Journal of African Population Studies (JAPS)

UAPS UEPA

Original Article

SMALL AREA POPULATION PROJECTIONS: SUITABILITY OF HAMILTON-PERRY MODEL IN UNDERTAKING POPULATION PROJECTIONS BY AGE AND SEX FOR SELECTED SUB-COUNTIES IN KENYA

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Citation: Mose, J.; Wakibi, S.; Agwanda, A. Small Area population projections: Suitability of Hamilton-Perry model in undertaking population projections by age and sex for selected sub-counties in Kenya. *Journal of African Population Studies* **2025**, *38(1)*, 5299. https://doi.org/10.59147/ksqmb588

Academic Editor: Ngianga-Bakwin Kandala
Received: 7 November 2024
Accepted: 12 May 2025
Published: 1 December 2025

Publisher's Note: JAPS stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract

Background: Devolution of services in Kenya from the National Government to the 47 County Governments has led to a rise in demand for reliable age and sex disaggregated population statistics at lower levels (sub-county and ward levels) for effective segmented programming and planning. **Objective:** The study was undertaken to determine the suitability of Hamilton-Perry model in undertaking sub-county population projections by age and sex using case of selected sub-counties in Nyeri and Vihiga Counties, Kenya. **Method:** The study used the 1999, 2009 and 2019 Kenya Population and Housing Census data for the selected sub-counties. Vihiga county was selected because it had the highest net out migration rate among the 47 counties of 97 per 1,000 in 2019 census while Nyeri was selected due to its stable Total Fertility Rete (TFR) and low out migration rate. **Results:** The Mean Absolute Percentage Error (MAPE) for the 2019 population projections for Nyeri county, Kieni East and Kieni West Sub-counties were 8.5, 11.5 and 17.5 respectively. That of Vihiga County, Emuhaya Sub-county and Vihiga Sub-county were 9.6, 19.3 and 7.9 respectively. This implies that the projection had very good precision for Nyeri County, Vihiga County and Vihiga Sub-county and had good precision for Kieni West, Kieni East and Emuhaya Sub-counties. **Conclusions:** The study results from the two sub-counties of Nyeri and Vihiga Counties, showed that the HP population projection model can be used reliably to undertake population projections for the sub-counties of Nyeri and Vihiga Counties, Kenya. The model produced population projections with very good precision in the Sub-counties with higher population size and its precision was shown to decrease with decrease in population size.

1. Introduction

Small-area population projections are important in programming, planning, research and policy purposes at lower geographic levels especially below sub-nationals. They have been used in estimating demand for basic human needs such as food, water and transportation; planning for basic amenities like schools, hospitals, market centers, etc.; and estimating the labor forces and potential consumptions at various levels among others [1, 2, 3]. According to [4], small area population projections have been useful in the review and redrawing of political and electoral boundaries. Additionally, many population statistics users across the public and private sectors require projections disaggregated by sex and age groups at lower levels for informed segmentation planning and programming. To assess the primary needs of people, which development programs aim to satisfy, it is important to have information on the expected size, composition and distribution of the population at different geographic units and points in a given time [5].

Generally, population projections are necessary for the distribution of resources, advocacy, research, planning and policy evaluation, and monitoring and evaluation of the impact of population programs in the intercensal periods[5]. Kenya has been conducting population and housing censuses after every 10 years since 1969 and among the census products has been an analytical report on population projections.

Kenya is divided into forty-seven (47) counties as per the First Schedule of the Constitution of Kenya 2010 each with various number of sub-counties [6]. Much of the planning for the population is currently being done at the county level and involves preparation of a four-year County Integrated Development Plan (CIDP) that guides the respective counties in coordinating and harmonizing planning, budgeting, implementation, monitoring, and evaluation of their development processes [7]. To effectively plan for the population, the respective county governments and other stakeholders require age and sex-disaggregated population projected at lower levels/sub-county levels. For the last two censuses; the 2019 Kenya Population and Housing Census (2019 KPHC) and 2009 KPHC, official population projections have been done up to the sub-national (county) level using the cohort-component population projection method.

