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Aim and Scope

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Estimation of Swaziland fertility: What do the methods tell us?

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ABSTRACT

This paper re-estimates the levels of fertility in Swaziland at national level using multiple data sources and methods. The re-examination of the historical fertility levels in Swaziland was done in view of their inconsistency as recorded in census reports and other sources. Published data on the 1976, 1986, 1997 and 2007 censuses were sourced and mainly used to estimate fertility levels using indirect methods: P/F ratio method, Rele's method, Gunasekaran-Palmore method and relational Gompertz model. Full birth history data using the 2006-07 Swaziland Demographic and Health Survey were used to estimate levels of fertility using the cohort-period fertility rate approach. Prior to assessment, data were investigated for errors prone to the measurement of fertility using basic demographic tools. The several methods applied indicate that the total fertility rate declined between 1976 and 2007 from 7 to 5 children per woman. The P/F ratio method, in particular the relational Gompertz model, has proved to be versatile, robust and dependable in preparing fertility estimates for Swaziland. A substantial fertility decline started in the year 1986, from which the pace of fertility transition was rapid. The indirect methods applied agree within acceptable limits on the magnitude of the levels of fertility in Swaziland. Limitations of the various methods should be taken into account in the interpretation of fertility estimates. The direct and population structure-based methods are taken to have been more or less understated fertility.

Key words:

Data quality, fertility estimates, direct estimation, indirect methods, Swaziland

1. Introduction

Estimating and re-examining levels of fertility with demographic and statistical methods is a high priority for sub-Saharan African (SSA) countries that often face data quality issues (Mhloyi, 1992; Cohen, 1993; Odimegwu, 1998; Moultrie and Timæus, 2002a; Muhwava, 2002; Arnaldo, 2004; Machiyama, 2010; Garenne, 2012; Palamuleni, 2013). Interest in reconstructing or measuring fertility levels is not only for establishing their accuracy, but also generated with a perspective of determining fertility transition in specific contexts.

In the period 1950–2010, a pre-transition fertility regime of pro-natalist behaviour has been observed in SSA, which has been higher than that of Latin American and Asian developing regions (Bongaarts and Watkins, 1996; Bongaarts and Casterline, 2012). This fertility pattern has been postulated to persist into the foreseeable future in SSA (Odimegwu and Adedini, 2012). As in most SSA countries, fertility in Swaziland is high (above 2.1 children per woman – replacement level fertility) (see Table 1).

Inevitably, high fertility stifles socio-economic development of the individual family, society or nation at large. Thus, an accurate estimate of fertility contributes to correct benchmarks for policy planning and formulation on many aspects of the population. Also, an understanding of the best and most robust method approaches to use in demographic data collection and measurement of fertility is enhanced. In African countries, due to paucity of reliable fertility data, further analyses of census and survey data using robust indirect demographic methods is common to establish plausible estimates of fertility.

In a number of countries, such as Zimbabwe (Mhloyi, 1992; Muhwava, 2002), South Africa (Moultrie and Timæus, 2002a; Palamuleni, 2013), Nigeria (Odimegwu, 1998) and Mozambique (Arnaldo, 2004), to name a few, scholarly published work in establishing fertility estimates is documented. For Swaziland, however, dated studies (Warren et al., 1992; Cohen, 1993) need to be updated with recent data and other available data, using improved indirect estimation techniques.

Fertility levels of Swaziland are commonly presented in census reports as estimates of the P/F ratio (lifetime/cohort fertility (P) to current/period fertility (F)) method original developed by William Brass in the 1960s and detailed mechanically in Manual X (United Nations, 1983). The P/F ratio (Brass-type) methods have been modified and improved recently by Moultrie and colleagues (Moultrie et al., 2013).

It has been recognised by Moultrie and Dorrington (2008) that alternative and/or improved methods of indirect fertility estimation are hardly applied in SSA countries. In particular, such methods include the relational Gompertz model, which requires careful judgement in application. To take note also is that available software such as the Microsoft Excel-based PASEX files methods of the US Census Bureau developed by Arriaga et al. (1994b) have been used scarcely for fertility estimation. Likewise, the dos-based EASWESPOP-fertility program (East-West Center, 1992b) has been less utilised due to change into the commonly used windows operating system.

The primary focus of this paper is to make a definitive set of fertility estimates for Swaziland through time. In doing so, the study seeks to present direct and indirect estimates of fertility obtained from various methods, using the 1976, 1986, 1997 and 2007 censuses and 2006-07 Demographic and Health Survey (DHS) in Swaziland at national level. Multiple demographic methods, the P/F method ratio method, relational Gompertz model, Rele's method, Gunasekaran-Palmore method and cohort-period fertility rates (CPFRs) are employed to compare and validate the results. Thus, ultimately, the fertility estimation method that performs better in the Swaziland context is set out.

Although fertility decline is underway in Swaziland (see Table 1), the implied levels shown by direct fertility estimates between 1966 and 2007, signify underreporting of children. In the four decades, a reduction of 1 birth – a decline of TFR from 5.2 to 3.8 children per woman – suggests rather a snail-paced fertility decline. Also, this is indicative of the poor quality of reported fertility data. The case of defective data is confirmed when indirect fertility estimates, which often are relied on, are higher than direct estimates. When data are not defective and accurate, the variation between indirect and direct estimates of fertility is minimal.

Table 1: Total fertility rate by data source and method of measurement, Swaziland

Data source	**TFR reported**	**Method applied**	**Source/ reference**
PHC 1966	5.2[d] [6.9[+]]	[d] direct; [+] method not stated	CSO (1979); Cohen (1993)
PHC 1976	5.7[d] [7.1[b]; 6.8[m]]	[d] direct; [b] (original) P/F ratio-Brass, [m] model not stated, but based on 'best fit' on Coale and Trussell parameters	CSO (1979)
PHC 1986	4.3[d][6.8[b];6.7[a,t]; 6.6/6.5[g];6.4[i]]	[d] direct; [b] P/F ratio-Brass; [a] P/F ratio-Arriaga variant; [t] P/F ratio-Trussell variant; [g](original) Brass relational Gompertz model; [i] Arriaga intercensal cohort method	CSO (1991)
FHS 1988	5.0	Direct/observed	Ministry of Health (1990)
DHS* 1991	5.6	Direct/observed	CSO (1998)
PHC 1997	4.3[d][4.5[a];5.3[t]]	[d] direct (own calculation); [a] P/F ratio-Arriaga variant; [t] P/F ratio-Trussell variant	CSO (1998)
PHC 2007	4.0[d][4.7[t]]	[d] direct; [t] P/F ratio-Trussell variant	CSO (2010b)
DHS 2007	3.8	Direct	CSO (2008)
MICS 2011	3.7	Direct	CSO and UNICEF (2011)

Notes: DHS = Demographic and Health Survey; DHS* = Demographic and Housing Survey; PHC = Population and Housing Census; MICS = Multiple Indicator and Cluster Survey; FHS = Family Health Survey. Direct method estimate involves computing TFR directly from reported births in the census data or full birth histories in survey data.

2. Data and Methods

Source and quality of data

The study uses data from five full censuses of Swaziland carried out in 1966, 1976, 1986, 1997 and 2007 as established in various published Swaziland census reports (CSO, 1979, 1980, 1986, 1988, 1991, 1998, 2010a, 2010b, n.d) for the respective five censuses. Due to difficulty in accessing complete raw census data and in maintaining consistency in deriving fertility estimates, published data were utilised in this study.

The demographic data collected in developing countries, with no exception to Swaziland, often yields errors of mistiming/misplacement, misreporting and/or omission or over-counting of births, bringing bias to fertility estimates (CSO, 1991; Warren et al., 1992; Cleland et al., 1994; Cleland, 1996; Cohen, 1998; Moultrie and Dorrington, 2008).

Published census reports of Swaziland (CSO, 1979, 1991, 1998, 2010b) indicate that direct estimates of fertility at some moments tend to be undesirably lower than indirect estimates in the African context of fertility transition (see Table 1). For instance, a total fertility rate (TFR) of 5.2 and 5.7 children per woman in 1966 and 1976, respectively (CSO, 1979) is indicative of underreporting of current fertility in Swaziland. Indirect fertility estimate rates show higher fertility rates close to 7 children per woman in Swaziland in the 1960s and 1970s – similar to those of other African countries in that era (CSO, 1979; Cohen, 1993; Cleland et al., 1994).

Cohen (1998) found that the earlier (1966, 1976 and 1986) censuses of Swaziland were of poor quality, especially with regard to age misreporting. The Whipple's index and Myers' summary index often are employed in assessing age reporting errors. The computed Whipple's (and Myers's) indices, namely 130.6 (14.4), 125.9 (11.7), 120.6 (8.0) and 99.8 (2.6) for 1976, 1986, 1997 and 2007 census data, respectively, indicate that overall age-sex data quality reporting has improved over time. The Whipple's index values for 1976 and 1986 censuses reflect that data quality were of rough quality, and in 1997 and 2007, the data became approximate and highly accurate, respectively. The Myers index maintains the same findings. With regard to this summary index for age preference, a value close to 0 indicates less heaping and its maximum value of 90 suggests massive heaping.

It is worth mentioning that even though baseline data is erroneous on some aspects, estimates of fertility of reasonable quality can be derived by making adjustments to some data. For example, el-Badry correction has been used to adjust data on women's parities of those with no children who have been misclassified as 'not stated' or 'not known' (United Nations, 1983). In light of the paucity and defectiveness of demographic data in Swaziland, several methods would be applied to establish robust fertility estimates and check for their consistency and plausibility.

The evaluation of fertility estimates from 2006-07 SDHS data was done using the P/F ratios (similar to those derived from the Brass P/F ratio method) derived from the CPFRs method, which is explained later. The 2010 Multiple Indicator Cluster Survey (MICS) is another potential survey data source to derive fertility estimates, but was not best suited to the application of the indirect methods used in this study.

The input data used for the various indirect methods is presented in the Appendix in Table A1. The focus on data is primarily for the period 1976 to 2007. Due to data problems noted above, estimates of fertility have to be derived using indirect estimation techniques. Fertility estimates can also be evaluated or validated when multiple and/or independent data sources are compared.

Indirect estimation methods

As a preliminary analyses step, age-sex data is often evaluated and adjusted as appropriate. In light of inaccessible raw census data (except for 1997), no smoothing or adjustment of age-sex data was made to improve its quality. However, fertility data on parities were corrected when the proportion of women in the reproductive lifespan with unknown parity is more than 2 per cent (Moultrie et al., 2013). The el-Badry method was applied to 1986 and 1997 census data to correct and adjust parity data before applying indirect estimation techniques. For 1966 and 2007 censuses, the el-Badry correction was not applied, since census tabulations on parity (including parity 'not stated' category) by age of woman could not be availed. The 1976 parity data appears to have been smoothed and hence, no el-Badry correction was made.

The study utilises the variants of the original Brass P/F ratio technique (Trussell, Arriaga, Feeney), refinements of the P/F ratio method (cohort-period fertility rates, relational Gompertz model), and population structure or regression-based methods (Rele’s, Gunasekaran-Palmore). Technical computational details of these methods are not presented in this paper since software programs or tailored Excel spreadsheets were employed. It is vital therefore to note that, due to a shortage of skilled demographers in Africa and in order to reduce computational mistakes, the use of demographic software to estimate fertility rates becomes inevitable.

The methods employed in this paper are operationalised in the EASWESPOP-fertility software (in Windows virtual pc environment), namely the Trussell variant of the Brass P/F ratio method, Rele’s method and Gunasekaran-Palmore regression. The Palmore regression and Own children methods were not applicable due to non-availability of raw census data. To validate the fertility estimates, the “FERTPF” application in the Mortpak program of the United Nations Population Division (2013) based on one census for the Arriaga variant of the P/F ratio method was used.

Indirect methods dependent on multiple (census) data, such as the Arriaga 2 or 3 census methods, although useful are not presented in this study. The Arriaga method is amenable to relative quality of the censuses data and the results can be problematic (Moultrie, 2010). The method is sensitive to varying completeness of parity data amongst data sources utilised. Thus, distorted or incorrect fertility estimates may be derived since the four censuses of Swaziland are of varying degrees of quality (CSO, 1998).

Also, the CPFRs on survey data and the relational Gompertz model based on the Excel spreadsheets by Moultrie et al. (2013) were utilised. For the Feeney method, an Excel spreadsheet developed by Moultrie (2009) was used. The above-mentioned applicable methods due to availability of the required input data in published census reports of Swaziland are explained in brief.

The original Brass P/F ratio has been modified into now commonly used variants of Trussell and Arriaga. The modification by Feeney (1998) is less known or applied, and the procedure is familiarised as the Feeney method. An adjusting factor (k) of the P/F ratio is employed to correct for errors in parity data arising mainly from omission of births and current fertility due to displacement of births. A value of k for women aged 20–24 is deemed more reliable as compared to that of the average of 20–24 and 25–29 age groups. This is because the method assumes that parity omission by younger women is negligible or accurate. The inherent assumption that fertility has been constant in the recent past is often violated for the Brass P/F ratio method when fertility has been declining (United Nations, 1983; Moultrie and Dorrington, 2008).

Alternative P/F methods have been pronounced where fertility is declining such as the Arriaga (Arriaga et al., 1994a) and Feeney (Feeney, 1998) variants of the P/F ratio method. The Feeney method estimates completed fertility for each cohort using the P/F ratio, and therefore a time trend of fertility estimates can be obtained.

A striking result, however, from a recent study by Moultrie and Dorrington (2008) suggests that the Brass P/F ratio can generate reasonable fertility estimates. Upscale of fertility occurs by small margins when fertility is declining, and even under generalised HIV epidemics, as is the case of Swaziland. This scenario is further tested in this study using the P/F ratio method.

The relational Gompertz model is also a more refined P/F ratio method to estimate TFR based on fitting a typical fertility schedule. The application of the method is appropriate for medium to high-fertility countries (Moultrie et al., 2013) and therefore suited for Swaziland. The default option 'Shape F – Level P' variant of the "FE_RelationalGompertz" Excel file by Moultrie et al. (2013) was used.

The refined relational Gompertz model has been rated as robust and best-suited for indirectly estimation of fertility (Moultrie, 2010; Moultrie et al., 2013). This study applied this procedure, to estimate TFR by fitting a straight line to P and F lines and eliminating suspicious points deviating from the line, especially for older or younger ages. The Arriaga's "REL–

GMPZ" PASEX file application of the relational Gompertz model estimates was applied for comparison and consistency checks. The TFR estimates for the Arriaga's version are modelled on both 2 F-points and 2P-points (or 3 F-points and 3P-points) without regard to elimination of problematic points outside the suited best line.

The Rele's method and Gunasekaran-Palmore method are quite useful regression or population structure-based indirect methods for estimating fertility (East-West Center, 1992a), but are rarely applied in Southern Africa, contrary to the widely applied P/F ratio method. Nonetheless, the quality of regression-based estimates depends on the accuracy of data used. Moultrie (2010) argues that the relationships in regression may not be robust if data are inaccurate in an individual country.

The Rele's method is based on the concept of stable population to derive a linear relationship between the child-woman ratio (CWR) and the gross reproduction rate (GRR) for a given mortality level. Two estimates of fertility were estimated, based on CWR [0-4] and CWR [5-9] for children aged 0–4 years referring on average to fertility 2.5 and 7.5 years before the census, respectively. In South Africa, Palamuleni (2013) obtained reasonable and consistent fertility estimates using the Rele's method.

The Gunasekaran-Palmore method, likewise to the Rele's method, estimates GRR and TFR based on female data on life expectancy at birth and age distribution of the population, assuming a sex ratio of 105 males per 100 females. The fertility estimates refer to the period 5 years preceding census enumeration (Gunasekaran and Palmore, 1984).

Cohort-period fertility rates

The CPFRs are derived from DHS data and are less erratic than period age-specific fertility rates. Further, they allow the direct computation of P/F ratios that are often used as a diagnostic tool for data quality (Moultrie and Timæus, 2002b; Moultrie et al., 2013). Using this procedure, two estimates of fertility were computed, that is, for 0–4 and 5–9 years before the survey estimated to be centred on the mid-point of the respective interval. The fertility rate for the latter period was obtained by assuming the cohort-period fertility rate for women aged 45–49 is the same as that of the respective age group 0–4 years prior the survey. Thus implying that fertility has been constant in the recent past for women aged 45–49. This is a probable assumption since the fertility pattern is not likely to change much in such a short time span.

In this regard, methods based either data on parities (children ever born), live births in previous year or population structure using one or more data sources, have been utilised in this study.

3. Findings and Interpretation

Reference period

The reference period or point to which fertility estimates refer to is usually ignored in most studies. More often, the estimates are referred to the year of survey or census and/or with no specific reference point.

The census night is declared 25 May 1966 (1966.40 in decimal faction), 25–26 August 1976 (1976.65), 25–26 August 1986, 11–12 May 1997 (1997.36) and 13/14 May 2007 (2007.36) for the 1966, 1976, 1986, 1997 and 2007 censuses, respectively. The data collection for the 2007 SDHS started in July 2006, ending in February 2007. The reference date for the 2007 SDHS estimated as 2006.88 (16 October 2006) was obtained using the mean of the century month code variable (v008) in the dataset. Thus, decimal fraction of the enumeration reference date can be converted into day and month of the enumeration, and vice versa.

With regard to the direct estimates of fertility, the recording of births refers to the last 12 months before the census enumeration date. Therefore the pattern of fertility was corrected by a one-half year lag before the survey to compensate for the fact that when women reported the births in the last year, they were on average six months younger. For the DHS survey, the births collected refers to a 3-year period and hence a one and a half year lag before the survey to which the fertility estimates refer.

With respect to indirect fertility estimates, the reference period years and points are inherent in the assumptions of the indirect techniques used as indicated in the respective tabulations. Overall, the fertility estimates from the P/F ratio methods (Arriaga, relational Gompertz model) refer to 12 months prior to the census reference date, while estimates from the P/F ratio-Trussell and Feeney variant, Gunasekaran-Palmore, Rele's method and CPFRs refer to a 5-year period or multiples of 5-year periods before the census or survey reference date. The latter methods, therefore, allow a two and a half year lag to which fertility estimates are referred.

P/F ratio method

The commonly used P/F ratio method – Trussell variant was employed to all (1966, 1976, 1986, 1997 and 2007) censuses using the EASWESPOP-fertility software. As noted earlier, an adjustment factor (k) of P/F ratio for age group 20–24 (k1) is deemed more precise than that of the average ratio of age groups 20–24 and 25–29 (k2) in determining the plausible TFR, but in this study both values of k are shown to indicate the sensitivity of this adjustment factor (Table 2). The results suggest choosing the preferred k1 value for the age group 20–24 to that of the average k2 generates no difference in TFR, and the difference, if any, is only marginally higher. The differences that may be due to data quality issues, especially for the 1966 census, should not be over-interpreted.

The results also are compared to those of the Arriaga method which, unlike the Trussell variant, relaxes the assumption that fertility has been constant in the recent past, allowing for a changing or declining fertility pattern. Outstandingly the fertility estimates are the same for both methods, indicating that fertility has fallen by 2 births in 3 decades (i.e. from 7 to 5 children per woman between 1976 and 2007). This trend of decline in fertility is similar to that depicted by the Feeney method (Table 2).

Table 2: Estimates of fertility based on P/F ratio method, Swaziland 1966–2007

Data source	**Enumeration reference date**	**TFR estimate**	**P/F method: variant**	**Reference period**	**Reference point**
PHC 1966	1966.40	7.9	Trussell (20-24)	1961-1966	1963.90
		7.5	Trussell (20-29)	1961-1966	1963.90
		7.4	Arriaga[1] (20-24)	1965-1966	1965.90
		6.8	Arriaga[1] (25-29)	1965-1966	1965.90
		7.1	Arriaga[1] (30-34)	1965-1966	1965.90
PHC 1976	1976.65	7.1	Trussell (20-24)	1971-1976	1974.15
		7.1	Trussell (20-29)	1971-1976	1974.15
		7.0	Arriaga[1] (20-24)	1975-1976	1976.15
		7.1	Arriaga[1] (25-29)	1975-1976	1976.15
		7.1	Arriaga[1] (30-34)	1975-1976	1976.15
		7.1	Feeney		1976.65
PHC 1986	1986.65	6.9	Trussell (20-24)	1981-1986	1984.15
		6.7	Trussell (20-29)	1981-1986	1984.15
		6.5	Arriaga[1] (20-24)	1985-1986	1986.15
		6.5	Arriaga[1] (25-29)	1985-1986	1986.15
		6.5	Arriaga[1] (30-34)	1985-1986	1986.15
		6.7	Feeney		1986.65
PHC 1997	1997.36	5.2	Trussell (20-24)	1992-1997	1994.86
		5.2	Trussell (20-29)	1992-1997	1994.86
		5.2	Arriaga[1] (20-24)	1996-1997	1996.86
		5.3	Arriaga[1] (25-29)	1996-1997	1996.86
		5.2	Arriaga[1] (30-34)	1996-1997	1996.86
		5.3	Feeney		1997.36
PHC 2007	2007.36	5.1	Trussell (20-24)	2002-2007	2004.86
		4.8	Trussell (20-29)	2002-2007	2004.86
		4.8	Arriaga[1] (20-24)	2006-2007	2006.86
		4.7	Arriaga[1] (25-29)	2006-2007	2006.86
		4.7	Arriaga[1] (30-34)	2006-2007	2006.86
		4.8	Feeney		2007.36

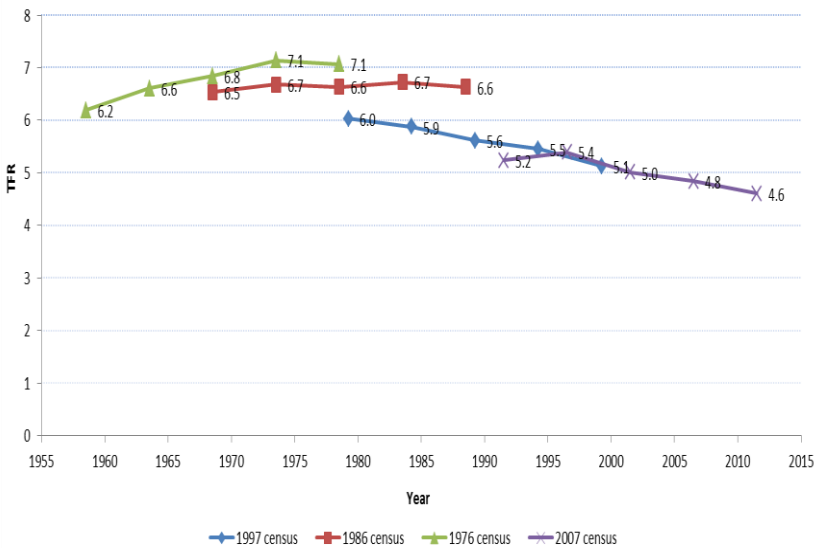
Note: Arriaga[1] implies Arriaga P/F ratio method based on one census data in the respective year. For the Feeney method, the reference periods are shown in Figure 1.

