II. WHAT KIND OF CENSUS DATA CAN BE USED AND WHY MAPPING VULNERABILITIES IS RELEVANT TO CLIMATE CHANGE ADAPTATION

Climate change vulnerability, and why the census is central to it

One of the most widely-used definitions of climate change vulnerability comes from the IPCC's Fourth Assessment Report, which suggests that vulnerability is:

> *"The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity."*

This definition raises a number of challenges in its measurement. The first is the complexity of the "system" referred to, which includes of course an extensive human component. The second is that according to this definition, vulnerability varies massively depending both on context and on specific climate hazards (Schensul and Dodman 2010).

One of the primary challenges of climate analysis is to fill in this broad definition of vulnerability with substantively, geographically and hazard-relevant data across a variety of sectors and thematic areas. Census data are a critical component because they are one of the only ways to get information on the human and social components of the system at a scale small enough to align with the geography of climate hazards and to capture variation in vulnerability across space.

Type of census data that can be used for climate change and environmental analysis

Fundamentally, the census provides data on the number, location and characteristics of households and dwellings. This basic information is directly relevant for determining risk associated with environment and climate hazards, yet is all too often left out of vulnerability assessments. Censuses provide information on the size, composition and characteristics of the population, which allows for the study of the situation and trends in the composition, structure by age and spatial distribution of the population.

The Principles and Recommendations for Population and Housing Censuses of the United Nations (United Nations, 2008) provides a comprehensive overview of the census process, including the suggested questions to be integrated and

the tabulations that need to be produced. In relation to environment, it concludes that: "… Population and housing censuses provide a powerful tool for assessing the impact of population on the environment, for example, on drainage basins and on water resource management systems. The spatial units for such a study may combine a group of local administrative areas. In this situation the availability of census databases with mapping capability (see paras. 1.126–1.128) is of great importance (United Nations, 2008, p. 241)." Despite their relevance, they are still used rather infrequently for the purpose of environmental studies. One of the main uses at the global level is related to the calculation of the indicators for sustainable development defined by the United Nations Division for Sustainable Development 6.

The potential of population and housing censuses to create a spatial base of human and social data for environmental analysis is indisputable. However, their use will largely be affected by the availability of the disaggregated geo-referenced data, the type of questions included and the categories of responses, the quality of the data, the capacity to link census and surveys data and, most importantly, the relevance that is given to the census data as key inputs for policy design.

Census data have some limitations: Censuses are conducted, in the best case, every ten years, so the data become quickly outdated. In addition, the potential use of information derived from the inclusion of specific questions related to the environment can be limited due to the characteristics of the census questionnaire which only allow for the inclusion of a selected number of questions and easily identifiable categories. The information collected is not so detailed as in surveys; for instance, poverty can be modelled using census data, but specific questions on income are seldom included.

In spite of these limitations, used alone or combined with data from surveys or administrative data, most of the information obtained in a census can be useful for environment and climate-change analysis. Censuses have the advantage that they cover the total population, including those living in households or collective residences, and they provide information on the whole country and allow for estimations for very small areas. This last characteristic permits a detailed analysis at the local level, which is impossible to do with household surveys.

Census data provide two categories data critical for climate change analysis: The first is information collected on issues directly related to the environment and climate vulnerability (water, electricity, sanitation, waste disposal, housing type and materials, etc.)[1]. The second refers to all other questions (sex, age, education, occupation and others) that can help in determining the adaptive capacity of the population, as well as some aspects of its consumption and emissions (see Dalton et al., 2008) (Guzman, 2010). Based on both types of information or a combination with other data, some of the indicators of sustainable development can be calculated (see Table 1).