Cohort component methods have been used widely to undertake population projections at national and large regional/sub-national levels. The method is, however, unsuitable for small areas because it requires migration, fertility and mortality data as inputs which are unavaible or unreliable at lower levels. The Cohort-component method is superior to mathematical methods as it involves a separate analysis of the changes affecting each component of the population [5, 8, 9]. At lower levels (small areas), population data suffer from geocoding inaccuracy, boundary changes, erratic demographic trends, and unpredictable population changes especially in the urban population [10, 11, 12] and it is, therefore, challenging to use cohort component models. The technique is therefore not appropriate in undertaking population projections at lower levels due to a lack of reliable inputs. There is therefore a need to identify the most suitable method that the counties can use to generate reliable age and sex disaggregated population projections at sub-county levels to enable them to make informed decisions while planning and programming for various segments of the populaton at those levels.

A number of methods for undertaking small-area population projections exist with various strengths and weaknesses. An analysis done by [13], enumerated the strengths and weaknesses of a number of small area population projection methods including: Simple extrapolative and comparative methods; model averaging and composite models; models incorporating socioeconomic variables and spatial relationships; models linking population and housing; small area microsimulation; and Hamilton–Perry and other simplified cohort-component methods, among others. According to [13, 14], to choose an appropriate method, one needs to consider its validity, effectiveness, data requirements, ease of application, among other strengths. Two studies [16, 15] noted that in recent years, the Hamilton-Perry (HP) model has been used extensively to produce reliable small area age-sex population projections with relatively little input data. It does not require fertility, mortality, and migration input data like the traditional cohort-component models, but produces reliable projections.

A major weakness of other small area population projection methods is that they do not produce age-sex disaggregated population projections [16]. They are applied to project population totals rather than age and sex-specific disaggregation.

The HP model has been used to project the populations in a number of regions for instance: projection of census tracts and block groups in the US census from 2000 to 2020 [17, 18], the populations of urban census tracts with spatial weighting applied to preliminary forecasts [19], and projecting the population for counties in Washington States and census tracts in New Mexico [20]. They have also been used in projecting population by age, sex and race for all counties of the US for 2020-2100 [21] and in the projection of population of the small areas of Japan [22] among others.

A review by [4] suggests that small area projection accuracy improves through constraining to total population extrapolative forecasts, using a mix of cohort change ratios (for declining populations) and cohort change differences (for growing populations), and modifying cohort change ratios over time in line with those from a larger population. Another study [23] noted that overall, errors tend to increase as population size decreases, with errors rising rapidly once population size declines below 10,000. The Hamilton-Perry method has fewer data requirements than the traditional cohort-component method and only requires population by age and sex from the two most recent censuses. The Hamilton-Perry method has been used widely to carry out population projections for small geographic areas in which mortality, fertility, and migration data are non-existent, unreliable, or very difficult to obtain, or for larger geographic areas where birth, death, and migration forecasts are not needed, not available, or are unreliable [16].

Use of the HP method, which is a variant of the traditional cohort component models of population projection, has gained popularity in recent years. In the recent past, it has demonstrated its practical value and accuracy in projecting population composition. Other studies like [19, 24] demonstrated that HP and cohort-component methods produced similar projections of the age-sex structure of the population for the U.S. states and counties in Florida.

Over time, official population projections in Kenya have been done at National and County levels. With the increased demand for age-sex disaggregated population projections at sub-county levels in Kenya, there is a need to have population projections at the lower levels to enable the County Governments and other stakeholders make informed planning and decision making. To determine the extent to which projections can be done at these levels, it is necessary to conduct some sensitivity analyses on the suitability of these methods. The sensitivity test used data from selected sub-counties of Nyeri and Vihiga counties. However, the HP Model's suitability for small area projections has not yet been evaluated to determine its consistency with census data for many developing countries, including Kenya. The study sought to address this need and provide population projections for the selected sub-counties.

According to [31], migration rates have an impact on both sending and receiving regions in terms of population change, age-sex compositions, and subsequent demographic processes, such as fertility, ageing, and further internal or international migration.

The main objective of the study was to determine the suitability of the Hamilton-Perry model in undertaking population projections by age and sex at the sub-county level using the case of selected sub-counties in Nyeri and Vihiga Counties, Kenya. Specific objectives were to:

1. Project 2019 Population by age and sex for the selected sub-counties of Nyeri and Vihiga Counties using the Hamilton-Perry method;
2. Assess the closeness or deviation of the output/results from the Hamilton-Perry projection model with observed 2019 census enumeration data for the selected sub-counties of Nyeri and Vihiga Counties;
3. Project 2029 Population by sex and age group for the selected sub-counties of Nyeri and Vihiga Counties.