For the Arriaga method, the most reliable adjustment factor for fertility rates is either for the age group 20–24, 25–29 or 30–34. Just like the Trussell variant, the (marginal) difference in fertility estimates for these adjustment factors is only noticeable in the 1966 census (Table 2). The P/F ratio-Arriaga variant fertility estimates adjusted for age group 25–29 were adopted for this study.

Moultrie and Dorrington (2008) found that for the Trussell variant, the P/F ratio for the age group 20–24 as an adjustment factor, is more preferable to the average scaling factor, k as well as more accurate than the Feeney estimation method. This study in the context of Swaziland, however, finds that the Feeney method tends to be robust and accurate. The results in the period 1976–2007 show that the fertility estimates from the Feeney method and Trussell variant (adopting the average P/F ratio k2 scaling factors) are equivalent (Table 2).

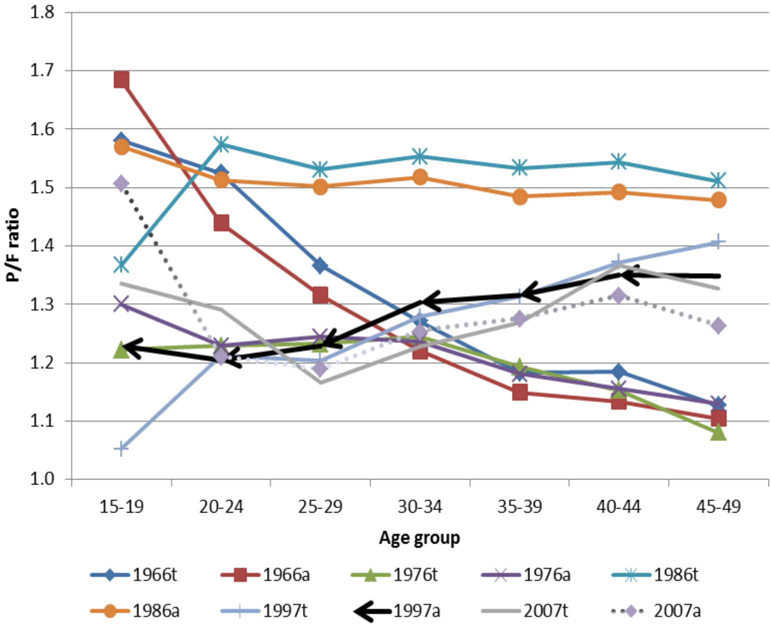
The Feeney method generates a projected (backward/forward) TFR time trend as shown in Figure 1 for each census reference date. The fertility time trend gives an impression of an increase in TFR prior 1975, which plateaus on average at 7 children per woman between 1975 and 1980. Onset of fertility transition (decline) is a recent occurrence in Swaziland, which could have started in the mid to late 1980s (Figure 1).

Figure 1: Fertility trends in Swaziland based on Feeney variant of the P/F ratio



The P/F ratios not only assess data quality and fertility levels, but can also be used to determine fertility trends as presented in Figure 2 and tabulated in Table A2 in the Appendix for the Arriaga and Trussell (equivalent to Feeney method) variants. For both methods, the P/F ratios decrease with the women's age for the 1966 and 1976 census data and hence, like the Feeney method (Figure 1), show that fertility has been increasing between 1966 and 1976. The declining trend in P/F ratios in the two datasets may also be attributable to underreporting of children ever born.

Figure 2: P/F ratios by age of women based on Trussell and Arriaga variants, Swaziland 1966–2007 censuses



Note: t represents Trussell variant P/F ratios for age group 20–29 for k2 scale factor a represents Arriaga's P/F ratios adjusting for age group 25–29

The rising trend of P/F ratios with age in the 1997 and 2007 datasets shows a true fertility decline, affirming the Feeney method fertility trend. In 1986 census data, the P/F ratios follow a fairly uniform and constant pattern for all ages (age group 15–19 is always excluded for interpretation or treated with caution), implying a constant fertility during the period as interpreted for the Feeney method. Alternatively, the constant misreporting of current fertility across all ages could be realistic.

The time trend of fertility estimates based on the Feeney method generated from the 1997 and 2007 census data seem to more consistent than from the 1976 and 1986 censuses, probably due to varying data quality issues in the censuses.

Cohort-period fertility rates

To further confirm the nature and onset of fertility transition in Swaziland, implied by the P/F ratio method – Arriaga, Trussell and Feeney variant and census data, an alternative type of data (2007 SDHS data) and P/F ratio type method (cohort-period fertility rates) were applied. Unlike in the former methods where P/F ratios are computed from the respective model, the P/F ratios (in panel F) from the CPFRs are obtained directly as a ratio of rates in panel D to those in panel E in the corresponding ages (see Table A3 in the Appendix).

The P/F ratios referring to the 0–4, 5–9, 10–14 and 15–19 years before the survey are increasing with the age of women in all the respective years. This indicates fertility has been declining in the matching years and hence, the period 1987–2007 agreeing with the results found earlier (see Figures 1 and 2). Although the pattern of fertility tends to be the same with the Feeney method, the level of fertility implied by CPFRs is lower by approximately one birth in the same periods. The CPFRs computed using the 2007 SDHS data in panel E of Table A3 in the Appendix estimate the TFR in 1997–2002 (mid-point 1999.38) and 2002–07 (2004.38) as 4.4 and 3.9 children per woman, respectively.

The onset of fertility decline using the P/F ratios (in panel F) is the average date between two periods when fertility was constant/unchanging (P/F ratios close to unity, i.e. 1982–87) and fertility started to decline (P/F ratios increase with age, i.e. 1987–92). Therefore, onset of fertility transition in Swaziland is estimated as the average of 1984.38 and

1989.38, that is, 1986.88. This finding is important, since it gives a clear picture that onset of sustained fertility decline started in the period just after the mid-1980s. With the Feeney method (Figure 1), fertility transition is approximated in the range of mid to late 1980s, consistent with the results from CPFRs.

The CPFRs in panel C and D further indicate that fertility has been declining for all age cohorts of women. This is shown by looking from right to left in both panels for all the groups, whereby the age-specific rates are declining, indicating a fertility decline. Also in both panels (C and D), possible omission of births by older women in the period over 25 years before the survey is noted. It is shown (reading up the diagonals for women aged 45–49) that the rates are lower than the adjacent cohort (40–44 age group) in 1977–82 and 1972–77 periods. The underreporting of births by older women aged 45–49 by the P/F ratio is less than 1 for the same cohort in panel F for the period 1977–82.

Relational Gompertz model

As noted earlier, the relational Gompertz model is a much more versatile and refined version of the Brass P/F ratio method. The model estimates of TFR using parity and fertility data in the form of P-points and F-points, respectively, and which are related to a standard fertility schedule, are presented in Table 3.

Likewise, TFR declined by 2 births in four decades on average from 7 to 5 children per woman between 1966 and 2007, as shown with the P/F ratio method earlier. Although the total fertility rates between the relational Gompertz model variants are consistent, the similarity somewhat depends on choosing either the 2 F-points and 2 P-points or that of 3 points on the Arriaga’s variant. The Arriaga’s version gives little room for eliminating erratic points, especially for older women.

Table 3: Estimates of fertility based on relational Gompertz method, Swaziland 1966–2007

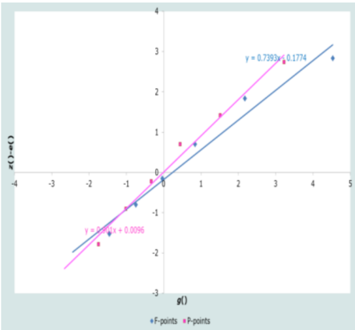
Data source	**Enumeration reference date**	**TFR estimate**	**Relational Gompertz method: variant**	**Reference period**	**Reference point**
PHC 1966	1966.40	7.0	Moultrie	1965-1966	1965.90
		6.5[6.8]	Arriaga	1965-1966	1965.90
PHC 1976	1976.65	6.9	Moultrie	1975-1976	1976.15
		6.6[7.0]	Arriaga	1975-1976	1976.15
PHC 1986	1986.65	6.4	Moultrie	1985-1986	1986.15
		6.3[6.6]	Arriaga	1985-1986	1986.15
PHC 1997	1997.36	5.0	Moultrie	1996-1997	1996.86
		5.2[5.4]	Arriaga	1996-1997	1996.86
PHC 2007	2007.36	4.6	Moultrie	2006-2007	2006.86
		4.7[5.0]	Arriaga	2006-2007	2006.86

Note: the estimates in square brackets []for the Arriaga's version of the Brass Relational Gompertz model are based on 3 P-points and 3 F-points on both CEB and ASFR for 15–49 age group; the estimates not in bracket are those fitted using 2 P-points and 2 F-points 15–39

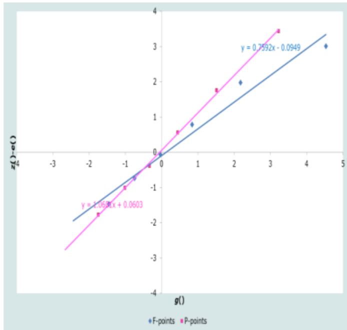
The estimated fertility levels for the relational Gompertz model-Moultrie variant adopted for this study have been used to establish fertility trends and accuracy of fertility data as represented in Figure 3. The F-points (F-line) curve downwards in all the five censuses, illustrating possible exaggeration of age or births by older women. The P-line (in pink) is above the F-line (in blue) and steeper, suggesting fertility was rising markedly – especially in 1966 and 1976. The fertility trend shown for 1986 indicates rather underreporting of current fertility by older women (aged 45–49 years) than possibly a fertility increase. This is similar to what was observed in Figure 2 for P/F ratios. The F-line is to the left of the P-line, showing a fertility decline in 1997. A fertility decline indicated in Figure 2 for 2007 is, however, not clear for panel e in Figure 3, since a similar pattern is shown, except probably age exaggeration or exaggeration of births by older women aged 45–49.

Figure 3: Relational Gompertz model diagnostic plots of fertility data for Swaziland censuses, 1966–2007

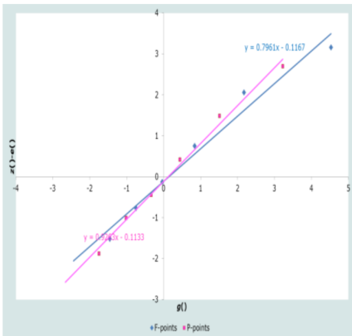
Panel a 1966



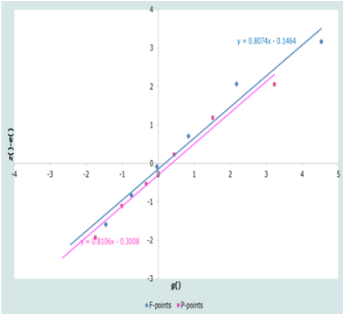
Panel b 1976



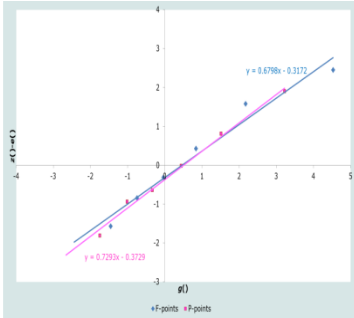
Panel c 1986



Panel d 1997



Panel e 2007



Population structure or regression-based indirect methods

The fertility estimates based on age-sex distribution are presented in Table 4 for the Rele's and Gunasekaran-Palmore regression-based methods. The validity of fertility estimates from both these methods depends on the accuracy of the age distribution, which is noted to be bad for 1976 and 1986 and moderate and good quality for the 1997 and 2007 censuses. Two estimates of TFR were prepared for the Rele's method for the period 0–4 years and 5–9 years preceding the census enumeration.

The results in Table 4 illustrate that the fertility estimates referring to the recent period before the census are reasonably similar for the Rele's and Gunasekaran-Palmore methods. The results show a similar decline in fertility trends, as shown with the P/F methods. However, the recent fertility estimates for the Rele's method and Gunasekaran-Palmore method are fairly lower, with a magnitude of a birth or slightly less, to those obtained from the P/F ratio method. The possible explanation is that age misreporting or underreporting of children could have led to an underestimation of fertility, as the methods are very sensitive to errors in age data.

Table 4: Estimates of fertility based on Rele's and Gunasekaran-Palmore method, Swaziland 1976–2007

Data source	**Enumeration reference date**	**TFR estimate**	**Method**	**Reference period**	**Reference point**
PHC 1976	1976.65	6.9	Rele[2]	1966-1971	1969.15
		6.1	Rele[1]	1971-1976	1974.15
		6.0	Gunasekaran-Palmore	1971-1976	1974.15
PHC 1986	1986.65	6.4	Rele[2]	1976-1981	1979.15
		5.7	Rele[1]	1981-1986	1984.15
		5.3	Gunasekaran-Palmore	1981-1986	1984.15
PHC 1997	1997.36	5.6	Rele[2]	1987-1992	1989.86
		4.4	Rele[1]	1992-1997	1994.86
		4.1	Gunasekaran-Palmore	1992-1997	1994.86
PHC 2007	2007.36	5.2	Rele[2]	1997-2002	1999.86
		3.8	Rele[1]	2002-2007	2004.86
		3.8	Gunasekaran-Palmore	2002-2007	2004.86

Note: TFR estimates are based on EASWESPOP-fertility software; Rele[1] implies fertility rates computed for children aged 0–4 years to women aged 15–49 years (i.e. CWR[0–4/15–49) , and Rele[2] refers to CWR[5–9/20–54].

From a different data source and method (2007 SDHS data and CPFRs), the TFRs 4.4 and 3.8 for 1997 and 2007, respectively, are consistent with those obtained with the Rele's method and Gunasekaran method. Birth history data, from which CPFRs are obtained, are subject to errors of mistiming of birth events or omissions, giving a false impression of fertility decline. The P/F ratios lower than the preceding adjacent cohort reading up the diagonal in panel F in Table A3 for older women aged 45–49 seem to suggest possible omission of births or age misstatement.

The TFR of 4.4 children per woman in 1997 from CPFRs was obtained by assuming constant fertility 5–9 years before the survey. That said, fertility has been declining during the period and hence, the TFR obtained could be an underestimate. A further investigation on the accuracy of birth history data in determining TFR when miscounting of children occurs is needed.

Estimates of fertility for Swaziland from various methods

All the indirect methods are claimed to produce plausible estimates of fertility, especially with reasonably good quality data irrespective of their similar or different assumptions. It should be noted, however, that the quality of data impacts on the accuracy of estimates depending on how each method corrects or adjusts for distortions in data. The estimates of fertility in Swaziland for comparable periods adopted from various methods as a summary are tabulated in Table 5. The summary results reveal a reasonable degree of consistency of fertility estimates reported in census reports with those computed from this study for the same methods. Fertility decline of 2 births in four decades between 1966 and 2007 is, however, at a slower pace.

Table 5: Summary of fertility estimates for Swaziland from various methods

Method\ Period	1965-66	1975-76	1985-86	1996-97	2006-07
Direct estimation	5.2	5.7	4.3	4.3	4.0
P/F Ratio-Trussell	7.5	7.1	6.7(6.7)	5.2 (5.3)	4.8(4.7)
P/F Ratio-Arriaga	7.1	7.1	6.5 (6.7)	5.1(4.5)	4.7
P/F Ratio-Feeney	----	7.1	6.7	5.3	4.8
RGM-Moultrie	7.0	6.9	6.4	5.0	4.6
RGM-Arriaga	6.5[6.8]	6.6[7.0]	6.3[6.6] (6.6/6.5)	5.2[5.4]	4.7[5.0]
CPFR	----	----	----	4.4	3.9
Gunasekaran-Palmore	----	6.0	5.3	4.1	3.8
Rele's	----	6.1	5.7	4.4	3.8

Notes: CPFR implies cohort-period fertility rate; RGM implies relational Gompertz model; the estimates in brackets () are those derived from census reports on respective methods; for the RGM-Arriaga method estimates in square brackets [] are derived from 3 P-points and 3 F-points, while those not in brackets are obtained from 2 P-points and 2 F-points.

This study has prepared fertility estimates for each census data using the same method of estimation on all the methods undertaken for this study. Thus, re-estimating levels of fertility for Swaziland was done, where data was available, using various estimation techniques undertaken in the study in the five censuses of 1966, 1976, 1986, 1997 and 2007.

The assumption of constant fertility in the Brass P/F ratio method-Trussell variant makes the method overestimate fertility slightly. The Arriaga and Feeney methods, though, relax this assumption to allow fertility change; their estimates are almost identical to those of the Coale and Trussell variant. The estimates from these three methods match those obtained from the relational Gompertz models. The acceptable degree of correspondence between the relational Gompertz model variants suggests both models are dependable.

Due to the reasonable degree of freedom in eliminating the outlier P-points and F-points, the versatile and much improved version of the relational Gompertz model-Moultrie variant is preferable. The consistency in total fertility rates in these methods for all the periods is reassuring. The conclusion made by Moultrie and Dorrington (2008) that the Brass P/F ratio-Trussell method appear to be robust even if its assumptions are violated, is corroborated in this study and hence cannot be overridden as a reliable method. The total fertility estimates obtained from this procedure are presumed to be upper-bound fertility levels for the respective reference periods.

The Gunasekaran-Palmore and Rele's methods are in good agreement with direct estimation results, although both estimates are more or less lower than the previous estimates from the P/F ratio methods. Equally, the CPFRs estimates correspond to the Gunasekaran-Palmore and Rele's methods. It is understood, however, that age distribution data and birth history data, from which regression-based methods and CPFRs suffer errors of omission, undercount and age exaggeration that need to be accounted or adjusted for (Arriaga et al., 1994a; Cleland, 1996).

4. Discussion and Conclusion

The study sought to re-estimate fertility levels in Swaziland at national level to obtain definitive fertility estimates using multiple methods of indirect estimation. The Rele's and Gunasekaran-Palmore regression or age distribution methods, P/F ratio methods (Trussell, Arriaga and Feeney variants), the relational Gompertz model and cohort-period fertility rates and total fertility rates using direct estimation were invoked for analysis.

Overall, between 1976 and 2007, a declining fertility trend has been observed in Swaziland. In that period, the TFR declined from 7 to slightly lower than 5 children per woman, which is a decrease of more than a quarter and which is indicative of fertility transition. Sustained fertility transition appears to have started the mid 1980s, in 1986 to be precise. Between 1986 and 2007, the pace of fertility decline has been rapid. In 2 decades, a reduction of 2 births has occurred, that is, TFR fell from an average of 6.4 to 4.6 children per woman. Prior to the mid 1980s, in the 1960s and 1970s, fertility appears to have been rising and levelling off in the late 1970s and early 1980s, as predicted with the Feeney method and P/F ratios in the respective periods.

Using published census data, this study finds that the computed unadjusted direct fertility estimates are equivalent to those of age distribution or regression-based methods. However, both direct and regression-based fertility rates are lower than those computed from P/F ratio methods by a birth or very close thereof in comparable periods. The estimates of fertility for the P/F ratio methods and the relational Gompertz model are matching in all the census years, likewise for the regression-based methods.

Further, there is a high degree of consistency of fertility estimates between the obtained census data for the Rele's and Gunasekaran-Palmore methods and from survey data using CPFRs for the 1996–1997 and 2006–2007 reference periods. Probably the fertility rates correspond as a result of the 1997 and 2007 reputable good quality census data. As a matter of caution, though, the difference among direct estimation, CPFRs and regression-based estimation estimates is negligible; these methods are easily affected by inaccuracy of age reporting, misreporting of births or undercount of children. These errors have been observed in the study and are likely to affect or understate fertility rates, hence, their lower estimates when compared to the Arriaga, Trussell and Feeney variants of the P/F ratio method and the relational Gompertz model (Arriaga and Moultrie modifications). Also, regression-based methods such as Rele's and Gunasekaran-Palmore have a weakness, such that when the required input data is incorrect, the errors tend to be replicated into the resulting estimates (Moultrie, 2010).

Notwithstanding the above-mentioned limitations or other probable errors, techniques of indirect estimation prove unabatedly useful for deriving fertility estimates with defective data. Further, they require little input data parameters, such that with little or no access to raw data for further adjustments to the data, reasonable fertility estimates may be derived. Thus, the P/F ratio methods which tend to account for these errors tend to be superior in generating fertility estimates if data are inaccurate.

In sum, methods based on the P/F ratio (Trussell, Arriaga, Feeney and relational Gompertz model) have proved dependable in deriving fertility estimates for Swaziland. More importantly, the Relational Gompertz model as noted by Moultrie et al. (2013) is much more versatile and dependable to derive fertility estimates in all circumstances of fertility transition. The P/F ratio is a useful diagnostic tool that tends to be used to compensate for underreporting of births 'adequately', although this is not the case with population structure or regression-based methods (Rele's and Gunasekaran-Palmore methods), and when data are unadjusted using the direct estimation method. This study therefore prefers fertility rates based on the P/F ratio methods, in particular the relational Gompertz model, to those based on age structure. Hence, the total fertility rates for Swaziland for the 1965–66, 1975–76, 1985–86, 1996–1997 and 2006–07 are estimated at 7.0, 6.9, 6.4, 5.0 and 4.6 children per woman, respectively.

This paper has contributed by illustrating the robustness or sensitivity of each method with varying data quality, even if with somewhat different or same assumptions and data requirements. An estimate of fertility and trends over time is instructive to policy planning and developmental intervention programmes.

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APPENDICES

Table A1: Average parity and age-specific fertility rates, Swaziland

Panel a	PHC 1966*		PHC 1976*		PHC 1986		PHC 1997		PHC 2007	
Age group	Parity	ASFR	Parity	ASFR	Parity+	ASFR	Parity+	ASFR	Parity	ASFR
15-19	0.3168	0.0904	0.3299	0.1184	0.2499	0.0825	0.1665	0.0728	0.1608	0.0541
20-24	1.6589	0.2166	1.6774	0.2574	1.5418	0.1931	1.1190	0.1929	0.8809	0.1383
25-29	3.0126	0.2206	3.2588	0.2490	2.9920	0.1905	2.3324	0.1989	1.6354	0.1469
30-34	4.1361	0.1995	4.7335	0.2119	4.4450	0.1714	3.6063	0.1622	2.6520	0.1545
35-39	4.8499	0.1523	5.6896	0.1606	5.4935	0.1260	4.6563	0.1305	3.6734	0.1400
40-44	5.4689	0.0953	6.1988	0.0937	6.1452	0.0655	5.4161	0.0645	4.5809	0.0900
45-49	5.7451	0.0591	6.3530	0.0555	6.4706	0.0361	5.9701	0.0354	5.1362	0.0656
Panel b										
LEbirth				46.2		56.3		60.0		43.0
LEfemale				49.5		59.9		62.6		43.1
Pop size				49534		681059		929718		1018449

Note: LEbirth implies life expectancy at birth; LEfemale refers to life expectancy for females, and Pop size refers to the de facto total population.

