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RURAL-URBAN POPULATION PROJECTIONS FOR KENYA AND IMPLICATIONS FOR DEVELOPMENT-SOME PRELIMINARY RESULTS

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1. INTRODUCTION

Kenya has one of the highest population growth rates in the world. The country had 5.4 million people in 1948; its population increased by 3.2 million in the period 1948-62 and by another 2.3 million people in the period 1962-1969, (Development Plan, 1974-1978, pp.99). This represents an annual growth rate of 3.2% in the period 1948-1962 and 3.4% in the period 1962-1969. The present population is about 14 million and the annual growth rate is about 3.5%. Hence, not only has Kenya's population been growing, but also the growth rate has increased substantially in the last two decades. At this rate of growth Kenya's population is expected to double within 20 years.

The principal source of Kenya's accelerated population growth has been a rapid decline in mortality; fertility has remained relatively constant. It is expected that with improving health services throughout the country, mortality will decline further whereas fertility is expected to remain constant, at least for the next two decades. The rapid population growth has created increasingly greater demands for employment, food, shelter, clothing and services such as education, water, sanitation, health, transportation, etc. Inspite of the efforts of the government to provide basic services throughout the country, the population growth is causing an increasing gap between the availability of economic goods and services and the corresponding demands of the population.

Estimates of current population characteristics, as well as population trends which may be expected in the future, are essential for assessing the needs of Kenya's society in the future. It is important to divide the population projections into urban and rural components since Kenya has a dual economy: agriculture (rural areas) is the backbone of the economy, and manufacturing and industry (mainly urban areas) constitute an important growth sector. It should be noted that agriculture and manufacturing will become complementary rather than competitive sectors of the economy in the sense that agriculture will provide both the raw materials for industrial exports and an expanding market for manufactured goods. About 85% of the population resides in the rural areas and the remaining 15% inhabits the urban areas. This is a low level of urbanization in comparison to many developing countries in Latin America and Asia. However, the rate of urbanization is high. In 1969, 1.1 million people resided in the urban areas; the present number is 2 million. This urbanization trend is likely to continue and may increase in the future.

The objective of this paper is to present some preliminary results on the projections of Kenya's rural and urban population under present trends (base run) and varying assumptions (scenarios 1 to 6) of fertility, mortality and migration. The methodology of multiregional demography is applied to this two region system (Rogers 1975). The advantage of this approach is that rural and urban populations can be projected simultaneously, as part of an interconnected two-region system.

A short review of the projection procedure is given in the Appendix. The actual simulation program used is described in detail elsewhere (Willekens and Rogers, 1978).

This paper is organized in seven sections. After this introduction, the origin of the input (base year) data is reviewed in detail and the procedures adopted to estimate missing data are discussed. The third section describes the six scenario's or alternative futures on which the alternative population projections are based. The demographic consequences of these alternative scenarios, i.e. the alternative population projections are discussed in Section 4. Population are projected by 5-year age groups. Implications for school enrolment, demand for health services and employment are analysed in Section 5. Finally Section 6 broadens the perspective of demographic growth in the two region (rural-urban) system. It proposes an approach of integrated demographic development of urban and rural areas through decentralized urbanization.

2. MEASUREMENT AND ESTIMATION OF INPUT DATA

a. Population

In Kenya the censuses of non-African population were held in 1921 and 1926; in 1931 a few African respondents employed by non-Africans were included. The first count of the entire population was carried out in 1948 and the second in 1962. In these two censuses the count was effected partly on a de jure basis and partly by sampling. The census of population held in 1969 was the third general census to be undertaken in Kenya and the first since independence in 1963. The 1969 census differs from the two previous ones in that, for the first time, an attempt was made to enumerate the population on a de facto basis throughout the country.

In this paper the rural and urban population projections of Kenya are based on the demographic characteristics of the population on August 24-25th of the 1969 census year. The population by age, sex and region is given in Table 1. The last age group is open-ended and contains the population of 65 and over. The data are contained in Kenyan Population Census, 1969, Vol. I and II (urban areas, defined as towns which reported more than 2,000 people, in Vol. II, Table 5, pp. 75-78; total in Vol. I, Table 3, p. 118-123). These data may also be found in the United Nations Demographic Yearbook (1974, Table 7) and in the ILO's Bachue-Kenya report (1977, Appendix, pp. 127-128). However, the census report gives, for ages above 30, the population in 10-year age groups. Therefore, the ILO-data have been used Table 1.

b. Fertility

The required fertility data are age-specific rural and urban birth rates for the total population (Table 2). They are expressed as the total number of births to women in a certain age group divided by the total population in this age group. The use of these fertility rates of the total population introduces a bias since the age of the father is omitted from consideration. However, the error introduced by such a female dominant approach is negligible and can be avoided by using a two-sex model.

The age-specific fertility rates of the total population are derived by multiplying the total fertility rates (births per women in certain age groups) by the proportion of women in each age group. The latter are derived from the Kenya Population Census Vol. IV, where the age-specific fertility rates for various districts in Kenya are given. The urban population of Kenya in 1969 was 1,079,908 and this included all centers with population of 2000 and above. In the derivation of the shape of the urban fertility schedule, the urban areas were assumed to consist of Nairobi and Mombasa only; these two cities account for 70% of the urban population. This assumption was made due to the lack of fertility data for the remaining 30% of the Kenyan urban area. The level of the fertility schedule, i.e. the area under the curve, was not taken from the Nairobi-Mombasa data. The relatively low fertility levels in those large cities are not representative for the fertility of all urban areas, including the small towns. Instead, it was assumed that the urban areas have a gross rate of reproduction of 2.75, whereas the rural areas have a GRR of 4.00. These numbers are derived from the ILO estimates of urban and rural total fertility rates (TFR) of 5.5 and 8.0 respectively, yielding a TFR for the country of 7.6 (ILO, Bachue-Kenya, 1977, Appendix p. 135). The implied sex ratio is unity.

c. Mortality

Rural and urban age-specific death rates are unknown. The number of deaths by age and sex in 1969 for the country as a whole are published by the United Nations (1974, pp. 540-541). However, the number of deaths with ages unknown is very high. They cannot be excluded and are therefore allocated proportionally to the various age groups (Table 3). The total number of deaths is divided by the total population yielding a national mortality schedule of the total population. To disaggregate this schedule into an urban and a rural mortality schedule, it is assumed that urban and rural crude death rates are 14% and 21%, respectively. This implies a national crude death rate of 20%. This disaggregation procedure is the same as the one used for migration. It will be described in the next section. The age-specific urban and rural death rates are given in Table 4. The implied urban and rural life expectancy is about 47 and 44 years respectively. This is below the official national estimates of 49 years, but closer to the 40 to 45 years observed in the 1962 census.

(Central Bureau of Statistics, 1971, p. 1.) Our estimates are therefore somewhat pessimistic.

d. Migration

The required migration data consist of annual age-specific rural and urban outmigration rates for the base year. These data are not available. Net migration rates are given by ILO-Bachue-Kenya (Table 5). A recent review of available data does not contain the necessary information (Rempel 1976). The male migration rates are disaggregated for 5-year age groups. The sum of the age-specific migration rates is 0.173, implying a gross-migra-production rate (GMR) of 0.865. The GMR is the area under the migration curve and is equal to the total of the age-specific rates times the age interval (in this case 5 years). Dividing the reference rates by the GMR yields a migration schedule with unitary GMR; namely, the unitary schedule. The problem now is to derive a set of age-specific migration rates which are consistent with the assumed crude rates. We assume that the sought migration schedules and the reference schedule have the same shape, which implies identical mean ages for each schedule. The problem therefore reduces to finding a GMR which is consistent with the assumed crude migration rates. We assume* a net rural outmigration rate of 5 per thousand. For 1969 this yields about 50,000 migrants. Note that a net rural outmigration rate of 5 per thousand is equivalent to a rural to urban migration rate of 5 per thousand and an urban to rural migration of 0 per thousand.

