0.3355 | 0.0112 | 0.0902 | 0.0055 |
| 24 | Pailin | 68150 | 0.2142 | 0.0185 | 0.0595 | 0.0063 | 0.0216 | 0.0027 | 7839 | 0.3958 | 0.0104 | 0.1724 | 0.0072 | 0.2453 | 0.0110 | 0.0547 | 0.0041 |

## District-level measures of poverty, stunting and underweight

| | | | | Poverty measures | | | | | | | Stunting measures | | | | | Underweight measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| province code | province | district code | district | population (whole) | P0 | se0 | P1 | se1 | P2 | se2 | population (child under five) | S2 | seS2 | S3 | seS3 | U2 | seU2 | U3 | seU3 |
| 1 | Banteay Meanchey | 2 | Mongkol Borei | 137671 | 0.2404 | 0.0141 | 0.0656 | 0.0047 | 0.0233 | 0.0020 | 14432 | 0.3925 | 0.0072 | 0.1694 | 0.0053 | 0.2951 | 0.0079 | 0.0753 | 0.0034 |
| | | 3 | Phnum Srok | 46051 | 0.2941 | 0.0237 | 0.0814 | 0.0084 | 0.0288 | 0.0038 | 4650 | 0.4217 | 0.0115 | 0.1884 | 0.0080 | 0.3289 | 0.0118 | 0.0896 | 0.0055 |
| | | 4 | Preah Netr Preah | 85056 | 0.2798 | 0.0192 | 0.0772 | 0.0067 | 0.0273 | 0.0029 | 9359 | 0.4266 | 0.0090 | 0.1925 | 0.0065 | 0.3385 | 0.0079 | 0.0941 | 0.0041 |
| | | 5 | Ou Chrov | 46259 | 0.2419 | 0.0183 | 0.0649 | 0.0060 | 0.0224 | 0.0026 | 5187 | 0.4049 | 0.0105 | 0.1767 | 0.0074 | 0.3077 | 0.0108 | 0.0783 | 0.0050 |
| | | 6 | Serei Saophoan | 88132 | 0.2264 | 0.0157 | 0.0620 | 0.0058 | 0.0229 | 0.0027 | 8205 | 0.3470 | 0.0094 | 0.1398 | 0.0055 | 0.2527 | 0.0082 | 0.0579 | 0.0033 |
| | | 7 | Thma Puok | 60992 | 0.2557 | 0.0207 | 0.0694 | 0.0072 | 0.0242 | 0.0032 | 6118 | 0.4139 | 0.0121 | 0.1851 | 0.0079 | 0.3202 | 0.0110 | 0.0867 | 0.0051 |
| | | 8 | Svay Chek | 55190 | 0.2606 | 0.0183 | 0.0697 | 0.0063 | 0.0240 | 0.0028 | 5592 | 0.4186 | 0.0102 | 0.1862 | 0.0069 | 0.3254 | 0.0106 | 0.0890 | 0.0049 |
| | | 9 | Malai | 41236 | 0.2889 | 0.0201 | 0.0812 | 0.0074 | 0.0296 | 0.0035 | 5227 | 0.4072 | 0.0126 | 0.1782 | 0.0093 | 0.2735 | 0.0113 | 0.0658 | 0.0048 |
| | | 10 | Paoy Paet | 102932 | 0.2677 | 0.0158 | 0.0747 | 0.0060 | 0.0282 | 0.0029 | 11042 | 0.3724 | 0.0151 | 0.1593 | 0.0101 | 0.2382 | 0.0115 | 0.0529 | 0.0044 |
| 2 | Battambang | 1 | Banan | 91128 | 0.2773 | 0.0154 | 0.0782 | 0.0056 | 0.0283 | 0.0025 | 9450 | 0.4202 | 0.0085 | 0.1881 | 0.0061 | 0.3070 | 0.0080 | 0.0793 | 0.0036 |
| | | 2 | Thma Koul | 111487 | 0.3099 | 0.0153 | 0.0894 | 0.0058 | 0.0339 | 0.0027 | 11209 | 0.3925 | 0.0089 | 0.1697 | 0.0064 | 0.3017 | 0.0083 | 0.0778 | 0.0038 |
| | | 3 | Battambang | 137738 | 0.1747 | 0.0126 | 0.0460 | 0.0043 | 0.0166 | 0.0019 | 11251 | 0.2990 | 0.0097 | 0.1123 | 0.0054 | 0.2091 | 0.0072 | 0.0426 | 0.0024 |
| | | 4 | Bavel | 99548 | 0.2921 | 0.0166 | 0.0829 | 0.0059 | 0.0301 | 0.0026 | 10750 | 0.4079 | 0.0093 | 0.1795 | 0.0069 | 0.3040 | 0.0083 | 0.0780 | 0.0037 |
| | | 5 | Aek Phnum | 66743 | 0.2100 | 0.0183 | 0.0564 | 0.0059 | 0.0195 | 0.0025 | 6550 | 0.4069 | 0.0131 | 0.1711 | 0.0100 | 0.3029 | 0.0079 | 0.0767 | 0.0038 |
| | | 6 | Moung Ruessei | 110629 | 0.3032 | 0.0138 | 0.0872 | 0.0053 | 0.0321 | 0.0025 | 12270 | 0.4160 | 0.0084 | 0.1844 | 0.0057 | 0.3206 | 0.0079 | 0.0832 | 0.0037 |
| | | 7 | Rotonak Mondol | 40419 | 0.2901 | 0.0245 | 0.0835 | 0.0095 | 0.0307 | 0.0045 | 4712 | 0.4234 | 0.0109 | 0.1912 | 0.0079 | 0.2792 | 0.0122 | 0.0670 | 0.0051 |
| | | 8 | Sangkae | 109414 | 0.2967 | 0.0168 | 0.0848 | 0.0061 | 0.0315 | 0.0028 | 10815 | 0.3988 | 0.0087 | 0.1719 | 0.0061 | 0.3023 | 0.0077 | 0.0772 | 0.0035 |
| | | 9 | Samlout | 38806 | 0.2836 | 0.0230 | 0.0806 | 0.0084 | 0.0294 | 0.0038 | 4429 | 0.4231 | 0.0117 | 0.1855 | 0.0084 | 0.2788 | 0.0135 | 0.0684 | 0.0054 |
| | | 10 | Sampov Lun | 34827 | 0.2152 | 0.0227 | 0.0592 | 0.0076 | 0.0210 | 0.0033 | 4012 | 0.4020 | 0.0158 | 0.1771 | 0.0109 | 0.2704 | 0.0135 | 0.0642 | 0.0056 |
| | | 11 | Phnom Proek | 49373 | 0.2238 | 0.0216 | 0.0618 | 0.0072 | 0.0220 | 0.0030 | 5996 | 0.3997 | 0.0144 | 0.1752 | 0.0101 | 0.2703 | 0.0119 | 0.0639 | 0.0050 |
| | | 12 | Kamrieng | 50185 | 0.2429 | 0.0206 | 0.0678 | 0.0073 | 0.0243 | 0.0033 | 5849 | 0.4040 | 0.0131 | 0.1763 | 0.0089 | 0.2672 | 0.0115 | 0.0627 | 0.0049 |
| | | 13 | Koas Krala | 25532 | 0.3566 | 0.0279 | 0.1052 | 0.0112 | 0.0396 | 0.0055 | 3039 | 0.4373 | 0.0116 | 0.1963 | 0.0089 | 0.2969 | 0.0123 | 0.0730 | 0.0052 |
| | | 14 | Rukhakkiri | 39540 | 0.3497 | 0.0252 | 0.1019 | 0.0098 | 0.0378 | 0.0045 | 5096 | 0.4736 | 0.0124 | 0.2247 | 0.0095 | 0.3133 | 0.0142 | 0.0811 | 0.0065 |