Table 1
Selected indicators of Sustainable Development that can be obtained using census data and/or a combination of census data and other sources

Issue covered	**Indicator**	**Census data that can be used to calculate this indicator**	**Relevance (extracted from the source document)**
Sanitation	% of Population using an improved sanitation facility	Type of sanitation Facilities	Assess sustainable development, especially human health. Accessibility to adequate excreta disposal facilities is fundamental to decreasing the faecal risk and the frequency of associated diseases.
Drinking water	% of population using an improved water source	Access to drinking Water	Access to improved water sources is of fundamental significance to lowering the faecal risk and frequency of associated diseases.
Access to energy	Share of households Without electricity or other modern energy services. Additional: % of population using solid	Type of energy for cooking and lighting	Lack of access to modern energy services contributes to poverty and deprivation and limits economic development. Adequate, affordable and reliable energy services are necessary to guarantee sustainable economic and human development. The use of solid fuels in households is a proxy for indoor air pollution, which is associated with increased mortality from pneumonia and other acute lower

[1] *These topics are the recommended questions in the Principles and Recommendations of the United Nations for Population and Housing Censuses (United Nations, 2008).*

	fuels for cooking		*respiratory diseases among children, as well as to increased mortality from chronic obstructive pulmonary disease and lung cancer (where coal is used) among adults.*
Living conditions	*% of urban population living in slums*	*Data on population and type of materials used for roofs, walls and ceilings and it combination with other sources*	*This indicator measures the proportion of urban-dwellers living in inadequate housing conditions. It is a key indicator for measuring the adequacy of dwellings for the basic human need for shelter. An increase in this indicator is a sign of deteriorating living conditions in urban areas.*
Vulnerability to Natural Hazards	*% of population living in hazard-prone areas*	*Data on population combined with other sources, such as elevation maps, flooding areas, etc.*	*Measures the extent of population vulnerability in a given country, thus encouraging long-term, sustainable risk reduction programmes to prevent disasters, which are a major threat to national development.*
Coastal Zone Risks	*% of total population living in coastal areas (i.e. low elevation coastal zones)*	*Data on population combined with other sources, such as elevation maps, etc.*	*Quantifies an important driver of coastal ecosystem pressure, and it also quantifies an important component of vulnerability to sea level rise and other coastal hazards.*

Source: United Nations (2007)

The use of household data

Access to water and sanitation

Two indicators for monitoring progress of Target 10 of MDG Goal 7 (Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation) merit consideration. While indicator 30 refers to the proportion of the urban and rural populations with sustainable access to an improved water source, indicator 31 asks for an increase in the proportion of the urban and rural populations with access to improved sanitation (United Nations, 2008).

A comparison of average household sizes and the average quantity of water used per person per day with the availability of water from the sources stated in the census can provide a basis to determine the sustainability of their use over time as the population continues to grow. Population and household projections could be used to demonstrate the imminence of an environmental crisis caused by the increasing need for water for drinking and sanitation. This is a key issue for adaptation to climate change.

The information on sanitation is relevant for studies on health-environment linkages, such as the impacts of access to toilet to a higher incidence of diarrheal disease and the links between sewage disposal and the contamination of water sources, among many others. For example, it has been pointed out that the discharge of untreated wastewater and excreta into the environment affects human health by polluting drinking water, by entering into the food chain, by bathing or other contact with contaminated waters and by providing breeding sites for flies and insects that spread diseases (WHO,UNICEF and WSSCC, 2012)[2]*.*

The UN Principle and Recommendations (UN, 2008) recommend a set of questions for both access to water as well as source of drinking water. The questions ask about the availability of piped water installation and the source of drinking water. The categories suggested are:

a) Piped water inside the unit: From the community scheme or from an individual source

b) Piped water outside the unit but within 200 metres: From the community scheme, for exclusive use or shared; from an individual source (for exclusive user or shared);

c) Other source (Borehole, Protected dug well, bottled water, river, etc.).

In relation to sanitation, the questions are related to:

a) Availability of toilet facilities within the housing unit: With toilet within housing unit (flush/pour flush); with toilet outside housing unit (flush/pour flush,

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[2] *WHO,UNICEF and WSSCC (2011).*10 Things You Need to Know About Sanitation. http://www.unwater.org/wwd08/docs/10Things.pdf

latrine, etc.) by type of use: exclusive use or shared ; and No toilet available

b) Sewage disposal : Empties into a piped system connected to a public sewage disposal plant or into a piped system connected to an individual sewage disposal system (septic tank, cesspool) or other (an open ditch, a pit, a river, the sea, etc.); and no disposal system

c) Bathing facilities: Availability of a separate room for bathing in the living quarters: with fixed bath or shower within and outside the housing unit (for exclusive use or shared) and no fixed bath or shower available.