The two study counties were chosen to establish the precision of the model in cases of extreme migration rates and stable Total Fertility Rate (TFR). Vihiga County had the highest out-migration rate of 97 per 1,000 persons in the 2019 census, while Nyeri had a stable TFR and population distribution structure, as well as a low out-migration rate, as indicated in Table 1.

2. Materials and Methods

The data used for this study were from the 1999, 2009, and 2019 Kenya Population and Housing Censuses. The methodological approach to census taking in Kenya is traditional/classic and de facto (persons are enumerated where they were physically present on the census reference date, regardless of whether they are usual and/or legal residents of the household/area. For this study, data from selected sub-counties of Nyeri and Vihiga Counties were used.

2.1 Data Analysis- The Hamilton-Perry Method

This study used the unmodified Hamilton-Perry model, a variant of the cohort-component population projection method, for small area population projections. The Hamilton–Perry method has been used widely to project population by age and sex using cohort-change ratios (CCR) computed from data from the two most recent population censuses. It has gained acceptance for its practical value and accuracy in projecting population composition at small areas. The method is based on the assumption that CCRs and Child Woman Ratios (CWRs) developed over the base period are held constant over the projection period [19].

CCR is computed as below:

$${}_nCCR^i_x={}_nP^i_{x+t,1}/{}_nP^i_{x,0} \quad \text{.......} 1$$

where

${}_n\mathbf{P}_{x+t,1}$ is the population age x+t to x+t+n;

$_nP_{x,0}$ is the population age x to x+n in the second recent census, and t is the number of years between the two most recent censuses;

'i^th^' is a given small area (sub-county)

Applying the above to the 1999 and 2009 Kenya Population and Housing Censuses population for Nyeri County, the CCR for the population aged 20-24 in 1999 was computed as below:

$$_5CCR_{20} = {}_5P_{30,2009} / {}_5P_{20,1999}$$

The projected population for year x+t was estimated using the Hamilton-Perry projection formula given by:

$$_nP_{x+z,t} = {}_nCCR_x * {}_nP_{x,1} \quad \ldots 2$$

Using the 1999 and 2009 Kenya Population and Housing Censuses population for Nyeri County, the formula for projecting the population age 20-24 in 2019 was computed as below:

$$_5P_{20,2019} = {}_5CCR_{20} * {}_5P_{10,2009} \text{ with } {}_5CCR_{20} = {}_5P_{30,2009} / {}_5P_{20,1999}$$

Taking into consideration the nature of CCRs, the youngest age group they can project is 10-14 years when the data is from 10-year population censuses and age 5-9 years when the data is from 5-year population censuses. Child Women Ratio (CWRs) are used to project the population for age groups less than 10 years for data from 10-year population censuses. CWR is defined as the population aged 0-4 divided by the population aged 15-44. To project the population aged 5-9, the CWR is defined as the population aged 5-9 divided by the population aged 20-49 [17]

The CWR for males and females aged 0-4 and 5-9, respectively, will be given by:

Females 0-4: $_5FP_{0,t} = ({}_5FP_{0,1} / {}_{30}FP_{15,1}) * {}_{30}FP_{15,t} \quad \ldots 3$

Males 0-4: $_5MP_{0,t} = ({}_5MP_{0,1} / {}_{30}FP_{15,1}) * {}_{30}FP_{15,t} \quad \ldots 4$

Females 5-9: $_5FP_{5,t} = ({}_5FP_{5,1} / {}_{30}FP_{20,1}) * {}_{30}FP_{20,t} \quad \ldots 5$

Males 5-9: $_5MP_{5,t} = ({}_5MP_{5,1} / {}_{30}FP_{20,1}) * {}_{30}FP_{20,t} \quad \ldots 6$

Where:

- 'FP' is the female population and 'MP' is the male population; and
- '1' is the census year and t is the target year.

To project the Nyeri County female population age 0-4 for the year 2019 using the CWR approach, the equation below was used:

$$_5FP_{0,2019} = ({}_5FP_{0,2009} / {}_{30}FP_{15,1999}) * {}_{30}FP_{15,2019}$$

To project the oldest age group, say, 85+, the CCR for this open-ended age group will be given as:

$$CCR_{75+} = P_{85+,1} / P_{75+,0} \quad \ldots 7$$

Using the 1999 and 2009 Kenya Population and Housing Census, the formula for projecting the population 85+ for the year 2019 will be given by:

$$P_{85+,2019} = (P_{85+,2009} / P_{75+,1999}) * P_{75+,2009} \quad \ldots 8$$

The above is applied to both sexes as follows:

Female age 85+ will be given by: $FP_{85+,2019} = (FP_{85+,2009} / FP_{75+,1999}) * FP_{75+,2009}$ while that for the males will be given by: $MP_{85+,2019} = (MP_{85+,2009} / MP_{75+,1999}) * MP_{75+,2009}$.