The crude migration rate from region i to region j is the weighted sum of the age-specific migration rates, the weights being the age structure of the population

$$M_{ij} = \sum_x m_{ij}(x)\ c_i(x) \qquad (1)$$

* The simple assumptions concerning migration in this preliminary paper will be treated in a more analytical and systematic manner in a later paper. We hope to incorporate migration data from the Urban 1968/69 Survey and the 1969 Population Census data.

where $m_{ij}(x)$ is the migration rate from i to j of age group x to x + 4.

$c_i(x)$ is the proportion of the population in age group x to x + 4 in region i. Equation (1) may be written as

$$M_{ij} = GMR_{ij} \sum_x m^u_{ij}(x) \ c_i(x)$$

where $m^u_{ij}(x)$ represents the unitary migration schedule. Assuming that M_{ij} and $c_i(x)$ are known, and that $m^u_{ij}(x)$ is equal to the reference schedule scaled to unit GMR, the GMR_{ij}, which is consistent with the crude migration rate M_{ij} is

$$GMR_{ij} = \frac{M_{ij}}{\sum_x m^u_{ij}(x) \ c_i(x)} \quad . \tag{2}$$

The derived values of GMR_{ur} and GMR_{ru} are 0.000 and 0.2380, respectively. The estimated migration schedule is given in Table 6.

From the given population distribution and the inferred age-specific rates, numbers of births, deaths and migrants have been computed (Table 7). These data provide the input information for the calculation of the multiregional life table and population projections (Willekens and Rogers, 1976, p.6). The aggregate data for the country as a whole are given in Table 8 and a summary of base-year data is provided in Table 9. (Note our basic assumptions of urban and rural crude death rates of 14 and 21 per thousand and the net rural-urban migration rate of 5 per thousand.) The urban and rural crude birth rates of 58 and 50 per thousand are consistent with the age composition of the population and the prevailing fertility schedule (analogous to equation (1)). The higher urban birth rate is caused by the high proportion of urban population in fertile age groups, relative to the rural population, which has a higher share of children (Table 7b). For example, in urban areas, 36% of the population is between 15 and 30 years old. In the rural areas, only 25% belong to this age category. This difference may be related to migration.

TABLE 1: KENYA: POPULATION BY SEX, AGE AND REGION: 1969

	URBAN			RURAL			TOTAL
Age	Male	Female	Total	Male	Female	Total	Total
0 - 4	84719.	83315.	168034.	1016143.	992407.	2008550.	2176584.
5 - 9	65775.	65002.	130777.	788928.	774279.	1563207.	1693984.
10 - 14	45997.	48037.	94034.	656843.	642171.	1299014.	1393048.
15 - 19	59689.	57518.	117207.	523086.	515289.	1038375.	1155582.
20 - 24	93552.	61245.	154797.	386155.	412727.	798882.	953679.
25 - 29	84733.	43657.	128390.	307257.	346769.	654026.	782416.
30 - 34	66285.	28236.	94521.	253336.	292296.	545632.	640153.
35 - 39	53893.	23041.	76934.	205972.	238518.	444490.	521424.
40 - 44	34165.	14099.	48264.	175809.	197769.	373578.	421842.
45 - 49	27207.	11374.	38581.	140004.	159539.	299543.	338134.
50 - 54	9918.	6159.	16077.	120563.	130354.	250917.	266994.
55 - 59	7584.	4829.	12413.	92196.	102198.	194394.	206807.
60 - 64	5625.	3646.	9271.	68386.	77170.	145556.	154827.
65 +	8334.	5839.	14173.	101314.	123575.	224889.	239062.
TOTAL	647476.	455997.	1103473.	4835992.	5005061.	9841053.	10944526.

Source: ILO, BACHUE-KENYA, 1977, Appendix, pp 127-128

Kenya Population Census (1969), Vol. I and Vol. II, Nov. 1970

TABLE 2 : AGE-SPECIFIC FERTILITY RATES FOR URBAN AND RURAL KENYA, 1969

Age	Births/Women (a)		Births/Total Population (b)	
	Urban	Rural	Urban	Rural
15 - 19	0.1112	0.1112	0.0871	0.0634
20 - 24	0.2423	0.2886	0.1529	0.1714
25 - 29	0.2432	0.2937	0.1319	0.1790
30 - 34	0.1699	0.2590	0.0810	0.1595
35 - 39	0.1185	0.1831	0.0566	0.1129
40 - 44	0.0564	0.1246	0.0263	0.0758
45 - 49	0.0303	0.0619	0.0143	0.0379
Total			0.0550	0.8000
Crude Birth Rate			0.0586	0.0505

Source:

(a) ILO, Bachue, Kenya, 1977, Appendix, p 140.

(b) Births/total population = (a)* female/(male + female).

TABLE 3 : DEATHS IN KENYA: 1969: BY AGE AND SEX

	Unadjusted (a)		Adjusted (b)		
	Male	Female	Male	Female	Total
0	5606.	4426.	9936.	7258.	17194.
5	326.	352.	578.	577.	1155.
10	163.	114.	289.	187.	476.
15	135.	129.	239.	212.	451.
20	175.	154.	310.	253.	563.
25	203.	157.	360.	257.	617.
30	235.	139.	417.	228.	644.
35	258.	131.	457.	215.	672.
40	278.	125.	493.	205.	698.
45	272.	166.	482.	272.	754.
50	310.	148.	549.	243.	792.
55	243.	96.	431.	157.	588.
60	312.	173.	553.	284.	837.
65	270.	119.	479.	195.	674.
70	269.	149.	477.	244.	721.
75	181.	89.	321. }2552	146. }1382	467. }3935
80	171.	147.	303.	241.	544.
85	279.	220.	495.	361.	855.
UNKNOWN	7482.	4500.			
TOTAL	17168.	11534.	17168.	11534.	28702.

Source:

(a) UN Demographic Yearbook, 1974, Table 25, pp 340-341.

(b) In the adjusted data, the unknown deaths are allocated proportionally to the various age groups.

TABLE 4 : AGE-SPECIFIC MORTALITY RATES FOR URBAN AND RURAL KENYA, 1969.

Age Group	Urban	Rural	Total
0 - 4	0.050561	0.060549	0.007899
5 - 9	0.004366	0.005226	0.000682
10 - 14	0.002191	0.002618	0.000342
15 - 19	0.002500	0.002990	0.000390
20 - 24	0.003779	0.004523	0.000590
25 - 29	0.005047	0.006047	0.000789
30 - 34	0.006443	0.007716	0.001007
35 - 39	0.008254	0.009879	0.001289
40 - 44	0.010588	0.012677	0.001654
45 - 49	0.014282	0.017099	0.002231
50 - 54	0.018971	0.022741	0.002967
55 - 59	0.018207	0.021796	0.002844
60 - 64	0.034624	0.042420	0.005404
65 +	0.105341	0.126156	0.016459
TOTAL	0.285122	0.341440	0.044546
Crude Rate	0.014000	0.021000	0.020294

TABLE 5: REPORTED RELATIVE NET MIGRATION RATE TO NAIROBI BY AGE AND SEX IN 1962 - 1969 PERIOD

Age (1)	Percent of Nairobi Net Immigrants 1962-69[b]		Percent of 1969 Rural Population[c]		Relative Migration Probability	
	Male (2)	Female (3)	Male (4)	Female (5)	(6)=(2)/(4) Male	(7)=(3)/(5) Female
0 - 14	19.59	30.16	49.84	47.46	0.39	0.63
15 - 19	14.06	25.54	10.72	10.31	1.31	2.47
20 - 24	34.91	32.34	7.99	8.15	4.37	3.97
25 - 29	21.17	11.68	6.50	6.93	3.26	1.69
30 - 59	9.00	- 0.82[a]	21.23	22.75	0.42	-0.04[a]
60+	1.26	1.09	3.73	4.40	0.34	0.25

a The negative value implies net outmigration for this age group.

b Nairobi City Council, Nairobi Metropolitan Growth Survey, Table 1.3

c Republic of Kenya, Population Census 1969

Source: ILO, BACHUE-KENYA, 1977, Appendix, p 146.

