Chapter 1: Introduction

All materials on the Earth's surface reflect, absorb, transmit and emit electromagnetic radiation in varying amounts dependent on wavelength (Short 2010). Remote sensing is the science of obtaining information about the Earth's surface using data acquired remotely from satellite and airborne sensors (Campbell 2002; Lillesand et al. 2004). Data obtained from satellite remote sensing can be used for acquiring environmental data for extensive areas of the Earth's surface at fine temporal and spatial resolution which would not be possible from other sources such as ground data collection. Consequently, satellite remote sensing has become a key component in monitoring environmental change particularly across areas with large spatial extents. Research has demonstrated the potential use of remotely sensed satellite data for monitoring socioeconomic conditions in urban areas (Section 1.4). Equally, remotely sensed satellite data could be uniquely placed to provide vital information on socioeconomic conditions, poverty and development for rural locations of developing countries.

This chapter gives a brief overview of the important issues surrounding poverty and its impacts on society, the current methods used to monitor poverty, and the uses of remote sensing for monitoring socioeconomic conditions in urban locations. These introductory concepts form the basis for the research aims. A more detailed theoretical basis for this research is presented in Chapter 2 along with specific research objectives required to achieve the research aims.

1.1 Poverty in rural areas of developing countries

Poverty is often described as a lack of income and resources required for an individual to fulfil their position in society. Put simply poverty translates as when people are unable, for various reasons, to access income, education, health and other resources that would enable them to perform the tasks expected of them (Jesuit and Smeeding 2003; Kanagawa and Nakata 2008; Townsend 2004; World Bank 2000).

It is estimated that 70% of the poorest people on Earth (living below the poverty line of less than $1.25 per day) live in rural areas (IFAD 2011). The inhabitants of rural areas in developing countries are often reliant on small holder agriculture and are highly vulnerable to climatic and environmental changes (Cutter et al. 2000). Chakraborty et al. (2005) highlighted that; "higher levels of vulnerability are correlated with higher levels of poverty…" (p. 24). The spatial distribution of rural poverty in developing countries is often clustered and this has led to suggestions that government resources and poverty alleviation should be spatially targeted (Bigman and Srinivasan 2002; Jalan and Ravallion 1996; Ravallion and Wodon 1997). Despite these suggestions monitoring of socioeconomic conditions and poverty alleviation strategies are often targeted at broader spatial scales such as the state. This is because it can be very expensive and time consuming to collect statistically representative data at finer spatial scales (Bigman and Srinivasan 2002).

1.2 Socioeconomic data for monitoring poverty and vulnerability

The data on socioeconomic conditions of rural populations which are vital for poverty monitoring and the development of poverty alleviation strategies are often derived from national censuses (Chakraborty et al. 2005; Clark et al. 1998). A census is the collection of core demographic data about individuals in a country. Censuses are conducted primarily to enable governments to allocate resources, evaluate previous policies and monitor longer term trends (Gregory and Ell 2005; Rindfuss and Stern 1998; UNSD 2008a). A census can also provide information for international bodies, such as the United Nations and the World Bank, to design poverty reduction strategies, monitor a country's progress towards the Millennium Development Goals (MDGs) (UNDP 2003) and identify areas that could slide into poverty because they are vulnerable to climatic changes such as increased flooding (Hutton et al. 2011; Thomalla et al. 2006).

There are several issues relating to census design, methods of collection and publication which can limit the use of the data collected for policy creation and academic research. Census enumeration is conducted during pre-defined time periods (Johnston et al. 2000; UNSD 2008b). The regular time intervals of census collection (typically every 10 years) enable detailed analysis of spatial and temporal population trends (Gregory and Ell 2005; Jones 1990). However, census publishing times can range from two years (Martin 2007) to four years (Census of India 2007). The typical 10 year time interval between enumeration periods in addition to data publishing times can limit the usefulness of census data for monitoring and planning purposes. Increasingly mobile populations and dynamic changes in population structures and characteristics have led some to argue that census data are accurate only on the date of collection (Shearmur 2010) and short term demographic changes could be missed as a result (Rigg 2006). The time lag for data collection could therefore have negative impacts on the use of census data for use in poverty alleviation strategies, monitoring the MDG and assessing populations vulnerable to climatic changes. For example, Cutter and Finch (2008) found that social vulnerability to natural hazards can vary spatially and temporally. Therefore, if vulnerability assessments are based on census data they may provide incorrect results and result in inefficiencies in government resource allocation.