| | | | | Poverty measures | | | | | | | Stunting measures | | | | | Underweight measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| province code | province | district code | district | population (whole) | P0 | se0 | P1 | se1 | P2 | se2 | population (child under five) | S2 | seS2 | S3 | seS3 | U2 | seU2 | U3 | seU3 |
| 3 | Kampong Cham | 1 | Batheay | 101689 | 0.2443 | 0.0137 | 0.0655 | 0.0048 | 0.0226 | 0.0021 | 10881 | 0.4371 | 0.0083 | 0.1997 | 0.0061 | 0.3546 | 0.0083 | 0.0995 | 0.0043 |
| | | 2 | Chamkar Leu | 109768 | 0.2143 | 0.0109 | 0.0586 | 0.0038 | 0.0207 | 0.0017 | 11976 | 0.4236 | 0.0080 | 0.1900 | 0.0058 | 0.3305 | 0.0070 | 0.0879 | 0.0034 |
| | | 3 | Cheung Prey | 82866 | 0.2621 | 0.0169 | 0.0708 | 0.0058 | 0.0249 | 0.0025 | 8927 | 0.4268 | 0.0079 | 0.1922 | 0.0060 | 0.3459 | 0.0089 | 0.0949 | 0.0044 |
| | | 4 | Dambae | 79488 | 0.2567 | 0.0188 | 0.0704 | 0.0066 | 0.0248 | 0.0029 | 10005 | 0.4673 | 0.0107 | 0.2208 | 0.0084 | 0.3501 | 0.0102 | 0.0989 | 0.0051 |
| | | 5 | Kampong Cham | 43395 | 0.1326 | 0.0163 | 0.0329 | 0.0052 | 0.0115 | 0.0023 | 3650 | 0.2838 | 0.0139 | 0.1065 | 0.0080 | 0.1973 | 0.0108 | 0.0398 | 0.0037 |
| | | 6 | Kampong Siem | 98771 | 0.1887 | 0.0132 | 0.0489 | 0.0042 | 0.0164 | 0.0017 | 10780 | 0.3909 | 0.0080 | 0.1679 | 0.0055 | 0.3096 | 0.0073 | 0.0789 | 0.0036 |
| | | 7 | Kang Meas | 89013 | 0.2169 | 0.0140 | 0.0574 | 0.0048 | 0.0196 | 0.0021 | 8966 | 0.4116 | 0.0090 | 0.1803 | 0.0062 | 0.3275 | 0.0075 | 0.0862 | 0.0037 |
| | | 8 | Kaoh Soutin | 60080 | 0.1848 | 0.0148 | 0.0478 | 0.0048 | 0.0160 | 0.0020 | 5617 | 0.3816 | 0.0110 | 0.1599 | 0.0071 | 0.2956 | 0.0089 | 0.0738 | 0.0041 |
| | | 9 | Krouch Chhmar | 92492 | 0.2221 | 0.0130 | 0.0593 | 0.0046 | 0.0204 | 0.0020 | 8700 | 0.4068 | 0.0098 | 0.1787 | 0.0070 | 0.3060 | 0.0098 | 0.0790 | 0.0041 |
| | | 10 | Memot | 146642 | 0.2289 | 0.0139 | 0.0622 | 0.0049 | 0.0218 | 0.0022 | 16704 | 0.4748 | 0.0109 | 0.2252 | 0.0087 | 0.3464 | 0.0073 | 0.0966 | 0.0039 |
| | | 11 | Ou Reang Ov | 79891 | 0.1894 | 0.0124 | 0.0491 | 0.0041 | 0.0164 | 0.0017 | 8569 | 0.4080 | 0.0087 | 0.1794 | 0.0064 | 0.3190 | 0.0076 | 0.0838 | 0.0036 |
| | | 12 | Ponhea Kraek | 132603 | 0.2084 | 0.0115 | 0.0552 | 0.0037 | 0.0189 | 0.0016 | 13551 | 0.4309 | 0.0101 | 0.1964 | 0.0076 | 0.3314 | 0.0077 | 0.0896 | 0.0037 |
| | | 13 | Prey Chhor | 123323 | 0.2350 | 0.0124 | 0.0627 | 0.0043 | 0.0217 | 0.0019 | 12535 | 0.4072 | 0.0069 | 0.1775 | 0.0050 | 0.3241 | 0.0068 | 0.0857 | 0.0035 |
| | | 14 | Srei Santhor | 85461 | 0.2011 | 0.0126 | 0.0526 | 0.0041 | 0.0178 | 0.0017 | 8832 | 0.4074 | 0.0092 | 0.1773 | 0.0065 | 0.3234 | 0.0082 | 0.0855 | 0.0039 |
| | | 15 | Stueng Trang | 118019 | 0.2281 | 0.0139 | 0.0619 | 0.0047 | 0.0216 | 0.0021 | 13950 | 0.4381 | 0.0076 | 0.2016 | 0.0059 | 0.3297 | 0.0069 | 0.0897 | 0.0034 |
| | | 16 | Tboung Khmum | 177279 | 0.2174 | 0.0124 | 0.0578 | 0.0041 | 0.0200 | 0.0018 | 18410 | 0.4121 | 0.0073 | 0.1836 | 0.0053 | 0.3129 | 0.0078 | 0.0817 | 0.0034 |
| | | 17 | Suong | 35287 | 0.1933 | 0.0207 | 0.0506 | 0.0074 | 0.0180 | 0.0034 | 3458 | 0.3705 | 0.0120 | 0.1601 | 0.0091 | 0.2681 | 0.0096 | 0.0651 | 0.0042 |
| 4 | Kampong Chhnang | 1 | Baribour | 55744 | 0.2583 | 0.0203 | 0.0718 | 0.0070 | 0.0256 | 0.0030 | 6183 | 0.4206 | 0.0114 | 0.1858 | 0.0083 | 0.3263 | 0.0081 | 0.0854 | 0.0044 |
| | | 2 | Chol Kiri | 31629 | 0.2970 | 0.0385 | 0.0835 | 0.0133 | 0.0301 | 0.0057 | 4074 | 0.4389 | 0.0196 | 0.1888 | 0.0142 | 0.3502 | 0.0128 | 0.0923 | 0.0062 |
| | | 3 | Kampong Chhnang | 41194 | 0.2423 | 0.0258 | 0.0652 | 0.0093 | 0.0242 | 0.0042 | 3462 | 0.3462 | 0.0135 | 0.1369 | 0.0087 | 0.2372 | 0.0122 | 0.0529 | 0.0048 |
| | | 4 | Kampong Leaeng | 44165 | 0.3179 | 0.0309 | 0.0905 | 0.0115 | 0.0330 | 0.0052 | 5692 | 0.4656 | 0.0143 | 0.2121 | 0.0104 | 0.3656 | 0.0102 | 0.1040 | 0.0051 |
| | | 5 | Kampong Tralach | 80130 | 0.2809 | 0.0173 | 0.0787 | 0.0064 | 0.0283 | 0.0029 | 8254 | 0.4200 | 0.0088 | 0.1866 | 0.0063 | 0.3286 | 0.0079 | 0.0886 | 0.0037 |
| | | 6 | Rolea B'ier | 91585 | 0.2381 | 0.0170 | 0.0647 | 0.0058 | 0.0227 | 0.0025 | 9796 | 0.4021 | 0.0068 | 0.1742 | 0.0050 | 0.3172 | 0.0074 | 0.0810 | 0.0035 |
| | | 7 | Sameakki Mean Chey | 64058 | 0.3026 | 0.0190 | 0.0847 | 0.0070 | 0.0304 | 0.0032 | 7172 | 0.4462 | 0.0081 | 0.2041 | 0.0065 | 0.3498 | 0.0082 | 0.0967 | 0.0041 |