There are several approaches for modifying CCRs and CWRs over the projection period which include averaging and trending them and using a synthetic method that bases county-level CCR and CWR change and applies them to the sub-county level [4]. This study applied the unmodified HP method to undertake the projections and evaluate the projection errors arising from the method using the actual 2019 census enumerated population for the selected sub-counties of Nyeri and Vihiga Counties.

The main limitation for the Hamilton-Perry method is that it can lead to unreasonably high projections in rapidly growing places and unreasonably low projections in places experiencing population losses in the recent censuses [25, 26]. Additionally, the model requires that geographic boundaries remain constant over time. According to [17], all boundary changes within the forecast period must be accounted for to realize accurate projections. The boundaries of the study counties and sub-counties were the same over the study period.

MAPE

The mean absolute percentage error (MAPE) is the average of the absolute percentage errors of projections. MAPE is commonly used to measure the accuracy of a projection method. It is calculated as follows:

$$MAPE = \sum \mid PE_t \mid / n,$$

where, $PE_t = [(Ft–- At) / At] \times 100$, and ''PE'' represents the percent error,''t'' the target year,''F'' the projected population,''A'' the actual enumerated population, and ''n'' the number of areas or categories.

Projections that are perfect and very accurate result in a MAPE of zero. A MAPE of less than 10 per cent indicates that the projection is very good, while a MAPE of 10-20 per cent indicates that the projection is good. The larger the value of the MAPE, the lower the precision of the projection[27].

MALPE

The mean algebraic percent error (MALPE) is used to measure projection bias. MALPE can be estimated using the following formula:

$$MALPE = \sum PE_t / n.$$

where'PE','t' and ''n'' are as defined above in section 5.2.1.

Negative values of MALPE indicate that the projections are low, while positive values indicate that the projections are tending to be too high.

3. Results

The summary of selected characteristics of Nyeri and Vuhiga Counties is presented in Table 1. The population of Nyeri County stood at 752,629 while that of Vihiga was 590,013 as enumerated during the 2019 Kenya Population and Housing Census.

Table 1: Summary of the selected demographic characteristics of Nyeri and Vihiga Counties

S/No.	County	Population Size		Intercensal Rate	Growth	TFR		CDR		Net Migration '000)	Out- (per
		2009	2019	1999-2009	2009-2019	2009	2019	2009	2019	2009	2019
1	Nyeri	689,437	759,164	0.7	0.9	2.9	2.9	12.6	10.2	12.5	11.7
2	Vihiga	553,633	590,013	1.3	0.4	4.5	3.5	16.8	9.4	33.0	97.0

Source: KNBS 2022, Vol. VI and VIII [28, 29]

CCR and CWR

The CCRs by sex for age-groups 10-15 to 90+ were computed from the 1999 and 2009 Kenya Population and Housing Census data for the Nyeri and Vihiga counties and the selected sub-counties using equation "1" and the results are presented in Appendix 1.

The CWR ratios for age-groups 0-4 and 5-9 were also computed using the populations for age 0-5 and 5-9 in the 2019 census data as a ratio of total women population age 15-44 and 20-49 respectively (Appendix 1).

3.1 Total projected 2019 population and projection errors

The model results are presented as total population projections and total projection errors at both county and selected sub-counties of Nyeri and Vihiga Counties. In Table 2, the total 2019 projected population for Vihiga County was 612,313, while the actual enumerated 2019 census population was 587,107. The projected population for Nyeri county was 723,471, and the actual enumerated 2019 census population was 752,629.