The increasing costs of undertaking a census combined with other influences such as political instability and natural disasters, have led to several countries in sub-Saharan Africa postponing enumeration (Leete and Mubiala 2003). The political and military instability in Sudan led to a gap of more than 15 years between the census in 1993 and 2008 (UNFPA 2007) and the last census conducted in Angola was in 1970 (Tatem and Linard 2011). Furthermore, the Canadian government proposed the end to the 'long form' census which is sent out to a 20% sample representative of the general population partly because it was too costly (Shearmur 2010). Alternative methods have been sought to ensure national datasets continue whilst costs are curtailed. Pommier (2003) suggested the continual collection of census information over a 10 year period. This has been adopted in France, where a representative 10% sample is taken each year (Desplanques 2008; INSEE 2010). Alternatively, continually updated national population registers are used in Denmark instead of a population census. Despite these alternative methods costs for continual enumeration and population registers are still likely to be too large for many developing nations (Leete and Mubiala 2003). Therefore, gaps will continue to appear in the census time series, which can affect the subsequent use of the data for government policy and academic research.

In an attempt to address the issues highlighted above, methods to update and add to the information contained within a census have been developed. Sample surveys such as the Demographic and Health Surveys (Measure DHS 2011) use census population statistics to target a representative sample of the population. Since these surveys have smaller sample sizes than the census they are able to collect more detailed information about specific variables of interest (such as health indicators over smaller scales). Methods have been developed, such as small area estimation (Rao 2003) and micro-level estimation (Elbers et al. 2003), to combine the detailed information in sample surveys with the census to provide estimates across entire countries. This means that demographic information can be spatially and temporally updated between census enumeration periods. However, sample surveys often have to be conducted close in time to the census to ensure that the sample used is statistically representative of the population. Consequently, the accuracy of sample surveys used for small area estimation and micro-level estimation may decrease with time.

1.3 Potential uses of remotely sensed data for monitoring poverty and development

The census and sample survey limitations discussed above have, in the past, led to suggestions that remotely sensed data could be used to supplement census data during intercensal periods (Brugioni 1983; Morrow-Jones and Watkins 1984) or when ground data collection is not feasible (Crews and Walsh 2009; de Sherbinin et al. 2002).

1.3.1 Population mapping using satellite sensor data

Several studies have combined census and remotely sensed data to provide spatially disaggregated information on population that are otherwise not widely available from published census data. Population density has been estimated by combining remotely sensed night time lights data[1] and population counts from the census (Pozzi et al. 2002). Two other global population products, Landscan and GRUMP combine population data from national censuses with remotely sensed data sets. The Landscan data product estimates the total population in a grid format using data sets such as road proximity, slope, land cover and night-time lights (Dobson et al. 2000). The Global Rural-Urban Mapping Project (GRUMP) provides urban population and extent information at the global scale which was built using a range of data sets including night-time lights (Small et al. 2005). Finally, the Afripop (www.afripop.org) data product provides data on human population distributions using textural and optical remote sensing products in combination with the finest spatial resolution national census data sets available (Tatem et al. 2007). A product providing similar human population distribution data for Asia (www.asiapop.org) is also being produced using similar methods to those used for the development of the Afripop product.

1.3.2 Remote Sensing for socioeconomic purposes

As well as being used for population mapping, remotely sensed data have also been utilized in studies examining socioeconomic conditions. When attempting to predict residential quality in Sydney Australia, Forster (1983) found that remotely sensed environmental factors yielded very similar results to separate models using economic data from land registers. These results suggested that remotely sensed environmental information could be used as a valuable tool in predicting residential quality when economic data were not available.