* The parities and ASFRs for 1966 and 1976 refer to the African women population. Parity+ indicates that the average parities that were corrected using the el-Badry technique

Table A2: P/F ratios based on Trussell and Arriaga variants, Swaziland 1966-2007

Source	PHC 1966		PHC 1976		PHC 1986		PHC 1997		PHC 2007	
Ref. date	1965.90		1976.65		1986.65		1997.36		2007.36	
Age\Method	Trussell	Arriaga	Trussell	Arriaga	Trussell	Arriaga	Trussell	Arriaga	Trussell	Arriaga
15-19	1.580	1.684	1.222	1.300	1.367	1.570	1.052	1.229	1.336	1.507
20-24	1.524	1.439	1.229	1.229	1.574	1.512	1.212	1.204	1.291	1.210
25-29	1.366	1.315	1.232	1.244	1.530	1.501	1.203	1.229	1.166	1.188
30-34	1.271	1.220	1.245	1.237	1.553	1.518	1.279	1.303	1.227	1.253
35-39	1.182	1.149	1.192	1.180	1.533	1.484	1.313	1.315	1.269	1.275
40-44	1.184	1.134	1.153	1.155	1.544	1.492	1.372	1.350	1.366	1.315
45-49	1.126	1.105	1.081	1.130	1.511	1.478	1.407	1.347	1.327	1.262

Table A3: Cohort-period fertility rates and P/F ratios, Swaziland 2007 DHS

		Years prior to survey						
		2002-07 0-4	1997-02 5-9	1992-97 10-14	1987-92 15-19	1982-87 20-24	1977-82 25-29	1972-77 30-34
Age group of cohort at survey								
A	**NO. WOMEN IN COHORT**	**NUMBER OF BIRTHS**						
15-19	1,273.5	263.2	4.4	0.0	0.0	0.0	0.0	0.0
20-24	1,046.1	864.5	266.2	0.7	0.0	0.0	0.0	0.0
25-29	728.8	687.5	661.3	202.5	7.7	0.0	0.0	0.0
30-34	615.8	502.5	639.4	611.2	188.8	7.4	0.0	0.0
35-39	502.6	334.7	470.6	547.5	551.6	185.8	6.4	0.0
40-44	437.6	148.7	332.6	470.6	535.8	567.8	202.6	15.1
45-49	382.6	27.9	153.4	326.6	402.6	538.9	470.7	175.4
B. COHORT PERIOD FERTILITY RATES								
15-19		0.041	0.001					
20-24		0.165	0.051	0.000				
25-29		0.189	0.181	0.056	0.002			
30-34		0.163	0.208	0.199	0.061	0.002		
35-39		0.133	0.187	0.218	0.220	0.074	0.003	
40-44		0.068	0.152	0.215	0.245	0.259	0.093	0.007
45-49		0.015	0.080	0.171	0.210	0.282	0.246	0.092

	Years prior to survey						
	2002-07 0-4	1997-02 5-9	1992-97 10-14	1987-92 15-19	1982-87 20-24	1977-82 25-29	1972-77 30-34
Age group of cohort at end of period							
C. COHORT PERIOD FERTILITY RATES							
15-19	0.041	0.051	0.056	0.061	0.074	0.093	0.092
20-24	0.165	0.181	0.199	0.220	0.259	0.246	
25-29	0.189	0.208	0.218	0.245	0.282		
30-34	0.163	0.187	0.215	0.210			
35-39	0.133	0.152	0.171				
40-44	0.068	0.080					
45-49	0.015	0.015					
D. CUMULATIVE FERTILITY OF COHORTS AT END OF PERIOD (P)							
15-19	0.207	0.254	0.278	0.307	0.370	0.463	0.458
20-24	1.081	1.185	1.299	1.467	1.760	1.689	
25-29	2.128	2.338	2.557	2.985	3.097		
30-34	3.154	3.493	4.060	4.149			
35-39	4.159	4.820	5.003				
40-44	5.160	5.404					
45-49	5.477						

		Years prior to survey						
		2002-07 0-4	1997-02 5-9	1992-97 10-14	1987-92 15-19	1982-87 20-24	1977-82 25-29	1972-77 30-34
E. CUMULATIVE FERTILITY WITHIN PERIODS (F)								
15-19		0.207	0.254	0.278	0.307	0.370	0.463	0.458
20-24		1.033	1.162	1.270	1.404	1.667	1.693	
25-29		1.976	2.200	2.360	2.629	3.076		
30-34		2.792	3.137	3.435	3.681			
35-39		3.458	3.897	4.289				
40-44		3.798	4.298					
45-49		3.871	4.370					
F. P / F RATIOS								
15-19		1.000	1.000	1.000	1.000	1.000	1.000	1.000
20-24		1.046	1.020	1.023	1.045	1.056	0.997	
25-29		1.077	1.062	1.083	1.135	1.007		
30-34		1.129	1.114	1.182	1.127			
35-39		1.203	1.237	1.167				
40-44		1.358	1.257					
45-49		1.415						

The applicability of the South African Census 2011 data for evidence-based urban planning

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ABSTRACT

In urban planning, it is important to understand settlements in terms of demographics, socio-economic and location characteristics. A key dataset used for such studies is a national census small area dataset. This paper provides three cases studies using the 2011 South African census small area data to highlight the value added as well as challenges identified in using these data. The data were used to study patterns in housing conditions for urban growth simulation, to determine new school locations in feeder catchments, and to aid air quality mapping. The methods undertaken for these case studies were an adaptation of *k*-means cluster analysis for distinguishing housing and household patterns in order to identify homogenous areas with similar demands for infrastructure and services; catchment analysis using Flowmap to determine new school locations; and Kriging with external drift to map an indicator of air quality. In all case studies, the census small area data were critical and the information derived is deemed useful for various urban planning decisions, including planning for the provision of essential services, planning for air pollution control at locations where regulatory levels of pollutants are exceeded frequently, and planning for the development of social infrastructure in areas that are under-serviced.

Key words:

Urban planning, spatial data quality, multi-stage cluster analysis, air quality mapping and urban simulation.

1. Introduction

In urban planning, it is important to understand settlements in terms of demographic, socio-economic, physical and political environmental characteristics. The objective is often to support municipalities, regional and national governments with long-term planning tools for the development of infrastructure, facilities and services. In a municipal context, planning relies on spatially explicit estimates of the future demand for services, which depend largely on where households will live, where they will work and how they will commute using the transportation networks available to them (Waddell, 2005), as depicted in Figure 1.

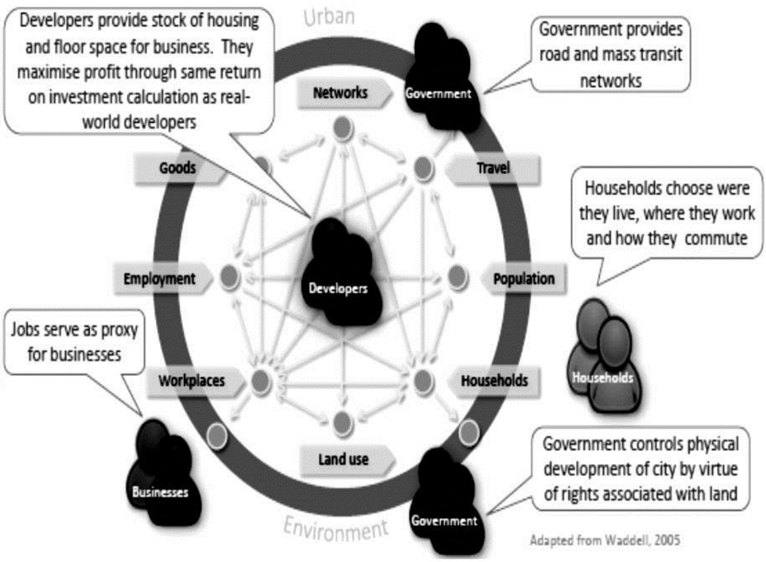

Figure 1: An illustration showing main actors and interactions within the urban environment. Source: Waldeck (2013)

Given the complexity of large cities as a system, modelling and simulation tools are valuable for municipal decisions regarding the likes of environmental quality and safety in settlements and stimulation of economic productivity through provision of infrastructure. Models cannot capture such a complex system entirely; however, they do allow integration of data indicative of factors shown in Figure 1 and their dynamics simplistically, for consumption by the relevant stakeholders. That is, they provide evidence upon which spatially equitable and sustainable planning of urban areas can be based (Cilliers et al., 2014).

A crucial dataset for evidence-based planning is a national census. With the release of the South African Census 2011 small area data in 2012 (Statistics South Africa, 2012a & 2012b), this paper reflects on research undertaken where an important input was this dataset. Specifically, we discuss how the census data were used in urban growth simulation, which is relevant for municipal services demand planning, catchment analyses to support municipal infrastructure planning, and urban air quality mapping to support planning for municipal and regional air pollution control. Given the intention to highlight the value added by the Census 2011 data for different case studies, an in-depth exposition of the different methods and results is not pursued in this paper. References for each case study are given in the appropriate sections. The paper proceeds with the materials section, Section 2, which introduces each case study and the variables that were selected from the census dataset. A summary of methods undertaken for each study is presented in Section 3, with findings following in Section 4. A discussion of what was achieved and challenges experienced with the Census 2011 data ensues in Section 5, and conclusions are given in Section 6.

2. Materials

The background of each case study is given here, with details of the applicable census data. The three case studies use the census small area data and are of the metropolitan areas of the Gauteng province. The urban growth simulation study focused on the Ekurhuleni Metropolitan Municipality due to the increasing growth and development observed and projected for this area. The Tshwane Metropolitan Municipality was of interest in the catchment analysis, given continued settlement growth in this city, especially of young families requiring education facilities. In mapping air quality, the whole Gauteng province was considered to provide a sufficient sample size for characterising the spatial distribution of the chosen air quality statistic. Generally, municipalities have less than eight air quality monitoring stations each, so we needed to pool stations over a wider region to make statistical mapping possible. From a regional air quality map, results for Ekurhuleni were extracted and discussed further with reference to housing types and location classes, determined from the household classification activity for urban simulations.

2.1 Urban growth simulations and household characteristics data

UrbanSim is a numerical modelling and simulation platform used at the Council for Scientific and Industrial Research (CSIR) to plan for urban growth (30-year planning horizon), with focus on demand for services within municipalities (Borning et al., 2008). Changes in demand for municipal services have implications for policy and infrastructure investment decisions. UrbanSim was created for and used in developed countries, and hence it was necessary to adapt it for use in South Africa, given the lack of spatial equity within our urban areas.

UrbanSim is an agent-based model where choices made by agents (households, property developers, businesses and government) in the urban system as shown in Figure 1 are maximised, based on the associated utility. For instance, the choice of a household to buy or rent a specific property depends upon household income, place of work and the presence of school-age children. Such demographic and socio-economic information is the basis upon which property demand can be evaluated. Expected or even assumed changes in demographic profiles, as translated from demographic and economic projections and policy changes where applicable, are then used to simulate growth in residential property demand. This demand output provides insight into which settlements are expected to grow significantly and therefore need attention regarding municipal services provision.

Historically, the demographic input for UrbanSim was the sub-place level ClusterPlus geo-demographic clusters dataset bought from a company called Knowledge Factory. Following discontinuation of ClusterPlus, the CSIR developed a method for classifying households at a small spatial scale using Census 2011 data. The small area layer (SAL) was used to determine homogenous groups of households that are expected to have similar demands for infrastructure and services.

Table 2: Final list of variables used in the household segmentation analysis

Broad variable classes (Factors)	**Key variables**
Dwelling location characteristics and density	Enumeration area type Density of dwellings within small areas
Dwelling type and conditions	Type of dwelling Household size Number of rooms
Socio-economic	Weighted average annual household income Employment status of head of household Highest education level of the head of household
Life cycle stage and household (family) structure	Marital status Age group Relationship structure within households
Demographics	Population group Gender of household head Gender of persons in households Property ownership of households

For the Ekurhuleni Metropolitan Municipality, 4,610 small areas from Census 2011 were considered. Key variables were identified and grouped as factors associated with socio-economic conditions, and demographic and housing characteristics, as shown in Table 1. All variables were categorical, with the exception of household income and density of dwellings. Further refinement of the categories using other government publications was performed to simplify the analysis and ensure the results fit the context. Although the data appear to be about either the households or the members thereof, they were aggregated and summarised at the level of small areas and not individual households.

2.2 Census school-age population data as a proxy for demand for schools

Infrastructure is necessary for stimulating economic growth and improving the quality of life of citizens by enabling the provision of municipal services (CSIR, 2011). Catchment analysis in urban planning is used to assess spatially whether current infrastructure is sufficient for associated services. Sufficiency is analysed in terms of the number and accessibility of service points (Green and Argue, 2012). Therefore, population information plays a critical role in such analyses, together with transportation networks and facilities inventories. Flowmap is specialised software enabling catchment analysis through an optimal assessment of flows of goods, services and people, using standards and other constraints to delineate areas that are under- or over-supplied (De Jong and Van der Vaart, 2013).

The Tshwane Metropolitan Municipality lies north of Ekurhuleni and it is currently experiencing settlement growth in various locations, especially in the northern, eastern and south-eastern areas. The residents in these areas are young working-class families who require educational institutions for their children. For public schools, the Department of Basic Education has standards concerning the number of learners per class and the size of the catchment that the school may service. These standards were set to ensure better quality of education through small learner-to-teacher ratios and better well-being of learners by minimising travel times to school. In this context, the research question was, which locations within Tshwane needed to be prioritised for investment into new schools? In response, a case study assessed the optimal location of new schools within Tshwane. The focus here is on the value added by the Census 2011 small area data. Reference is made to the impact that a faulty inventory of schools had on the location-allocation decisions.

The feeder catchments for schools within Tshwane were determined using Census 2011 data for 4,524 small areas (Schmitz and Eksteen, 2014). The population variable of interest was the number of school-age individuals per small area, namely those aged between 6 and 18 years. This group was divided into the pre-school age group of less than 6 years old, the primary school age group of between 6 and 12 years old, and the secondary school age group of between 13 and 18 years old. Land-use data from GeoTerra Image was also used.

In processing the population small area data, the municipal area was tessellated in Flowmap, using hexagons of 350 m per side. These were smaller than the smallest small area polygon. To redistribute the number of learners from the Census 2011 small areas into hexagons, land-use and the school-age population data were used to re-allocate proportionately the counts of learners into the hexagons

(Schmitz and Eksteen, 2014), resulting in a finer scale spatial distribution of the learners. This is shown in Figure 2, where higher concentrations in school-age children are observed along the north-west to south-east directions from the CBD.

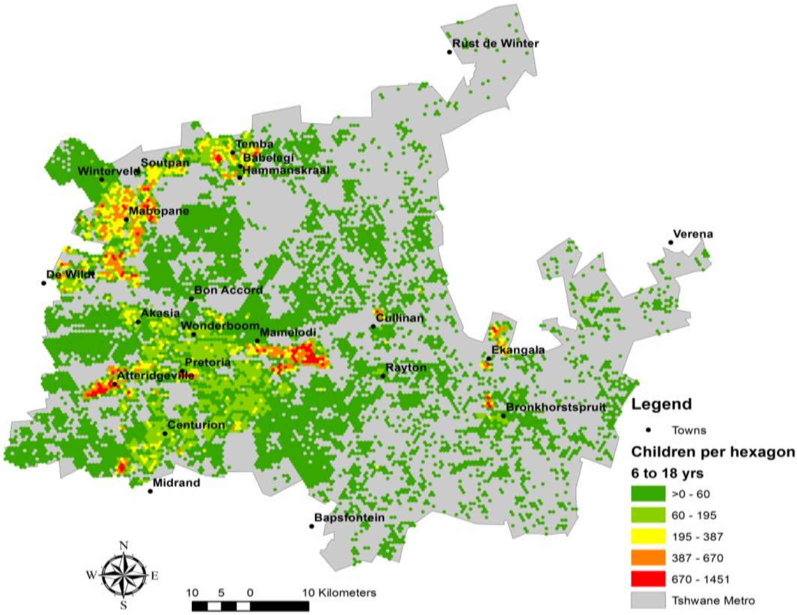

Figure 2: Spatial distribution (using hexagon tessellation) of the school-age population (children aged 6–18 years) from the SA Census 2011 data for the City of Tshwane (Schmitz and Eksteen, 2014)

2.3 Urban air quality mapping with proxy variables for domestic particulate matter emissions from the census dataset

A study was undertaken to map how often the South African air quality standard for PM_{10} was exceeded in the Highveld region, between September 2009 and August 2012. The study region included parts of Mpumalanga bordering Gauteng, to have an adequate sample size (number of air quality monitoring stations) to develop valid statistical models mapping PM_{10} exceedances. Key anthropogenic sources of PM_{10} in the study area include industries, domestic combustion of alternative energy fuels and vehicles, and dust from unpaved roads and mine dumps. Domestic combustion of alternative energy fuels has been related to heavy haze events, mainly in less affluent areas (informal settlements) of the study area (Piketh et al., 2004; Norman et al., 2007; Wright et al., 2011). Therefore, in mapping PM_{10} concentrations for this region, we considered household information such as dwelling type and energy use, obtained from the Census 2011 small area data.

A total of 24,584 small areas covering parts of Gauteng and Mpumalanga were considered. From the output, results for Ekurhuleni were extracted and are discussed in Section 4. Census variables of interest, shown for Gauteng in Figure 3, were the percentage of households residing in informal dwellings (Figure 3(a)) and the percentage of households using alternative energy sources for heating (Figure 3(b)). These were used as explanatory variables in mapping the annual exceedance rate of the RSA PM_{10} standard. The total number of dwellings per small area (a proxy for dwelling density) and alternative energy used for cooking were the other two variables considered.

White spaces in Figures 3(a) and 3(b) are non-residential small areas, typically industrial areas including mines and quarries. Informal settlements (those with more than 80% of the small area being informal dwellings) are seen in Figure 3(a) as slivers of red throughout the province, typically on the periphery of industrial or mining areas. On the southern boundary of Ekurhuleni, a moderate to high proportion of informality is observed, attributable to a mixture of informal settlements and formal residences (townships such as

Vosloorus, Thokoza, Katlehong and Tsakane) with backyard shack dwellings. Figure 3(b) shows that household use of biomasss for heating is more prevalent in the same areas where high proportions of informality were observed.

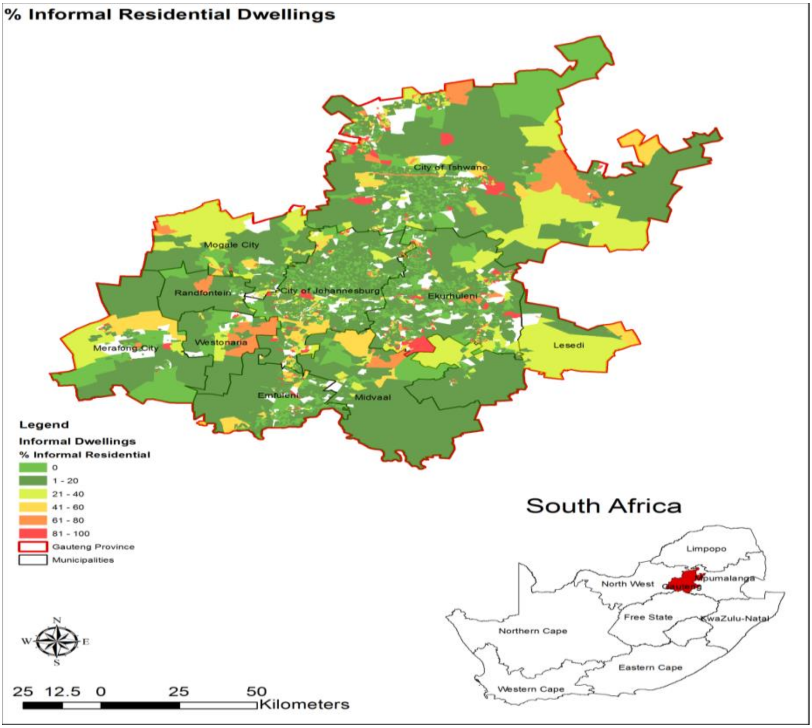

Figure 3(a): Percentage of dwellings in each small area categorised as informal from the SA Census 2011 small area layer for Gauteng. These data were used as covariate information in mapping PM_{10} exceedance rates

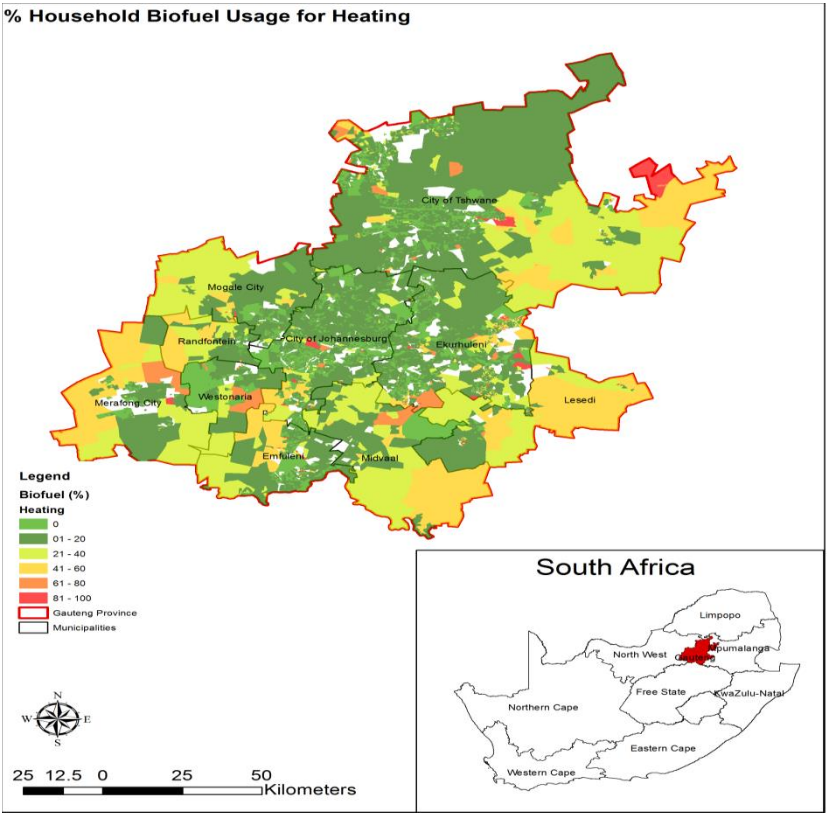

Figure 3(b): Percentage of dwellings in each small area categorised as using biomass for their heating needs. These data extracted from the SA Census 2011 small area layer for Gauteng were used as covariate information in mapping PM$_{10}$ exceedance rates

3. Methods

In the previous section, the contexts and variables of interest for each case study were discussed. In this section, key methods related to using census data are given for each case study, but for more details, see Dudeni-Tlhone et al. (2013); Khuluse and Stein (2013); and Schmitz and Eksteen (2014).