Table 2: Projected Population and Errors by sex and region

County/Sub-County	Sex	Projected	Enumerated	TAPE	MAPE	MALPE
Vihiga County	Male	293,796	282,189	4.1	10	3.7
	Female	318,517	304,918	4.5	10.2	2.8
	Total	**612,313**	**587,107**	**4.3**	**9.6**	**3.1**
Emuhaya Sub-County	Male	39,488	46,439	15	18.7	-10.3
	Female	43,719	50,579	13.6	20	-9.7
	Total	**83,207**	**97,018**	**14.2**	**19.3**	**-10**
Vihiga Sub-County	Male	48,086	45,344	6	9.9	2.9
	Female	51,536	49,148	4.9	8.3	1.9
	Total	**99,622**	**94,492**	**5.4**	**7.9**	**2.2**
Nyeri County	Male	355,463	370,047	3.9	11.3	1.1
	Female	368,008	382,582	3.8	7.8	-1.7
	Total	**723,471**	**752,629**	**3.9**	**8.5**	**-0.9**
Kieni West Sub-County	Male	45,768	43,595	5	15.3	8.9
	Female	45,939	44,409	3.4	11.1	3.7
	Total	**91,707**	**88,004**	**4.2**	**11.5**	**5.4**
Kieni East Sub-county	Male	57,299	54,877	4.4	21.8	9
	Female	57,576	54,736	5.2	16.3	5.2
	Total	**114,875**	**109,613**	**4.8**	**17.5**	**6.3**

Results in Table 2 show that the 2019 population projections for the individual sub-counties were slightly higher compared with the actual enumerated 2019 census population, except for Emuhaya Sub-county, which was slightly lower than the enumerated 2019 census population.

TAPE

The total absolute percent projection error for Vihiga County was 4.3 per cent, while that of Nyeri County was 3.87 per cent which indicates that the forecast precision was very good. Also, the projections for Emuhaya sub-county had a relatively higher total absolute percent error compared with all the other population projections

Absolute percentage error for the projection by age group and sex

Absolute percentage error for the projections was computed by age group and sex as presented in Appendix 2. The absolute percentage error for age group 0-4 was generally higher for Vihiga county and its sub-counties as compared to Nyeri county and its sub-counties. The absolute percentage error for Emuhaya sub-county was higher between ages 10 and 60, and also for age 80+.

MAPE

The Mean Absolute Percentage Error (MAPE) for Nyeri county, Kieni East and Kieni West Sub-counties were 8.5, 11.5, and 17.5 per cent, respectively as shown in Table 2. Those of Vihiga County, Emuhaya, and Vihiga Sub-counties were 9.6, 19.3, and 7.9 per cent respectively as presented in Table 2. This implies that the projection was very good for Nyeri County, Vihiga County and Vihiga Sub-county. Additionally, the forecast precision was good for Kieni West, Kieni East and Emuhaya Sub-counties. A high MAPE indicates that the projected values are, on average, far from the actual values. This means the model's predictions are less reliable, which can impact decision-making processes for Emuhaya Sub-county.

MALPE

From the projection results, the HP model had downward bias for Emuhaya Sub-county and Nyeri county projections, with Emuhaya Sub-county recording the highest downward bias of 10.0 per cent. The model had an upward bias for the rest of the regions, with Kieni East recording the highest at 6.3 per cent.

3.2 Population projections for the selected sub-counties of Nyeri and Vihiga Counties for the year 2029

Having established that the HP model projects population at lower levels with good precision, it was applied to undertake 2029 population projections for Nyeri and Vihiga Counties, and the selected sub-counties presented in Table 2. The projected 2029 population for Vihiga County is 613,100, while that of Nyeri County is 806,018 as presented in Table 3. The projected population by age group is presented in Appendix 3.

Table 3: Projections of 2029 Population by region and sex

County/Sub-County	Sex	2019 Census	Projected 2029 Population
	Male	282,189	298,377
	Female	304,918	314,723
Vihiga County	**Total**	**587,107**	**613,100**
	Male	46,439	59,351
	Female	50,579	62,349
Emuhaya Sub-County	**Total**	**97,018**	**121,700**
	Male	45,344	46,898
	Female	49,148	49,806
Vihiga Sub-County	**Total**	**94,492**	**96,704**
	Male	370,047	398,795
	Female	282,582	407,223
Nyeri County	**Total**	**752,629**	**806,018**
	Male	43,595	47,314
	Female	44,409	48,078
Kieni West Sub-County	**Total**	**88,004**	**95,392**
	Male	54,877	60,652
	Female	54,736	61,753
Kieni East Sub-county	**Total**	**109,613**	**122,405**

4. Discussion

The Cohort-Change Ratios (CCRs) computed for age 0-4 were more than 1 for both sexes in all the counties and the selected sub-counties (Appendix 1). This indicates that there was either an increase in births during the study period or more immigrants in that age group. The Child Woman Ratios (CWRs) for Nyeri County and its sub-counties were lower than those of Vihiga County and its sub-counties. From the 1999, 2009 and 2019 censuses, Nyeri County has generally been recording lower birth rates compared to Vihiga County. This may explain the noted difference in the CWRs for the two regions.