Since the research by Forster (1983) several studies have explored further the potential of remotely sensed environmental data for predicting Quality of Life (QOL) measures in urban areas. The remotely sensed normalised difference vegetation index (NDVI)[2], a measure of vegetative greenness that is associated with vegetation health, was found to be an indicator of higher incomes in Georgia, USA (Lo and Faber 1997). Increases in the amount of vegetation between 1975 and 1992 detected from remotely sensed satellite imagery of Detroit, USA was

---

[1] For introduction to Night-time lights see Doll (2008)

[2] For an introduction to NDVI see Weier and Herring (2011).

found to be an indicator of urban areas with the highest incidences of poverty (Ryznar and Wagner 2001). Mennis (2006a) found that NDVI was an indicator of lower population density in Denver, USA. A principal component analysis of QOL and environmental metrics revealed that environmental data (greenness, impervious surfaces and temperature) had the same capabilities of predicting income as a factor describing income derived from the census (Li and Weng 2007). Similarly, an exploratory study by Avelar et al. (2009) found that remotely sensed imagery could be used to partially identify rich and poor regions of Lima, Peru.

Remote sensing cannot feasibly be used to replace the census entirely because it is not possible to acquire all information required for government monitoring of socioeconomic conditions from imagery alone. However, Ogneva-Himmelberger et al. (2009) stated that; "if the relationship between environmental and socio-economic conditions were understood, practitioners, and policymakers could develop an understanding of the geographic distribution of social well-being and quality of life based on a map of vegetation [or land] cover" (p. 2). Therefore, if associations between land cover features and census variables could be found then the high frequency revisit capability of remotely sensed imagery could enable a limited but potentially valuable understanding of general socioeconomic conditions between census enumeration periods which could be used to help target development assistance.

The above studies by Forster (1983), Lo and Faber (1997), Ryznar and Wagner (2001), Mennis (2006a), Li and Weng (2007) and Avelar et al. (2009) demonstrated the large potential for using environmental data acquired remotely to indicate quality of life. To the author's knowledge no studies have explored the use of remotely sensed satellite sensor data to estimate QOL or poverty metrics in rural areas of developing countries. However, if research in rural areas of developing countries returned similar results to those in urban areas it could potentially enable more up-to-date targeting of government policies for poverty reduction, vulnerability assessments and development assistance.

1.4 Wider Significance

The repeatability and universality of a census are vital to chart a country's development over time and space, to develop future government policies that are focused on the existing problems (Rindfuss and Stern 1998). Socioeconomic data within the census are also an important component of assessing social vulnerability to natural hazards such as floods (Chakraborty et al. 2005; Clark et al. 1998; Hutton et al. 2011). However, the limitations of the census in its current guise can result in inefficient resource allocation and government policy (Bigman and Srinivasan 2002; Jalan and Ravallion 1996). The data contained within the census can be limited by the decennial collection methods. For example, a 2008 to 2010 study of vulnerability to flood and drought in Assam, northeast India used information contained within the 2001 National census of India (Hutton et al. 2011). Thus, the community level vulnerability estimates were limited by the age of the census data. These limitations of the census have led to suggestions that data collected remotely using aerial and satellite based sensor imagery could be used as sources of important data between census enumeration periods (Ogneva-Himmelberger et al. 2009) or when ground based social surveys are not feasible (de Sherbinin et al. 2002).

Past studies have found links between quality of life assessments and remotely sensed environmental data in urban locations (Avelar et al. 2009; Forster 1983; Li and Weng 2007; Lo and Faber 1997; Ryznar and Wagner 2001). Chapter 2 highlights several potential associations between socioeconomic variables and environmental factors. There is great potential to explore the spatial associations between socioeconomic variables derived from the national census and environmental data derived from remotely sensed satellite sensor imagery. Combining remotely sensed data with the more detailed information available in census and sample surveys could provide methods for monitoring socioeconomic changes using more up-to-date information for policy creation such as development assistance and poverty alleviation.

1.5 Research Aims

This research will explore and quantify associations between socioeconomic conditions derived from national census data and environmental metrics derived from remotely sensed imagery from Earth observation satellites. If non-causal associations can be found between census-based socioeconomic variables and remotely sensed environmental metrics it may be possible to use remotely sensed imagery as a limited, but valuable source of information regarding socioeconomic conditions of rural communities. The increased temporal resolution that remotely sensed imagery offers over the traditional ground survey methods used to obtain socioeconomic data may, in the future, increase the relevance and understanding of information available to policy makers for monitoring socioeconomic conditions.