3.1 Household classification for urban growth simulation

Modelling urban growth in UrbanSim requires as input classified household information for the municipal area of interest, as explained in Section 2.1. To make these typologies readily available for any South African municipal area that may be of interest for urban simulations, a generic method for classifying households using census small area data had to be developed. Internationally, geo-demographic classification for public policy-related applications is an active area of research, with clustering techniques having been applied successfully to small area census data to identify homogenous groups of households (Vickers and Rees, 2007; Adnan et al., 2010; Ojo et al., 2013; Dudeni-Tlhone et al., 2013). The most popular technique used is the *k*-means algorithm because of its efficiency in minimising the intra-cluster variances and efficiency in processing large numeric data, particularly with many clusters (MacQueen et al., 1967; Huang, 1998; Jain et al., 1999; Adnan et al., 2010). The *k*-means algorithm partitions *n*-dimensional datasets into k clusters, where k is the number of cluster centroids m_j, $j = 1,2,\ldots,k$. The objective is to minimise the average squared distance $\left(x_i^{(j)} - m_j\right)^2$ between observations and their cluster centroids. Therefore, the objective function is a measure of how well the centroids represent observations in the relevant clusters, and is given by:

$$O = \sum_{j=1}^{k}\sum_{i=1}^{n_j}\left(x_i^{(j)} - m_j\right)^2$$

Running the *k*-means algorithm on the observations as described, with all variables considered at once, can be defined as a single-stage approach. The multi-stage *k*-means clustering approach can be defined as grouping observations by considering subsets of variables sequentially, until the desired number of clusters is obtained and all variables have been considered. The multi-stage approach was developed to minimise the incidence of outliers, which is a common problem with single-stage *k*-means clustering.

A multi-stage *k*-means clustering method was implemented in Ekurhuleni to detect groups of small areas exhibiting similar characteristics concerning housing, demographics and socio-economic conditions. Two iterations were performed. The first iteration was to identify problems with the data and to gain insight on how best to set up the various stages of the algorithm. Firstly, the dwelling density variable was removed and the first stage of the clustering was done purely on the enumeration area (EA) type variable. An EA is synonymous with a census tract and the EA type encodes the dominant land-use within the EA. There were cases where small areas belonged to more than one EA type (mixed) and some that had no EA type assigned. These atypical small areas formed only 2% of the total, but non-homogeneity in clusters was observed where these atypical small areas were placed. To overcome this, atypical small areas were reallocated into existing land-use categories, using an independent building-based land-use dataset.

In the final set-up of the algorithm, the initial stage involved implementing the *k*-means clustering technique on all small areas, separately for each of the five factors given in Table 1. Each factor is a group of census variables relevant for the household characteristic the factor represents. Therefore, the initial stage resulted in five groups of clusters, each group corresponding to a factor as shown in Figure 4. The subsequent stages consisted of consolidating the groups of clusters from the initial stage, by applying the *k*-means algorithm on clusters from the different groups, sequentially until all the groups had been considered and a final set of clusters was obtained. To avoid outlying clusters in this final set-up, consolidation of a subset of clusters within each group rather than the whole group was performed.

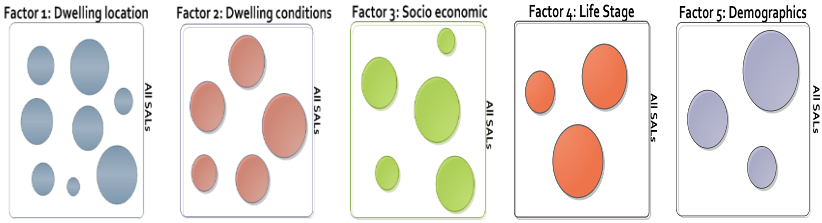

Figure 4: Illustrating the formation of k-means clusters for each factor in the first stage of our initial multi-stage approach. These clusters are then subjected to further clustering, where the clusters from the different factors are consolidated sequentially

The order of consolidation, shown in Figure 4, was based on the importance associated with each factor in differentiating between households and land-use types. The small areas were first split according to the clusters of the "Dwelling location" factor, which was defined as the first stage group. One characteristic of *k*-means clustering is its sensitivity to outliers, and this can be used in clustering out the outliers (Yoon et al., 2007). This characteristic was exploited to remove the small groups from clustering that differed from the predominantly residential population, such as clusters dominated by farms. In the second stage of the clustering, the residential clusters (low-density formal, high-density formal and informal) were split further by the clusters from the dwelling type and conditions factor. This helped separate the small areas further according to dwelling type, dwelling size and household size. The resulting clusters, excepting small clusters with fewer than ten small areas, were then clustered with those corresponding to the "socio-economic" factor. No further clustering was done because the lack of data on family composition per household made it difficult to describe life-stage and family structures within small areas. Therefore the remaining two factors, life-stage and demographics, were used to analyse descriptively each cluster that resulted from the integration of clusters formed when the dwelling location, dwelling condition and socio-economic condition factors were considered. This post-processing of clusters helped identify whether there were large intra-cluster variations necessitating further separation.

3.2 Delineating catchments for schools in Flowmap

Flowmap is used to derive optimal locations, based on distance and accessibility from the target population. For schools, the school-age population determines the demand. For Tshwane, the school-age population was derived at a finer spatial scale using the Census 2011 data, as discussed in Section 2.2. For Flowmap to assess flows between demand and target locations, a roads dataset from the municipality was used. Two different school inventories were considered for comparison.

Two iterations of catchment analysis using Flowmap were performed; the first using an unverified school inventory (containing inaccurate locations) and the second using a verified inventory. In Flowmap, schools were the destinations and the residential areas of the school-age population were the origins. School capacities and a maximum travel distance of 5 km were criteria used to assign learners to schools. If more than one school was located in the same hexagon, the capacity was computed as the sum of each school's capacity (Schmitz and Eksteen, 2014).

Figure 5 shows the resulting catchments for north-western Tshwane, based on the number of learners that can be accommodated by each school and/or are within 5 km of the school, when the verified inventory was used. The grey areas in Figure 5 were not allocated to a school and were subsequently used by Flowmap to determine potential locations of new schools to accommodate the population in these areas. Finally, twenty new school allocations (10 primary and 10 high schools), obtained using the verified schools inventory, were compared to those obtained using the unverified inventory. The differences were used to deriving an estimate of the financial impact of poor quality spatial data by considering the cost of building a new school (Schmitz and Eksteen, 2014).

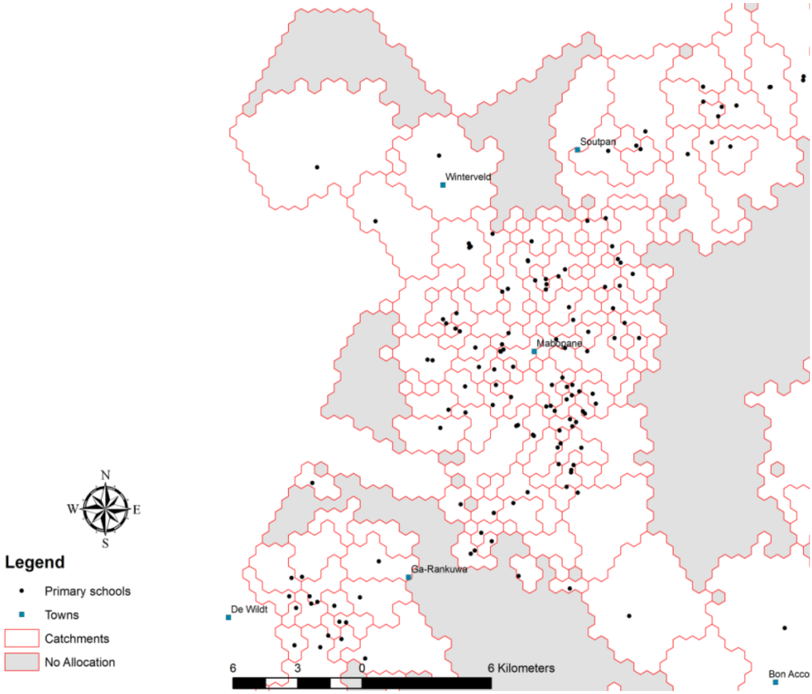

Figure 5: School catchment areas, where the grey spaces represent areas where there was demand for new schools

3.3 Urban air quality mapping

The South African PM_{10} air quality standard stipulates that the daily average PM_{10} concentrations in an area should be below 120 µg/m^3 (RSA *Government Gazette*, 2009). Air quality monitors are installed with the purpose of monitoring compliance with air quality standards. However, these are stationed in specific locations, which is a challenge given that the need is for a pollutant concentration surface over the whole region of interest. Spatial interpolation techniques enable estimation of regional pollution surfaces from in situ air quality monitoring data. Kriging is a spatial interpolation technique, a distance-weighted average, where the weights are assigned to the observations modelled by a function of the correlation between pairs of points as a function of their separation (Bivand et al., 2008). Points in this case are the locations of air quality monitors in the study area. Distances between pairs of locations are considered in this case study and two variants, ordinary Kriging and Kriging with external drift, were explored. In ordinary Kriging, only the spatial variation of the response variable is considered. In Kriging with external drift, an assumption is of a spatial trend in the target or response variable that is explained by relating the response variable with variables capturing that underlying trend. Fluctuations remaining after removing the spatial trend are the local spatial variation and are modelled by means of a spatial correlation function.

4. Findings

In this section, findings from the three case studies are highlighted, focusing on the use of the census data and the outcomes thereof.

4.1 Findings in urban growth simulation

4.1.1 Household classification results

The final set of clusters for Ekurhuleni was a homogeneous group of small areas, where household characteristics and housing types met expectations for residential areas in this municipality. For instance, townships and informal settlements cover a large area in Ekurhuleni. Typical township formal houses have four rooms, inclusive of the living room, kitchen and two bedrooms. This corresponds with the substantial percentage (21%) of small areas characterised by four-roomed houses, occupied by six or more people with annual average income below the overall average for the municipality, and low education levels and employment amongst household heads.

To establish how well final classifications based on census data can be sufficiently accurate for urban modelling applications dependent on land-use characteristics, it was necessary to compare the census enumeration area (EA) type (the dominant land-use and the base for clustering) with an independent land-use dataset, the building-based land-use dataset of GeoTerra Image (GTI). The GTI dataset is derived from very high-resolution satellite images and aerial photography and municipal cadastral information (GeoTerra Image, 2012). The two datasets were overlaid on a map, so that small area boundaries could be superimposed on the GTI spatial point dataset, as shown in Figure 6. There were differences in definition of dwelling types between the two datasets. For informal dwellings, the census had two categories, differentiating free-hold informal dwellings from informal backyard structures. GTI also had these categories with an additional “transitional informal” dwellings category, which defines dwellings that cannot be classified as formal, free-hold or backyard informal structures. Due to these differences, complete agreement between the two datasets was not expected, but moderate to high agreement (more than 60%) was anticipated for most categories.

Figure 6: An overlay of small area boundaries on GTI building-based land-use point data for validation of Census 2011 dwelling type data

An interrater agreement statistic, namely the proportion of the agreement statistic (Cicchetti and Feinstein, 1990), was used for comparing the census and the GTI land-use information. Overall, the consensus between the two datasets as shown in Table 2 was high, with the highest level of agreement observed for formal residences, which includes detached, semi-detached and cluster housing. Moderate agreement was observed for backyard informal dwellings, which could be attributed to the GTI data having an additional transitional informal category, which was absent from the census data. The lowest agreement was for high-rise apartments (flats). This could be attributable to differences in the unit of measure used in the different sources, e.g. GTI counts dwellings and therefore a block of flats would count as one unit, whilst in the census, each household within a block of flats is counted. It was concluded that the census EA type data was satisfactory for the purpose of classifying households required for urban modelling applications.

Table 3: Interrater statistics obtained in an assessment of validity of the census land-use (dwelling types) counts per small area against the GTI building-based land-use data

Dwelling type	**Observed agreement (as %)**
Formal semi/fully detached house	85
Informal house NOT in backyard	75
Informal house IN backyard	69
Flats or apartment	68
Cluster house	80

4.1.2 Comparing simulated and actual growth in household numbers

Urban growth simulations for the period between the 2001 and 2011 censuses were done in UrbanSim using household classification information. To validate the results, the simulated growth in number of households was compared with the actual growth during the same period, according to censuses 2001 and 2011 and GTI's building-based land-use dataset. A larger spatial unit of analysis (modified sub-places) was considered. The method used for adjusting census counts for changes in sub-place boundaries is described in Section 5.4.

Most of the outliers in the comparisons of simulated and actual household growth in Figure 7(a) could be explained. For instance, some outliers were attributable to delays in legal processes experienced by real-life developers but not known to developers in the model. If these outliers are excluded, the predictive accuracy of the model is estimated at about two housing units per hectare. The comparison also suggests that errors inherent in the model are similar in magnitude to the differences between actual observations of two reputable sources (Figure 7(b)) over approximately the same period.

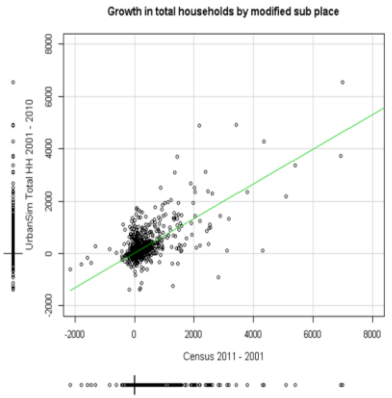

Figure 7 (a): Household growth between 2001 and 2011: Comparing UrbanSim predictions with Census 2011 data

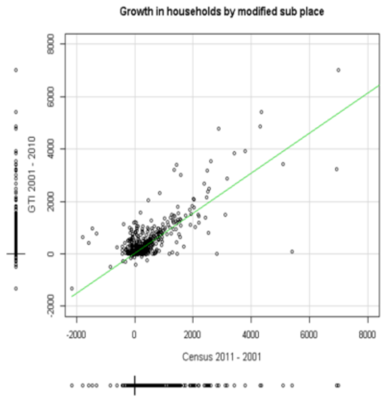

Figure 7 (b): Household growth between 2001 and 2011: Comparing GTI dwelling counts with Census 2011 data

4.2 Catchment analysis results

For the schools catchment analysis in Tshwane, distances between school locations from the unverified and the verified inventories were determined. When comparing school locations between these two inventories, 65% of schools were within 100 m of the correct locations, while 2% (nine schools) were more than 5 km from the correct location. While the latter discrepancy seems insignificant, the financial implications are significant. For instance, the locations of ten new primary and ten new secondary schools were determined in Flowmap using the two inventories. With the verified inventory, only six new primary schools were needed, and the locations of two new secondary schools differed from those determined through the unverified inventory. Therefore, using an inaccurate inventory of schools would have led to an infrastructure misspend of over R 120 million (Schmitz and Eksteen, 2014).

4.3 Urban air quality mapping

The purpose of mapping the PM_{10} exceedances was to assess which areas have poor air quality and to determine what drives the observed patterns. An understanding of such drivers can inform strategies to control pollution at the source. Statistical mapping of the observed PM_{10} annual exceedance rate proceeded by means of Kriging, with the data from 36 air quality monitors considered. The results from implementing ordinary Kriging show areas west of Gauteng, highlighted by the box in Figure 8 (top-left), as having high exceedance rates. Upon inspection, the high PM_{10} concentrations occur in high-density residential areas, hence the decision was to incorporate dwelling data in the Kriging model.

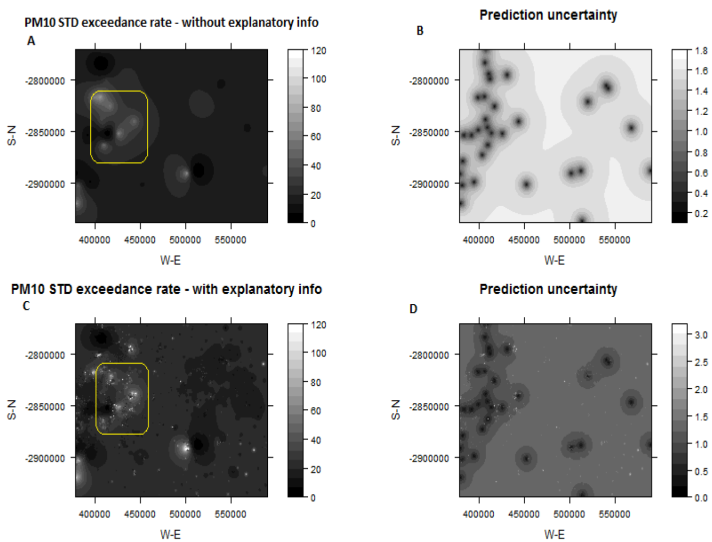

Figure 8: Resulting PM_{10} exceedance rate map, with and without use of explanatory information (A and C, respectively). The corresponding prediction uncertainty surfaces are shown as maps B and D

A description of the four explanatory variables considered in Kriging with external drift is given in Section 2.3. The number of dwellings per SAL was not a statistically significant explanatory variable, whereas the percentage of informal dwellings and biomass energy used for cooking and heating were significant. The advantage of using additional explanatory spatial variables that are significantly correlated with the response variable is an improved map. Kriging with external drift, using the percentage of informal dwellings per small area as the explanatory variable, resulted in a more nuanced pattern of spatial variation, as observed on the bottom-left map in Figure 8 (in comparison to the top-left map). The maps on the right of Figure 8 show the prediction error variance, a measure of precision. Precision was lowest (high prediction error variance) in areas without air quality stations (as expected). However, in adding an explanatory variable prediction, uncertainty is reduced – especially in areas without air quality monitors.

Biomass energy use variables were then included in the model, in addition to the informal dwelling percentage. Similar patterns were observed for the Highveld region. Results for the Ekurhuleni municipal area were extracted and are shown in Figure 9(a). Considering Figure 9(b), it can be deduced that locations of poor air quality in Ekurhuleni (high PM_{10} exceedance rates), are characterised by typical township housings, including four-room type houses and RDP houses, inter-twined with informal dwellings as backyard shacks within townships, and stand-alone shacks in informal settlements. Therefore, this study found that domestic fuel combustion was a significant contributor to poor air quality in urban areas in Gauteng, confirming the results of previous environmental health studies in this region (Norman et al., 2007; Wright et al., 2011). Financial constraints could be the reason for such biomass energy use in these areas; hence strategies to curb pollution would need to consider the socio-economic conditions in these areas.

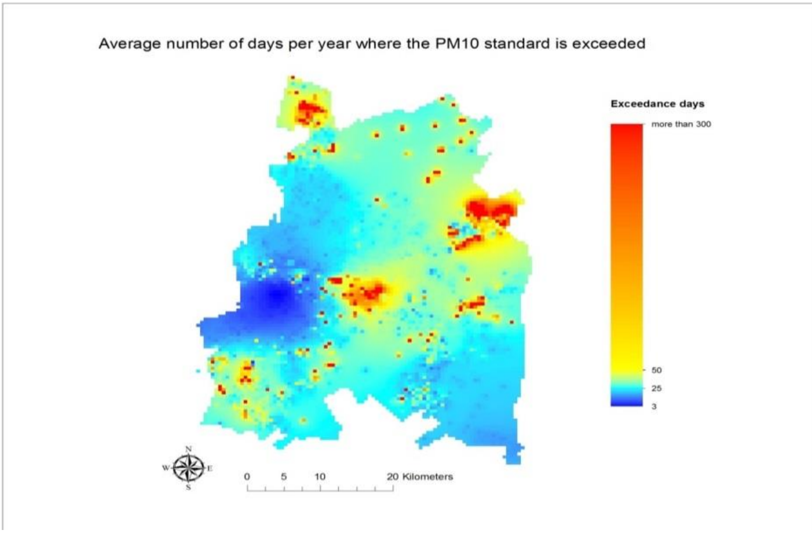

Figure 9(a): Predicted number of daily exceedance per year of the PM_{10} standard in Ekurhuleni with informal dwelling proportion and domestic use of biomass energy used as explanatory information

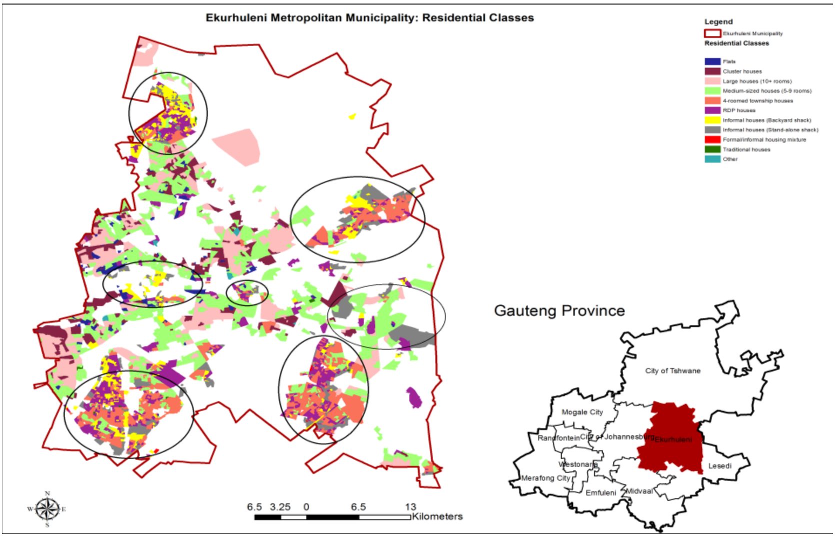

Figure 9(b): Map of Ekurhuleni Metropolitan Municipality with residential classes derived from the first two stages (consolidating 'dwelling location' and 'dwelling condition' clusters) of the multi-stage k-means procedure

5. Discussion

Governments, specifically municipalities, have a responsibility in ensuring there is adequate infrastructure for stimulating and sustaining local economic growth and for securing a better quality of life for their citizens. Planning in metropolitan areas in South Africa, particularly in Gauteng, has moved away from master spatial planning into alternatives that advocate for linkages between human settlement planning, infrastructure development and ecosystem preservation (Gotz et al., 2004; Todes et al., 2010; Todes, 2012). A key resource for this approach to planning is the availability of good quality socio-demographic and housing data, such as national census data, which can be disaggregated to small areas. This was illustrated in this paper through three studies, showing how the South African Census 2011 data were processed to successfully assess demand growth for municipal services and infrastructure, and to identify areas of concern for pollution control. Another desirable property of census data for urban planning is the possibility of linking these data to household and travel surveys.