The projected 2019 census population figures for Nyeri and Vihiga Counties and their selected sub-counties were within the acceptable error margins. The total absolute percentage error was low for county-level projections and higher in Emuhaya sub-county, which had the least population in 1999, when compared with the rest of the sub-counties. The precision of the HP population projection model was very good at the county level, and the precision decreased with a decrease in population size that was projected. Previous studies have also established that population size affects the precision of population projects [10, 24].

The absolute percentage error for Emuhaya sub-county was higher between ages 10 and 60, possibly due to the higher effects of migration, while the errors for age 80+ were high, most likely because of the lower numbers in this age-groups[30]

A measure of bias of the model was undertaken, and it was noted that the model had a slight upward bias for most of the regions except Emuhaya sub-county. Therefore, there is a need to undertake further examination of the data sets in order to minimize the bias of the model. Also, there is a need to cover more sub-counties while taking into consideration the diversity of the various regions to evaluate the magnitude of the bias and accuracy of the model.

5. Conclusions

The study results from the two sub-counties of Nyeri and Vihiga Counties have shown that the HP population projection model can be used reliably to undertake population projections for the sub-counties of Nyeri and Vihiga Counties, Kenya. The model can therefore be used to undertake population projections for sub-counties with similar characteristics for planning purposes. The model gives population projections with very good precision when the population size to be projected is high, and the precision of the model decreases with a decrease in population size. However, there is a need to adjust the outlier CCRs for some age groups or set ceilings to ensure that the projections for all the age groups are reliable. Additionally, the suitability of the model in high-mortality and fertility sub-counties needs to be tested.

Appendix

Appendix 1: CCRs and CWRs for Vihiga and Nyeri Counties and Selected Sub-Counties

Age Group	Vihiga County		Emuhaya Sub-County		Vihiga Sub-County		Nyeri County		Kieni West Sub-County		Kieni East Sub-county	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
0 - 4	0.38	0.376	0.391	0.387	0.369	0.356	0.24	0.228	0.276	0.268	0.25	0.234
5 - 9	0.454	0.443	0.447	0.451	0.452	0.43	0.269	0.263	0.327	0.308	0.283	0.269
10 - 14	1.034	1.056	1.043	1.072	1.024	1.048	1.024	1.038	1.094	1.11	1.119	1.108
15 - 19	0.863	0.874	0.825	0.862	0.889	0.865	0.903	0.859	0.923	0.841	0.963	0.962
20 - 24	0.441	0.572	0.399	0.528	0.438	0.571	0.647	0.687	0.639	0.646	0.858	0.902
25 - 29	0.451	0.581	0.428	0.53	0.45	0.582	0.67	0.768	0.68	0.873	0.901	1.079
30 - 34	0.79	0.73	0.774	0.718	0.807	0.747	0.82	0.806	0.911	0.915	0.881	0.93
35 - 39	0.896	0.764	0.934	0.796	0.861	0.754	0.86	0.81	0.999	0.902	0.823	0.894
40 - 44	0.943	0.828	0.983	0.826	0.912	0.804	0.846	0.84	0.947	0.921	0.821	0.903
45 - 49	0.963	0.875	1.019	0.89	0.934	0.89	0.935	0.896	1.019	0.948	0.911	0.909
50 - 54	1.015	0.948	1.082	0.962	1.011	0.962	0.92	0.965	0.985	1.014	0.876	0.993
55 - 59	1.019	0.917	1.102	0.958	0.981	0.901	0.897	0.865	0.945	0.912	0.838	0.796
60 - 64	1.025	0.879	1.069	0.89	1.001	0.881	0.899	0.883	0.97	0.929	0.834	0.862
65 - 69	0.913	0.862	0.911	0.938	0.934	0.897	0.92	0.945	0.962	0.921	0.784	0.946
70 - 74	0.834	0.806	0.889	0.801	0.832	0.823	0.839	0.836	0.821	0.852	0.803	0.819
75 - 79	0.682	0.671	0.67	0.703	0.679	0.692	0.749	0.785	0.757	0.838	0.748	0.759
80 - 84	0.508	0.58	0.544	0.546	0.534	0.576	0.533	0.644	0.56	0.696	0.483	0.614
85 - 89	0.434	0.553	0.433	0.545	0.383	0.528	0.527	0.647	0.662	0.701	0.504	0.58
90 +	0.306	0.391	0.299	0.404	0.25	0.336	0.372	0.468	0.396	0.515	0.512	0.691