TABLE 6 : AGE-SPECIFIC NET RURAL OUT-MIGRATION RATES, KENYA, 1969

Age Group	Net Rural Out-migration Rate (a)	Adjusted Net Rural Outmigration Rate (b)
0 - 4	0.043700	0.012020
5 - 9	0.003900	0.001073
10 - 14	0.003900	0.001073
15 - 19	0.013100	0.003603
20 - 24	0.043700	0.012020
25 - 29	0.032600	0.008967
30 - 34	0.004200	0.001155
35 - 39	0.004200	0.001155
40 - 44	0.004200	0.001155
45 - 49	0.004200	0.001155
50 - 54	0.004200	0.001155
55 - 59	0.004200	0.001155
60 - 64	0.003400	0.000935
65 +	0.003400	0.000935
TOTAL	0.172900	0.047559
Crude Rate		0.005000

Source:

(a) The migration rate in age-group 0 - 4 is taken to be the same as that of age-group 20 - 24, which implies that children move with their parents.

(b) Assuming a crude net outmigration rate of 0.005.

TABLE 7

REGIONAL POPULATION, BIRTHS, DEATHS AND MIGRATIONS, BY AGE

a. absolute value

AGE	POPULATION	BIRTHS	DEATHS	MIGRATION FROM URBAN TO URBAN	MIGRATION FROM URBAN TO RURAL
0	168034.	0.	8496.	0.	0.
5	130777.	0.	571.	0.	0.
10	94034.	0.	206.	0.	0.
15	117207.	10203.	293.	0.	0.
20	154797.	23672.	585.	0.	0.
25	128390.	16937.	648.	0.	0.
30	94521.	7653.	609.	0.	0.
35	76934.	4355.	635.	0.	0.
40	48264.	1268.	511.	0.	0.
45	38581.	550.	551.	0.	0.
50	16077.	0.	305.	0.	0.
55	12413.	0.	226.	0.	0.
60	9271.	0.	321.	0.	0.
65	14173.	0.	1493.	0.	0.
TOTAL	1103473.	64638.	15450.	0.	0.

Region Rural

AGE	POPULATION	BIRTHS	DEATHS	MIGRATION FROM RURAL TO URBAN	MIGRATION FROM RURAL TO RURAL
0	2008550.	0.	121616.	24143.	0.
5	1563207.	0.	8170.	1677.	0.
10	1299014.	0.	3401.	1394.	0.
15	1038375.	65868.	3105.	3742.	0.
20	798882.	136924.	3613.	9603.	0.
25	654026.	117075.	3955.	5865.	0.
30	545632.	87025.	4210.	630.	0.
35	444490.	50203.	4391.	514.	0.
40	373578.	28327.	4736.	432.	0.
45	299543.	11352.	5122.	346.	0.
50	250917.	0.	5706.	290.	0.
55	194394.	0.	4237.	225.	0.
60	145556.	0.	6029.	136.	0.
65	224889.	0.	28371.	210.	0.
TOTAL	9841053.	496774.	206662.	49207.	0.

b. percentage distribution

REGION URBAN

AGE	POPULATION	BIRTHS	DEATHS	MIGRATION FROM URBAN TO URBAN	RURAL
0	15.2277	0.0000	54.9903	0.0000	0.0000
5	11.8514	0.0000	3.6958	0.0000	0.0000
10	8.5216	0.0000	1.3333	0.0000	0.0000
15	10.6216	15.7848	1.8964	0.0000	0.0000
20	14.0282	36.6224	3.7864	0.0000	0.0000
25	11.6351	26.2029	4.1942	0.0000	0.0000
30	8.5658	11.8398	3.9417	0.0000	0.0000
35	6.9720	6.7375	4.1100	0.0000	0.0000
40	4.3738	1.9617	3.3074	0.0000	0.0000
45	3.4963	0.8509	3.5663	0.0000	0.0000
50	1.4569	0.0000	1.9741	0.0000	0.0000
55	1.1249	0.0000	1.4628	0.0000	0.0000
60	0.8402	0.0000	2.0777	0.0000	0.0000
65	1.2844	0.0000	9.6634	0.0000	0.0000
TOTAL	100.0000	100.0000	100.0000	0.0000	0.0000
M.AGE	22.2713	25.8206	19.7767	0.0000	0.0000

REGION RURAL

AGE	POPULATION	BIRTHS	DEATHS	MIGRATION FROM RURAL TO	
0	20.4099	0.0000	58.8478	49.0642	0.0000
5	15.8846	0.0000	3.9533	3.4081	0.0000
10	13.1999	0.0000	1.6457	2.8329	0.0000
15	10.5515	13.2591	1.5025	7.6046	0.0000
20	8.1179	27.5626	1.7483	19.5155	0.0000
25	6.6459	23.5671	1.9138	11.9190	0.0000
30	5.5444	17.5180	2.0371	1.2803	0.0000
35	4.5167	10.1058	2.1247	1.0446	0.0000
40	3.7961	5.7022	2.2917	0.8779	0.0000
45	3.0438	2.2851	2.4784	0.7032	0.0000
50	2.5497	0.0000	2.7610	0.5893	0.0000
55	1.9753	0.0000	2.0502	0.4573	0.0000
60	1.4791	0.0000	2.9173	0.2764	0.0000
65	2.2852	0.0000	13.7282	0.4268	0.0000
TOTAL	100.0000	100.0000	100.0000	100.0000	0.0000
M.AGE	20.3484	27.9948	20.4843	13.3839	0.0000

M Age : Mean Age

Table 8

Total Population, Births, Deaths and Migration, by Age

AGE	POPULATION ABSOLUTE	POPULATION PERCENT	BIRTHS ABSOLUTE	BIRTHS PERCENT	DEATHS ABSOLUTE	DEATHS PERCENT	MIGRATION ABSOLUTE	MIGRATION PERCENT	OBSERVED RATES BIRTH	OBSERVED RATES DEATH	OBSERVED RATES MIGRATION
0	2176580.	19.8874	0.	0.0000	130112.	58.5795	24143.	49.0642	0.000020	0.059778	0.011092
5	1693980.	15.0779	0.	0.0000	8741.	3.9354	1677.	3.4081	0.000020	0.005160	0.000990
10	1393743.	12.7283	0.	0.0000	3627.	1.6240	1394.	2.8329	0.000000	0.002589	0.001001
15	1155582.	10.5545	76071.	13.5499	3398.	1.5299	3742.	7.6046	0.065829	0.002941	0.003238
20	953679.	8.7155	160596.	28.6057	4198.	1.8900	9603.	19.5155	0.168396	0.004402	0.010269
25	762011.	7.[illegible]	134012.	23.8705	4673.	2.0724	5865.	11.9190	0.171280	0.005883	0.007496
30	641153.	5.8491	94678.	16.8643	4219.	2.1696	630.	1.2803	0.147899	0.007528	0.000984
35	521424.	4.7632	54558.	9.7180	5026.	2.2628	514.	1.0446	0.104653	0.009639	0.000986
40	421882.	3.8594	29595.	5.2715	5247.	2.3623	432.	0.8779	0.070157	0.012438	0.001024
45	338124.	3.0954	11902.	2.1200	5673.	2.5541	346.	0.7032	0.035200	0.016778	0.001023
50	266009.	2.4195	0.	0.0000	6011.	2.7063	290.	0.5893	0.000000	0.022514	0.001236
55	2[illegible]7.	1.[illegible]	0.	0.0000	4463.	2.0093	225.	0.4573	0.000000	0.021581	0.001268
60	15[illegible]27.	1.[illegible]	0.	0.0000	6350.	2.8589	136.	0.2764	0.000000	0.041014	0.000878
65	239[illegible]62.	2.[illegible]	0.	0.0000	29364.	13.4455	210.	0.4268	0.000027	0.124922	0.000878
TOTAL	10944526.	100.0000	561412.	100.0000	222112.	100.0000	49207.	100.0000	0.763394	0.337165	0.041835
CRUDE									0.051296	0.020294	0.004496
M.AGE		20.5023		27.7445		29.4351		13.3839	30.1748	47.1072	22.2756