| | | 8 | Tuek Phos | 56409 | 0.3185 | 0.0238 | 0.0913 | 0.0089 | 0.0335 | 0.0040 | 6208 | 0.4450 | 0.0089 | 0.2055 | 0.0072 | 0.3509 | 0.0097 | 0.0977 | 0.0049 |

| | | | | Poverty measures | | | | | | | Stunting measures | | | | | Underweight measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| province code | province | district code | district | population (whole) | P0 | se0 | P1 | se1 | P2 | se2 | population (child under five) | S2 | seS2 | S3 | seS3 | U2 | seU2 | U3 | seU3 |
| 5 | Kampong Speu | 1 | Basedth | 118865 | 0.2812 | 0.0200 | 0.0779 | 0.0071 | 0.0277 | 0.0032 | 12992 | 0.4415 | 0.0072 | 0.2028 | 0.0053 | 0.3543 | 0.0085 | 0.0987 | 0.0040 |
| | | 2 | Chbar Mon | 45802 | 0.2371 | 0.0200 | 0.0638 | 0.0074 | 0.0237 | 0.0035 | 4047 | 0.3368 | 0.0136 | 0.1363 | 0.0084 | 0.2363 | 0.0105 | 0.0519 | 0.0042 |
| | | 3 | Kong Pisei | 111888 | 0.2332 | 0.0194 | 0.0626 | 0.0064 | 0.0216 | 0.0026 | 11068 | 0.4068 | 0.0080 | 0.1771 | 0.0057 | 0.3217 | 0.0079 | 0.0845 | 0.0037 |
| | | 4 | Aoral | 29676 | 0.3345 | 0.0284 | 0.0967 | 0.0109 | 0.0356 | 0.0051 | 4389 | 0.4953 | 0.0133 | 0.2418 | 0.0109 | 0.3652 | 0.0133 | 0.1051 | 0.0072 |
| | | 5 | Odongk | 117780 | 0.2522 | 0.0185 | 0.0692 | 0.0063 | 0.0245 | 0.0027 | 13082 | 0.4157 | 0.0076 | 0.1833 | 0.0054 | 0.3215 | 0.0072 | 0.0839 | 0.0033 |
| | | 6 | Phnum Sruoch | 94144 | 0.2855 | 0.0182 | 0.0810 | 0.0063 | 0.0294 | 0.0028 | 11021 | 0.4409 | 0.0075 | 0.2035 | 0.0059 | 0.3402 | 0.0085 | 0.0928 | 0.0042 |
| | | 7 | Samraong Tong | 139399 | 0.2341 | 0.0180 | 0.0635 | 0.0062 | 0.0222 | 0.0026 | 14190 | 0.3981 | 0.0077 | 0.1729 | 0.0052 | 0.3090 | 0.0070 | 0.0788 | 0.0033 |
| | | 8 | Thpong | 50537 | 0.3058 | 0.0259 | 0.0861 | 0.0095 | 0.0311 | 0.0043 | 6373 | 0.4611 | 0.0103 | 0.2156 | 0.0078 | 0.3498 | 0.0098 | 0.0963 | 0.0050 |
| 6 | Kampong Thom | 1 | Baray | 165874 | 0.2617 | 0.0138 | 0.0725 | 0.0047 | 0.0258 | 0.0021 | 18147 | 0.4280 | 0.0067 | 0.1942 | 0.0051 | 0.3456 | 0.0069 | 0.0960 | 0.0035 |
| | | 2 | Kampong Svay | 87927 | 0.3064 | 0.0191 | 0.0879 | 0.0074 | 0.0323 | 0.0035 | 10384 | 0.4502 | 0.0083 | 0.2071 | 0.0062 | 0.3506 | 0.0078 | 0.0976 | 0.0040 |
| | | 3 | Stueng Saen | 51974 | 0.2243 | 0.0180 | 0.0609 | 0.0068 | 0.0221 | 0.0032 | 4992 | 0.3633 | 0.0098 | 0.1516 | 0.0069 | 0.2687 | 0.0080 | 0.0654 | 0.0039 |
| | | 4 | Prasat Ballangk | 46737 | 0.3856 | 0.0263 | 0.1149 | 0.0108 | 0.0434 | 0.0052 | 5889 | 0.4967 | 0.0122 | 0.2431 | 0.0095 | 0.3969 | 0.0129 | 0.1214 | 0.0075 |
| | | 5 | Prasat Sambour | 39166 | 0.2964 | 0.0244 | 0.0833 | 0.0085 | 0.0300 | 0.0038 | 4399 | 0.4511 | 0.0103 | 0.2100 | 0.0074 | 0.3634 | 0.0095 | 0.1057 | 0.0051 |
| | | 6 | Sandan | 48538 | 0.3233 | 0.0234 | 0.0931 | 0.0089 | 0.0342 | 0.0041 | 6238 | 0.4814 | 0.0101 | 0.2346 | 0.0087 | 0.3850 | 0.0105 | 0.1158 | 0.0062 |
| | | 7 | Santuk | 79453 | 0.3022 | 0.0175 | 0.0859 | 0.0065 | 0.0312 | 0.0029 | 9441 | 0.4495 | 0.0085 | 0.2091 | 0.0066 | 0.3507 | 0.0083 | 0.0982 | 0.0043 |
| | | 8 | Stoung | 102864 | 0.2856 | 0.0167 | 0.0806 | 0.0062 | 0.0291 | 0.0028 | 11390 | 0.4684 | 0.0089 | 0.2221 | 0.0071 | 0.3792 | 0.0089 | 0.1116 | 0.0049 |
| 7 | Kampot | 1 | Angkor Chey | 72109 | 0.1863 | 0.0138 | 0.0479 | 0.0045 | 0.0159 | 0.0019 | 7019 | 0.3889 | 0.0094 | 0.1658 | 0.0060 | 0.3135 | 0.0086 | 0.0803 | 0.0043 |
| | | 2 | Banteay Meas | 82629 | 0.2069 | 0.0138 | 0.0541 | 0.0045 | 0.0183 | 0.0019 | 7989 | 0.4075 | 0.0087 | 0.1781 | 0.0057 | 0.3303 | 0.0079 | 0.0889 | 0.0036 |
| | | 3 | Chhuk | 99297 | 0.2259 | 0.0151 | 0.0605 | 0.0051 | 0.0209 | 0.0021 | 10756 | 0.4331 | 0.0083 | 0.1966 | 0.0064 | 0.3376 | 0.0081 | 0.0922 | 0.0040 |
| | | 4 | Chum Kiri | 46255 | 0.2563 | 0.0213 | 0.0689 | 0.0072 | 0.0238 | 0.0031 | 5098 | 0.4411 | 0.0103 | 0.2017 | 0.0076 | 0.3578 | 0.0096 | 0.1019 | 0.0052 |
| | | 5 | Dang Tong | 53793 | 0.2490 | 0.0220 | 0.0671 | 0.0072 | 0.0233 | 0.0030 | 5905 | 0.4293 | 0.0088 | 0.1924 | 0.0066 | 0.3452 | 0.0088 | 0.0954 | 0.0045 |
| | | 6 | Kampong Trach | 85166 | 0.2541 | 0.0158 | 0.0689 | 0.0055 | 0.0242 | 0.0024 | 8223 | 0.4342 | 0.0079 | 0.1959 | 0.0058 | 0.3463 | 0.0077 | 0.0962 | 0.0042 |
| | | 7 | Tuek Chhou | 105685 | 0.2580 | 0.0149 | 0.0712 | 0.0051 | 0.0254 | 0.0023 | 11294 | 0.4204 | 0.0076 | 0.1885 | 0.0059 | 0.3288 | 0.0075 | 0.0875 | 0.0039 |
| | | 8 | Kampot | 35165 | 0.1848 | 0.0196 | 0.0497 | 0.0074 | 0.0182 | 0.0035 | 2769 | 0.3137 | 0.0144 | 0.1231 | 0.0083 | 0.2243 | 0.0103 | 0.0499 | 0.0043 |