Appendix 2: Absolute percentage error for the projection by age group and sex

Age-Groups	Vihiga County			Emuhaya Sub-County			Vihiga County			Nyeri County			Kieni West Sub-County			Kieni East Sub-County		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Total	4.3	4.1	4.5	14.2	15.0	13.6	5.4	6.0	4.9	3.9	3.9	3.8	4.2	5.0	3.4	4.8	4.4	5.2
0 - 4	41.5	43.5	39.6	13.6	15.0	12.3	41.0	43.9	38.2	0.6	1.9	0.7	19.1	20.4	17.8	14.2	16.5	11.9
5 - 9	10.7	12.6	8.8	15.3	15.5	15.2	14.1	16.5	11.7	2.2	2.8	1.7	16.9	19.5	14.2	17.8	21.1	14.5
10 - 14	2.5	2.3	2.7	16.2	16.3	16.2	4.3	5.5	3.1	2.9	2.8	3.0	5.9	5.3	6.5	9.6	11.5	7.6
15 - 19	1.3	2.2	0.5	21.1	24.7	17.4	3.5	7.4	0.4	4.8	4.4	5.3	3.1	1.7	4.7	3.9	3.6	4.2
20 - 24	8.3	18.6	1.3	24.1	30.9	18.2	10.3	22.3	1.6	9.7	12.4	7.0	7.4	2.2	13.0	19.4	16.8	22.2
25 - 29	0.7	2.5	3.4	20.6	20.0	21.1	1.7	3.0	0.7	1.5	1.9	1.2	18.5	11.4	25.5	20.8	14.9	26.5
30 - 34	6.5	4.9	7.7	23.9	24.8	23.3	3.9	0.9	6.2	9.3	6.5	11.9	1.0	4.4	5.8	4.0	3.3	4.6
35 - 39	5.4	8.7	2.4	16.2	20.7	12.2	10.1	12.7	7.8	9.2	8.3	10.0	1.1	6.6	8.1	3.3	4.9	1.8
40 - 44	5.9	7.8	4.2	20.4	20.1	20.7	6.0	6.9	5.2	10.1	11.6	8.6	2.8	3.3	2.3	6.2	9.7	2.6
45 - 49	0.7	3.8	2.1	15.4	17.6	13.5	1.4	11.4	8.4	4.6	5.9	3.3	0.6	2.2	3.4	5.3	7.6	3.0
50 - 54	1.3	1.8	0.9	14.4	13.5	15.1	4.2	4.6	3.9	7.6	11.9	3.6	7.7	10.7	4.9	9.2	13.3	5.1
55 - 59	2.0	0.1	3.7	15.6	16.6	14.8	3.5	3.1	3.7	8.5	8.2	8.7	9.3	8.6	10.1	17.2	14.3	20.5
60 - 64	5.4	2.2	8.1	17.4	15.3	19.2	1.7	0.7	2.7	7.3	10.3	4.5	8.2	9.9	6.6	11.2	15.3	7.1
65 - 69	6.5	3.6	9.0	15.7	19.0	12.9	2.0	2.9	1.2	1.8	4.2	0.5	4.4	5.2	3.7	13.0	18.7	7.5
70 - 74	7.2	5.2	9.0	14.9	10.4	19.2	3.6	1.1	5.9	7.8	4.6	10.5	11.8	8.0	15.0	11.9	8.0	15.5
75 - 79	6.2	3.7	13.1	16.2	9.6	20.4	0.4	9.8	6.0	0.1	13.3	8.0	1.4	9.7	3.2	5.6	12.6	16.7
80 - 84	6.0	0.5	9.6	10.7	4.6	20.6	5.1	7.2	12.9	7.5	7.1	7.7	7.5	13.2	3.2	19.4	26.1	13.8
85 - 89	2.8	12.4	2.9	2.1	7.4	1.4	6.9	4.4	8.5	9.2	16.8	5.0	15.3	37.5	2.9	8.0	32.2	7.3
90 +	60.8	53.8	65.3	72.0	52.9	85.6	27.2	24.2	29.1	56.9	80.3	47.5	76.2	110.9	60.7	131.8	163.4	116.9