Crude: crude rate

M. Age: mean age

Table 9

Base Year (1969) Population Characteristics

REGION	POPULATION			RATES OF NATURAL INCREASE			INTERNAL MIGRATION RATES			
	IN THOU-SAND	PERCENT-AGE	MEAN AGE	BIRTH	DEATH	GROWTH	OUT	IN	NET	GROWTH RATE
URBAN	1103.	10.0824	22.2713	0.058577	0.014001	0.044576	0.000000	0.044593	0.044593	0.089168
RURAL	9841.	89.9176	20.3484	0.050480	0.021000	0.029480	0.005000	0.000000	0.005000	0.024480
TOTAL	10945.	100.0000	20.5423	0.051296	0.020294	0.031002	0.004496	0.004496	0.000000	0.031002

3. ASSUMPTIONS FOR PROJECTIONS

The base run assumes that during the projection period there will be no changes in the fertility, mortality and migration trends as discussed in the previous section. Table 10 shows the assumptions of the alternative scenarios. All changes are assumed to be linear in absolute terms over the period 1979-1999. Since the effects of these changes, for example fertility trends, become apparent after an extended time period, the results of the projections are given up to the year 2024.

Base Run

The assumptions on fertility, mortality and migration are given in Section 2 and it is assumed that these trends will continue up to the year 2024 (no change scenario).

Scenario 1

This is an all change scenario. Fertility (GRR) in the urban areas is assumed to decline linearly by 25% over the period 1979-1999 and then remain constant at this level up to the year 2024. Rural fertility remains unchanged. Infant mortality is assumed to decline linearly by 50% (urban areas) and 25% (rural areas) over the period 1979-1999 and then remain constant at this level up to the year 2024. It should be noted that here infant mortality is defined as the mortality of the age group 0 - 4 years. Therefore, a change in the mortality is measured by a variation in the mortality rate of the 0 - 4 year age group. Rural to urban migration is assumed to increase linearly by 60% over the period 1979-1999, i.e. GMR_{ru} increases from 0.2380 to 0.3808. This implies an increase of the crude net migration rate to about 0.8%.

This scenario is in a sense a likely one since trend changes in fertility, mortality and migration occur simultaneously. However, it would also be interesting to investigate the individual effect of changes in fertility, mortality or migration. These aspects are considered in the following Scenarios 2 to 6.

Scenario 2

Fertility in the urban areas is assumed to decline linearly by 25% over the period 1979-1999 and remains constant at this level up to the year 2024. This scenario is relevant since the standard of living in the urban areas is much higher than the rural areas and it is expected that the first decline in fertility is likely to occur in the urban areas. Not that fertility is measured in terms of the gross rate of reproduction (GRR).

Scenario 3

Fertility in the urban and rural areas is assumed to decline linearly by 25% over the period 1979-1999 and remains constant up to the year 2024. The Government in Kenya gives high priority to the development of the rural areas and it is feasible that with rapid development some fertility decline in the rural areas may be expected.

Scenario 4

This scenario is concerned with the decline in infant mortality. Infant mortality (mortality rate of age group 0 - 4 years) is assumed to decline linearly by 50% (urban areas) and 25% (rural areas) over the period 1979-1999 and remains constant up to the year 2024. In recent years the rapid and extended development of health services, and in particular child health services, has caused a substantial decline in infant mortality; this trend is likely to continue.

Scenario 5

As mentioned in Section 2, our assumption of a life expectancy of 47 in the urban areas and 44 in the rural areas is pessimistic in comparison to the published (Kenya Statistical Digest, June 1971) overall life expectancy of about 49 years. In this scenario we assume that life expectancy will increase linearly to 66 years in both the urban and rural areas over the years 1979-1999 and remain constant to the year 2024. It should be noted that a life expectancy of 66 years in 1999 will continue to increase up to the year 2024; for comparison with other scenarios, however, we have assumed that it remains constant.

Scenario 6

The assumption here is that net rural-urban migration will increase linearly by 60% from GMR_{ru} = 0.2380 in 1979 to GMR_{ru} = 0.3808 in 1999. Due to the present lack of data, only one scenario on migration is presented.

TABLE 10: ALTERNATIVE SCENARIOS USED (ALL CHANGES ARE LINEARLY OVER THE PERIOD 1979 - 1999)

	Fertility		Mortality				Migration
			Infant		Total		Net
	U	R	U	R	U	R	R-U
Base Run	constant	constant	constant	constant	constant	constant	constant
Scenario 1	-25%	const.	-50%	-25%	N.A.	N.A.	+60%
Scenario 2	-25%	const.	const.	const.	const.	const.	const.
Scenario 3	-25%	-25%	const.	const.	const.	const.	const.
Scenario 4	const.	const.	-50%	-25%	N.A.	N.A.	const.
Scenario 5	const.	const.	N.A.	N.A.	e(0) = 66 years		const.
Scenario 6	const.	const.	const.	const.	const.	const.	+60%

4. RESULTS OF THE PROJECTIONS

The base run and the alternative scenarios show that in the year 1999 Kenya will have a population two and a half to three times as great as her population in 1969. We first discuss the results of scenarios 2 to 6 together with the base run and then consider the results of Scenario 1, which is the most likely to occur.

Scenario 2 (urban fertility decline) and Scenario 3 (urban and rural fertility decline) show that the total population in the year 2024 is 59.4 million and 45.8 million, respectively. There is a significant decrease compared with the base run projection of 62.9 million. Note that there is a drastic reduction in the growth rates; in the year 2024 the corresponding growth rates are 2.1%, 2.89%, and 3.08%. The figures for the average growth rates in the period 1969 - 2024 are 2.6%, 3.08% and 3.18%. The breakdown of these results for the rural and urban population are shown in Table 11.

The results of Scenario 4 (infant mortality decline) and Scenario 5 (overall mortality decline) show that the population in the year 2024 will be 69.7 million and 77.6 million, respectively. The corresponding average growth rates for the period 1969 - 2024 are 3.37% and 3.56%, respectively. In these scenarios the projected urban population (about 20.5 million for Scenarios 4 and 5) is of the same order, whereas there is a significant difference in the projected rural population (Scenario 4, 49.3 million and Scenario 5, 57.1 million). This occurs because the present level of urbanization in Kenya is low.

The results of Scenario 6 (migration) show that the urban population in the year 2024 will be 22.3 million compared to 17.8 million in the base run. Note that due to rural-urban migration, the average growth rate in the period 1969 - 2024 has decreased to 2.55% from 2.77% (base run) in the rural areas and increased in the urban areas to 5.47% from 5.10% (base run).

TABLE 11: RESULTS OF ALTERNATIVE SCENARIOS:

Projections of:

a. Population in thousand and

b. Annual Growth Rates.

A. POPULATION : TOTAL

	BASE RUN	SCENARIOS					
		1	2	3	4	5	6
1969	10945	10945	10945	10945	10945	10945	10945
1974	12789	12789	12789	12789	12789	12789	12789
1979	15019	15019	15019	15019	15019	15019	15019
1984	17658	17693	17629	17426	17724	17842	17656
1989	20745	20851	20647	20009	20962	21342	20738
1994	24341	24544	24103	22747	24830	25771	24318
1999	28544	28875	28063	25616	29485	32031	28493
2004	33453	33931	32662	28940	34984	38280	33356
2009	39200	39865	37999	32653	41537	45706	39034
2014	45918	46813	44162	36707	49363	54572	45650
2019	53744	54898	51244	41070	58674	65114	53328
2024	62866	64292	59397	45804	69730	77614	62240