An important finding to emerge from the case studies was the importance of the geo-demographic classification from census data and the potential to use these in other urban modelling initiatives. In geo-demographic classification, comprehensive small area information from a census is condensed into classes or segments that describe the people (households) and the characteristics of the areas in which they live (Ojo et al., 2013). The household classification tool was developed for modelling within UrbanSim. However, we demonstrated that these household classes are also applicable in interpreting the spatial distribution of exceedances of PM_{10} air quality standards, in our case leading to the conclusion that informal settlements are areas of poor air quality due to alternative energy similarly to findings of previous environmental health studies in Gauteng. Geo-demographic classification of census data to support planning decisions has a long history in the United Kingdom and the United States of America (Singleton and Spielman, 2014), with uptake in developing nations also gaining momentum. For instance, for the Philippines, a three-tier hierarchical geo-demographic classification was developed to support policy related questions (Ojo et al., 2013) and for Nigeria, 774 local government areas based on geo-demographic classification were created to enable understanding of the local population needs and provide evidence for planning and related policymaking (Ojo et al., 2012).

5.1 Challenges in calculating dwelling density per small area

Dwelling density was calculated using the number of dwellings in the census data and the area of the SAL, but Figure 10 gives a mapped example highlighting the problem of using density in this manner: the green polygons represent the small areas clustered as high-density formal housing, while the brown polygons are the low-density formal housing. On closer inspection, it was clear that the density of the dwellings is similar in these clusters, but the presence of open spaces or schools, i.e. multiple land-uses, in the brown polygons created a lower density value, implying these areas were less built-up than those in the green polygons. As a result, dwelling density had to be removed from the location characteristic factor in household segmentation, and only the census classification of EA type was used.

Figure 10: First layer of clusters based on density and location characteristics. Although small areas in green should be classified as those coloured in brown, they were misclassified because the presence of open spaces

5.2 Distortions caused by class definitions

It is known that in urban areas, such as in Gauteng, enumeration classification can be fraught with difficulties. In particular, some residential areas classified as informal in the census data give a clear impression of formalised housing on a map. Similarly, examples were found of small areas incorrectly classified as having collective living quarters. Although such examples were found, it is difficult to check and rectify individual enumeration area types in a pure data clustering activity, involving 4,160 small areas say, but the consequence of not correcting such errors may be that certain areas are profiled incorrectly for demand for services. Therefore, a method for isolating such cases by using auxiliary information is of interest, particularly in areas that have developed into formal residential areas but are still being recorded as informal.

Another issue with dwelling type classification was the creation of outlier clusters due to lack of clarity in names. In particular, the definition of “traditional” is not clear, because one would assume that it refers to structures that involve traditional building materials, such as thatched roof huts. On close inspection of these small areas using Google Earth however, only one such small area could be seen that actually contained “traditional” dwellings according to this definition. Similar problems also arose with the “caravan/tent” classification. Therefore, going forward, it will be necessary to treat such atypical dwelling types in a different manner to that of other dwelling types in the clustering process, to prevent creating outlier clusters from small areas which are in fact not outliers.

5.3 Problems identifying life-stage characteristics

During the cluster consolidation stages in our algorithm, clusters corresponding to factors 4 and 5 in Table 1 were initially derived, but were not considered for consolidation. Rather, the variables forming these factors were used descriptively on clusters formed by consolidating clusters corresponding to the first three factors. In particular, the 'life cycle stage and household (family) structure' factor was of interest in attempting to derive from the census data, the mobility of households within a small area. Life-stages of people in a household can be related to their probability of moving to other areas and their demand for services. With only the totals available for all categories in the life-stage key variables for each small area, it was impossible to group families, determine family types and subsequently derive information on their mobility. The clusters with people who were "never married" were the ones with all the children (above average values for the lower age groups), and small areas dominated by married and divorced people with below average numbers of children seemed illogical. It was later established that all children are classified as “never married” in the data, even though they are too young to marry. Such clusters were difficult to interpret. If further information on family structures was available from the census data, it would enhance our understanding of the needs of households within a small area.

5.4 Consistency of spatial scales

The spatial scale of the data used in all three case studies was the small area. Consistency and appropriateness in spatial scales in census data is important in spatial urban planning, as the data are used to derive information for many factors and processes that interplay in the urban environment. The data are also used to track changes, through comparison with past censuses and other survey datasets, re-iterating the importance of consistency in spatial scales. An issue is that some small areas cover a much larger area than the average small area size. This is done to protect the anonymity of those living in less populated areas. However, for the purpose of modelling, similarly sized spatial entities are often preferred and in the case of urban areas, the smaller the better, due to the high spatial density of buildings. This was a reason for the development of the Geographic Analysis Platform (GAP) geoframe with similar-sized mesozones to which statistics are disaggregated (Naudé et al., 2007).

Another spatial scale issue concerns sub-places. The country is divided into 22,108 areas delineating the boundaries of suburbs, sections and sub-villages. Suburbs are mostly found in built-up areas. Areas at the fringes of built-up suburbs are normally small or agricultural holdings. All other areas on the sub-place scale are then classed as non-urban (NU), e.g. Tshwane NU. Some NUs are large and consist of multiple, disjoint polygons, but are represented spatially as a single feature or area, as shown in Figure 11(a). The census data for these areas are also aggregated, as if the NU covers a single geographic location and not one that is dispersed over a large area. Therefore, it becomes a challenge to do a meaningful analysis where such NUs form a significant part of one's area of interest. A solution that was developed to enable urban growth modelling was to create a modified spatial representation of the sub-places, referred to as "modified sub-places", as shown in Figure 11(b). These modified sub-places were derived by subdividing all sub-places larger than 3 km^2 into smaller hexagons, as shown in Figure 11(b). The 3 km^2 was chosen because it corresponded to the 75^{th} percentile of the area in Gauteng. By making use of GTI's auxiliary datasets indicating the actual locations of dwellings, the data for each of the modified sub-places were calculated and apportioned from the data for the entire NU.

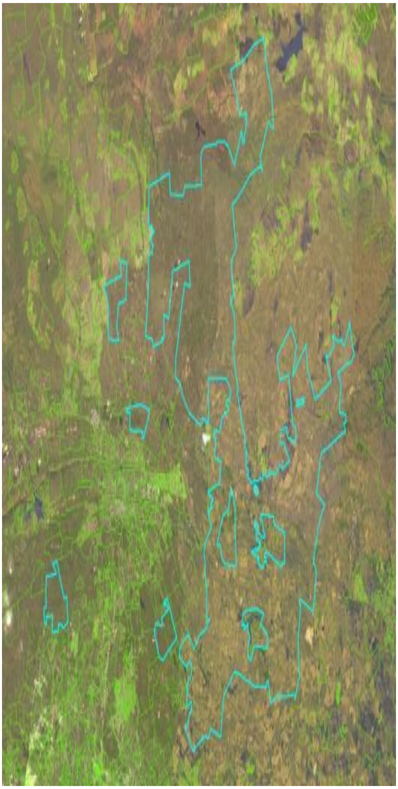

Figure 11(a): This map shows a large area, consisting of multiple suburbs, which is classified as a single non-urban (NU) area at sub-place level for Tshwane municipality

Figure 11(b): Illustrating how large sub-places were modified into smaller hexagonal polygons, which were then named 'modified sub-places'

5.5 Lack of workplace data

Information on place of work, i.e. the geographic location where workers carry out their occupations, is important in planning. Although a question about the place of work had been included in the household questionnaires of some previous South African censuses (but not in the Census 2011), the availability and reporting of the number of workers by place of work at a practical geographical level have been scarce. In the previous census, the resolution of place of work was main-place, unless the answer to another question about working and living in the same sub-place place was true, in which case the place of work could be resolved to sub-place. It is not certain whether this is due to the quality of the responses or whether it can be attributed to inappropriateness of automatic geocoding, which is only possible where street addresses or aliases are available. The location of informal activities and of activities of variable location, such as construction, adds complications.

The lack of suitable workplace data in South Africa requires additional expensive and *ad hoc* surveys for various studies. The United Nations recommends that place of work be included in national censuses (United Nations, 2007). In countries such as the United States of America, United Kingdom, Australia, New Zealand and Ireland, workplace data have been successfully collected during censuses and reported over a number of years. Sometimes the results of additional surveys, such as the American Community Survey (ACS), have been used to enhance the census information (Statistics New Zealand, 2013; UK Office for National Statistics, 2014). Statistics New Zealand's standard for workplace address is a nine-page document dealing with operational issues, classification criteria, outputs, coding process and related standards. This information has been used in numerous studies of commuting patterns, workplace population analyses, calculating daytime population and visualising worker movements at various geographical levels (Statistics New Zealand, 2009; UK Office for National Statistics, 2013; UK Office for National Statistics, 2014; McKenzie et al., 2014; Rapino et al., 2014).

One possible solution for the lack of place of work data we are considering is combining the census 10% sample with other surveys (undertaken or facilitated by Statistics South Africa), such as the labour force and national household travel surveys. Each has particular strengths. The 10% sample provides the best characterisation of person and household attributes, the labour force survey the best information on the type of work, while the household travel survey has the best information on origin, destination and mode and cost of travel. This will, however, have to be done in collaboration with Statistics South Africa because it requires sample-specific information not ordinarily released for reasons of confidentiality.

6. Conclusions

There were three main contributions made by this paper. Firstly, successful experiences in using the South African Census 2011 small area data in modelling that resulted in valuable input for urban planning were shared. The second contribution is the use of statistical interrater measures to show the similarity of a census housing-type classification to an independent building-based land-use classification dataset. Thirdly, according to the authors' knowledge, this is the first paper to highlight the challenge of lack of workplace information from the South African census and to present a possible way to overcome this problem.

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Migration and Settlement Change in South Africa: Triangulating Census 2011 with Longitudinal Data from the Agincourt Health and Demographic Surveillance System in the Rural North-east

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ABSTRACT

This paper examines internal migration and settlement change in both national and sub-district settings of South Africa using Census 2011 data and an external data source, namely the Agincourt Health and Demographic Surveillance System (HDSS). The period under consideration is the 5 years between 2006 and 2011. Census 2011 data revealed that 5,3% of South Africa's population has migrated internally between 2006 and 2011, with metropolitan areas being the significant origin and destination locations of internal migrants. In general, the Census analysis indicates that more urban settlement types appear to gain population as a result of net migration, while the less urban settlement types tend to lose population to migration. However, migration trends evident from the national census data present a blend of permanent and temporary moves; the Agincourt HDSS analysis reveals a large proportion of migration in contemporary South Africa that is temporary (comprising approximately 25% of the population). Such migration is primarily economically driven and is undertaken by males (60% of 30- to 49-year-olds) and increasingly, young adult females (33% of 20- to 39-year-olds in 2010/2011). The study concludes that metropolitanisation is a key finding at the national level, however, a proportion of this urban-ward movement is temporary. There remain strong interdependencies between rural and urban areas, which should be taken into consideration in public service and spatial planning.

Key words:

Internal Migration, Urbanisation, South Africa, Census, Health and Demographic Surveillance System

1. Introduction

The 2011 population census presents an opportunity to revisit the question of what is happening to settlement patterns in South Africa, 20 years after the country's transition to democracy. Following Census 2001, it was evident that contemporary patterns of migration within South Africa were unique in the Southern African region, and continued to mirror dynamics that had taken hold in the country during the colonial period, and beyond into the apartheid era. Urbanisation was occurring, but with marked variations across origin areas and between population groups (Kok *et al* 2003). Most notably, circular mobility remained a characteristic of labour migrants, who maintained ties with rural homes while working in the larger cities (Posel & Casale 2003). Ten years later, it is with much interest that patterns of migration and settlement change in contemporary South Africa are revisited, using the most recent population census data.

Using data from Census 2011 representing the period 2006 to 2011, this paper presents a descriptive analysis of migration flows between five municipal settlement types in order to explore how settlement types across the country are changing as a result of internal migration. The paper goes on to analyse more fine-tuned dynamics of temporary and permanent migration using prospective data from the Agincourt Health and Demographic Surveillance System (HDSS) located in the country's north-east. The HDSS provides a ground-level perspective of the geographical distribution of migrants, and allows for a more precise temporal dimension to be embedded in the examination of migration trends within the same time frame, 2006–2011. The census and the HDSS data sources differ with respect to the methods of data collection (cross-sectional versus longitudinal) as well as the size and structure of the populations under study. The paper employs triangulation to consolidate and harmonise these two perspectives on internal migration and settlement change. On the basis of this triangulated approach, the paper concludes with a discussion of how the process of urbanisation is unfolding in South Africa.

2. Literature review

2.1 Urbanisation in South Africa

The African continent is experiencing concurrent demographic, economic and urban transitions, all of which connect to and influence the process of socio-economic development (UN-Habitat, 2014). Over the coming decades, rapid growth in urban populations has been projected for the continent, and levels of urbanisation, currently estimated at 40%, are expected to reach 50% by the year 2035 (UN-Habitat, 2014; United Nations, 2014). Within the Southern African region, approximately 62% of the population presently resides in urban areas, and the urban population is projected to increase to 68% by the year 2030 (United Nations, 2014).

Within the Southern African region, South Africa presents a unique set of circumstances which has shaped its urban transition. The country's socio-political economy of apartheid and the colonial periods preceding it significantly influenced the process of urbanisation and patterns of migration within the region. Controlled migration was introduced during the colonial period as a mechanism to curb permanent urban settlement of the black African population who were recruited from surrounding areas to the cities as a part of an urban workforce (Zlotnik 2006). What followed was the formalised system of apartheid that legislated patterns of settlement and restricted the black African population from residing permanently in urban areas (Wentzel & Tlabela 2006). A system of oscillatory labour migration ensued, whereby predominantly male workers would move between urban places of employment and rural homelands where families were accommodated (Gelderblom & Kok 1994). By the end of the apartheid era, South Africa's settlement profile was reflective of government's attempts to curb permanent urbanisation of the black African population (Kok *et al* 2003). The 1990s saw an increase in the proportion of black South Africans classified as urban-dwellers, from an estimated 42% at the end of apartheid in 1994 (Anderson 2006) to a level of approximately 48% in 2001 (Kok & Collinson 2006). Following the 2001 population census, the level of urbanisation for South Africa as a whole was estimated at 56,26% (Kok & Collinson 2006).

Into the 2000s, it was expected that the rate of urbanisation would continue to increase, and this is supported in South African national data. The most recent United Nations estimate indicates that 64% of the South African population resides in urban areas (United Nations, 2014). Interestingly, and in contrast to the trends observed elsewhere on the continent, there has been a decline in the growth rate in South Africa's urban areas, which is not attributed to decreases in internal migration but rather to decreases in natural population growth in the context of a high infectious disease burden (Turok 2012). Nevertheless, the United Nations projects that the proportion of South Africa's urban population will reach 77% by 2050. Thus understanding patterns of migration is all the more significant in this region.

South Africa holds a dominant position in the region's economy, and attracts increasing numbers of international migrants (Landau & Segatti 2009). Within the country's borders, levels of migration are high. South Africa's process of urbanisation is driven largely by economic opportunity and the search for employment (Cross 2006; Turok 2012). The Gauteng province (comprising the Johannesburg, Tshwane and Ekurhuleni metropolitan areas) is the most economically productive and accounts for approximately 32% one-third of national economic output (South African Cities Network, 2011; Turok 2012). The Cape Town and eThekwini municipalities follow with collective contributions of approximately 20% of national output (Turok 2012). In correspondence with levels of economic productivity, employment opportunities and earnings are also concentrated in the country's more populous metropolitan areas (South African Cities Network, 2011). It is then not surprising that these regions are also the most attractive destinations for internal migrants.

National data confirm Gauteng as the most attractive province for migrants, with positive net migration observed in both the 2001 and 2011 population censuses (Statistics South Africa, 2012a). Although at a considerably lower level, the Western Cape consistently demonstrates positive net inflows of migrants from other provinces (Statistics South Africa, 2012a). While the dominant flows in the country are in the direction of the large metros, the National Development Plan highlighted that approximately 78% of migration from rural areas and smaller towns was directed towards similar settlement types (National Planning Commission, 2011). Furthermore, there is evidence that patterns of temporary migration, a legacy of apartheid's labour migration system, have persisted and migrants often keep a foot in their rural origin areas following a move to the city (Collinson *et al* 2007; Hosegood *et al* 2005). Migration in these instances operates as an important livelihood strategy to maintain rural homes through remittance income (Casale & Posel 2006). Within South Africa, migration streams are becoming increasingly feminised as more females seek employment opportunities in urban and surrounding areas (Collinson *et al* 2006; Posel and Casale 2003). Thus contemporary patterns of movement within South Africa are diverse. The questions of who moves, at what distance, to where and for how long are all pertinent in this context.

South Africa's National Development Plan (NDP), which presents a vision for South Africa for 2030, emphasises the reduction of poverty and inequality as critical for South Africa over the coming decades (National Planning Commission, 2011). In order to achieve this vision, a set of priorities are articulated. These focus on, amongst others, the promotion of economic development and the transformation of human settlements (National Planning Commission, 2011). Economic development requires job creation and more integrated rural participation. The urban expansion may be viewed as a positive force, but improving infrastructure and service delivery, and in particular conditions in informal settlements, are policy imperatives (Turok 2012). These changes cannot be effected without a sufficient handle on South Africa's current population trends and settlement patterns.

2.2 Data constraints

The study of migration and urbanisation is challenged by issues relating to definitions, data availability, data quality and methodology. Estimates of urbanisation are underpinned by a set of criteria defining urban spaces and there may be difficulties in classifying a continuum of different settlement types into a simplified urban-rural dichotomy (Kok & Collinson 2006). Furthermore, there is a lack of consistency across countries on ways in which urban spaces are defined (National Research Council, 2003), which may hamper comparisons. Definitions of migration rely on specifications regarding the spatial boundaries that constitute a move and the duration attached to the migration. These are often study or context specific. The definition of a household also plays an important role in how migration is measured.

Population censuses are the most utilised sources of national-level demographic data; however, due to their scale, they are conducted infrequently and in some African countries, not at all. The census has the strong advantage of sample size and inclusivity, and it therefore provides a powerful snapshot of a population's composition and characteristics at a point in time. However, due to its cross-sectional nature, the census is not always an effective source of data on change. Cross-sectional surveys such as the Demographic and Health Surveys or Statistics South Africa's Community and Labour Force Surveys provide retrospective survey data on population mobility or related dynamics. However, when applied to the study of urbanisation and migration, such cross-sectional data often conceal underlying population dynamics. These instruments fail to capture temporary, circular or return migrations and they often overlook the interactive nature of families across rural and urban settlement types.

Longitudinal methodologies have the advantage of allowing for the collection of prospective measures on repeated events such as migration. These data are particularly valuable for studies of migration and related dynamics. HDSSs accumulate longitudinal health and demographic data for the total population of a defined geographical area. These data are used to monitor population dynamics, analyse trends and investigate outcomes (INDEPTH Network, 2002). HDSS data enable the discrimination of permanent from temporary migration, and can reveal the more nuanced links between rural and urban spaces. An analysis that combines the strengths of the census that highlights the national perspective, with a more fine-tuned sub-district level perspective, will enhance the current understanding of contemporary migration and settlement change in South Africa.

Against this background, the current study presents a descriptive analysis employing two data sources: Census 2011 and longitudinal data from the Agincourt HDSS, a rural sub-district of South Africa in order to 1) identify the contemporary patterns of migration and settlement change in

South Africa; 2) discuss the role of temporary migration in relation to these trends; 3) employ a triangulated approach to draw some conclusions about the process of urbanisation underway in South Africa.

3. Methods

The analysis of migration and changing settlement patterns conducted in this paper is based on two data sources. Census 2011 is used to analyse national-level data, and Agincourt HDSS data are used to obtain a fine-grained measurement of migration patterns at the sub-district level. The approaches for each will be discussed below.

3.1 Census 2011 analysis

The national census defines a household as ‘a group of persons who live together and provide themselves jointly with food or other essentials for living, or a single person who lives alone’ (Statistics South Africa, 2012b). This is referred to as the *de facto* household membership which implies that people are enumerated according to where they were on census night

(Statistics South Africa, 2012b). Migration information was recorded in Census 2011 by enquiring whether each individual in the household had moved since 2001. A migration captured in the census therefore represents a change in an individual's usual place of residence between 2001 and 2011. If an individual moved more than once during this time frame, the migration event captured represents the most recent change in usual place of residence. The migration events recorded in the census are therefore not equally distributed over the ten-year time frame. For this reason, and in order to minimise recall bias, the period analysed using the census data has been narrowed to a five-year interval between 2006 and 2011. The Census 2011 database used for the analysis was prepared by Statistics South Africa and a modified version of this analysis can be seen in the Census 2011 report 'Migration Dynamics in South Africa' (Statistics South Africa, 2015).

3.1.1 Derivation of settlement categories

In order to analyse settlement change, data obtained from the census on an individual's present and previous place of residence (in the case of migration) are located in local municipalities, which are categorised into one of five settlement types (see Table 1). Settlement types are determined using a classification of municipalities according to the population size of the largest town or city in the municipal area (see Graeme Gotz, of the Gauteng City Regional Observatory, published in 'Differentiated urbanization – analysis of urban/rural settlement dynamics' [Gotz 2014]). Local municipalities frequently include both rural and urban areas, the proportions of which are assessed in assigning municipalities into the hierarchy of settlement types. The classification system allocates municipalities according to the largest settlement type within the municipality. This allows for an examination of which settlement types are growing and which are shrinking as a result of internal migration. This approach provides an alternative to the provincial-level analysis of internal movements; however, this classification system may result in an under-representation of rural areas if urban municipalities include some rural portions.