| | | | | Poverty measures | | | | | | | Stunting measures | | | | | Underweight measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| province code | province | district code | district | population (whole) | P0 | se0 | P1 | se1 | P2 | se2 | population (child under five) | S2 | seS2 | S3 | seS3 | U2 | seU2 | U3 | seU3 |
| 8 | Kandal | 1 | Kandal Stueng | 99064 | 0.1373 | 0.0092 | 0.0345 | 0.0028 | 0.0113 | 0.0011 | 9951 | 0.3667 | 0.0084 | 0.1524 | 0.0054 | 0.2888 | 0.0071 | 0.0701 | 0.0034 |
| | | 2 | Kien Svay | 167711 | 0.1727 | 0.0122 | 0.0446 | 0.0039 | 0.0154 | 0.0016 | 15594 | 0.3644 | 0.0083 | 0.1530 | 0.0055 | 0.2736 | 0.0072 | 0.0659 | 0.0028 |
| | | 3 | Khsach Kandal | 115625 | 0.1816 | 0.0116 | 0.0472 | 0.0038 | 0.0158 | 0.0016 | 12473 | 0.3925 | 0.0070 | 0.1682 | 0.0050 | 0.3102 | 0.0076 | 0.0794 | 0.0033 |
| | | 4 | Kaoh Thum | 139897 | 0.1917 | 0.0121 | 0.0500 | 0.0039 | 0.0169 | 0.0016 | 12297 | 0.4182 | 0.0105 | 0.1863 | 0.0076 | 0.3056 | 0.0076 | 0.0772 | 0.0035 |
| | | 5 | Leuk Daek | 53813 | 0.2157 | 0.0184 | 0.0578 | 0.0060 | 0.0200 | 0.0025 | 5108 | 0.3985 | 0.0110 | 0.1726 | 0.0077 | 0.3090 | 0.0094 | 0.0797 | 0.0042 |
| | | 6 | Lvea Aem | 65966 | 0.1672 | 0.0151 | 0.0426 | 0.0047 | 0.0141 | 0.0019 | 7248 | 0.3915 | 0.0106 | 0.1657 | 0.0072 | 0.2968 | 0.0076 | 0.0726 | 0.0034 |
| | | 7 | Mukh Kampul | 89412 | 0.1537 | 0.0123 | 0.0398 | 0.0040 | 0.0133 | 0.0017 | 9114 | 0.3765 | 0.0093 | 0.1605 | 0.0061 | 0.2909 | 0.0072 | 0.0716 | 0.0031 |
| | | 8 | Angk Snuol | 119575 | 0.1208 | 0.0085 | 0.0295 | 0.0025 | 0.0096 | 0.0010 | 12984 | 0.3560 | 0.0086 | 0.1444 | 0.0056 | 0.2752 | 0.0065 | 0.0659 | 0.0029 |
| | | 9 | Popnhea Lueu | 113673 | 0.1677 | 0.0121 | 0.0433 | 0.0038 | 0.0146 | 0.0015 | 11714 | 0.3838 | 0.0078 | 0.1637 | 0.0051 | 0.2902 | 0.0064 | 0.0714 | 0.0029 |
| | | 10 | S'ang | 192371 | 0.1686 | 0.0099 | 0.0440 | 0.0032 | 0.0149 | 0.0013 | 18170 | 0.3923 | 0.0081 | 0.1707 | 0.0055 | 0.3007 | 0.0064 | 0.0756 | 0.0028 |
| | | 11 | Ta Khmau | 75929 | 0.1206 | 0.0129 | 0.0295 | 0.0041 | 0.0102 | 0.0018 | 6322 | 0.2932 | 0.0133 | 0.1105 | 0.0074 | 0.1882 | 0.0084 | 0.0364 | 0.0028 |
| 9 | Koh Kong | 1 | Botum Sakor | 19148 | 0.1948 | 0.0265 | 0.0515 | 0.0088 | 0.0175 | 0.0037 | 2416 | 0.4213 | 0.0179 | 0.1863 | 0.0122 | 0.3305 | 0.0131 | 0.0923 | 0.0074 |
| | | 2 | Kiri Sakor | 6928 | 0.1482 | 0.0400 | 0.0370 | 0.0127 | 0.0119 | 0.0052 | 790 | 0.3893 | 0.0276 | 0.1657 | 0.0182 | 0.2904 | 0.0182 | 0.0702 | 0.0087 |
| | | 3 | Kaoh Kong | 7285 | 0.1502 | 0.0393 | 0.0383 | 0.0122 | 0.0127 | 0.0050 | 810 | 0.4158 | 0.0274 | 0.1788 | 0.0191 | 0.2870 | 0.0180 | 0.0729 | 0.0084 |
| | | 4 | Khemarak Phuomin | 25462 | 0.1636 | 0.0187 | 0.0416 | 0.0061 | 0.0147 | 0.0028 | 2407 | 0.3570 | 0.0153 | 0.1485 | 0.0093 | 0.2311 | 0.0125 | 0.0504 | 0.0052 |
| | | 5 | Mondol Seima | 14465 | 0.0893 | 0.0209 | 0.0216 | 0.0062 | 0.0067 | 0.0024 | 1629 | 0.3663 | 0.0231 | 0.1543 | 0.0158 | 0.2477 | 0.0164 | 0.0560 | 0.0067 |
| | | 6 | Srae Ambel | 36364 | 0.2600 | 0.0234 | 0.0719 | 0.0087 | 0.0262 | 0.0041 | 4261 | 0.4258 | 0.0103 | 0.1963 | 0.0077 | 0.3402 | 0.0098 | 0.0944 | 0.0053 |
| | | 7 | Thma Bang | 4948 | 0.2225 | 0.0399 | 0.0585 | 0.0137 | 0.0198 | 0.0060 | 664 | 0.4736 | 0.0179 | 0.2267 | 0.0162 | 0.3406 | 0.0193 | 0.0965 | 0.0108 |
| 10 | Kratie | 1 | Chhloung | 52171 | 0.2801 | 0.0223 | 0.0795 | 0.0082 | 0.0292 | 0.0037 | 5902 | 0.4184 | 0.0095 | 0.1898 | 0.0068 | 0.2972 | 0.0105 | 0.0767 | 0.0046 |
| | | 2 | Kracheh | 28966 | 0.2617 | 0.0304 | 0.0740 | 0.0118 | 0.0285 | 0.0057 | 2876 | 0.3381 | 0.0138 | 0.1377 | 0.0089 | 0.2364 | 0.0119 | 0.0525 | 0.0046 |
| | | 3 | Preaek Prasab | 58964 | 0.2655 | 0.0229 | 0.0736 | 0.0085 | 0.0262 | 0.0039 | 6425 | 0.4131 | 0.0087 | 0.1821 | 0.0068 | 0.3145 | 0.0095 | 0.0805 | 0.0043 |
| | | 4 | Sambour | 54960 | 0.3692 | 0.0249 | 0.1120 | 0.0098 | 0.0432 | 0.0047 | 7901 | 0.4834 | 0.0116 | 0.2352 | 0.0089 | 0.3664 | 0.0108 | 0.1036 | 0.0056 |
| | | 5 | Snuol | 60392 | 0.2952 | 0.0234 | 0.0855 | 0.0088 | 0.0316 | 0.0040 | 7902 | 0.4690 | 0.0109 | 0.2227 | 0.0087 | 0.3260 | 0.0103 | 0.0863 | 0.0049 |
| | | 6 | Chitr Borie | 57511 | 0.3536 | 0.0248 | 0.1056 | 0.0098 | 0.0400 | 0.0047 | 7218 | 0.4694 | 0.0093 | 0.2240 | 0.0076 | 0.3565 | 0.0099 | 0.0992 | 0.0051 |