B. GROWTH RATES: TOTAL

	BASE RUN	1	2	3	4	5	6
1969	3.10	3.10	3.10	3.10	3.10	3.10	3.10
1974	3.15	3.15	3.15	3.15	3.15	3.15	3.15
1979	3.19	3.19	3.19	3.19	3.19	3.19	3.19
1984	3.20	3.23	3.17	2.99	3.26	3.29	3.20
1989	3.16	3.21	3.11	2.78	3.28	3.31	3.16
1994	3.15	3.20	3.05	2.60	3.32	3.32	3.13
1999	3.13	3.19	3.00	2.40	3.37	3.25	3.11
2004	3.13	3.18	2.99	2.39	3.39	3.23	3.10
2009	3.12	3.17	2.99	2.33	3.41	3.22	3.09
2014	3.11	3.15	2.94	2.24	3.41	3.22	3.07
2019	3.10	3.13	2.92	2.15	3.40	3.22	3.05
2024	3.08	3.10	2.89	2.10	3.40	3.20	3.03
Avg. Growth Rate	3.18	3.22	3.08	2.60	3.37	3.56	3.16

A. POPULATION: URBAN

YEAR	BASE RUN	SCENARIOS 1	2	3	4	5	6
1969	1103	1103	1103	1103	1103	1103	1103
1974	1616	1616	1616	1616	1616	1616	1616
1979	2190	2190	2190	2190	2190	2190	2190
1984	2868	2913	2840	2835	2884	2884	2926
1989	3715	3862	3616	3593	3768	3785	3910
1994	4756	5070	4518	4461	4887	4935	5193
1999	6058	6615	5576	5460	6331	6575	6872
2004	7621	8487	6830	6619	8099	8356	8907
2009	9524	10772	8323	7961	10297	10651	11396
2014	11819	13520	10063	9467	13019	13498	14410
2019	14544	16760	12044	11042	16341	16686	18006
2024	17835	20629	14367	12956	20442	20596	22343

B. GROWTH RATES: RURAL (NATURAL GROWTH RATE IN PARENTHESIS)

YEAR	BASE RUN	1	2	3	4	5	6
1969	8.92(4.46)	8.92(4.46)	8.92(4.46)	8.92(4.46)	8.92(4.46)	8.92(4.46)	8.92(4.46)
1974	6.57(3.04)	6.57(3.04)	6.57(3.04)	6.57(3.04)	6.57(3.04)	6.57(3.04)	6.57(3.04)
1979	5.61(2.53)	5.61(2.53)	5.61(2.53)	5.61(2.53)	5.61(2.53)	5.61(2.53)	5.61(2.53)
1984	5.13(2.38)	5.42(2.32)	4.98(2.21)	4.92(2.23)	5.22(2.48)	5.18(2.44)	5.48(2.40)
1989	4.93(2.53)	5.33(2.35)	4.64(2.18)	4.53(2.21)	5.09(2.70)	4.99(2.60)	5.46(2.54)
1994	4.85(2.73)	5.26(2.42)	4.42(2.19)	4.28(2.25)	5.08(2.99)	4.90(2.80)	5.46(2.72)
1999	4.63(2.73)	5.07(2.32)	4.07(2.00)	3.89(2.06)	4.96(3.09)	4.60(2.74)	5.30(2.72)
2004	4.44(2.69)	4.80(2.33)	3.93(1.97)	3.71(2.02)	4.78(3.06)	4.43(2.71)	4.98(2.71)
2009	4.28(2.66)	4.56(2.32)	3.77(1.91)	3.47(1.93)	4.64(3.06)	4.26(2.66)	4.71(2.70)
2014	4.15(2.65)	4.34(2.30)	3.60(1.84)	3.23(1.82)	4.54(3.08)	4.12(2.64)	4.50(2.71)
2019	4.09(2.70)	4.19(2.31)	3.53(1.85)	3.10(1.81)	4.49(3.14)	4.12(2.71)	4.36(2.74)
2024	4.02(2.71)	4.05(2.30)	3.47(1.85)	3.02(1.81)	4.41(3.16)	4.09(2.75)	4.21(2.74)
Avg. Growth Rate	5.10	5.32	4.67	4.48	5.31	5.32	5.47

A. POPULATION: RURAL

YEAR	BASE RUN	SCENARIOS 1	2	3	4	5	6
1969	9841	9841	9841	9841	9841	9841	9841
1974	11174	11174	11174	11174	11174	11174	11174
1979	12829	12829	12829	12829	12829	12829	12829
1984	14789	14781	14789	14592	14840	14957	14730
1989	17031	16989	17031	16416	17195	17557	16828
1994	19584	19474	19584	18286	19943	20836	19125
1999	22486	22261	22486	20156	23154	15456	21621
2004	25832	25444	25832	22321	26885	29924	24449
2009	29676	29093	29676	24692	31240	35055	27638
2014	34099	33293	34099	27240	36344	41074	31240
2019	39200	38139	39200	29696	42333	48428	35322
2024	45030	43664	45030	32849	49289	57018	39897

B. GROWTH RATES: RURAL
(NATURAL GROWTH RATE
IN PARENTHESIS

YEAR	BASE RUN	1	2	3	4	5	6
1969	2.45(2.99)	2.45(2.99)	2.45(2.99)	2.45(2.99)	2.45(2.99)	2.45(2.99)	2.45(2.99)
1974	2.66(3.17)	2.66(3.17)	2.66(3.17)	2.66(3.17)	2.66(3.17)	2.66(3.17)	2.66(3.17)
1979	2.78(3.30)	2.78(3.31)	2.78(3.31)	2.78(3.31)	2.78(3.31)	2.78(3.31)	2.78(3.31)
1984	2.82(3.35)	2.80(3.41)	2.82(3.35)	2.61(3.14)	2.88(3.41)	2.92(3.45)	2.74(3.35)
1989	2.77(3.30)	2.73(3.40)	2.78(3.30)	2.39(2.90)	2.89(3.41)	2.95(3.47)	2.62(3.30)
1994	2.74(3.25)	2.66(3.40)	2.74(3.25)	2.19(2.68)	2.89(3.40)	2.95(3.44)	2.50(3.24)
1999	2.73(3.24)	2.63(3.45)	2.73(3.24)	1.99(2.49)	2.94(3.45)	2.91(3.39)	2.42(3.24)
2004	2.74(3.25)	2.64(3.50)	2.74(3.25)	2.00(2.50)	2.95(3.47)	2.89(3.37)	2.42(3.24)
2009	2.75(3.27)	2.66(3.49)	2.75(3.27)	1.97(2.46)	2.98(3.50)	2.91(3.40)	2.42(3.25)
2014	2.75(3.26)	2.67(3.50)	2.75(3.26)	1.89(2.38)	3.00(3.53)	2.93(3.42)	2.41(3.24)
2019	2.73(3.24)	2.66(3.49)	2.73(3.24)	1.80(2.28)	3.00(3.52)	2.91(3.39)	2.39(3.21)
2024	2.71(3.23)	2.65(3.48)	2.71(3.23)	1.74(2.22)	2.99(3.51)	2.88(3.37)	2.37(3.19)
Avg. Growth Rate	2.77	2.71	2.77	2.19	2.93	3.19	2.55

The above results have shown the effect of independent changes in fertility, mortality and migration. In reality these changes occur simultaneously and hence in the present discussion we consider the results of the "all-change" Scenario, which is the one most likely to occur. Note that in these preliminary results we have restricted the mortality decline to a reduction in infant mortality. We could also consider a decrease in the overall mortality, i.e. an increase in life expectancy. The total projected population in the years 1999 and 2024 will be 28.9 million and 64.3 million, respectively (the base run projection yields 28.5 million and 62.9 million). In spite of a reduction in urban fertility, (rural fertility decline was not considered since in the authors' view, this event is unlikely to occur within the next two decades), the urban population has been growing at an average growth rate of 5.32% in the period 1969-2024, as compared with the base run figure of 5.1%. This is a result of the increased rural to urban migration and the constant fertility in the rural areas. The results of this scenario show that Kenya's population is expected to increase six-fold by the year 2024, and the growth rate in the year 2024 will be 3.1%.

5. APPLICATION OF PROJECTIONS

As mentioned in the introduction, population projections may be useful for the planning of the needs of Kenya's society in the future. Alternative projections of total population, pre-school age (0 - 4), school-age (5 - 14), active age (15 - 59), persons over 60, dependancy ratio, are tabulated in Table 12. It should be noted that in Kenya the active age group is considered to be 15 - 59 years. This is a modification* of the more usual international assumption of 64 years, as the upper age limit of members of the labour force. Here we will discuss only the result of the all-change Scenario 1.