Source of energy for cooking and lighting

Target 9 (Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources) of Goal 7 of the Millennium Development Goals (MDGs) (Ensure environmental sustainability) has, as one of its indicators, the proportion of the population using solid fuels. This indicator is important because it provides a link between household solid fuel use, indoor air pollution, deforestation, soil erosion and greenhouse gas emissions (United Nations, 2008). Therefore, this information is very relevant from the point of view of the mitigation of climate change. Access to electricity is also a relevant indicator for environmental analysis. The need to increase accessibility to and affordability of energy services for the poorest populations in developing countries is considered essential in strategies to alleviate poverty and to contribute to social and economic development (IAEA, 2005). The environmental impact of sources of energy for cooking and lighting are best demonstrated when combined with information on other factors such as densities, occupational distribution, land-use and tenure patterns and the level of urbanization.

United Nations (UN, 2008) recommends collecting information on the fuel used (the one used most often) for cooking by each housing unit (fuel used predominantly for preparation of principal meals). Although the classification of fuels used for cooking depends on national circumstances, the suggestion is to include the following: Gas, Electricity; Liquefied petroleum gas, Kerosene/paraffin (petroleum-based); Oil (including vegetable oils used as fuel); Coal; Firewood; Charcoal; Animal dung; Crop residues (for example, cereal straw from maize, wheat, paddy rice, rice hulls, coconut husks, groundnut shells,

etc.). The fact that the question includes just the predominant fuel used can limit use of this information, particularly when more than one fuel type is used simultaneously.

Additional relevant information includes energy used for lighting in the housing unit: electricity, gas, oil lamp and others sources. When the energy used is electricity it is also suggested to collect information on the source of electricity: From the main network, from a community supply, private generating plant or some other source (solar panel, industrial plant, mine and so on).

Waste disposal

The amount of waste generated, its composition and mode of disposal are important variables that are relevant for environmental analysis. Censuses usually only collect information on the method of waste disposal. Where household waste (solid or liquid) is dumped into streets, drains or streams, or burned (therefore creating emissions of carbon dioxide), especially in high density areas, the environmental consequences will be greater than in areas where such waste is either composted or collected through an organized sewerage system. But a collection system is not enough: It must be joined by a 'cleaning' or management system. If it is not, other areas (where the waste is disposed without treatment) will be affected. This is, therefore, an important component of (local) environmental policies aimed at reducing toxicity and the volume of waste generated by the population at large, as well as increasing the coverage of households with waste collection and helping in the design of appropriate management of waste disposal.

The data are reported by municipal authorities, thus the results refer primarily to urban areas and waste collected by municipal trucks. While these components were included in Questionnaire 2008 on Environmental Activities by the United Nations Statistics Division (UNSD) and the United Nations Environment Programme (UNEP), the use of census data for this purpose is not mentioned. However, cross-referencing this information with census data would allow for a better measurement of the population covered by waste collection services.

UN recommendations on this topic are the following: Questions should be asked about the usual manner of collection and disposal of solid waste/garbage

generated by occupants of the housing unit, taking into considerations the following categories: collected on a regular basis by authorized collectors, on an irregular basis by authorized collectors, collected by self-appointed collectors, disposal of solid waste in a local dump supervised (or not) by authorities, burn, burry or created compost of solid waste, disposal of solid waste into river/sea/creek/pond, or other arrangement.

Other relevant questions at the household level

Some countries may incorporate other questions linked directly to environmental issues and that can be associated with the previous questions and produce new indicators. These may include questions on the type of kitchen in the household unit, the type of energy used for heating, availability of hot water, the availability of piped gas and others. Additionally, censuses usually include question that allows for a better definition of housing conditions such as the type of dwelling, the year of construction, the materials used in the walls, floors and roof, property tenure. Finally, there are also questions on the assets availability of cars, trucks and other means of transportation for the household, the accessibility of IT, access to TV cable, Internet, etc.). All these questions can be used to help define the characteristics of the households, including poverty level (assets-based definition) an others indicators of the quality of life that can be relevant for environment and climate change analysis.