| | | | | Poverty measures | | | | | | | Stunting measures | | | | | Underweight measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| province code | province | district code | district | population (whole) | P0 | se0 | P1 | se1 | P2 | se2 | population (child under five) | S2 | seS2 | S3 | seS3 | U2 | seU2 | U3 | seU3 |
| 11 | Mondul Kiri | 1 | Kaev Seima | 18856 | 0.3151 | 0.0328 | 0.0934 | 0.0129 | 0.0355 | 0.0063 | 2745 | 0.4871 | 0.0165 | 0.2359 | 0.0139 | 0.3023 | 0.0165 | 0.0785 | 0.0081 |
| | | 2 | Kaoh Nheaek | 15091 | 0.3581 | 0.0392 | 0.1062 | 0.0164 | 0.0402 | 0.0082 | 2274 | 0.4979 | 0.0161 | 0.2412 | 0.0126 | 0.3508 | 0.0187 | 0.0964 | 0.0090 |
| | | 3 | Ou Reang | 3879 | 0.2826 | 0.0571 | 0.0807 | 0.0210 | 0.0297 | 0.0098 | 518 | 0.4756 | 0.0324 | 0.2239 | 0.0267 | 0.3018 | 0.0283 | 0.0763 | 0.0134 |
| | | 4 | Pech Chreada | 10146 | 0.2767 | 0.0452 | 0.0770 | 0.0154 | 0.0275 | 0.0067 | 1451 | 0.4894 | 0.0236 | 0.2378 | 0.0173 | 0.2988 | 0.0235 | 0.0760 | 0.0111 |
| | | 5 | Saen Monourom | 11460 | 0.1550 | 0.0315 | 0.0414 | 0.0106 | 0.0147 | 0.0047 | 1440 | 0.4065 | 0.0176 | 0.1828 | 0.0143 | 0.2587 | 0.0172 | 0.0620 | 0.0079 |
| 12 | Phnom Penh | 1 | Chamkar Mon | 171773 | 0.0646 | 0.0107 | 0.0125 | 0.0024 | 0.0036 | 0.0008 | 10203 | 0.2412 | 0.0187 | 0.0838 | 0.0094 | 0.1473 | 0.0121 | 0.0261 | 0.0037 |
| | | 2 | Doun Penh | 116657 | 0.0828 | 0.0130 | 0.0165 | 0.0033 | 0.0049 | 0.0012 | 7012 | 0.2559 | 0.0183 | 0.0920 | 0.0094 | 0.1575 | 0.0141 | 0.0277 | 0.0046 |
| | | 3 | Prampir Meakkakra | 90038 | 0.0855 | 0.0152 | 0.0169 | 0.0037 | 0.0050 | 0.0013 | 4933 | 0.2347 | 0.0182 | 0.0802 | 0.0094 | 0.1387 | 0.0139 | 0.0198 | 0.0039 |
| | | 4 | Tuol Kouk | 163447 | 0.0737 | 0.0132 | 0.0145 | 0.0031 | 0.0042 | 0.0011 | 10179 | 0.2568 | 0.0178 | 0.0899 | 0.0090 | 0.1467 | 0.0125 | 0.0252 | 0.0038 |
| | | 5 | Dangkao | 177702 | 0.1773 | 0.0167 | 0.0386 | 0.0046 | 0.0122 | 0.0018 | 16141 | 0.3787 | 0.0212 | 0.1590 | 0.0139 | 0.2272 | 0.0173 | 0.0530 | 0.0069 |
| | | 6 | Mean Chey | 250799 | 0.1377 | 0.0137 | 0.0287 | 0.0036 | 0.0088 | 0.0013 | 19674 | 0.3414 | 0.0207 | 0.1376 | 0.0129 | 0.1953 | 0.0154 | 0.0404 | 0.0055 |
| | | 7 | Ruessei Kaev | 162842 | 0.1425 | 0.0162 | 0.0297 | 0.0045 | 0.0091 | 0.0017 | 13572 | 0.3348 | 0.0200 | 0.1334 | 0.0121 | 0.2065 | 0.0163 | 0.0434 | 0.0061 |
| | | 8 | Saen Sokh | 113331 | 0.1299 | 0.0172 | 0.0272 | 0.0045 | 0.0084 | 0.0016 | 9438 | 0.3262 | 0.0202 | 0.1283 | 0.0124 | 0.1774 | 0.0135 | 0.0361 | 0.0047 |
| 13 | Preah Vihear | 1 | Chey Saen | 20527 | 0.4344 | 0.0402 | 0.1320 | 0.0167 | 0.0507 | 0.0083 | 2852 | 0.5034 | 0.0166 | 0.2500 | 0.0131 | 0.3495 | 0.0187 | 0.0999 | 0.0096 |
| | | 2 | Chhaeb | 16602 | 0.4315 | 0.0421 | 0.1348 | 0.0176 | 0.0531 | 0.0089 | 2664 | 0.5011 | 0.0170 | 0.2471 | 0.0139 | 0.3813 | 0.0168 | 0.1130 | 0.0090 |
| | | 3 | Choam Khsant | 24433 | 0.3171 | 0.0298 | 0.0918 | 0.0114 | 0.0339 | 0.0053 | 3312 | 0.4597 | 0.0157 | 0.2188 | 0.0121 | 0.3345 | 0.0166 | 0.0948 | 0.0083 |
| | | 4 | Kuleaen | 23736 | 0.3347 | 0.0386 | 0.0977 | 0.0146 | 0.0363 | 0.0067 | 2896 | 0.4859 | 0.0148 | 0.2357 | 0.0124 | 0.3709 | 0.0154 | 0.1095 | 0.0092 |
| | | 5 | Rovieng | 35218 | 0.3712 | 0.0276 | 0.1102 | 0.0111 | 0.0416 | 0.0055 | 4649 | 0.4869 | 0.0111 | 0.2385 | 0.0095 | 0.3731 | 0.0121 | 0.1065 | 0.0067 |
| | | 6 | Sangkom Thmei | 17098 | 0.3679 | 0.0368 | 0.1074 | 0.0144 | 0.0400 | 0.0068 | 2022 | 0.4670 | 0.0137 | 0.2234 | 0.0111 | 0.3650 | 0.0142 | 0.1043 | 0.0073 |
| | | 7 | Tbaeng Mean Chey | 9067 | 0.3984 | 0.0536 | 0.1204 | 0.0222 | 0.0462 | 0.0111 | 1236 | 0.4867 | 0.0190 | 0.2367 | 0.0155 | 0.3516 | 0.0201 | 0.0963 | 0.0100 |
| | | 8 | Preah Vihear | 19871 | 0.2217 | 0.0254 | 0.0608 | 0.0093 | 0.0222 | 0.0044 | 2215 | 0.3888 | 0.0133 | 0.1679 | 0.0103 | 0.2478 | 0.0118 | 0.0560 | 0.0051 |

| | | | | Poverty measures | | | | | | | Stunting measures | | | | | Underweight measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| province code | province | district code | district | population (whole) | P0 | se0 | P1 | se1 | P2 | se2 | population (child under five) | S2 | seS2 | S3 | seS3 | U2 | seU2 | U3 | seU3 |
| 14 | Prey Veng | 1 | Ba Phnum | 72038 | 0.1962 | 0.0137 | 0.0505 | 0.0044 | 0.0168 | 0.0018 | 7338 | 0.4104 | 0.0081 | 0.1802 | 0.0054 | 0.3264 | 0.0090 | 0.0852 | 0.0044 |
| | | 2 | Kamchay Mear | 72985 | 0.1989 | 0.0138 | 0.0510 | 0.0045 | 0.0169 | 0.0019 | 7091 | 0.4174 | 0.0080 | 0.1838 | 0.0059 | 0.3313 | 0.0087 | 0.0891 | 0.0043 |