* The modification is based on the different conditions of life expectancy in Kenya, Kenya Statistical Digest, June 1971,pp.4.

TABLE 12: RESULTS OF ALTERNATIVE SCENARIOS:

Total, Rural and Urban Projections (1969, 1999, 2024) of:

a. Population

b. Pre-School Age (0- 4)

c. School Age (5-14)

d. Active Age (15-59)

e. Persons 60+

f. Dependancy Ratio

AGE GROUPS	Base Year (1969) Data '000		Base Run: No Change in Fertility, Mortality and Migration Trends '000				SCENARIO 1: Fertility Mortality and Migration trends change '000				SCENARIO 2: Urban Fertility Decline '000				SCENARIO 3: Urban and Rural Fertility Decline '000			
	1969		1999		2024		1999		2024		1999		2024		1999		2024	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
TOTAL																				
Population	10,945	100.0	28,544	100.0	62,866	100.0	24,544	100.0	64,293	100.0	28,063	100.0	59,397	100.0	25,616	100.0	45,804	100.0
Pre-School Age (0 - 4)	2,177	19.9	5,895	20.7	12,842	20.4	5,013	20.4	12,629	19.6	5,630	20.1	11,728	19.8	4,400	17.2	7,642	16.7
School Age (5 - 14)	3,087	28.2	7,832	27.4	17,097	27.2	6,910	28.2	17,743	29.4	7,640	27.2	15,829	26.7	6,587	25.7	11,086	24.2
Active Age (15 - 59)	5,048	46.1	13.962	48.9	30,899	49.2	11,896	48.5	31,880	49.6	13,938	49.7	29,811	50.2	13,773	53.8	25,048	54.7
Persons 60 +	394	3.6	855	3.0	2,028	3.2	725	3.0	2,040	3.2	855	3.1	2,028	3.4	855	3.3	2,028	4.4
Dependency Ratio	112.1		104.4		103.5		106.3		101.7		101.3		99.2		86.0		82.9	
URBAN																				
Population	1,103	100.0	6,058	100.0	17,835	100.0	5,070	100.0	20,629	100.0	5,577	100.0	14,367	100.0	5,460	100.0	12,956	100.0
Pre-School Age (0 - 4)	168	15.2	1,173	19.4	3,370	18.9	897	17.7	3,415	16.6	908	16.3	2,257	15.7	874	16.0	1,964	15.2
School Age (5 - 14)	225	20.4	1,632	26.9	4,798	26.9	1,412	27.9	5,483	26.6	1,440	25.8	3,530	24.6	1,371	25.1	3,061	23.6
Active Age (15 - 59)	687	62.3	3,078	50.8	9,157	51.3	2,630	51.9	11,144	54.0	3,054	54.8	8.071	56.2	3,040	55.7	7,422	57.3
Persons 60 +	23	2.1	175	2.9	509	2.9	130	2.6	587	2.9	175	3.1	509	3.5	175	3.2	509	3.9
Dependency Ratio	60.6		96.8		94.8		92.7		85.1		82.6		78.0		79.6		74.6	
RURAL																				
Population	9,841	100.0	22,486	100.0	45,030	100.0	19,474	100.0	43,664	100.0	22,486	100.0	45,030	100.0	20,156	100.0	32,849	100.0
Pre-School Age (0 - 4)	2,009	20.4	4,722	21.0	9,471	21.0	4,116	21.1	9,214	21.1	4,722	21.0	9,471	21.0	3,526	17.5	5,677	17.3
School Age (5 - 14)	2,862	29.1	6,200	27.6	12,299	27.3	5,498	28.2	12,261	28.1	6,220	27.7	12,299	27.3	5,217	25.9	8,025	24.4
Active Age (15 - 59)	4,600	46.7	10,883	48.4	21,741	48.3	9,266	47.6	20,736	47.5	10,883	48.4	21,741	48.3	10,667	52.9	17,627	53.7
Persons 6) +	370	3.76	681	3.03	2,519	3.37	595	3.1	1,453	3.3	681	3.0	1,519	3.4	681	3.4	1,519	4.6
Dependancy Ratio	113.9		106.6		107.1		110.1		110.6		106.8		107.1		88.3		86.4	

AGE GROUPS	Base Year (1969) Data		Base Run; No Change in Fertility, Mortality and Migration Trends				SCENARIO 4: Urban and Rural Infant Mortality Decline				SCENARIO 5: General Mortality Decline				SCENARIO 6: Rural-Urban Migration Increase			
	'000				'000				'000				'000				'000	
	1969		1999		2024		1999		2024		1999		2024		1999		2024	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
TOTAL																		
Population	10,945	100.0	28,544	100.0	62,866	100.0	29,486	100.0	69,731	100.0	32,031	100.0	77,615	100.0	28,493	100.0	62,241	100.0
Pre-School Age (0 - 4)	2,177	19.9	5,895	20.7	12,842	20.4	6,158	20.9	14,504	20.8	6,210	19.4	14,854	19.1	5,859	20.6	12,560	20.2
School Age (5 - 14)	3,087	28.2	7,832	27.4	17,097	27.2	8,378	28.4	19,819	28.4	8,511	26.6	20,355	26.2	7,815	27.4	16,852	27.1
Active Age (15 - 59)	5,048	46.1	13,962	48.9	30,899	49.2	14,094	47.8	33,380	47.7	14,341	44.8	34,521	44.5	13,964	49.0	30,789	49.5
Persons 60 +	394	3.6	855	3.0	2,028	3.2	855	2.9	2,028	2.9	2,968	9.3	7,885	10.2	856	3.0	2,040	3.3
Dependancy Ratio	112.1		104.4		103.5		109.2		108.9		123.2		124.8		104.1		102.2	
URBAN																		
Population	1,103	100.0	6,058	100.0	17,835	100.0	6,332	100.0	20,442	100.0	6,575	100.0	20,596	100.0	6,872	100.0	22,343	100.0
Pre-School Age (0 - 14)	168	15.2	1,173	19.4	3,370	18.9	1,258	19.9	3,994	19.5	1,212	18.4	3,723	18.1	1,358	19.8	4,255	19.0
School Age (5 - 14)	225	20.4	1,632	26.9	4,798	26.9	1,788	28.2	5,842	28.6	1,712	26.0	5,384	26.1	1,898	27.6	6,072	27.2
Active Age (15 - 59)	687	62.3	3,078	50.8	9,157	51.3	3,112	49.1	10,097	49.4	3,117	47.5	9,815	47.7	3,436	50.0	11,429	51.2
Persons 60 +	23	2.1	175	2.9	509	2.9	175	2.8	509	2.5	535	8.1	1,674	8.1	180	2.6	587	2.6
Dependancy Ratio	60.6		96.8		92.7		103.5		102.5		111.0		109.8		100.0		95.5	
RURAL																		
Population	9,841	100.0	22,486	100.0	45,030	100.0	23,154	100.0	49,289	100.0	25,457	100.0	57,018	100.0	21,621	100.0	39,897	100.0
Pre-School Age (0 - 4)	2,009	20.4	4,722	21.0	9,471	21.0	4,900	21.2	10,510	21.3	4,999	19.6	11,131	19.5	4,500	20.8	8,304	20.8
School Age (5 - 14)	2,862	29.1	6,200	27.6	12,299	27.3	6,591	28.5	13,977	28.4	6,800	26.7	14,971	26.3	5,917	27.4	10,780	27.0
Active Age (15 - 59)	4,600	46.7	10,883	48.4	21,741	48.3	10,982	47.4	23,283	47.2	11,225	44.1	24,705	43.3	10,528	48.7	19,360	48.5
Persons 60 +	370	3.76	681	3.03	1,519	3.37	681	2.9	1,519	3.1	2,434	9.6	6,211	10.9	676	3.1	1,453	3.6
Dependancy Ratio	113.9		106.6		107.1		110.8		111.7		126.8		130.8		105.4		106.1	

EDUCATION

In 1969 the total pre-school age population was 2.2 million and this will increase to 5.0 million in the year 1999 and 12.6 million in the year 2024. The corresponding figures of the school age population are 3.1 million (1969), 7.8 million (1999) and 17.1 million (2024). In other words, government investment in basic education will have to cater for one and a half times and four and a half times the 1969 school age population in the years 1999 and 2024, respectively. Table 13 shows the school enrollment and government expenditure in 1975 and the projections for the years 1999 and 2024. The results show that total government expenditure will have to increase by a factor of about three times in 1999 and by a factor of about seven times in 2024 as compared with the 1975 expenditure; in 1975 the government expenditure on primary and secondary education amounted to 40% of all expenditure on social services including education, health and other social services. The projected government expenditure on education are rough orders of magnitude. In fact the already implemented government policy of universal free primary education (and a resultant increased demand for secondary education) will require government expenditure higher than that projected in Table 13.