The hierarchy of settlement types is presented in Table 1. The core-metropolitan municipalities are the most urbanised settlement types, with population sizes exceeding one million people. Six metropolitan municipalities (Johannesburg, Tshwane, eThekwini, Cape Town, Bloemfontein, Nelson Mandela Bay) have been identified as falling into this 'most urban' category. These municipalities vary by area size, population size and density. The smallest metropolitan municipality in terms of area size is Johannesburg, measuring 1 645 km^2, and the largest is Tshwane with a size of 6 345 km^2. Nelson Mandela Bay has the smallest population numbering 1 152 115 persons, and Johannesburg the largest with a population of 4 434 827 persons. Correspondingly, population densities across these municipalities vary from the least dense, Tshwane, which comprises 460 persons per km^2 to Johannesburg, the most dense, which comprises 2 696 persons per km^2. The mostly rural municipalities number 77 and include settlement types that are tribally held (former homeland areas), as well as commercial agricultural areas and game farms.

Table 4: Settlement categories in 2011

Settlement category	Total rural population in category	Total urban population in category	% urban	Example of municipalities included	Number of municipalities in category
Metro core municipalities More than 1 000 000 urban	742 874	18 126 409	96,1%	Example: Johannesburg, Cape Town, Ethekwini	6
Secondary city municipalities 200 000 - 999 999 urban	1 442 504	6 117 637	80,9%	Example: Mangaung, Buffalo City, Rustenburg, Newcastle, Kimberley	16
Major town municipalities 50 000 - 199 999 urban	4 034 661	6 133 173	60,3%	Example: George, Stellenbosch, Mafikeng, Knysna, Oudtshoorn, Kokstad	67
Small town municipalities 20 000 - 49 999 urban	5 072 480	2 366 782	31,8%	Example: Mussina, Tzaneen, Giyani, Ulundi	68
Mostly rural municipalities Fewer than 20 000 urban	6 999 666	734 376	9,5%	Example: Port St Johns, Nkandla, Prince Albert	77
Total	18 292 185	33 478 377	64,7%		234

Source: Gotz 2014

3.1.2 Settlement transition matrix

Residential information collected in the 2011 national census may be used to generate internal migration flows within the country for the five-year period 2006–2011. Migration flows are derived for any moves reported between or within the five municipal settlement types: ‘metro core’, ‘secondary city’, ‘major town’, ‘small town’ and ‘mostly rural’. These migration flows or ‘transitions’ are represented in a series of settlement type transition matrices.

The settlement transition matrix aggregates each migration occurring between a previous place or ‘origin local municipality type’ and a present place or ‘destination local municipality type’, over the period 2006–2011. The cells on the diagonal of the transition matrix represent moves that take place within the same settlement type. The triangle of cells that lie above and to the right of the diagonal represent counter-urbanising transitions, or migrations from more urban to less urban local municipalities. The triangle of cells that are presented below and to the left of the diagonal represent urbanising settlement transitions, i.e. migration from a less urban to a more urban place (urbanisation).

3.2 Agincourt Health and Socio-Demographic Surveillance System (HDSS) data

The Agincourt sub-district of Bushbuckridge, Mpumalanga province, is situated about 500 kilometres north-east of Johannesburg and lies adjacent to South Africa's north-eastern boundary with Mozambique. The field-site was selected as representing an area typical of South African rural society (located some distance from a tar road or township settlement), with research aims directed towards understanding the population's health status and determinants, and addressing issues of decentralised health systems development (Tollman 1999).

Commencing in 1992, the sub-district has been the site of health and socio-demographic surveillance for over 20 years. The field-site initially contained 21 village communities and measured 400 km². The total surveillance population currently comprises 91 178 individuals living in 11 500 households, residing in 27 villages (see Collinson *et al* 2002; Kahn *et al* 2012 for further information on the Agincourt HDSS). The Agincourt HDSS offers an ideal data source to triangulate with the census-based settlement transitions matrices, especially in showing how the rural municipalities are linked to the rest of the settlement system through migration. The use of triangulation from two dissimilar sources of data is an effective means of gaining a complimentary perspective of the dynamics under study (UNAIDS, 2010).

The HDSS comprises a registration system of all demographic events that bring people into and out of the sub-district. These include an exhaustive capturing of births, deaths and in- and out-migration in the area. As a result, the exact population size, determined by the demographic equation, may be calculated at any time. The surveillance operation uses the *de jure* household definition, which includes as household members any significant absent individuals who should be resident at the time of the census interview are away at work or at an educational institution. These members usually remit something back to the household.

Migrants may then be classified as permanent or temporary. A permanent migrant is a person who enters or leaves a household with a permanent intention. Thus permanent migration adds to or subtracts from a rural household, making it larger or smaller in size. A temporary migrant is a household member who is away the majority of the time, but retains a significant link to his/her base household. In analyses, a six month per year cut-off point is chosen to differentiate 'temporary migrants' from 'local residents'. Thus, people referred to as temporary migrants are those who were absent from the household for more than six months of the year preceding observation, but who nevertheless consider the index household to be their home base. The temporary migration rate represents the prevalence rate of temporary migration in a year, whereas the permanent migration rate represents the incidence of new in- or out-migration events that bring people into or out of the population within a year.

The information presented from the HDSS on permanent migration is obtained from ongoing records made of people moving into or out of the surveillance population. Information is captured on the geography of rural and urban places of origin or destination, as well as individuals' reasons for the move. To obtain more detail on the temporary migrants, the surveillance operations conduct a periodic survey, in five-yearly intervals, of every temporary migrant in the *de jure* population. The present analysis uses data from the 2007 and 2012 surveys of temporary migrants to describe temporary migrant destinations. Temporary migration prevalence rates are collected annually and reported on for the period 2006 to 2011.

4. Findings

4.1 Census 2011: Migration status and settlement transitions

The national census captures the spatial distribution of the population at a point when people are at their usual place of residence. Migration events represent the most recent changes in individuals' usual places of residence in the five years preceding the census data collection in 2011. The distribution of the South African population by settlement type captured in 2011 is presented in Table 2. In each settlement type the proportion of non-migrants, total migrants, or migration-status unspecified is given, therefore the figures presented in the tables represent proportions rather than rates. Of the full South African population (50 961 448 people), 5,3% experienced an internal migration in the five years preceding the census, 1,5% had migrated into South Africa from destinations outside of the country, 91,7% had not migrated over the period and 1,6% had migration status unspecified.

Of the five settlement types, core metropolitan municipalities accommodate 36,3% of the total population, and about 6,2% of those residents in core-metros (2,3% of the whole population) are internal migrants. Metropolitan municipalities are the most likely type of settlement to have received a migrant prior to the census. The second most populous settlement types are the large town municipalities (19,5% of the population resides in large towns). These are also the second most likely type of settlement to receive a migrant (1,2% of the overall population indicated a migration to this settlement type, and 6,0% of people living in this settlement type were internal migrants). The remaining population is fairly equally distributed between the three other settlement types with 14,5% residing in secondary cities, 14,4% in small towns and 15% in mostly rural areas. The mostly rural municipalities have the lowest percentage of internal migrants in the five years preceding the census (0,4% of the total population and 2,8% of people living in this settlement type are internal migrants).

Table 3 shows the settlement type transition matrix for internal migrants of both sexes and for all population groups. Percentages given represent the proportion of total internal migrants who moved from one settlement type to another between 2006 and 2011. Cells located on the matrix diagonal represent migration events occurring within the same settlement type. The most likely type of migration is from a core-metro municipality to core-metro municipality (comprising 15,6% of internal migrations). The corresponding percentage of movements occurring within the 'large town' category is 3,8% of migrations and, within the secondary city settlements types, 2,9% of migrations. Each other cell in the matrix represent migrations that connect one type of settlement with another, resulting in settlement type change. The largest values appear in the first column, which represents moves into or within the core-metropolitan municipalities. A total of 42,8% of migrations have core-metro municipalities as destinations. Of the total internal migrations reported, 7,5% are moves from a secondary city to a metropolitan municipality, 8,9% are migrations from a large town to a metropolitan municipality, 5,6% are relocations from a small town to a metropolitan municipality, and 5,3% are moves from a mostly rural municipality to a core-metro municipality.

Counter flows are represented in the matrix in triangle of cells above and to the right of the diagonal. The first row represents migrations from a core-metro municipality. A total of 33,8% of migrations originate from a core-metropolitan municipality. 5,6% of total internal migrations are from a core-metro to a secondary city, 7,5% of migrations are from a core-metro to a large town, 2,9% of migrations are from a core-metro to a small town, and 2,2% from a core-metro municipality to a mostly rural municipality. Cells in the settlement type transition matrix can be paired to compute net flows between two settlement types, i.e. 8,9% of flows are from large towns to metros and 7,5% are in the reverse direction from core-metros to large towns. This indicates a strong flow and counter-flow between these settlement types, with a small net gain for core-metros municipalities of 1,4% of migrants (35 968 people) and a net loss for large town municipalities of the same number.

This pattern is replicated in relation to other pairings of settlement types and urban-ward flows tend to have counter-flows in the opposite direction, but at a smaller magnitude. The more urban municipalities gain population at the expense of the less urban municipalities, but substantial flows exist in both directions. The only exception is the link between large town and secondary city municipalities where 4,2% of migrations are from secondary cities to large towns and 3,4% of migrations are from large towns to secondary cities. In this instance, the more urban municipality has a net loss compared to the less urban municipality, although there remain substantial flows in both directions.

Tables 4 and 5 represent migrant status and settlement transition for the black African population as a whole. These data are presented in order to enable a triangulation with more fine-grained migration data from a former homeland sub-district, namely the Agincourt sub-district in rural north-east Mpumalanga. Since the black African population make up 79% of South Africa's population, there is not a vast difference between these trends and those of the total population distribution. Where differences do exist, it indicates that the white, coloured and Asian populations differ quite markedly from the black African population distribution.

The main difference in the population distribution of black South Africans as compared to the whole population is that a somewhat lower proportion of the black population (31% compared to 36,3% for the whole population) reside in core-metro areas; whereas the proportion residing in the mostly rural settlement type is lower for the whole population and higher for the black African population (18,2% compared to 15% for the whole population). Table 4 indicates that 4,8% of black South Africans migrated internally in the five years preceding the census.

These population group differences carry over into the migrants' settlement type transition matrix (Table 5). Migration within the core-metros is lower amongst black African internal migrants (12,2%) compared to the whole population (15,6%). However, the population group differences of movement into the core-metros varies by place of origin. In contrast to the full population, black African males and females are more likely to move into a core-metro municipality from a small town (6,9% vs. 5,6% for the whole population) and from a mostly rural municipality (6,4% vs. 5,3% for the whole population). Conversely, migration flows from a core-metro to a large town municipality is less likely for the black African population group (6,1%) compared to all population groups (7,5%). Aside from these modest differences, the census data indicate that the black African population has a similar settlement type transition profile to that of the whole population.

Table 5: Municipal settlement type by migrant status: males and females, all population groups

	Destination local municipality type - 2011							
	Core-metro		Secondary City		Large Town		Small Town	
	N	% Of Total Population	N	% Of Total Population	N	% Of Total Population	N	% Of Total Population
Internal Migrants	1 150 327	2,26%	452 812	0,89%	591 009	1,16%	279 666	0,55%
Immigrants	416 859	0,82%	103 264	0,20%	112 312	0,22%	81 059	0,16%
Total Migrants	1 567 186	3,08%	556 076	1,09%	703 320	1,38%	360 725	0,71%
Non-migrant	16 546 394	32,47%	6 725 989	13,20%	9 117 552	17,89%	6 925 877	13,59%
Unspecified	396 621	0,78%	108 433	0,21%	100 588	0,20%	46 478	0,09%
Total population	**18 510 201**	**36,32%**	**7 390 499**	**14,50%**	**9 921 461**	**19,47%**	**7 333 079**	**14,39%**

Table 6: Municipal settlement type by migrant status: males and females, all population groups (concluded)

	Destination local municipality type - 2011					
	Mostly Rural		**Unknown**		**Total**	
	N	**% Of Total Population**	**N**	**% Of Total Population**	**N**	**% Of Total Population**
Internal Migrants	216 682	0,43%	~	~	2 690 495	5,28%
Immigrants	26 529	0,05%	~	~	740 023	1,45%
Total Migrants	243 211	0,48%	~	~	3 430 518	6,73%
Non-migrant	7 389 657	14,50%	~	~	4 670 5469	91,65%
Unspecified	31 482	0,06%	141 859	0,28%	825 461	1,62%
Total population	**7 664 350**	**15,04%**	**141 859**	**0,28%**	**50 961 448**	**100,00%**

Table 7: Municipal settlement type migrants transition matrix: males and females, all population groups

Origin local municipality type - from 2006	Destination Local Municipality Type - 2011					
	Core-metro		Secondary City		Large Town	
	N	% Of Total Internal Migrants	N	% Of Total Internal Migrants	N	% Of Total Internal Migrants
Core-metro	418 520	15,56%	151 269	5,62%	202 756	7,54%
Secondary city	200 502	7,45%	77 933	2,90%	114 110	4,24%
Large town	238 724	8,87%	92 045	3,42%	101 742	3,78%
Small town	151 451	5,63%	83 519	3,10%	93 407	3,47%
Mostly rural	141 129	5,25%	48 045	1,79%	78 994	2,94%
Total Internal Migrants	**1 150 327**	**42,76%**	**452 812**	**16,83%**	**591 009**	**21,97%**

Table 8: Municipal settlement type migrants transition matrix: males and females, all population groups (concluded)

Origin local municipality type - from 2006	Destination Local Municipality Type - 2011					
	Small Town		Mostly Rural		Total	
	N	% Of Total Internal Migrants	N	% Of Total Internal Migrants	N	% Of Total Internal Migrants
Core-metro	77 051	2,86%	60 356	2,24%	909 952	33,82%
Secondary city	62 431	2,32%	35 502	1,32%	490 478	18,23%
Large town	57 053	2,12%	41 245	1,53%	530 810	19,73%
Small town	49 765	1,85%	38 967	1,45%	417 109	15,50%
Mostly rural	33 367	1,24%	40 612	1,51%	342 147	12,72%
Total Internal Migrants	**279 666**	**10,39%**	**216 682**	**8,05%**	**2 690 495**	**100,00%**

Table 4: Municipal settlement type by migrant status: black males and females

	Destination local municipality type - 2011							
	Core-metro		Secondary City		Large Town		Small Town	
	N	% Of Total Population	N	% Of Total Population	N	% Of Total Population	N	% Of Total Population
Internal Migrants	806 696	2,00%	326 746	0,81%	404 999	1,00%	203 538	0,50%
Immigrants	327 544	0,81%	86 536	0,21%	88 920	0,22%	69839	0,17%
Total Migrants	**1 134 241**	**2,81%**	**413 282**	**1,02%**	**493 919**	**1,22%**	**273 377**	**0,68%**
Non-migrants	11 171 650	27,64%	558 7047	13,82%	7 365 591	18,23%	6 123 286	15,15%
Unspecified	238 544	0,59%	76 523	0,19%	66 914	0,17%	35 095	0,09%
Total population	**12 544 434**	**31,04%**	**6 076 852**	**15,04%**	**7 926 425**	**19,61%**	**6 431 758**	**15,91%**

Table 4: Municipal settlement type by migrant status: black males and females (concluded)

	Destination local municipality type - 2011					
	Mostly Rural		Unknown		Total	
	N	% Of Total Population	N	% Of Total Population	N	% Of Total Population
Internal Migrants	186 878	0,46%	~	~	1 928 857	4,77%
Immigrants	20 841	0,05%	~	~	593 681	1,47%
Total Migrants	**207 719**	**0,51%**	**~**	**~**	**2 522 538**	**6,24%**
Non-migrants	7 108 204	17,59%	~	~	37 355 778	92,43%
Unspecified	28 164	0,07%	89 854	0,22%	535 094	1,32%
Total population	**7 344 087**	**18,17%**	**89 854**	**0,22%**	**40 413 410**	**100,00%**

Table 5: Municipal settlement type migrants transition matrix: black males and females

Origin local municipality type - from 2006	**Destination Local Municipality Type - 2011**					
	Core-Metro		**Secondary City**		**Large Town**	
	N	**% Of Total Internal Migrants**	**N**	**% Of Total Internal Migrants**	**N**	**% Of Total Internal Migrants**
Core-metro	234 873	12,18%	97 136	5,04%	117 427	6,09%
Secondary city	148 869	7,72%	52 812	2,74%	76 641	3,97%
Large town	166 522	8,63%	65 272	3,38%	65 658	3,40%
Small town	132 427	6,87%	69 091	3,58%	75 535	3,92%
Mostly rural	124 006	6,43%	42 435	2,20%	69 739	3,62%
Total internal migrants	**806 696**	**41,82%**	**326 746**	**16,94%**	**404 999**	**21,00%**

Table 5: Municipal settlement type migrants transition matrix: black males and females (concluded)

Origin local municipality type - from 2006	**Destination Local Municipality Type - 2011**					
	Small Town		**Mostly Rural**		**Total**	
	N	**% Of Total Internal Migrants**	**N**	**% Of Total Internal Migrants**	**N**	**% Of Total Internal Migrants**
Core-metro	50 142	2,60%	50 725	2,63%	550 302	28,53%
Secondary city	46 895	2,43%	29 543	1,53%	354 760	18,39%
Large town	40 556	2,10%	35 533	1,84%	373 542	19,37%
Small town	38 782	2,01%	33 389	1,73%	349 224	18,11%
Mostly rural	27 162	1,41%	37 688	1,95%	301 029	15,61%
Total internal migrants	**203 538**	**10,55%**	**186 878**	**9,69%**	**1 928 857**	**100,00%**

4.2 Findings from the HDSS

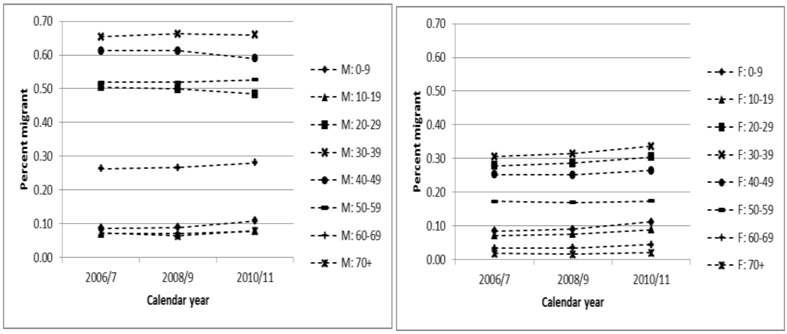
In order to refine the understanding of the national census and explore how a rural population may be linked to other settlement types, an analysis of permanent migration and temporary (circular) migration captured in the Agincourt HDSS is presented. The migrations captured in the HDSS may be compared to the cells in the migrants' settlement type transition matrixes that represent moves between mostly rural municipalities and another settlement types, as well as moves between mostly rural municipalities. As with the census, the distributions presented in the tables represent migration proportions.

4.2.1 Temporary migrants

In the HDSS study population, approximately 25% of the population were identified as temporary migrants in 2011 (there were 22 802 temporary migrants in a population of 90 919 people in 2011). The age–sex profiles of the temporary migrants are presented in Figures 1(a) and 1(b) for males and females. Temporary migration is highly prevalent amongst males and has become increasingly prevalent for young adult females. Figure 1(a) shows the male temporary migration profiles. There is a stable trend of a large proportion of male temporary migrants, which indicates that the migrant labour pattern is being perpetuated in time. The proportion of male temporary migrants is very high within the Agincourt male population: approximately 60% of male 30- to 49-year-olds, and 50% of males aged 20–29 or 50–59 were identified as temporary migrants in 2011. Amongst older males aged 60–69 years, 27% were temporary migrants in 2011, while the lowest proportion of temporary migrant males were aged 10–19 years (8%). This age group tends to be more residentially stable due to the need to attend school. Over the period 2006–2011, approximately 10% of male children aged 0–9 years were classified as temporary migrants, representing moves undertaken together with a parent (particularly a mother).

The profiles of female temporary migration are presented in Figure 1(b). The figures reveal a high proportion of female adult temporary migrants, especially between the ages of 20–59. Temporary migration amongst Agincourt females is most prominent in young adults aged 20–39. In 2006/7 approximately 27% of 20- to 39-year-old females were identified as temporary migrants, and this had increased to about 33% of 20- to 39-year-old women in 2010/11. Approximately 10% of younger females aged 0–19 years were temporary migrants in 2011, reflecting moves accompanied by mothers or caregivers. Older adult females have a lower likelihood of being temporary migrants compared with males of the same ages. Only about 5% of females in their 60s and 2% of females aged above 70 were classified as temporary migrants in 2011, compared with 27% of 60- to 69-year-old males and 8% of males older than 70 who held temporary migrant status in this year.

Figure 1: Temporary migrant profiles, Agincourt, 2006–2011



1(a). Percent Male Temporary Migrants, Agincourt, 2006-2011

1(b). Percent Female Temporary Migrants, Agincourt, 2006-2011

Table 6 shows the geographical distribution of temporary migrants from the Agincourt sub-district, using the same settlement category classification as was used in analysing the census data. Temporary migrants of both sexes tend to move less locally than permanent migrants, with approximately 45% of temporary migrants relocating to core-metropolitan municipalities (the majority of these are moves to the Gauteng metropolis 500 km away). Conversely, temporary migrants are far less likely to move to mostly rural areas or small towns because of the lower likelihood of finding employment in these destinations. Approximately 10% of temporary migrant woman and 6% of temporary migrant males circulate to and from small towns, while only around 2% of temporary migrants move between other mostly rural areas. An important set of destinations for temporary migrants are the large towns, which are more popular destinations for temporary migrant males and females than are the secondary cities (approximately 30% of temporary migrants move to a large town, as compared with about 14% who relocate temporarily to secondary cities).

Table 6: Geographical distribution of Agincourt temporary migrant destinations, 2007, 2012

	2007		**2012**		**Total**	
	Male	Female	Male	Female	Male	Female
Destination	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Core-Metro	4273	2206	4398	2509	8671	4715
	47%	46%	45%	45%	46%	45%
Secondary City	1207	556	1632	808	2839	1364
	13%	12%	17%	15%	15%	13%
Large Town	2842	1453	3074	1522	5916	2975
	31%	30%	31%	27%	31%	29%
Small Town	597	475	524	536	1121	1011
	7%	10%	5%	10%	6%	10%
Mostly Rural	139	137	139	169	278	306
	2%	3%	1%	3%	1%	3%
Other Country	18	6	14	5	32	11
	0%	0%	0%	0%	0%	0%
Total	9076	4833	9781	5549	18857	10382
	100%	100%	100%	100%	100%	100%

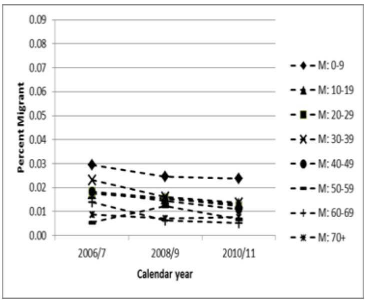
4.2.2 Permanent migrants

Permanent migration is recorded in the HDSS when an individual changes their place of residence with a permanent intention. The permanent migration trends presented in this section refer to moves that cross the boundary of the HDSS.