| | | 3 | Kampong Trabaek | 107574 | 0.2212 | 0.0115 | 0.0583 | 0.0039 | 0.0198 | 0.0017 | 12124 | 0.4272 | 0.0070 | 0.1910 | 0.0052 | 0.3340 | 0.0080 | 0.0894 | 0.0040 |
| | | 4 | Kanhchriech | 54415 | 0.1852 | 0.0144 | 0.0476 | 0.0046 | 0.0158 | 0.0019 | 5734 | 0.4103 | 0.0091 | 0.1783 | 0.0065 | 0.3270 | 0.0093 | 0.0858 | 0.0043 |
| | | 5 | Me Sang | 89310 | 0.2036 | 0.0123 | 0.0523 | 0.0039 | 0.0173 | 0.0016 | 9415 | 0.4319 | 0.0076 | 0.1929 | 0.0056 | 0.3426 | 0.0081 | 0.0938 | 0.0040 |
| | | 6 | Peam Chor | 66977 | 0.2298 | 0.0185 | 0.0604 | 0.0058 | 0.0205 | 0.0024 | 6886 | 0.4409 | 0.0091 | 0.1960 | 0.0066 | 0.3278 | 0.0081 | 0.0871 | 0.0038 |
| | | 7 | Peam Ro | 59990 | 0.2093 | 0.0154 | 0.0556 | 0.0052 | 0.0194 | 0.0023 | 5777 | 0.3949 | 0.0089 | 0.1701 | 0.0060 | 0.3003 | 0.0074 | 0.0754 | 0.0039 |
| | | 8 | Pea Reang | 106256 | 0.1907 | 0.0129 | 0.0486 | 0.0040 | 0.0160 | 0.0016 | 10790 | 0.4151 | 0.0076 | 0.1832 | 0.0054 | 0.3279 | 0.0079 | 0.0868 | 0.0039 |
| | | 9 | Preah Sdach | 109631 | 0.2612 | 0.0134 | 0.0711 | 0.0048 | 0.0249 | 0.0022 | 12220 | 0.4414 | 0.0070 | 0.2016 | 0.0051 | 0.3453 | 0.0076 | 0.0952 | 0.0038 |
| | | 10 | Prey Veng | 22482 | 0.1398 | 0.0188 | 0.0347 | 0.0058 | 0.0116 | 0.0024 | 1828 | 0.3475 | 0.0124 | 0.1435 | 0.0096 | 0.2625 | 0.0108 | 0.0628 | 0.0052 |
| | | 11 | Kampong Leav | 28951 | 0.1753 | 0.0190 | 0.0441 | 0.0059 | 0.0143 | 0.0025 | 2994 | 0.4249 | 0.0121 | 0.1849 | 0.0090 | 0.3210 | 0.0117 | 0.0832 | 0.0059 |
| | | 12 | Sithor Kandal | 55283 | 0.1916 | 0.0168 | 0.0490 | 0.0051 | 0.0162 | 0.0020 | 5507 | 0.4147 | 0.0103 | 0.1817 | 0.0074 | 0.3225 | 0.0107 | 0.0838 | 0.0049 |
| | | 13 | Svay Antor | 90129 | 0.1950 | 0.0132 | 0.0499 | 0.0042 | 0.0165 | 0.0017 | 9301 | 0.4214 | 0.0070 | 0.1871 | 0.0054 | 0.3390 | 0.0082 | 0.0926 | 0.0040 |
| 15 | Pursat | 1 | Bakan | 124176 | 0.2948 | 0.0162 | 0.0829 | 0.0060 | 0.0299 | 0.0027 | 13833 | 0.4327 | 0.0065 | 0.1957 | 0.0049 | 0.3324 | 0.0070 | 0.0889 | 0.0034 |
| | | 2 | Kandieng | 57545 | 0.3064 | 0.0195 | 0.0875 | 0.0076 | 0.0321 | 0.0036 | 5893 | 0.4435 | 0.0092 | 0.2022 | 0.0069 | 0.3366 | 0.0081 | 0.0912 | 0.0038 |
| | | 3 | Krakor | 81138 | 0.2949 | 0.0197 | 0.0843 | 0.0073 | 0.0309 | 0.0034 | 9168 | 0.4352 | 0.0093 | 0.1968 | 0.0068 | 0.3367 | 0.0083 | 0.0914 | 0.0041 |
| | | 4 | Phnum Kravanh | 58754 | 0.3030 | 0.0200 | 0.0863 | 0.0075 | 0.0315 | 0.0035 | 6702 | 0.4395 | 0.0094 | 0.2014 | 0.0070 | 0.3366 | 0.0088 | 0.0911 | 0.0046 |
| | | 5 | Pursat | 57434 | 0.2405 | 0.0160 | 0.0678 | 0.0056 | 0.0251 | 0.0026 | 5398 | 0.3715 | 0.0090 | 0.1589 | 0.0057 | 0.2746 | 0.0077 | 0.0674 | 0.0036 |
| | | 6 | Veal Veaeng | 12912 | 0.2715 | 0.0429 | 0.0761 | 0.0151 | 0.0273 | 0.0067 | 1665 | 0.4544 | 0.0169 | 0.2104 | 0.0128 | 0.2926 | 0.0165 | 0.0718 | 0.0076 |
| 16 | Ratanak Kiri | 1 | Andoung Meas | 10057 | 0.4846 | 0.0534 | 0.1667 | 0.0264 | 0.0717 | 0.0148 | 1460 | 0.5428 | 0.0233 | 0.2823 | 0.0201 | 0.3837 | 0.0286 | 0.1117 | 0.0152 |
| | | 2 | Ban Lung | 27319 | 0.1759 | 0.0232 | 0.0455 | 0.0074 | 0.0159 | 0.0032 | 3176 | 0.4035 | 0.0154 | 0.1797 | 0.0107 | 0.2407 | 0.0117 | 0.0546 | 0.0051 |
| | | 3 | Bar Kaev | 19751 | 0.3107 | 0.0341 | 0.0918 | 0.0132 | 0.0346 | 0.0062 | 2510 | 0.5053 | 0.0192 | 0.2536 | 0.0165 | 0.3428 | 0.0237 | 0.0963 | 0.0121 |
| | | 4 | Koun Mom | 15257 | 0.3117 | 0.0375 | 0.0894 | 0.0138 | 0.0328 | 0.0063 | 2136 | 0.4901 | 0.0173 | 0.2399 | 0.0140 | 0.3395 | 0.0163 | 0.0934 | 0.0083 |
| | | 5 | Lumphat | 18480 | 0.3131 | 0.0385 | 0.0905 | 0.0146 | 0.0334 | 0.0068 | 2845 | 0.5179 | 0.0167 | 0.2590 | 0.0143 | 0.3623 | 0.0179 | 0.0981 | 0.0093 |
| | | 6 | Ou Chum | 17835 | 0.3993 | 0.0432 | 0.1267 | 0.0182 | 0.0510 | 0.0092 | 2449 | 0.5212 | 0.0227 | 0.2626 | 0.0186 | 0.3374 | 0.0277 | 0.0923 | 0.0131 |
| | | 7 | Ou Ya Dav | 16257 | 0.3624 | 0.0392 | 0.1106 | 0.0172 | 0.0431 | 0.0090 | 2156 | 0.5265 | 0.0226 | 0.2685 | 0.0193 | 0.3593 | 0.0261 | 0.1017 | 0.0132 |
| | | 8 | Ta Veaeng | 5749 | 0.5095 | 0.0570 | 0.1763 | 0.0263 | 0.0761 | 0.0143 | 753 | 0.5266 | 0.0244 | 0.2658 | 0.0203 | 0.3417 | 0.0301 | 0.0922 | 0.0157 |
| | | 9 | Veun Sai | 16415 | 0.4073 | 0.0421 | 0.1302 | 0.0194 | 0.0528 | 0.0103 | 2404 | 0.5358 | 0.0179 | 0.2714 | 0.0157 | 0.3911 | 0.0228 | 0.1128 | 0.0117 |