The situation in the urban areas is expected to be even more demanding due to the much higher growth rates of the school age population. The 1976 Statistical Abstract, page 221, give a figure of 153,120 children (6 - 12 years) in primary school in 1975. The projected school age (6 -14 years) population in the urban areas in 1999 will be 1,412,000 (average annual growth rate of about 9.3% for the period 1975-1999) and in 2024 will be 5,483,000 (average annual growth rate of about 7.3% for the period 1975-2024). The magnitude of the task of providing education for the rural and urban areas is great and long-term planning is crucial if these requirements are to be fulfilled.

TABLE 13: EDUCATION AND GOVERNMENT EXPENDITURE

	1975	1999	2024	Average Growth Rate 1975-2024
Primary School Enrolment (Age 6 - 12)	2.9 million	5.5 million	11.6 million	2.8%
Secondary School Enrolment (Age 13 - 14)	0.1 million	1.4 million	5.9 million	8.3%
Total School Enrolment	3.0 million	6.9 million	17.7 million	3.6%
Number of Schools: (including 1160 secondary)	9341	21000	54000	3.6%
Average Number/School	330	330	330	
Government Expenditure:				
Primary School	K£43.6 million	K£104.9 million	K£221.3 million	3.3%
Secondary School	K£10.5 million	K£ 30.8 million	K£129.8 million	5.1%
Total Government Expenditure	K£54.1 million	K£135.7 million	K£351.1 million	3.8%

Source: 1977 Economic Survey of Kenya
1976 Statistical Abstract, Kenya
Projections Scenario 1.

Exchange Rate: K£1.00 = U.S.$ 8.31 (31st Dec. 1976)

Assumptions:

1. Secondary school education comprises Forms 1 - 6 and age group 13 - 18. For comparing school age population up to 14 we have assumed secondary education to be equivalent to Forms 1 and 2.

2. In the years 1999 and 2024, 20% and 33% of primary school children will enter secondary school. This compares with 17% of primary school children entering secondary school in 1976/77. Since 1975 primary education in Kenya has been free.

3. The cost of providing per capita primary and secondary education in 1999 and 2024 will be the same as in 1976 (i.e. an underestimate).

HEALTH SERVICES

Table 14 shows some projections for health services in Kenya. The 1973 figures are derived from the Kenya Statistical Abstracts, 1976. Projections A assume that the proportion per thousand of hospital beds, doctors and nurses in 1999 and 2024 will be the same as in 1973. Projections B are based on an improvement in health services in Kenya. According to WHO publications, in Africa as a whole the number of medical doctors per thousand of the population was 0.125 in 1965. This is higher than the 1973 figure of 0.07 per thousand of the population in Kenya. It should also be noted that a high proportion of the doctors tend to be concentrated in the urban areas in Kenya. These figures can be compared with those of the developed countries: in 1975 the number of doctors per thousand of the population in Europe was 2.5 and in the Soviet Union 3.5; the number of hospital beds in Europe varies from 8 to 12 per thousand of the population. It would, perhaps, be very optimistic to assume that Kenya in the years 1999 and 2024 will reach the level of the present health services in Europe. For this reason we have assumed even lower figures, as shown in Table 14. An analysis of these projections shows that with improved health services Kenya will require a total of 88,750 hospital beds and 14,950 doctors in the year 1999 and 384,100 hospital beds and 77,300 doctors in 2024. This amounts to average growth rates in hospital beds of 7% (for the period 1973 - 1999) and 6% (for the period 1973-2024), and average growth rates in the number of doctors of 11% (for the period 1973 - 1999) and 9% (for the period 1973-2024).

The availability of health services in the rural and urban areas of Kenya by the year 1999 will require substantial investments within the next decade. For example in 1975 the enrollment in the Faculty of Medicine at the University of Nairobi was 569. In order to have available about 36,000 doctors/dentists by the year 1999 entails an annual enrollment increase of 14.3%. In fact the required increase will be about 20% since all that enrol do not necessarily graduate. Hence very large investments for training of medical personnel and healh services with early planning is essential to achieve reasonable urban health services in Kenya by the year 1999 and the year 2024.

TABLE 14: HEALTH SERVICES

		Population	No. of Hospital Beds	Hospital beds per thousand	No. of Doctors / Dentists	No. of Doctors per thousand	Registered Nurses	Registered Nurses per thousand
1973	Rural	11.2 m	10500	0.93	892	0.07	4990	0.40
	Urban	1.6 m	4000	2.50				
Projections A								
1999	Rural	22.3 m	21000	0.93	2023	0.07	9156	0.40
	Urban	6.6 m	16500	2.50				
2024	Rural	43.7 m	40641	0.93	4508	0.07	25760	0.40
	Urban	20.7 m	51750	2.50				
Projections B								
Improved Health Services: Projections Using Scenario 1								
1999	Rural	22.3 m	55750	2.50	36125	1.25	72250	2.5
	Urban	6.6 m	33000	5.0				
2024	Rural	43.7 m	218500	5.0	161000	2.5	322000	5.0
	Urban	20.7 m	165600	8.0				

EMPLOYMENT

In 1975 the total population of Kenya was about 12.8 million and the population of active age was 6.4 million; of this the urban population of active age was 876,000 and the rural population of active age was 5,500,000. In the urban areas* 387,210 were in wage employment, and about 74,100 were in the urban informal establishments. Of the remaining 414,690, some were receiving higher education (University and Popytechnic 10,000, secondary and higher education 90,000), and the remaining 315,000 were seeking employment and/or were inactive. In the rural areas, 3,720,000 were in the small farm sector, about 150,000 were receiving secondary or higher education, 387,210 were in wage employment and the remaining 1.25 million people were working in the rural non-agricultural sector, in the large farms as pastoralists and seeking employment.

About 60% of the population of active age are working in the small farm sector. Table 15 gives some data on the population, and type of employment and earnings in the small farm sector. The small farm sector is extremely important in that, according to the government plan, in the future a considerable proportion (50%) of the entrants in the labour force will have to find their livelihood in the small farm sector. At the present the farm earnings in this sector are very low (average earnings K£29.9) and the overall average of K£49.5 is a result of other employment earnings (31% of total income) and transfers received (15% of total income). In comparison, the earnings from wage employment in Kenya are considerably higher. Table 16 shows the data on wage employment and earnings in the modern sector in Kenya. In 1975, the total wage labour force was 819,086 and this consisted of 53% in the urban areas and 37% in the rural areas. Here again there is a considerable difference in the rural earnings (average earnings K£98.8) and the urban earnings (average earnings K£213.5). This wide differential in urban and rural incomes is one of the reasons for the increasing rural to urban migration in Kenya and unless a considerable increase in rural incomes occurs, it is expected that rural to urban migration will

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* Source: Statistical Abstracts, Kenya, 1976, pp 271 and Economic Survey, Kenya, 1977, pp 40.

increase at rates much higher than the rates assumed in the projections of Scenario 1.