Appendix 3: Projected 2029 Population by age-group, sex and region

Age-Group	Vihiga County			Emuhaya Sub-County			Vihiga Sub-County			Nyeri County			Kieni West Sub-County			Kieni East Sub-County		
	Total	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**
Total	**613,100**	**298,377**	**314,723**	**121,700**	**59,351**	**62,349**	**96,704**	**46,898**	**49,806**	**806,018**	**398,795**	**407,223**	**95,392**	**47,314**	**48,078**	**122,405**	**60,652**	**61,753**
0 - 4	66,774	33,070	33,704	13,810	6,855	6,955	10,226	5,103	5,123	70,494	35,656	34,838	8,448	4,242	4,206	11,571	5,862	5,709
5 - 9	83,685	41,633	42,052	17,300	8,620	8,680	12,991	6,521	6,470	74,797	37,631	37,166	9,523	4,796	4,727	11,940	5,946	5,994
10 - 14	65,741	32,308	33,433	13,751	6,742	7,009	10,058	4,903	5,155	72,825	36,645	36,180	9,106	4,564	4,542	11,615	5,811	5,804
15 - 19	68,711	34,281	34,430	14,350	7,330	7,020	10,414	5,105	5,309	69,312	35,554	33,758	8,681	4,508	4,173	10,716	5,360	5,356
20 - 24	48,367	23,615	24,752	9,163	4,296	4,867	7,656	3,815	3,841	56,134	28,626	27,508	6,059	3,210	2,849	8,425	4,289	4,136
25 - 29	37,588	17,254	20,334	7,263	3,289	3,974	5,922	2,552	3,370	53,054	25,666	27,388	6,093	3,031	3,062	8,718	4,304	4,414
30 - 34	34,613	17,207	17,406	6,567	3,208	3,359	5,661	2,845	2,816	52,386	25,779	26,607	5,620	2,774	2,846	8,049	4,003	4,046
35 - 39	28,161	14,271	13,890	5,255	2,654	2,601	4,754	2,350	2,404	44,628	22,079	22,549	4,679	2,271	2,408	6,619	3,153	3,466
40 - 44	31,000	15,107	15,893	5,909	2,892	3,017	4,875	2,284	2,591	50,483	24,733	25,750	5,590	2,720	2,870	7,785	3,716	4,069
45 - 49	25,552	13,221	12,331	4,663	2,434	2,229	4,399	2,351	2,048	50,302	25,245	25,057	5,937	2,845	3,092	7,715	3,870	3,845
50 - 54	25,065	12,236	12,829	4,714	2,278	2,436	4,003	1,898	2,105	48,601	24,502	24,099	6,091	3,031	3,060	7,435	3,702	3,733
55 - 59	21,539	10,725	10,814	4,305	2,186	2,119	3,571	1,840	1,731	41,570	21,002	20,568	5,349	2,642	2,707	6,424	3,247	3,177
60 - 64	19,389	9,194	10,195	3,870	1,880	1,990	3,080	1,439	1,641	36,907	18,471	18,436	4,820	2,446	2,374	5,163	2,659	2,504
65 - 69	17,740	7,786	9,954	3,518	1,591	1,927	2,835	1,276	1,559	30,651	15,124	15,527	3,600	1,838	1,762	4,179	2,134	2,045
70 - 74	15,745	7,141	8,604	2,999	1,399	1,600	2,463	1,121	1,342	19,403	8,983	10,420	2,152	991	1,161	2,357	1,122	1,235

75 - 79	10,809	4,556	6,253	2,112	884	1,228	1,673	710	963	13,758	5,690	8,068	1,438	622	816	1,591	665	926
80 - 84	6,776	2,828	3,948	1,183	486	697	1,127	462	665	10,946	4,548	6,398	1,159	492	667	1,199	555	644
85 - 89	3,606	1,163	2,443	632	202	430	581	188	393	5,737	1,782	3,955	684	194	490	545	149	396
90 +	2,239	781	1,458	336	125	211	415	135	280	4,030	1,079	2,951	363	97	266	359	105	254

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