| | | | | Poverty measures | | | | | | | Stunting measures | | | | | Underweight measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| province code | province | district code | district | population (whole) | P0 | se0 | P1 | se1 | P2 | se2 | population (child under five) | S2 | seS2 | S3 | seS3 | U2 | seU2 | U3 | seU3 |
| 17 | Siem Reap | 1 | Angkor Chum | 53369 | 0.3466 | 0.0242 | 0.1000 | 0.0092 | 0.0368 | 0.0042 | 6310 | 0.4804 | 0.0119 | 0.2308 | 0.0088 | 0.4106 | 0.0122 | 0.1287 | 0.0072 |
| | | 2 | Angkor Thum | 23960 | 0.3727 | 0.0373 | 0.1109 | 0.0152 | 0.0420 | 0.0074 | 3330 | 0.5002 | 0.0136 | 0.2486 | 0.0120 | 0.4305 | 0.0154 | 0.1392 | 0.0089 |
| | | 3 | Banteay Srei | 39924 | 0.2916 | 0.0248 | 0.0830 | 0.0095 | 0.0303 | 0.0045 | 4972 | 0.4729 | 0.0128 | 0.2258 | 0.0106 | 0.3776 | 0.0128 | 0.1120 | 0.0069 |
| | | 4 | Chi Kraeng | 124400 | 0.3272 | 0.0175 | 0.0945 | 0.0065 | 0.0348 | 0.0030 | 14627 | 0.4700 | 0.0089 | 0.2239 | 0.0071 | 0.3780 | 0.0081 | 0.1116 | 0.0044 |
| | | 6 | Kralanh | 57103 | 0.3084 | 0.0230 | 0.0875 | 0.0083 | 0.0320 | 0.0037 | 6185 | 0.4681 | 0.0096 | 0.2212 | 0.0076 | 0.3870 | 0.0100 | 0.1181 | 0.0058 |
| | | 7 | Puok | 111187 | 0.3046 | 0.0173 | 0.0882 | 0.0067 | 0.0326 | 0.0032 | 12873 | 0.4415 | 0.0081 | 0.2046 | 0.0061 | 0.3685 | 0.0087 | 0.1087 | 0.0048 |
| | | 9 | Prasat Bakong | 60249 | 0.2331 | 0.0215 | 0.0637 | 0.0071 | 0.0224 | 0.0030 | 6993 | 0.4329 | 0.0098 | 0.1952 | 0.0072 | 0.3491 | 0.0091 | 0.0968 | 0.0045 |
| | | 10 | Siem Reap | 220746 | 0.1804 | 0.0113 | 0.0490 | 0.0039 | 0.0181 | 0.0018 | 24042 | 0.3642 | 0.0095 | 0.1519 | 0.0062 | 0.2619 | 0.0075 | 0.0628 | 0.0030 |
| | | 11 | Soutr Nikom | 97383 | 0.2861 | 0.0182 | 0.0809 | 0.0070 | 0.0294 | 0.0032 | 10997 | 0.4424 | 0.0084 | 0.2034 | 0.0062 | 0.3510 | 0.0076 | 0.0987 | 0.0040 |
| | | 12 | Srei Snam | 30420 | 0.3763 | 0.0288 | 0.1109 | 0.0120 | 0.0416 | 0.0060 | 4028 | 0.4798 | 0.0120 | 0.2297 | 0.0095 | 0.3999 | 0.0121 | 0.1230 | 0.0066 |
| | | 13 | Svay Leu | 24848 | 0.3481 | 0.0329 | 0.1019 | 0.0125 | 0.0380 | 0.0059 | 3905 | 0.4938 | 0.0144 | 0.2430 | 0.0118 | 0.3703 | 0.0134 | 0.1075 | 0.0074 |
| | | 14 | Varin | 31122 | 0.3500 | 0.0296 | 0.1020 | 0.0112 | 0.0379 | 0.0052 | 4382 | 0.4923 | 0.0144 | 0.2389 | 0.0120 | 0.3883 | 0.0126 | 0.1179 | 0.0066 |
| 18 | Preah Sihanouk | 1 | Preah Sihanouk | 87467 | 0.1309 | 0.0141 | 0.0319 | 0.0045 | 0.0110 | 0.0019 | 7620 | 0.3166 | 0.0142 | 0.1224 | 0.0083 | 0.2080 | 0.0097 | 0.0423 | 0.0033 |
| | | 2 | Prey Nob | 91650 | 0.2174 | 0.0155 | 0.0590 | 0.0053 | 0.0206 | 0.0023 | 9627 | 0.4076 | 0.0106 | 0.1782 | 0.0073 | 0.3208 | 0.0077 | 0.0829 | 0.0036 |
| | | 3 | Stueng Hav | 19915 | 0.1395 | 0.0215 | 0.0364 | 0.0071 | 0.0123 | 0.0030 | 2108 | 0.3888 | 0.0188 | 0.1682 | 0.0130 | 0.2686 | 0.0145 | 0.0619 | 0.0063 |
| | | 4 | Kampong Seila | 16400 | 0.1948 | 0.0283 | 0.0517 | 0.0093 | 0.0177 | 0.0039 | 1906 | 0.4077 | 0.0146 | 0.1801 | 0.0108 | 0.3030 | 0.0141 | 0.0786 | 0.0069 |
| 19 | Stung Treng | 1 | Sesan | 16678 | 0.3160 | 0.0389 | 0.0902 | 0.0139 | 0.0329 | 0.0063 | 2181 | 0.5033 | 0.0168 | 0.2509 | 0.0136 | 0.3621 | 0.0158 | 0.1019 | 0.0081 |
| | | 2 | Siem Bouk | 14370 | 0.3067 | 0.0381 | 0.0859 | 0.0141 | 0.0308 | 0.0065 | 1867 | 0.4720 | 0.0151 | 0.2186 | 0.0119 | 0.3349 | 0.0136 | 0.0888 | 0.0064 |
| | | 3 | Siem Pang | 18214 | 0.3927 | 0.0421 | 0.1197 | 0.0167 | 0.0462 | 0.0081 | 2750 | 0.5356 | 0.0165 | 0.2745 | 0.0141 | 0.4308 | 0.0184 | 0.1398 | 0.0106 |
| | | 4 | Stueng Traeng | 27564 | 0.1957 | 0.0233 | 0.0525 | 0.0084 | 0.0189 | 0.0039 | 2789 | 0.3696 | 0.0134 | 0.1572 | 0.0090 | 0.2532 | 0.0109 | 0.0584 | 0.0049 |
| | | 5 | Thala Barivat | 30220 | 0.3784 | 0.0321 | 0.1137 | 0.0127 | 0.0434 | 0.0062 | 4487 | 0.5088 | 0.0131 | 0.2544 | 0.0111 | 0.4027 | 0.0124 | 0.1255 | 0.0071 |
| 20 | Svay Rieng | 1 | Chantrea | 24722 | 0.2085 | 0.0213 | 0.0548 | 0.0074 | 0.0186 | 0.0033 | 2444 | 0.4180 | 0.0133 | 0.1779 | 0.0092 | 0.3229 | 0.0115 | 0.0833 | 0.0056 |
| | | 2 | Kampong Rou | 57363 | 0.1901 | 0.0140 | 0.0487 | 0.0046 | 0.0161 | 0.0019 | 5406 | 0.4144 | 0.0101 | 0.1804 | 0.0071 | 0.3374 | 0.0104 | 0.0892 | 0.0052 |
| | | 3 | Rumduol | 46554 | 0.1911 | 0.0145 | 0.0487 | 0.0046 | 0.0160 | 0.0019 | 4686 | 0.4183 | 0.0103 | 0.1828 | 0.0076 | 0.3432 | 0.0108 | 0.0922 | 0.0053 |
| | | 4 | Romeas Haek | 108314 | 0.2048 | 0.0123 | 0.0526 | 0.0040 | 0.0174 | 0.0016 | 10882 | 0.4283 | 0.0085 | 0.1900 | 0.0060 | 0.3479 | 0.0078 | 0.0962 | 0.0039 |