Census issues directly relevant to climate change collected at a more aggregated level

There are least two countries that have included a module on environment and natural disasters or capacity to respond to them in their national census. The Dominic Republic is one such country, in which census instruments have been created to ask explicit questions about natural disasters at the enumeration area level. The elaboration of the questionnaire has been done through a close collaboration between the NSO and the Ministry of Environment. In this case, key-informant based data collection, which is more subjective than census enumerations, changes the nature, quality and comparability of the data. It is therefore important to validate the results of these data collection processes. However, the information coming from these questions can be matched and complemented with more objective information coming from other sources. Argentina also has included a set of questions to be collected by enumeration

area, and Indonesia collects similar information at the village level, one aggregation up from enumerator area.

What about Demographic Data other than Census Data?

Many national statistical offices or national institutions also collect additional information through periodic surveys. Such survey data include ones conducted individually by countries or institutions, as well as major international survey programs such as the Demographic and Health Surveys (DHS), the Multiple Indicator Cluster Surveys (MICS) and the Living Standards Measurement Surveys (LSMS). These surveys are based on sampling frames derived from the decennial census and are nationally representative. They tend to ask many more questions than a census could ever contain, since the survey are conducted through extensive in-person interviews. They usually include more information on social, environmental and demographic issues such as child well-being and survival, fertility, household assets and disease than censuses commonly do and this information could be very useful in many climate-related applications.

However, the level of spatial disaggregation of these surveys is typically the first-order administrative unit (such as provinces), or even more aggregated than that, and even with new directions to collect geographic coordinates for survey clusters, there are limitations on its use at more disaggregated levels. Such data can be harnessed in creative ways, for example, by associating environmental characteristics with the survey clusters (see for example, Balk et al., 2004) or by using the regional information in a multi-level model, as appropriate. The triangulation of information from different sources – censuses, household surveys and administrative statistics – is probably the better way to extract the best of these sources: coverage from censuses and administrative records and better quality and details from surveys. This is the case, for example, of poverty measurement, which uses a combination of survey and census data to generate small area poverty estimates; the results are highly relevant for the geography of vulnerability.

The use of individual data on demographic and socio-economic characteristics of the population

Key socio-economic and demographic indicators can be obtained or estimated using census data. Variables such as sex, age, kinship provide the basis data for calculating the population of different group of age by sex, defining the weight of different demographic groups that can be exposed to different

degrees of vulnerabilities. It has been demonstrated that children women and older persons tend to be more vulnerable to some climate related events.

Education questions also provide an important human capital element of adaptive capacity to climate change. Several indicators can be calculated as shown in a good example of this kind of analysis performed by the Statistical Office of Vietnam using data from the 2009 Population and Housing Census[3].

But the census also allows for the estimation of indicators of fertility, mortality, particularly infant mortality and migration that can be also used to better describe the dynamics of the population in a given space (UN, 2008). By using the results of the questions on children ever born, children surviving and date of birth of last child born alive, estimates of fertility rates and infant and child mortality rates can be obtained. These estimates require a minimum number of cases to be reliable; therefore, for small census units some aggregate estimation of fertility and mortality can be used as a proxy for more sophisticated estimates. For example, an indicator of fertility for enumeration areas of a census could be the mean number of children ever born of women 25-39 years. And indicator for child mortality could be the proportion of children that have died among the children ever born to women 25-39.

Why census data is relevant to climate change adaptation and how it can be to map vulnerabilities

National Statistical Offices conduct censuses that allow to count the total population of a given territory and to know the basic characteristics of the population. Equally important are the demographic and socioeconomic characteristics. While the information collected in censuses varies among countries, some of the most common ones are housing characteristics, education or schooling levels and status, employment status and occupation, and race and ethnicity. Some countries collect information on income, poverty or basic-needs proxies (see, for example, Feres and Mancero 2001).

We have mentioned above that one relevant objective of using census data for adaptation to climate change is to measure the different levels of vulnerability. Below we will describe how these different types of variables are useful in determining different aspects of vulnerability.