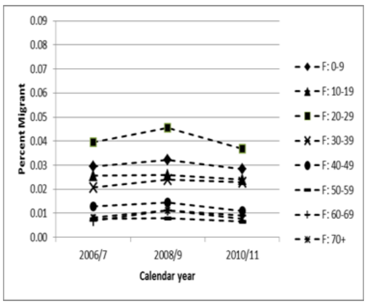
In 2011, permanent out-migrants from the Agincourt HDSS numbered 1 570 (1,7% of the population of 90 919), while permanent in-migrants numbered 1 749 individuals (1,9% of the population of 90 919). The age–sex profiles of permanent external in- and out-migrants to the sub-district are presented in Figure 2. Figures 2(a) and 2(b) reveal that in-migrants are mostly young adult women and children. Young adult females aged 20–29 (3,7% in 2011) are the most mobile category of in-migrants to the sub-district, followed by male and female children aged 0–9 (approximately 3% in 2011) who are likely to be moving together with their mothers. Thereafter, females aged 10–19 and 30–39 (comprising 2,5% of females in both age groups in 2011) are the next most likely individuals to be relocating to the HDSS area. A similar age–sex pattern is evident in the case of permanent out-migration

(Figures 2[c] and 2[d]). Young adult females (3,6% of females aged 20–29 in 2011) and young children (on average of 3,8% of children aged 0–9 in 2011) are the most likely to out-migrate permanently from the sub-district. In the case of permanent in-migration, and even more so in instances of permanent out-migration, there is a declining trend over time, which suggests that women may be transitioning from permanent to temporary migration.

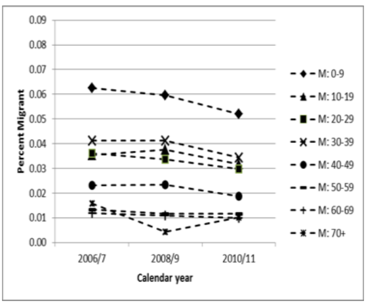
Figure 2: Permanent migrant profiles, Agincourt 2006, 2011



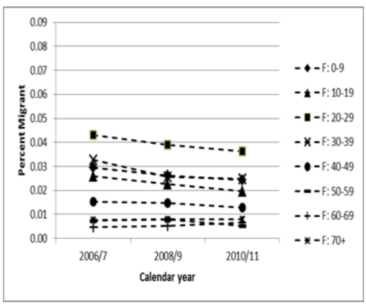
2(a). Percent Male Permanent External In-migrants, Agincourt, 2006-2011



2(b). Percent Female Permanent External In-migrants, Agincourt, 2006-2011



2(c). Percent Male Permanent External Out-migrants, Agincourt, 2006-2011



2(d). Percent Female Permanent External Out-migrants, Agincourt, 2006-2011

Tables 7 and 8 present the geographical distribution of permanent migrants over the period 2006 to 2011. The settlement patterns for individuals entering and leaving the sub-district on a more permanent basis differ from the distribution of destinations of the temporary migrants. Table 7 reveals that permanent out-migrants of both sexes most commonly move to other mostly rural areas or small towns (in 2011, 29% and 32% of females and 25% and 33% of males permanently moved to these settlement types respectively). Conversely, core-metros and secondary cities are less attractive permanent destinations for migrants from the HDSS, with approximately 8% of both males and females permanently resettling in core-metropolitan areas in 2011.

Table 8 indicates that the largest proportions of permanent in-migrants of both sexes originate from other mostly rural areas (28% of female and 24% of male in-migrants in 2011). There is a smaller flow of permanent in-migrants from the core-metros to the rural sub-district, 16% of male in-migrants and 12% of female in-migrants in the year 2011. There is also a small, but increasing, flow of people migrating into the sub-district from other countries (comprising approximately 7,5% of permanent in-migrations over the period).

Table 7: Geographical distribution of Agincourt permanent out-migrants, 2006, 2011

	2006		2011		Total	
	Male	Female	Male	Female	Male	Female
Destination	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Core-Metro	108	141	51	82	159	223
	14%	13%	8%	8%	12%	11%
Secondary City	50	86	44	64	94	150
	7%	8%	7%	7%	7%	7%
Large Town	144	210	129	201	273	411
	19%	19%	21%	21%	20%	20%
Small Town	249	360	198	310	447	670
	32%	32%	33%	32%	33%	32%
Mostly Rural	195	302	152	280	347	582
	25%	27%	25%	29%	25%	28%
Other Country	19	20	28	30	47	50
	2%	2%	5%	3%	3%	2%
Unknown	4	6	0	1	4	7
	1%	1%	0%	0%	0%	0%
Total	769	1125	602	968	1371	2093
	100%	100%	100%	100%	100%	100%

Table 8: Geographical distribution of Agincourt permanent in-migrants, 2006, 2011

	2006		**2011**		**Total**	
	Male	Female	Male	Female	Male	Female
Origin	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Core-Metro	83	120	107	131	190	251
	14%	12%	16%	12%	15%	12%
Secondary City	55	75	70	100	125	175
	9%	8%	10%	9%	10%	8%
Large Town	149	236	114	208	263	444
	25%	24%	17%	19%	21%	22%
Small Town	124	228	152	255	276	483
	21%	23%	23%	24%	22%	23%
Mostly Rural	145	254	163	302	308	556
	24%	26%	24%	28%	24%	27%
Other Country	35	65	66	79	101	144
	6%	7%	10%	7%	8%	7%
Unknown	1	9	1	1	2	10
	0%	1%	0%	0%	0%	0%
Total	592	987	673	1076	1265	2063
	100%	100%	100%	100%	100%	100%

5. Discussion: Triangulation of Census and HDSS data

This paper presents an analysis of migration flows in the population at two spatial levels, the national level based on population census data, and the sub-district level based on data from the Agincourt HDSS. The sub-district level data offers two perspectives on migration by differentiating between permanent and temporary moves. Each of these perspectives (national, sub-district permanent and sub-district temporary) offers a unique and valid perspective, and each contributes a different frequency and scale of migration. The triangulation of national census 2011 migration flows and the sub-district level data produces a more integrated picture of internal migration within the country. Through this complimentary perspective, it is possible to gain insight into how settlement patterns and levels of urbanisation are changing within South Africa.

The national census data locate each member of the population at a place which falls within one of 234 local municipalities. A migration is recorded if there was a change in a person's usual place of residence between 2006 and 2011. Out of the population of 51 million people, 2,7 million (5,3% of the population) migrated internally. The analysis of migration flows between five municipal settlement types reveals that core-metropolitan municipalities are the most common destination and origin settlement type and are also the most populated. The metropolitan areas with large-scale economies are also the locations where employment is most likely to be found and it therefore follows that they would be attractive destinations for migrants. However, large towns are also important settlement types for a large proportion of the South African population. Next, in order of prominence, are secondary cities, small towns and rural areas. This overall pattern is consistent with step or chain migration whereby people migrate to the next higher place in the urban hierarchy, rather than jumping levels and going straight to a big city. Counter-flows bring the migrants back so that, although the urban place grows by net-migration, there is a circulation of people between the settlement types (see Ravenstein 1885).

The national data at first glance suggest that metropolitan areas are growing incrementally. But upon closer inspection it is evident that metropolitanisation is only part of the settlement transition dynamics underway. Flows and counter-flows exist between each pairing of settlement types. However, the more urban settlement types gain population through net-migration and the less urban settlement types lose population. In particular, there is a large imbalance in the flow and counter-flow between the core-metro and rural settlement types, with 5,3% of migrations leaving rural settlements to enter a core-metro settlement, and 2,2% of migrations leaving core-metro for mostly rural settlements.

The value of the national census is its coverage and scale; every location in the country contributed migrants to the census database as represented in the transition matrices. However, the migrations in the national census represent a mix of permanent and temporary movements, which can't easily be discriminated. At the time of the census, people tend to be based at their locations of employment. Therefore the national census includes temporary migrants who may be residing away from home in a large town or metropolitan area. The triangulation with the sub-district data from the rural north-east suggests that large proportions of rural to metropolitan migration flows observed using the census data may be of a temporary nature, and the working migrant population in the cities may have a rural or peri-urban home where the rest of the family lives.

In contrast to the census, which assumes a *de facto* household definition (the household comprises all resident members at the time of the census), the HDSS includes in the household roster any temporary migrants who retain a link to the origin household while away (*de jure* household definition). These different perspectives are important for this analysis because they allow for temporary migrants to be defined and identified, which enables a better understanding of the dynamic connections between rural and urban areas. The trend towards metropolitanisation observed in the national census fails to take into account the temporary migrants linking the rural areas with the metropolitan areas. In this way, an important piece of the picture is missed for understanding key resource flows for poorer households.

Approximately 25% of the HDSS study population were identified as temporary migrants in 2011. These individuals tend to be working-age adults (between ages 20 and 59) and with males outnumbering females. These currently circulating temporary migrants are moving mostly for labour-related reasons, with almost half relocating to the core-metropolitan areas (in particular, the Gauteng province). These migrants return home periodically (and ultimately when they have stopped oscillating) and many are likely to remit something back to the rural households during their temporary absences.

Permanent migration into or out of the Agincourt sub-district occurred at far lower levels as compared to temporary migration, with approximately 2% of the HDSS population involved in permanent in- or out-migration during 2011 respectively. These moves involved primarily women moving in or out, sometimes accompanied by children. Permanent migration is more localised and the majority of such moves were to or from other mostly rural areas. These moves can be compared to the cells in the migrant's settlement type transition matrixes that represent migration between or within mostly rural municipalities.

The Agincourt sub-district analysis suggests that such levels of permanent migration may be declining over time, which may be explained by a shift towards temporary migration as labour market aspirations grow for young women who increasingly embark on labour migration.

The paper employs two data sources that vary in terms of the methods of collection, the size and structure of the populations under study and the time frame under consideration (cross-sectional versus longitudinal). These census and HDSS methods each have strengths and weaknesses, however, the triangulation of these perspectives strengthens the interpretation of the study findings and offers a means of gaining a more consolidated perspective on settlement change in South Africa.

The census has a wide spatial perspective and full representativeness, but shallow temporal perspective; in other words it is less conducive to showing dynamics. The HDSS is spatially limited, but it offers temporal capability and data that are collected prospectively. The HDSS is able to discriminate temporary and permanent migration, which enables a more accurate accounting of the circular migrants. A direct comparison between the HDSS and the national census is not straightforward, because each represents different levels of the population; the census represents the national level (about 5,2 million people) and the HDSS represents a population of 115 000 individuals residing in a rural sub-district. Furthermore, these data sources do not allow for a comparison of census and HDSS data for the same individuals. Despite these limitations, the use of dissimilar data sources provides a more expansive view than would have been obtained using either of the two sets of data in isolation (UNAIDS, 2010).

6. Conclusions

The study highlights two important findings: the growing importance of the metropolitan municipalities, and the continued prevalence of temporary migration that connects people in urban places of employment to rural households. These rural-urban links are missed if the temporary nature of the rural to urban migration is undetected.

Understanding migration dynamics and trends has an impact on how to think about, and plan for, South Africa in urban transition. Twenty years following democracy, issues of transformation remain pertinent to South Africa. Economic disparities, inequality and unemployment, particularly amongst the country's youth, are pervasive (Mayosi & Benatar

2014). Lack of access to services and inadequate living conditions may further impact on quality of life, health and well-being (Mayosi & Benatar 2014). Migration provides an avenue that people may employ to alleviate poverty and gain access to the country's economy (Venter & Badenhorst 2014). Urban living holds the promise of improved conditions and the potential to share in an urban culture and lifestyle. Urban thinking and lifestyle are further conveyed to rural areas by returning temporary migrants. Urbanisation and migration are therefore critical issues that underlie the nature of reality that people experience.

However, urban expansion is not without its consequences and many relocating to South Africa's metropolitan areas have to contend with crowded living conditions, informal housing, inadequate sanitation, possible exposure to crime and violence and difficulties accessing education, employment and health care (Turok 2012). In situations where migration to an urban area is temporary, migrants tend to live on as little as possible, selecting the cheapest accommodation available in close proximity to places of work. In so doing, migrants maximise the amount of remittance income they are able to send back to rural households. Temporary migrants will anticipate ultimately returning to their rural origin areas at retirement or earlier, in cases of ill health (Clark *et al* 2007; Collinson 2009).

The policy response to many of these issues has been lacking in the past (Turok 2012); however, new initiatives in the areas of urban and rural development and spatial planning are underway. The National Development Plan (NDP) has highlighted the issues around spatial transformation and integration, and emphasised the interdependencies between rural and urban areas, the need for collaboration between municipalities and provinces, and the importance of an integrated planning system across territories (National Planning Commission, 2011). The NDP further highlights the need for data and analysis that can inform and support these endeavours. This paper makes a contribution to this and offers a unique perspective of dynamics relating to the distribution of South Africa's population.

The present analysis highlights the need for public sector services planning to recognise the high level of rural-urban interconnection through temporary migration. This would involve, for example, ensuring that migrants are able to access health care in destination as well as origin areas. Such services should take account of the possibility that labour migrants, who weren’t counted by the national census in their rural households, may return home ill and require care and treatment. This shifts the health care burden of caring for them in their terminal illness to their families and the rural health care system, with significant consequences for the distribution and allocation of health care resources.

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Repositioning South Africa to implement the 2030 agenda for sustainable development: A demographic perspective

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ABSTRACT

The United Nations Sustainable Development Summit of 2015 embarked on a new agenda that involves 17 Sustainable Development Goals (SDGs) with 169 associated targets. This paper presents the demographic profile of South Africa to ascertain whether the country is ready to monitor the SDGs. There is a two-fold challenge to the purpose of the paper. Firstly, demography was not a popular subject during the apartheid era and 22 years after establishing the democratic state the situation has not changed much. It is therefore not unusual to find planners for key sectors (e.g. education, health and labour) without any idea on how to incorporate demographic variables into planning. Secondly, the lack of up-to-date demographic data for planning purposes has negatively affected any effort to change the *status quo*.

The basic demographic processes describe migration, mortality and fertility and include family planning, reproductive health, HIV and AIDS, environment and population-related development issues. Demographic data identifies international migration as a serious problem in

South Africa – receiving heavy migration inflow from other African countries, but significant lighter migration outflow mainly to Europe, Australia and New Zealand. The actual numbers involved in migration remains an estimate, which has serious implications on development planning. As far as mortality is concerned, the expectation of life at birth has increased by 8 years since 2002 because the country has made significant strides in dealing with the HIV and AIDS epidemic. However, maternal mortality is still high. Health facilities have serious inadequacies, particularly in rural areas. In South Africa, fertility levels have been reduced to the extent that the national average is close to replacement level. However, the decline in fertility and mortality rates has been side-tracked in that teen and pre-teen pregnancies/fertility is now exceptionally high for school learners. The paper describes the demographic challenges in South Africa and provides recommendations on how to address these challenges so that the country can be in a position to implement the 2030 agenda for sustainable development.

Key words:

Sustainable Development Goals, Demography, Demographic Training, Demographic Data, Demographic Dividend, South Africa.

1. Introduction

The importance of demography on developmental matters has not been emphasised in many countries. In fact, discussions at the 1994 International Conference on Population and Development (ICPD) held in Cairo did not place any emphasis on technical demography which created negative implications on the discipline. Ever since then, the United Nations Population Fund (UNFPA) and other development partners who are at the forefront of support of demographic training are directing the focus once again towards demography. The United Nations Sustainable Development Summit of 2015 put a lot of emphasis on data and demographic indicators when they adopted the new Sustainable Development Goals (SDGs). This indicates that demography is once again in the limelight. In addition, there has been a discussion about reviving demography as a discipline and its role in a country's developmental agenda (Yousif 2009). There is a need therefore to reassess the state of demography in participating countries and find out if countries are well positioned to monitor the SDGs.

Demography has been negatively affected by many factors in South Africa, including the apartheid regime when there was no emphasis on the discipline. The end of apartheid in 1994 was followed by the period of implementing the ICPD Plan of Action which, as indicated above, did not take demography seriously. So it can be said that there was a double blow to demography in South Africa. Given that the implementation of SDGs needs demography, the purpose of this paper is to find out if South Africa is demographically able to monitor the SDGs. The following two questions are addressed in this paper. Is the country in a position to acquire all the demographic indicators that need to be used? Does South Africa have demographic expertise to deal with implementation of SDGs?

The study uses the desktop review and analysis. There are key documents that are used in this study: the description of the SDGs (United Nations, 2015); the Mellon support in training demography in South Africa (Menken et al 2002); the evaluation of demography training in South Africa (Gaisie & Groenewald 2007); and the demography project (Population Association of Southern Africa, 2013). The next section briefly discusses the SDGs and how they relate to demography. This is followed by a presentation of the evolution of demographic training in Africa in general, and South Africa in particular. A summary of the demographic profile of South Africa is then presented, followed by a description of the demographic challenges facing the country. Finally, the concluding remarks are presented.

2. Sustainable Development Goals

Over 150 world leaders met in New York City from 25–27 September 2015 for the United Nations Sustainable Development Summit. This was a special occasion because they adopted the post-2015 agenda that indicates the framework to be used by participating countries in the world until the year 2030. The new ambitious agenda comprises 17 SDGs and are accompanied by 169 measureable targets. It took more than two years of negotiations to reach consensus. The main documents/summits that contributed to establishing the new agenda include the 1992 Rio Environmental Summit (including Rio+20 conference), the 1994 Cairo International Conference on Population and Development, the 2000

Millennium Development Goals, and the 2002 Johannesburg World Summit for Sustainable Development. Other less known meetings offering a contribution include the 2011 Busan Partnership for Effective Development Cooperation and the 2015 Addis Ababa Conference on Financing for Development.

In this paper, sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Thiam 2012). The vision of SDGs clearly states that the signatories *"envisage a world free of poverty, hunger, disease and want, where all life can thrive. ... a world free of fear and violence. A world with universal literacy."* (United Nations, 2015:3) *"...A world of universal respect for human rights and human dignity, the rule of law, justice, equality and non-discrimination; of respect for race, ethnicity and cultural diversity; and of equal opportunity permitting the full realization of human potential and contributing to shared prosperity."* (United Nations, 2015:4). *"... a world in which every country enjoys sustained, inclusive and sustainable economic growth and decent work for all."* (United Nations, 2015:4). In brief, the SDGs aim to deal with the complex realities of poverty, inequality, climate change, sustainable consumption of resources, and human rights violation.

As indicated in the Millennium Development Goals (MDGs), three out of the eight goals (37,5%) were health/demographic goals. These are Goal 4 (*Reduce child mortality*), Goal 5 (*Improve maternal health*), and Goal 6 (*Combat HIV/AIDS, Malaria and other diseases*). On the contrary, in the SDGs only Goal 3 (*Ensure healthy lives and promote well-being for all at all ages*) out of the 17 goals (5,9%) is a health/demographic goal. This does not necessarily mean that emphasis on health and demographic issues has been weakened, but it implies rather that priority areas have been broadened. The nine targets corresponding to SDG 3 show that there is a lot that needs to be done in the health and demographic arena. Another observation is that SDGs indirectly support the already existing debate on how to revamp training in demography in Africa. This discipline has been negatively affected by a number of adverse situations, but there is once again emphasis on using demographic variables for monitoring and evaluation purposes. Countries therefore need to be well equipped with demographic skills and all the necessary tools needed for monitoring and evaluation (M & E) purposes. This emphasis needs to be appreciated and embraced because it is an opportunity for demography to position itself in this competitive and challenging world.

The SDGs have put emphasis on availability of data for M & E purposes. This involves collection of both baseline data and data that will assist in measuring progress made while implementing the SDGs. The following extract from the UN report summarises the intentions:

“We recognize that baseline data for several of the targets remain unavailable, and we call for increased support for strengthening data collection and capacity building in Member States, to develop national and global baselines where they do not yet exist. We commit to addressing this gap in data collection so as to better inform the measurement of progress, in particular for those targets below which do not have clear numerical targets” (United Nations, 2015:11).

It is therefore important for countries to assess both the situation of demographic training in the country and the availability of data for measuring the relevant indicators. The next two sections deal with these two aspects.

3. Evolution of demography training in Africa

Demography became popular as a discipline when demographers documented the rapid world population growth as well as describing its causes in the 1950s. The idea of population growth as a social problem in part influenced governmental and non-governmental organisations to invest in demographic training, especially of people from developing countries so they could assume leadership roles in population research, training and policy formulation. In the early years of demography, the subject was mainly confined to the basic demographic processes (fertility, mortality and migration) and their underlying social factors (Menken et al 2002). With time, the need for demographers expanded and became multidisciplinary to include family planning, reproductive health, HIV and AIDS, environment and population-related development issues (Menken et al 2002; Ntozi 2011).

However, during the expansion of demography in the early years, technical demography of data collection and analysis continued to remain important in the training of demography (Ntozi 2011).

In the 60s and 70s, the interest in demographic training in Africa peaked and regional population centres funded by governments and non-governmental organisations were established to train population scientists. The demand for population scientists became crucial in the aftermath of political independence in most African countries. At the time, the major population issues were population censuses and demographic surveys. Thus, there was an emphasis on training technical demographers to conduct these inquiries (Ntozi 2011). In Africa, UNFPA and the United Nations Economic Commission for Africa (UNECA) largely drove demographic training and research. The UNFPA was instrumental in setting up the regional training centres: the Cairo Demographic Centre (CDC), United Nations Regional Institute for Population Studies (RIPS) in Ghana and the *Institut de formation et de recherche démographiques* (IFORD) in Cameroon (Bah 2001; Menken et al 2002).

The CDC was the first regional demographic training centre established in Africa in 1963, mainly funded by the UNFPA. In January 1992, the CDC was declared an independent institution, which marked the end of about three decades of UNFPA support for the centre. Since then the CDC has mainly been funded by the Egyptian government (CDC, n.d.). About a decade after the establishment of the CDC, the United Nations and other agencies provided funding for the establishment of other regional population studies centres in Ghana (RIPS) and Cameroon (IFORD) to serve English- and French-speaking countries respectively. The United Nations Regional Institute for Population Studies (RIPS) is a regional centre based at the University of Ghana since 1972 and was funded to a large extent by UNFPA with the aim of training population scientists from English-speaking African countries. However, in 1999 the UNFPA withdrew its funding to RIPS, which led to a drastic decline in the activities of the Institute (RIPS, 2015). Aside from establishing these regional training centres in the continent, the UNFPA was also instrumental in setting up the Global Training Programmes and other demographic training centres such as the one in Botswana, Kenya, Tanzania, Democratic Republic of the Congo, Togo, Mali and Ivory Coast. However, in the late 1990s UNFPA reduced or completely withdrew funding to these institutions (also see Bah 2001; Menken et al 2002).