| | | 5 | Svay Chrum | 119270 | 0.1981 | 0.0121 | 0.0512 | 0.0037 | 0.0171 | 0.0015 | 13128 | 0.4247 | 0.0076 | 0.1891 | 0.0053 | 0.3354 | 0.0070 | 0.0902 | 0.0034 |
| | | 6 | Svay Rieng | 38898 | 0.1207 | 0.0120 | 0.0298 | 0.0038 | 0.0098 | 0.0016 | 3256 | 0.3441 | 0.0123 | 0.1396 | 0.0082 | 0.2559 | 0.0089 | 0.0603 | 0.0041 |
| | | 7 | Svay Teab | 45758 | 0.1840 | 0.0181 | 0.0470 | 0.0057 | 0.0155 | 0.0024 | 4469 | 0.4072 | 0.0098 | 0.1756 | 0.0072 | 0.3280 | 0.0099 | 0.0853 | 0.0051 |
| | | 8 | Bavet | 35880 | 0.1106 | 0.0160 | 0.0276 | 0.0050 | 0.0089 | 0.0020 | 3310 | 0.3696 | 0.0139 | 0.1519 | 0.0092 | 0.2818 | 0.0104 | 0.0677 | 0.0046 |

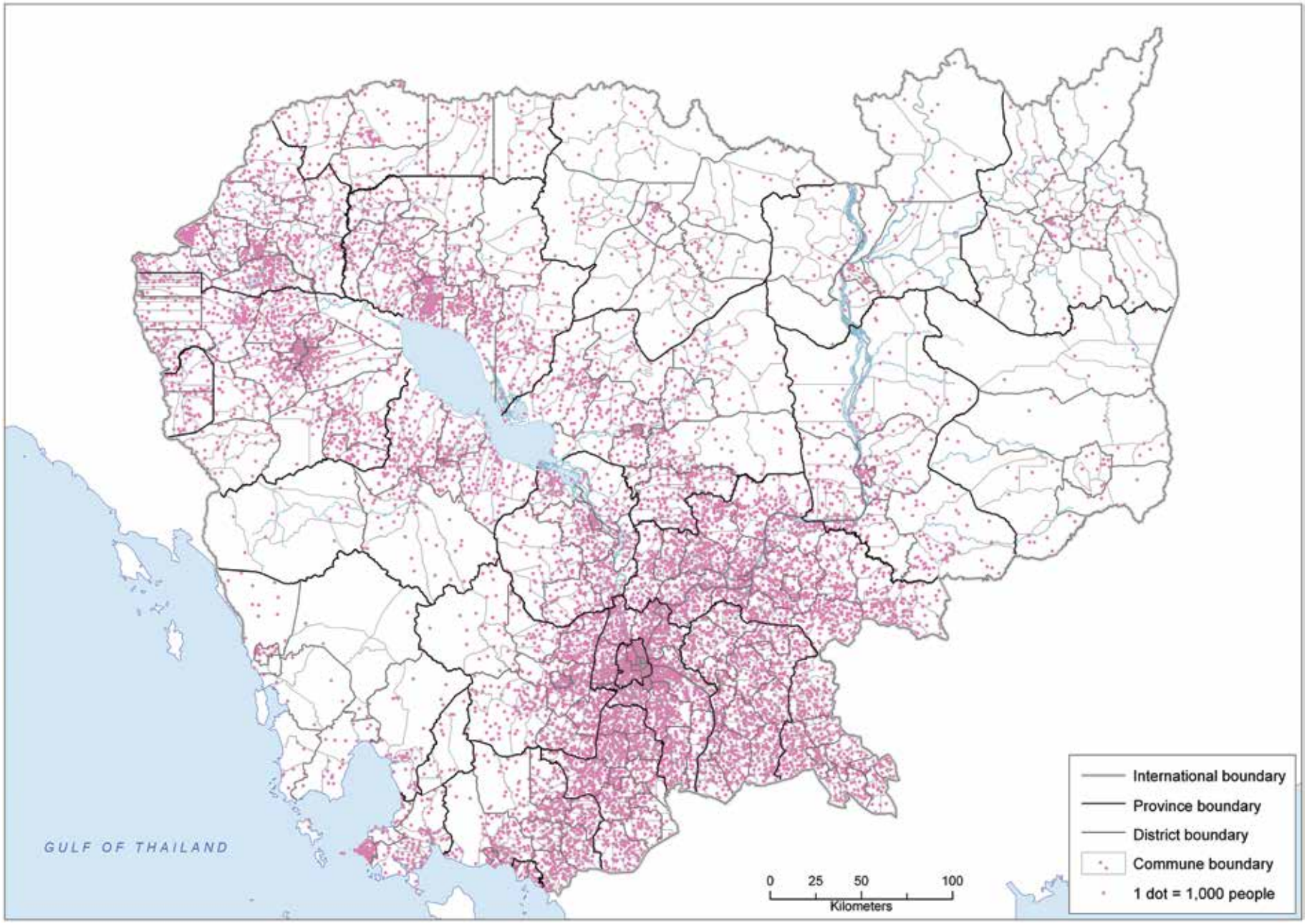
| | | | | Poverty measures | | | | | | | Stunting measures | | | | | Underweight measures | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| province code | province | district code | district | population (whole) | P0 | se0 | P1 | se1 | P2 | se2 | population (child under five) | S2 | seS2 | S3 | seS3 | U2 | seU2 | U3 | seU3 |
| 21 | Takeo | 1 | Angkor Borei | 45934 | 0.2010 | 0.0214 | 0.0519 | 0.0067 | 0.0173 | 0.0027 | 4465 | 0.4258 | 0.0114 | 0.1889 | 0.0084 | 0.3204 | 0.0099 | 0.0824 | 0.0045 |
| | | 2 | Bati | 129872 | 0.1813 | 0.0101 | 0.0471 | 0.0033 | 0.0158 | 0.0014 | 13100 | 0.4040 | 0.0078 | 0.1754 | 0.0055 | 0.3222 | 0.0071 | 0.0851 | 0.0033 |
| | | 3 | Borei Cholsar | 25695 | 0.2163 | 0.0248 | 0.0567 | 0.0082 | 0.0192 | 0.0035 | 2791 | 0.4283 | 0.0149 | 0.1874 | 0.0108 | 0.3209 | 0.0116 | 0.0812 | 0.0055 |
| | | 4 | Kiri Vong | 96796 | 0.1973 | 0.0127 | 0.0517 | 0.0041 | 0.0175 | 0.0017 | 9060 | 0.4229 | 0.0088 | 0.1881 | 0.0063 | 0.3300 | 0.0081 | 0.0873 | 0.0038 |
| | | 5 | Kaoh Andaet | 47739 | 0.2273 | 0.0173 | 0.0605 | 0.0059 | 0.0208 | 0.0026 | 4816 | 0.4147 | 0.0102 | 0.1816 | 0.0073 | 0.3264 | 0.0095 | 0.0872 | 0.0045 |
| | | 6 | Prey Kabbas | 94759 | 0.1688 | 0.0128 | 0.0430 | 0.0038 | 0.0142 | 0.0015 | 9681 | 0.3973 | 0.0076 | 0.1703 | 0.0055 | 0.3135 | 0.0071 | 0.0811 | 0.0036 |
| | | 7 | Samraong | 107137 | 0.2028 | 0.0118 | 0.0527 | 0.0040 | 0.0177 | 0.0017 | 11471 | 0.4136 | 0.0072 | 0.1831 | 0.0049 | 0.3315 | 0.0072 | 0.0888 | 0.0037 |
| | | 8 | Doun Kaev | 39605 | 0.1543 | 0.0153 | 0.0395 | 0.0051 | 0.0134 | 0.0022 | 3381 | 0.3583 | 0.0099 | 0.1496 | 0.0068 | 0.2805 | 0.0085 | 0.0683 | 0.0042 |
| | | 9 | Tram Kak | 151013 | 0.1923 | 0.0101 | 0.0500 | 0.0033 | 0.0168 | 0.0014 | 15769 | 0.4104 | 0.0067 | 0.1802 | 0.0047 | 0.3321 | 0.0070 | 0.0888 | 0.0032 |
| | | 10 | Treang | 98430 | 0.2075 | 0.0129 | 0.0540 | 0.0043 | 0.0182 | 0.0018 | 9171 | 0.4112 | 0.0080 | 0.1798 | 0.0056 | 0.3319 | 0.0077 | 0.0877 | 0.0036 |
| 22 | Oddar Meanchey | 1 | Anlong Veaeng | 37617 | 0.2713 | 0.0261 | 0.0778 | 0.0092 | 0.0287 | 0.0042 | 4794 | 0.4238 | 0.0124 | 0.1928 | 0.0091 | 0.2724 | 0.0119 | 0.0664 | 0.0050 |
| | | 2 | Banteay Ampil | 40146 | 0.3204 | 0.0274 | 0.0893 | 0.0096 | 0.0318 | 0.0043 | 4025 | 0.4631 | 0.0134 | 0.2170 | 0.0100 | 0.3329 | 0.0141 | 0.0899 | 0.0066 |
| | | 3 | Chong Kal | 21582 | 0.3465 | 0.0342 | 0.0996 | 0.0129 | 0.0365 | 0.0059 | 2362 | 0.4615 | 0.0129 | 0.2181 | 0.0106 | 0.3293 | 0.0152 | 0.0890 | 0.0074 |
| | | 4 | Samraong | 49440 | 0.3435 | 0.0226 | 0.1034 | 0.0091 | 0.0405 | 0.0045 | 5732 | 0.4291 | 0.0101 | 0.1983 | 0.0079 | 0.2914 | 0.0105 | 0.0749 | 0.0051 |
| | | 5 | Trapeang Prasat | 32173 | 0.3062 | 0.0272 | 0.0876 | 0.0099 | 0.0321 | 0.0045 | 4389 | 0.4578 | 0.0141 | 0.2142 | 0.0108 | 0.2785 | 0.0149 | 0.0673 | 0.0061 |
| 23 | Kep | 1 | Damnak Chang'aeur | 22839 | 0.2574 | 0.0341 | 0.0705 | 0.0113 | 0.0249 | 0.0048 | 2600 | 0.4586 | 0.0138 | 0.2132 | 0.0106 | 0.3542 | 0.0130 | 0.0977 | 0.0066 |
| | | 2 | Kaeb | 12478 | 0.2221 | 0.0358 | 0.0602 | 0.0121 | 0.0216 | 0.0053 | 1200 | 0.3895 | 0.0166 | 0.1667 | 0.0125 | 0.2945 | 0.0160 | 0.0737 | 0.0082 |
| 24 | Pailin | 1 | Pailin | 35180 | 0.2017 | 0.0197 | 0.0561 | 0.0071 | 0.0207 | 0.0033 | 3903 | 0.3745 | 0.0117 | 0.1597 | 0.0082 | 0.2303 | 0.0111 | 0.0504 | 0.0043 |
| | | 2 | Sala Krau | 32970 | 0.2275 | 0.0236 | 0.0632 | 0.0081 | 0.0226 | 0.0035 | 3936 | 0.4184 | 0.0128 | 0.1857 | 0.0092 | 0.2603 | 0.0133 | 0.0589 | 0.0053 |

# Appendix D. Maps

**Map D.1 Administrative Units in Cambodia**

## Map D.2 Ecological Zones in Cambodia

**Map D.3 Population Density (General Population Census of Cambodia, 2008)**



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