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[3] General Statistical Office, (2011), Vietnam Population and Housing Census 2009. Education in Vietnam: An analysis of key indicators. Ha Noi, 2011.
http://vietnam.unfpa.org/webdav/site/vietnam/shared/Census%20publications/5_Monograph-Education.pdf

Linking basic census data, such as population size, to the geographic area allows for the calculation of population density, a classic indicator for environmental study, particularly in urban areas. It also allows for the characterization of urban settlements: slums, sprawl, concentration and dispersion of the population. For adaptation policies, this indicator is still more relevant when it is combined with variables such as the type and quality of housing, source of water, energy, mode of waste disposal, patterns of occupational distribution and land use and tenure. It also helps to define the sustainability of the use of resources in particular locations and to highlight both environmental and related social vulnerabilities.

Counts of total population or population by age and gender (as well as by other population subgroups), allow for the basic description of who is at risk as well as producing denominators of exposed population to specific events. For example, the Indian Ocean Tsunami of 2004 had a differential impact on men, women and children. Of course, simply knowing that more women and children were killed by the tragedy is significant, but further understanding that more men were at risk (since men are typically fishermen rather than women, for example) means that differential mortality to women, children and the elderly was even greater (Frankenberg et al., 2011). To estimate rates of age and gender-specific mortality, age and gender-specific population denominators are necessary.

Similarly, occupation data may help to identify vulnerabilities (e.g., fishermen to identify persons who work in close proximity to the sea) and employment data to help vulnerability. Education data may be especially valuable with respect to climate adaptation. Understanding education differences among the population may be necessary for developing effective resilience strategies to target different groups (illiterate vs. literate). Education levels may also be used to identify which groups in the population may be early adapters to new technologies aimed at mitigation of or adapting to climate change. Additionally, education has been shown to be a powerful development tool (both as a consequence and cause) and there is a close association between adaptation and development planning.

The number and main characteristics of people living in informal settlements vulnerable to coastal flooding is rarely documented locally, and even less internationally. Census data can help in the identification of the slum population most at risk of suffering from flooding and other environmental hazards. They can also show that slums are not uniform[i] and that people living

there can face different level of vulnerability. As sea levels rise, however, persons living in informal dwellings in coastal cities are especially likely to suffer large health burdens. They may already be affected regularly by floods, and indeed many have adopted coping strategies in an attempt to minimize the impact (Few, 2003). Sea level rise and more severe storms are likely to overwhelm these strategies, however. Especially where sturdy protection is simply too costly to implement, the obvious solution is to negotiate resettlement.

The residents of informal settlements are often not so much planned for as planned against (Hardoy, Mitlin, and Satterthwaite, 2001). Efforts to improve conditions are inhibited by a range of factors, including the lack of economic resources available to the residents; the weaknesses of local government; the unwillingness of local governments to prioritize (or in some cases even allow) public support for these informal settlements; and an unwillingness of international agencies to support assistance to these settlements (Satterthwaite, 2007).

A lack of systematic data on these dwelling exacerbates the problem and inhibits planning measures. Increased awareness in National Statistical Offices on the importance of such data is an important part of improving the measurement of hard-to-capture populations. Housing information varies a lot from one census to the next. Some censuses collect no such information, others simply ask whether the respondent owns or rents the unit or the age of the dwelling.

Censuses vary widely to the degree that informal settlements are specifically identified as such, but some census – South Africa, is a good example – make an effort to note several types of informal settlements in their housing information (Lemanski, 2009). The South African census collects information of 'backyard dwellings' among other types of formal and informal units through the standard survey questionnaire. This is bolstered by additional efforts at the municipal level using aerial photography, for example in Cape Town. The map shown in Figure 1 is the result of such efforts, and was created in part to locate informal dwellers as an aid to disaster preparedness (City of Capetown, 2008; Rodriques et al., 2006).While this map locates these dwellings, the census information supplies a wide-range of additional information that could be linked to more fully describe the potential vulnerability of the informal dwelling residents.