Despite the establishment of these population centres on the African continent, most of the highly qualified demographers were trained in developed countries like the United States of America, United Kingdom and Australia. Menken et al (2002) noted that the majority of population scientists with doctoral qualifications from developing countries received their degrees from universities in the developed countries. In contrast, universities in developing countries provided much of the training of population scientists at a Master's level. Unfortunately, most of the population scientists at a doctoral level do not return to their own countries after completing their training in developed countries, largely because of limited career opportunities (Menken et al 2002).

4. Factors affecting training of demography in Africa

a) Decreasing role played by UNFPA

Because of the heavy reliance of African population training centres on funding and/or support from the UNFPA and other international agencies, the contraction or complete withdrawal of funding from these institutions in the 1990s saw a dramatic decrease in the activities of these institutions. Menken et al (2002) observed that demographic institutions suffered in various forms including lack of visiting instructors, teaching materials and training of their instructors. Hence, some population training centres collapsed, some continued with minimal activity and others reshaped their programmes in order to survive. The withdrawal or decrease in funding by the UNFPA and the United States Agency for International Development (USAID) had an enormous effect, especially in Africa in the 1990s. The most noticeable effect was the decrease in or withdrawal of funding for training at a doctoral and Master's level. Even though new donors such as The

William and Flora Hewlett Foundation, The Andrew W. Mellon Foundation and International Development Research Centre (IDRC) have injected a lot of funding into demographic training in Africa, training in demography on the continent is yet to regain the heights it reached between the 1960s and 1990s (Menken et al 2002).

b) Change of emphasis after 1994 ICPD

In addition to the decreasing role played by the UNFPA and other international agencies in demographic training and research in the 1990s, the attention of donors was further diverted from demographic training and research by the Programme of Action adopted at the 1994 International Conference on Population and Development (ICPD) in Cairo, which focussed on reproductive health. A number of scholars have lamented the effect of the 1994 ICPD on demography as a discipline; Westoff (1995) noted that at the ICPD conference in Cairo, demographic targets were dismissed as potentially coercive, arguing that population issues were submerged in the rhetoric of reproductive rights and sustainable development. As noted by Westoff (1995:11) that "*[i]n fact, it* *became almost mandatory to explicitly denigrate the whole subject of population growth and subordinate it to other issues."* Cleland (1996) referred to this as the feminisation of population and development issues. The adoption of a human rights perspective to address population growth and development that focussed on reproductive health marked the beginning of the most recent transformation of the international population research and training agenda (Hodgson & Watkins 1997), which appears to ignore technical demography.

c) Lack of funding for demographic research

Demographic research is largely associated with solutions to social problems; hence, donors heavily influence research in the discipline. Ntozi (2011) noted that the donors' insistence on adhering to research priorities is a challenge to demographic research and training of African population scientists. He observed that donors often decide that their research money is given to investigate particular topics, which might not necessarily coincide with the research priorities of the training institutions or the countries concerned.

Moreover, because demography is highly data-dependent, the willingness of donors to fund data collection projects is crucial to advancing the field (Menken et al 2002). Ntozi (2011) observed that the lack of research grants to academic staff in demography departments has discouraged staff from doing demographic research (especially technical demography) where several students can benefit by using the data for their dissertations. This problem has also created low morale among academic staff that is not permitted to publish and hence cannot be promoted and develop their careers, leading to the staff spending much of their time doing consultancies, often leading to them abandoning their academic career for outside opportunities to fulfil their goals and ambitions (Ntozi 2011). Many demographers who stick to the academia opt to conduct research outside their discipline where funding is available.

The emphasis of the 1994 ICPD on reproductive health had serious implications for funding demographic training and research. Because of the 1994 ICPD Programme of Action, governments and non-governmental organisations concentrated on funding reproductive health research to the neglect of technical demographic training and research. In the past, demographers, through research, successfully described population growth and fertility decline. After the 1994 ICPD in Cairo, however, funding organisations who appear to have so much influence on the global research agenda appeared to direct their attention towards the ICPD Programme of Action. Indeed, this perhaps led to population scientists emphasising new priorities including topics such as gender issues, access to and delivery of contraceptives and reproductive health (Menken et al 2002).

The paradigm shift associated with the 1994 ICPD has had major implications for the population movement. This in part can be attributed to the need for increased funding to support the ICPD Programme of Action, which some scholars argue was an expensive programme to undertake (Finkle & McIntosh 1996). Five years after the ICPD, preliminary assessments of funding levels showed that the promises made by donor countries at Cairo were only modestly successful (Menken et al 2002; Finkle & McIntosh 1996). For example, the focus on family planning as a vehicle to reduce fertility, especially in developing countries, diverted the attention to achieving this objective to the neglect of research and training on technical demographers (also see Ntozi 2011).

d) Shifting from formal long-term training to short-term projects

Menken et al (2002) observed that the funding strategy of the two formerly prominent donors (UNFPA and USAID) shifted from long-term post-graduate training towards an emphasis on short-term practical training targeted at specific issues. They further observed that reports of fertility declines beginning in the mid-1970s contributed to the mistaken notion that the population "crisis" was over and at the same time, many developing countries had successfully achieved the goal of having a trained cadre of population specialists, so further long-term training was no longer a top priority. Hence, donors began to question the cost effectiveness of long-term training in developed-country institutions in light of the high cost per trainee. The alternative of short-term training for many more individuals, and trainees in developed countries who did not return to their countries of origin or returned to positions unrelated to their training, has created a shortage of population scientists in the continent.

It appears that this approach to training population scientists has been adopted by the relatively new donors such as the Bill and Melinda Gates Foundation, the Davis and Lucile Packard Foundation, and the Turner Foundation. Even though their training strategies vary, it does not necessarily include traditional long-term graduate degree training; rather they have focused on policy-oriented training for "population leaders". Increasingly, the funding provided by private foundations is used to support collaborative research projects between universities in developed and developing countries. Aside from research itself, these projects can include other elements that promote training such as faculty exchanges, research fellowships, the development of networks of researchers, and joint short-term courses. The flexibility of foundation grants compared to the funding mechanisms of most government and international agencies has allowed universities to experiment with a range of alternatives to traditional training models (Menken et al 2002).

5. Training of demography in South Africa

During the apartheid era in South Africa, the foremost universities involved in demographic training were mostly Afrikaans-based universities (or formally advantaged universities) such as the University of Pretoria, University of Stellenbosch and some of the universities in the former TBVC states (Transkei, Bophuthatswana, Ciskei and Venda). Bah (2001) further noted that to some extent, some demographic training took place at the University of the Witwatersrand, University of Cape Town and the University of the Western Cape. Aside from these educational institutions, there were some form of demographic expertise at the Human Science Research Council (HSRC), Statistics South Africa, the Medical Research Council (MRC) as well as at the demographic surveillance sites such as the one at Agincourt or Hlabisa. For example, at Statistics South Africa there was a formal in-house demographic training programme that started around 1992 and continued until 1997 after which it was discontinued (Bah 2001). However, during the post-apartheid era, formerly disadvantaged and English-speaking universities initiated population training and research programmes. Indeed, most of the teaching and training in the population studies departments in South Africa are currently being run by non-South Africans (mostly other Africans) as there remains a paucity of national population expertise. Indeed, many academic experts in allied disciplines like sociology and development studies have moved sideways into research and training in demography (Menken et al 2002).

The Mellon Foundation injected funds in the late 1990s to develop the academic base for demography in South Africa. This benefitted especially population training centres in three universities (University of the Witwatersrand, University of KwaZulu-Natal, and University of Cape Town) to attract a number of post-graduate level students. These existing demographic centres in South Africa have been supplemented by the programmes offered by the North-West University (established in 1990s independent of the Mellon grant) as well as the Walter Sisulu University (where the population programme is still not yet fully developed). It should be noted, however, that there was visibility of demographic training in South Africa after the 2000s compared to the 1990s.

Despite all these efforts by donors and the South African government to strengthen demographic training and research, some scholars (Bah 2001) noted that more demographic expertise needs to be developed in South Africa. Bah (2001) opined that the possible reasons for this have to do with the complex circumstances surrounding the development of demography in South Africa. Concerning the situation of demography in South Africa, Du Plessis (1995) aptly observed that, "*[t]o evaluate the role of demography in South Africa, the implementation and development of the family-planning programme and the population development programme (PDP) should be considered. Much of South African demography evidently became a subsidiary of a larger governmental enterprise that sought to assign to social scientific research on population issues the role of handmaiden in family-planning programmes*" (Du Plessis, 1995:55–56).

Because demography is not a popular discipline in South Africa, it is often overlooked in the job market and even jobs which should typically be done by trained demographers are being done by non-demographers. As noted by Du Plessis (1995), one of the challenges facing demography in South

Africa is the need to educate consumers of demographic data and specifically draw attention to the fact that interventions normally takes generations to exhibit measurable changes.

In South Africa, Statistics South Africa employs a significant number of population specialists and other branches of the government, such as the National Population Unit. A few posts exist in research organisations outside the university sector, such as the Human Sciences Research Council, the Medical Research Council and the Demographic Surveillance Systems (DSSs), and in for-profit firms providing market research and information services.

Similarly to other African countries, decentralisation of government and other sectors, especially the health sector, in South Africa has increased the need for population experts at local levels of government. However, jobs that are supposed to be done by population scientists/demographers are done by other people who do not have demographic training (Population Association of Southern Africa, 2013). This can perhaps be attributed to people's lack of knowledge of the discipline. In addition, there is the impression that there is a disparity between the requirements and needs of the job market and the supply of population experts with appropriate skills in South Africa as espoused by Bah (2001) who argued that demographic training in South Africa needs to be repositioned to meet the demands of a country in transition.

A point that needs to be emphasised here is that there is still an acute shortage of demographers in South Africa. As elaborated above, the situation can even be worse than it looks if all jobs in the country that need to be done by demographers insist to be filled by the qualified people. We therefore urge the Department of Higher Education and Training to reassess the decision to reclassify demography as a none-scarce skill discipline.

6. Demographic profile of South Africa

a) International migration

South Africa, during both the apartheid and post-apartheid period, has been a pole of attraction for migrants of all categories from Africa and beyond. Adepoju (2003) noted that about 100 nationalities from other countries were living in South Africa. From the early 1970s, South Africa received a large inflow of migrants and after independence in 1994. The prospects of a booming economy in a democratic setting opened the floodgate for immigration into South Africa from a variety of countries in Africa and even outside the continent. The disparities in economic development and living standards between South Africa and other African countries, and the remarkable transition to post-apartheid rule attracted most migrants of all categories from Africa (Adepoju 2003).

Even though South Africa is the hub of migrants from other African countries and beyond, it also loses highly skilled professionals such as engineers and doctors who are emigrating to Australia, Canada, Britain, and the United States (Adepoju 2000). Despite the complex migration dynamics in South Africa, there is limited data on migration in the country (Posel 2004; Gabriel 2008; Statistics South Africa, 2012). Indeed, it is perhaps because of the lack of data on migration that Adepoju (2003) referred to migration data as “imaginary figures”. Adepoju (2003) observes that imaginary figures, between 8 and 10 million “illegal” immigrants live in South

Africa, adding that the so-called illegal immigrants are heterogeneous and include highly skilled professionals and other informal sector operatives who entered illegally as well as those who entered legally, but overstayed the term permitted.

b) Fertility

South Africa has the lowest fertility in sub-Saharan Africa (Kaufman et al 2001). Fertility has been declining gradually in South Africa in the past four decades, dropping from a total fertility rate (TFR) of about 6,7 children per woman during the late 1960s to about 2,8 children per woman in 2001 (Statistics South Africa, 2010). More recently (in 2014), the TFR was estimated to be 2,6 (Statistics South Africa, 2014a). However, there are significant differentials by population group, with the white (TFR = 1,8) and Indian (TFR = 2,0) groups already experiencing below the replacement level fertility, whilst coloureds (TFR = 2,5) and black Africans (TFR = 2,9) remain above the replacement level (Statistics South Africa, 2010). The fertility breakdown by province also shows massive disparities. For instance, Gauteng (2,0) had below replacement fertility while Limpopo, North West and Eastern Cape had a TFR of more than 3 births per woman (Statistics South Africa, 2014a).

Although the level of fertility in South Africa is low by sub-Saharan African standards, there is a problem of teen and pre-teen pregnancies which are exceptionally high, especially for school learners. Teenage pregnancy has been a social problem in South Africa over the years (Jewkes et al 2001; Makiwane 2010; Mkhwanazi 2010; Mturi 2015). Results from the General Household Survey showed that 5,4% of females in the age group 14–19 years were pregnant during the 12 months preceding the survey. The prevalence of teenage pregnancy increased with age, increasing from 0,7% for females aged 14 years to 12,1% for females aged 19 years (Statistics South Africa, 2014b). Teenage pregnancy has serious consequences for teenagers' educational achievement in South Africa despite the fact that they are usually allowed to remain in school while pregnant and go back to school after delivery (Chigona & Chetty 2007; Grant & Hallman 2008).

c) Mortality

Mortality has been declining in South Africa over the years. In 2014, it was observed that various mortality indicators improved drastically. For instance, crude death rate decreased from 13,9 to 10,2 and infant mortality rates declined from 58 per 1 000 live births in 2002 to 34 per 1 000 live births in 2014 (Statistics South Africa, 2014a). The expectation of life at birth had increased from 53,4 years in 2002 to 61,2 in 2014; a national increase of 8 years in a dozen years. Among males, the expectation of life at birth increased from 51,1 years in 2002 to 59,1 years in 2014 and among females, it increased from 55,7 years in 2002 to 63,1 years in 2014 (Statistics South Africa, 2014a). The mortality differentials by province also do exist. Statistics South Africa (2014a) reports that the highest mortality province is Free State (53,6) and the lowest provinces are Western Cape (67,9) and Gauteng (66,4). Decline of mortality is mainly due to halting of the HIV and AIDS epidemic. For instance, a study done in rural KwaZulu-Natal in South Africa demonstrated that in 2003, the year before antiretroviral drugs became available in the public-sector health system, adult life expectancy was

49,2 years, and by 2011 it had increased to 60,5 years (Bor et al 2013).

Although it has been noted that the mortality rate has been declining over the years, there are still gaps in the health system that need serious attention. The high level of maternal mortality is one of the challenges. Recent estimates of maternal mortality ratios in South Africa show that maternal mortality is increasing. Udjo and Lalthapersad-Pillay (2014) demonstrated that the maternal mortality ratio increased from about 473 per 100 000 live births in 2001 to about 764 per 100 000 live births in 2007, representing an annual increase of about 11% between 2001 and 2007. In addition, Garenne et al (2011) also showed that the maternal mortality increased from 542 per 100 000 live births in 2001 to 702 per 100 000 live births 2007, representing about 29% increase between 2001 and 2007 higher than the value estimated from the 2001 census data. Even though the values for these estimates appear to be different, the underlying factor is that maternal mortality is increasing in South Africa. Another challenge is that there are disparities in the provision of health services in the country. This is partly observed through the maternal mortality differentials by province. Whilst Western Cape has the lowest maternal mortality ratio (102), Eastern Cape has the highest figure of 1 639 deaths per 100 000 live births (Udjo & Lalthapersad-Pillay 2014). In South Africa, socio-economic status is very important in access to health care. Harris et al (2011) showed that race, insurance status, and urban-rural location were associated with access to health care, with black Africans, poor, uninsured and rural respondents, experiencing the greatest barriers (Harris et al 2011).

7. Challenges

The discussion thus far has shown that South Africa has a number of demographic challenges that will affect implementation of the 2030 agenda. This section describes the challenges further by categorising them into four main broad groups: change in population structure; the challenges of international migration; lack of demographic skills, especially in planning; and lack of demographic data.

a) Challenge 1: Change in population structure

The transition from high fertility and high mortality, to low fertility and low mortality results in a transitory shift in the composition of the population until a steady state is once again achieved. The decline of fertility and mortality in South Africa presents an important opportunity for the country. Oosthuizen (2013) noted that since mortality declines before fertility, the demographic transition creates a boom generation: a series of cohorts that are unusually large. The immediate effect of this dynamic puts pressure on the working-age cohorts, who face increased demands on the resources earned. However, as fertility falls and these large cohorts age, the working-age population grows relative to the dependent population. This fall in dependency releases resources that can be used to raise living standards, invest in human capital or save, and is termed the first demographic dividend (Oosthuizen, 2013).

However, the demographic dividend is not a given if the fertility and mortality all decrease. Without the right policy environment, countries will be too slow to adapt to their changing age structure and, at best, will miss an opportunity to secure high growth. At worst, where an increase in the working-age population is not matched by increased job opportunities, they will face costly penalties, such as rising unemployment and perhaps also higher crime rates and political instability. With no policies in place to provide for rising numbers of old people, many will face destitution in their final years. Having a larger, healthier and better-educated workforce will only bear economic fruit if the extra workers can find jobs. Solid institutions that can gain the confidence of the population and markets alike may help countries to reap the potential benefit created by their demographic transition (Bloom et al 2007).

The increase in the youth is a result of changes in population structure whereby the bulk of the population are aged 15–50. If most of these youth are employed, the economy benefits a lot. This happened in a number of countries in south-east Asia such as Democratic Republic of Korea. If most of these youth are unemployed and uneducated, it is a good ingredient for trouble. Some scholars associate the problems in Tunisia, Egypt and other countries in

North Africa to be mainly as a result of the educated but unemployed youth (Momani 2013). It is clear that South Africa is going through this state. The question that now has to be posed is whether the country is prepared to reap the benefits of the demographic dividend? A quick conclusion from what is happening in the country (e.g. problems with the higher education sector and service delivery challenges) is that South Africa still does not have a conducive environment to reap the benefits of the demographic dividend. Zulu (2014) has tipped African governments to focus on harnessing the demographic dividend by investing in education, investing in public health, steering economic growth and job creation and finally improve on governance and accountability.

b) Challenge 2: International Migration

As indicated above, South Africa hosts heavy volumes of international migrants, most of which come from other African countries. Unfortunately, illegal and undocumented migrants dominate (Adepoju 2003). This creates an impossible scenario in planning especially for health and social services. There has been dissatisfaction in getting health and social services which have resulted in many strikes around the country including xenophobic attacks. The government and development partners need to take this challenge seriously by looking at ways to address the problem. The first step is to know the number of international migrants in the country and identify places where they are located. Then put necessary measures to deal with the challenge such as integrating them into the communities and make sure that they take part in developmental activities.

c) Challenge 3: Lack of demographic skills in development planning

When there is lack of demographic skills in the country, then the one area that is most affected is planning. Most government planners do not understand population issues, hence it is impossible for them to incorporate demographic variables into development planning. This has serious consequences to sectors such as education, health, human settlement, and labour. For instance, there can be over- or under-utilization of resources in the education sector if schools are built without knowing the current and future demographics of the area under consideration. If there are many more learners than anticipated, then this is not good for planning. The opposite is also not good i.e. having fewer learners than anticipated for a school. The lack of demographic skills also affects other areas. For instance, many jobs for demographers are done by people without the needed demographic skills (Population Association of Southern Africa, 2013). As a result work is not done properly in those areas.

d) Challenge 4: Lack of demographic data

The Republic of South Africa is doing very well in conducting decennial population censuses, household surveys, and it has (relative to other African countries) a good vital registration system (VRS). These data sets assist to derive some demographic indicators, but not all; most of which are estimated indirectly. For instance, fertility estimates can only be estimated using indirect methods of estimation from population census data or household surveys which do not collect birth history information. The use of VRS data in estimating fertility is also limited in South Africa because it is still not clear the degree of under coverage of the registration of births. The same applies to mortality and migration. Many African countries deal with this challenge by conducting Demographic and Health Surveys (DHS) after every five years. Although DHS data does not solve all demographic data problems, it has been very useful in providing reliable demographic indicators that can be used for planning purposes. After it became a democratic state in 1994, South Africa has also conducted two DHSs in 1998 and 2003. But they are prone to various problems such as being too old (i.e. the last one was conducted 13 years ago), released for public consumption very late (both DHSs were released approximately 5 years after data collection), and there is a number of errors (e.g. underestimation of births) identified especially in 2003 which are not as serious in other countries. In conclusion, it can be said that South Africa has a lot of data, but not necessarily the required demographic data.

It should be noted that the collection, analysis and dissemination of data in South Africa are governed by the Statistics Act (Act No. 6 of 1999). The Act has entrusted Statistics South Africa with collection, analysis and dissemination of “official statistics” under the leadership of the Statistician General. The Act also defines the National Statistics System (NSS), which is a systemic partnership of institutional users, producers and suppliers of official statistics. However, the establishment of NSS in South Africa faces a number of challenges hence its coordination functions are not yet fully developed (Khuluvhe 2013). We argue that the National Statistics System needs to respond to the data demands imposed by the new agenda of the 17 SDGs. Indeed, Stats SA, in its most recent strategic plan (2015/16–2019/20), has stated a need for statistical reform in South Africa. We hope that the lack of demographic data emphasised in this paper will be part of the reform.

8. Concluding Remarks

This paper has addressed the question on whether South Africa is demographically ready to monitor the SDGs. In doing so, it has discussed the evolution of demography training in Africa in general and South Africa in particular. Among the factors affecting demographic training in Africa, the following have been identified: the decreasing role played by UNFPA; the change of emphasis on demography after the 1994 International Conference on Population and Development; lack of funding for demographic research; and shifting from formal long-term demographic training to short-term projects. The history of demographic training in South Africa is even more problematic, hence the loss of popularity as a discipline in the country. The discussion of the demographic profile of South Africa suggests that there was progress made during recent years, but there are also challenges that need special attention.

There are four recommendations: Firstly, the government needs to establish mechanisms through which the demographic dividend can be 'reaped'. This includes investing strategically in the education, health, and labour sectors. Secondly, there is a need to assess training in demography and find ways to promote the discipline. The government needs to appreciate the need for these skills and identify all areas in the government, private sectors, NGOs, etc. where demographers are required and mobilise those sectors accordingly. The first step to achieve this involves the government, through the Department of Higher Education and

Training, to reverse the decision to reclassify demography as a none-scarce skill. Thirdly, the non-availability of necessary demographic data needed should be rectified. This is a challenge to the entire National Statistics System. Emphasis should also be placed on collecting disaggregated demographic data by rural/urban, province, sex, disability, and race so that differentials within the population can be identified as stipulated by SDGs. Fourthly, the country should have a clear understanding of the demographic indicators needed during implementation of the 2030 agenda and the way they will be monitored to facilitate the collection of data.

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