One study found that urban disasters and environmental hot spots are concentrated in coastal areas (De Sherbinin, Schiller, and Pulsipher, 2007). As a consequence of both sea-level rise and increasing storm severity, climate change is likely to increase flood risks in coastal areas, and along in-land waterways. Floods can have a broad range of health impacts: drowning and bodily injuries resulting from floodwaters; the health effects of exposure to sewage; the disruption of clean water supplies; and the loss of housing and livelihoods (Ahern and Kovats, 2006). Flooding will not be born equally across age and gender, and therefore having the ability to combine data on populations at risk, infrastructure at risk, access to services, and environmental factors will become increasingly important.

In low income urban settings, and especially where responses to weather events are delayed or inadequate, the secondary health effects of flood disasters are likely to be particularly significant. In many countries, these conditions are chronic, though often in the after math of an acute event, which means that certain relevant data layers could be readied in anticipation of specific events. For example, diarrheal diseases, which do not appear to be an appreciable risk associated with flooding in affluent countries, emerge as a very important public health problem in lower income countries (Ahern et al., 2005), and one where spatial demographic data can play a critical role. In their description of the health impacts of the Mozambique floods of 2000, Cairncross and Alvarinho (2006) note that thousands of urban septic tanks overflowed; piped water supplies in eight small towns were damaged; the incidence of diarrhea increased; and there were outbreaks of cholera. These were all spatially delineated events and could be matched with spatial populations at risk. Another example comes from Dhaka, Bangladesh, where flooding has been linked to large increases in diarrhea incidence, a phenomenon described not only in academic studies but also by layperson accounts in the press (Alam and Rabbani, 2007). Flooding is an intrinsically spatial event, and while matching it with incident data is common, further matching it with population at risk data is uncommon. While the documentation of these outbreaks may be the purview of departments of health, understanding the magnitude of these impacts depends in part of having the right population and subgroup denominators.

Summarizing, census data can be put to great use to describe vulnerabilities not just limited to the age and sex composition of the population but also in terms of education, housing, racial or ethnic composition, linguistic groups and

income, fertility, mortality and even crude indicators of migration. Each of these variables has the potential to describe potentially vulnerable groups, and therefore the population at risk of climate related hazards. This information has been largely underutilized by planners in their efforts to create for climate adaptation strategies.

Analysis steps for census-based climate vulnerability

Step 1: Indicators common to all climate hazards

In the first round of analysis, indicators can be used to construct generalized vulnerability and adaptive capacity across space. At the minimum, this involves developing key proxies from census items as inputs to the framework derived above. For demographic variables, it means locating the population in space, in terms of number of people, population density, and population composition according to age and sex. This can be done across social and administrative spaces, and it can also be done with respect to specific climate geographies like flood plains, temperature bands, low elevation coastal zones and others.

For the physical structure of communities, mapping common indexes of housing and service access will provide the most consistent and comparable results. One particularly useful index in this regard may be the Secure Tenure Index (STI, http://unstats.un.org/unsd/accsub/2002docs/mdg-habitat.pdf), which has been part of tracking MDG 7.10 on slum dwellers. The STI has five inputs: access to water, permanency of housing, regulatory compliance of housing, connection to sewer and connection to electricity. Four of these five inputs (the exception being regulatory compliance) can be taken from the census, and these four provide a strong approximation of the STI. An index (or a significant part of it) that is generally only calculated at national, provincial or sometimes municipal level can therefore be calculated at the small-area level that is critical for climate analysis.

On the human and economic capital inputs to vulnerability, even the rough, census-based employment and occupation data can provide a proxy of relative economic vitality as it is distributed across space. Literacy and school completion can be used as broad spectrum input to adaptive capacity, and mapped as stand-alone inputs.

As suggested above, poverty modeling can also be undertaken using the census, though in combination with other sampled datasets. Information from censuses alone that can be used for poverty modeling include some consumption indicators depending on the census (e.g. bedrooms per resident of households, radio ownership), household headship status and characteristics and other demographic characteristics. However, though poverty mapping can be an important tool for vulnerability analysis, the full version is methodologically complex and requires integration with survey data; explanation of this method is beyond the scope of this guide.

Step 2: Hazard Specific Vulnerability Indicators

Results from step 1 are essential for generating a base understanding of climate vulnerability, but will only take the analysis so far. The next step, integration of hazard specific indicators, ties the analysis to contextually specific climate hazards. One aspect of this, as mentioned earlier, is conducting analysis within geographically exposed areas. This is important but by no means the only necessary analytical geography, given that climate impacts will not be geographically constrained: migration of people and goods constitutes a critical part of adaptation. Nonetheless, this manual makes the point strongly that identifying climate geography and integrating it with census data is at the core of successful analysis of this type.

Beyond hazard geographies, hazard specific analysis involves identifying specific census-based variables and their relationship to specific hazards. Climate hazards vary significantly in type, time frame and severity, as well as in strategies to prepare for and respond to them. As a result, a large part of census-based climate analysis must be catered to specific hazards, in addition to the general indicators which also apply to people's ability to adapt to the threat of specific hazards. Some examples follow of hazards and the census-based additions to vulnerability analysis that they invite.

Flood vulnerability

Once flood exposure geography has been developed and overlaid onto census data, and basic demographics within the exposed areas are summarized, analysis should be directed to the census-based components of flood vulnerability. The first point of departure is housing characteristics, and in particular the combination of materials for walls and floors and the presence of pit latrines or unimproved toilets, which are particularly vulnerable to rising

water tables and can exacerbate the risk of cholera, diarrhoea and other communicable diseases during flooding. These features can be easily combined to produce a measure of the proportion of dwellings at risk in the event of a flood.

In addition, escape routes are extremely important in flood prone areas. Lack of public spaces, including open street routes, housing on steep slopes prone to landslides, and areas lacking infrastructure such as staircases for escape are important aspects of flood vulnerability. While the census alone cannot provide such detailed information, population distribution and population density from the census can be combined with analysis of aerial photography or remote sensing data to identify the ratio of public to private space together with population density in private spaces. This ratio could be used as a proxy for ease of escape.

Analysis of general climate indicators, coupled with the application of flood plain analysis to the location of low elevation coastal zones may be sufficient to understand human and social vulnerability and adaptive capacity specific to sea level rise.

Heat wave vulnerability

Temperature increase will lead to more frequent and severe instances of heat waves. Heat island effects in urban areas may exacerbate this problem. The geography of temperature increases and heat wave risk is often derived from remote sensing of night-time temperatures. This geography can be combined with housing material and water access – piped water into or outside of the home, for instance, an input to the STI – to identify households within exposed areas that are particularly vulnerable.

Declining agricultural output

Due to changing precipitation patterns, shortened growing seasons, and more variation in weather, agricultural output in many places is expected to decline. Because agricultural outputs are not constrained to where they are grown, the specific geography of farming is less critical than identifying the areas that rely heavily on agriculture for livelihoods. Proportion of the population employed in agriculture can be derived from the census and provides a proxy of this reliance. It is better to examine this indicator within urban or rural areas, rather than comparing the two, given that rates will inevitably be much higher in rural areas. However, reliance on agriculture is hardly confined to rural

areas, given the increasing importance of urban and peri-urban agriculture to livelihoods, and in many urban areas proportion of agricultural employment will actually be quite high.

Local deforestation

While deforestation at the global or regional level is generally associated with large scale industry and consumption, there are increasing instances of local deforestation driven by local fuel needs. The geography of local deforestation can be determined through remote sensing techniques, particularly the analysis of time series land use/land cover layers. Most censuses in developing countries ask about sources of energy for lighting and cooking, with wood or charcoal as a very common source. To the extent that climate change enhances deforestation, and local energy use does the same, this leaves these households increasingly vulnerable to energy insecurity.

Step 3: Refining the analysis through crosstabs

The universal sample of the census provides the ability not just to analyze and display data for small areas, but to do so with different kinds of relevant subsets and interactions within these areas. In other words, the analysis need not be limited to the proportion elderly, or women headed households, or houses with earth floors or semi-permanent structures, but can look at various important combinations. This is critical because when doing a geographically based analysis, in which data are aggregated from individual and household records to some spatial extent, results can be open to the ecological fallacy.

Take two important variables with counts aggregated to the level of a census enumerator area: proportion of female headed households and proportion of households lacking water access. There may be a correlation between the summary values of the two at the level of enumerator area – perhaps a negative one, in which the higher the proportion of women headed households, the lower the proportion of households with water access. However, this correlation cannot illuminate whether it is in fact the women headed households, rather than other households around them, that actually lack water access. To find out, new aggregates of household level records to enumerator area are necessary. These new aggregates, representing important crosstabs, can significantly deepen a census-based analysis of vulnerability, as well as help to uncover the mechanisms, not just the correlates, driving it. Some examples of relevant crosstabs follow.

Crosstab 1: Female headed households

Differences between male and female headed households are very commonly cited in the literature on poverty, food security, disaster impacts and climate change. Female headship is nearly universally considered a component of vulnerability, partly due to assumptions derived from either the ecologically fallacy or other inferences that may or may not be found in the data. Running both the CCVIs and the HSVIs above, disaggregated by household headship, is relatively simple once the data have been aggregated to small area level in the appropriate way. Important results could emerge from crosstabs of headship with each of the three main components of the CCVI analysis, and could also help to inform specific hazard related vulnerability. For instance, it has oft been reported that women had higher mortality in the 2004 tsunami. In an analysis of flood plains and low elevation coastal zone, it may therefore be important to generate and map enumerator area level tallies of housing materials by headship. (At the same time, where such disaggregation does not make sense is in population density, which is a characteristic at the spatial level, not the individual or household level.)

Crosstab 2: Elderly-only or adolescent headship households

Certain household types may indeed leave the residents more vulnerable just on the basis of household composition. Two examples are those where only elderly people are present, a factor commonly associated with heat wave vulnerability (REF), and those where there are only adolescents or children in the household, which may have fewer resources and choices at their disposal. There are not likely to be large numbers of these households in many countries, but identification of these households, which involves the combination of multiple census items (hence the crosstab), can illuminate a vulnerable and often hidden component of the population.

Crosstab 3: Migrant sending and receiving households

The nature of climate vulnerability and adaptive capacity among both sending and receiving households continues to be a puzzle, with relatively few sources of data, and essentially none that can be mapped outside of censuses. Crosstabbing migrant sending and receiving households with some of the CCVIs and HSVIs to generate comparisons to non- sending or receiving households in climate exposed areas, as well as more broadly, would significant source of information on the links between climate change and migration.

Step 4: Use results to feed back to base geography and link to policy

As with any policy relevant analysis, the final outputs should be structured to have meaning for the policies to be affected. Climate change responses can be stand-alone climate policies, or can be part of efforts to mainstream climate change into development, poverty reduction, infrastructure projects and the like. Depending on the policy in question, and how the analysis is structured, the geography of results is critical.
For instance, for climate specific response, the right output geography could be climate exposed areas. This means ensuring that census analysis results are delivered according to the geography of exposure. Analysis like the ones suggested above should therefore be done for these geographies, rather than for enumerator areas, and outputs should be structured as population size, composition and vulnerability variation in exposed areas. Similarly, for sectoral responses, for instance water, which comes with its own geography of catchment area, the analysis should be reported with that geography.

However, for a wide range of development policies, the geography that matters may be administrative boundaries or social ones such as neighborhoods. In these instances, identifying the most vulnerable enumerator areas according to the analyses suggested above might be the best choice. Alternatively, aggregating enumerator areas back into administrative or budget-relevant polygons could ensure the greatest policy relevance.

These decisions depend greatly on the purpose of the analysis and local decisions about the best means of getting the results integrated into policy discussions. One of the key points of this type of analysis is that each option is possible within the framework of the technology.

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[i] *Overview of migration, poverty and health dynamics in Nairobi City's slum settlements. Eliya M. Zulu,[1] Donatien Beguy,[2] Alex C. Ezeh,[2] Philippe Bocquier,[3] Nyovani J. Madise,[4] John Cleland,[5] and Jane Falkingham[4]. J Urban Health. 2011 June; 88(Suppl 2): 185–199.*