In 1999 the active age of the urban and rural populations in Kenya will be 2.6 million and 9.3 million, respectively. The corresponding figures for the year 2024 are 11.1 million and 20.8 million. This represents a growth in the labour force of 4.5% annually over the period 1975 - 1999 and 5.2% annually over the period 1975 - 2024 in the urban areas and in the rural areas the annual growth rates in the labour force are 2.2% (1975 - 1999) and 2.7% (1975 - 2024). Table 17 shows employment projections for the urban areas. These results show that even if the creation of employment in the urban areas continues at a high rate of 3.5%, those unemployed or inactive will grow from 36% of the urban labour force in 1975, to 46% and 65% of the labour force in 1999 and 2024, respectively.

In the rural areas the situation is worse since agricultural land in Kenya is limited, amounting to 52,047,000 hectares. However only 19.1% (9,942,000 hectares) has medium high agricultural potential whereas the remaining 42 million hectares has low agricultural potential. In 1975 the good agricultural land per person of active age in the rural areas was 1.8 hectares and 0.5 hectares, respectively. Hence there will be a very rapid increase in the employment pressure in the agricultural sector and it is crucial that employment opportunities in the agricultural as well as the non-agricultural sector be created. This is also essential for the large number of unemployed people in the urban areas. In order to fulfill these requirements, an integrated approach to the development of the rural and urban areas is necessary. This is discussed in the next section.

TABLE 15: SOME DATA ON POPULATION, EMPLOYMENT AND EARNINGS IN THE SMALL FARM SECTOR IN KENYA 1974 / 75

Total small farm population	10,341,174	
Active age small farm population	3,948,661	
Total land area of small farms	2,506,900	hectares
Total cultivated land area of small farms	2,506,900	hectares
Per capita land area of small farms	0.33	hectares
per capita cultivated land area of small farms	0.24	hectares
Total Income of Small Farms	K£195,269,000	
Income from farming	K£105,007,000	
Income from other (urban) employment	K£ 60,647,000	
Income from transfers (e.g. urban remittances)	K£ 29,615,000	
Average earnings from farming (Number of people is 3,517,636)	K£ 29.9	
Average earnings from other employment (Number of people is 410883)	K£147.6	
Average income of active age small farm population	K£49.5	
Per capita small farm income	K£16	
G.N.P. per capita in Kenya	K£76	

Small Farm Active Age Population

Type of Employment	Number of People
Heads of small farms	1,187,924
Operate another holding	20,142
Labour on another holding	48,339
Other rural work	132,301
*Teaching/Government employment	101,892
*Urban Employment	126,377
Other	1,974
Unpaid family labour on small farms	2,329,712
TOTAL	3,948,661

* Assumed to be wage employment

Source: Integrated Rural Survey (1974/75), Republic of Kenya, 1977.

TABLE 16: WAGE EMPLOYMENT AND EARNINGS IN THE MODERN SECTOR IN KENYA, STATISTICAL ABSTRACT 1976

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Average Growth Rate 1966-1975	1999 Assuming Same Growth rates as 1966-1975	1999 Scenario 1 Total Active Age	% Outside Wage Employment
Total Wage Employment	585421	597369	606410	627214	644481	691186	719777	361375	826263	819086	857200	3.7%	2,005,820	11,896,000	83%
Total Urban Wage Employment	282682	297084	303948	302780	303575	322710	348706	354286	386291	387210	-	3.5%	896,900	2,630,000	66%
Total Rural Wage Employment	302739	300285	302462	324434	340906	368476	371071	407089	439972	431876	-	4.0%	1,108,920	9,266,000	88%
Total Wage Earnings (K£m)	125.6	136.3	144.3	150.1	162.0	185.4	206.9	231.2	274.3	312.3	378.8	10.1%	3,543.7	-	-
Total Urban Wage Earnings (K£m)	93.6	107.6	110.4	109.8	110.8	129.9	141.4	153.5	185.7	213.5	-	9.2%	1,924.8	-	-
Total Rural Wage Earnings (K£m)	32.0	28.7	33.9	40.3	51.2	55.5	65.5	77.7	88.6	98.8	-	12.5%	1,618.9	-	-
Average Wage Earnings (K£m)	214.5	228.2	238.0	239.3	251.4	268.2	287.5	303.7	332.0	381.2	442.0	6.4%	1,766.7	-	-
Average Urban Wage Earnings	331.1	362.2	363.2	362.6	365.0	402.5	404.8	433.3	480.7	551.4	-	5.7%	2,146.1	-	-
Average Rural Wage Earnings	105.7	95.6	112.1	124.2	150.2	150.6	176.5	190.9	201.4	228.8	-	8.6%	1,459.9	-	-

TABLE 17: EMPLOYMENT PROJECTIONS IN THE URBAN AREAS

URBAN AREAS	1975	1999	2024
Total Active Age Population	876,000	1,600,000	11,100,000
Urban Wage Employed	387,210	896,900	2,151,600
Informal Establishments	74,100	277,400	1,097,000
Higher Education	100,000	232,000	556,000
Unemployed/Inactive	315,000	1,193,700	7,195,400
% Unemployed/Inactive	36%	46%	65%

Assumptions

1. The annual growth rate in wage employment in urban areas in Kenya was 3.5% for the period 1966 - 75. This rate of growth is assumed to continue to 2024.

2. Informal establishments are assumed to grow at 5.5% annually over the period 1975 - 1999 and 1975 - 2024. This is equivalent to half the growth rate of 11.0% over the period 1974 - 76.

3. The active age population receiving higher education is assumed to grow at 3.5% annually up to 2024.

6. URBANIZATION IN KENYA AND SOME IMPLICATIONS

Table 18 gives some data on past and projected urbanization in Kenya. In 1969 the cities of Nairobi and Mombasa accounted for 70% of the urban population in Kenya. At this time the major part of the modern sector (industry) was located in these two urban centres and hence these two cities were the major choice of the rural-urban migrants. The policy of the Government of Kenya is to develop (industrialize) other towns (Nakuru, Kisumu, Thika and Eldoret) and official projections for the population of these towns for 1980 are shown in the table. We have assumed that beyond 1980, the growth rates of Nairobi and Mombasa will be 4.5% and the growth rates of the remaining four towns will be 4%. This assumption is based on the consideration that beyond 1980 the urban facilities in the four towns will be at a level sufficient to attract industrial development and hence absorb a significant share of the rural-urban migrants. Also note that the high growth rates in the government urban population projections up to 1980 have not been used since these growth rates represent the government policy to very rapidly develop specific urban centres (see Table 18) and over a longer time horizon we have assumed lower growth rates; the use of the official high growth rates of the urban centres would lead to an urban population of 8 million in 1999 whereas the projected urban population in 1999 is about 5 million.

From Table 18 it can be seen that the distribution of the urban population in the various centres is as follows:

% of Urban Population	1948	1962	1969	1980	1999	2024
Nairobi and Mombasa	70.3	78.5	69.9	70.2	71.6	54.3
Main Urban Centres (6)	85.1	92.9	80.4	84.7	84.0	62.6
Remaining Towns (11)	14.9	7.1	19.6	15.3	16.0	37.4

The distribution of the urban population as shown above is such that the urban centres and towns are spread throughout the country. One possible path of development would be to treat the 6 urban centres as mainly industrial centres and the remaining 11 towns as agricultural centres (e.g. some agro-processing, storage and

TABLE 18: URBANIZATION IN KENYA. (POPULATION '000)

	1948*	1962*	1969*	1980*	% Annual Growth* Rate 1969 - 80	Assumed % Annual Growth 1980 - 99 1980 - 24	SCENARIO 1 1999	SCENARIO 1 2024
Urban Population	276	671	1082	2200	6.5%	5.2%	5070	20629
% of Total Population	5.1	7.8	9.9	15.1	-	-	20.7	32.1
NAIROBI	119	347	509	1098	7.0	4.5	2581	7953
MOMBASA	75	180	247	447	5.4	4.5	1051	3238
NAKURU	18	38	47	79	4.7	4.0	169	459
KISUMU	11	24	33	124	12.0	4.0	265	721
THIKA	4	14	18	50	9.3	4.0	107	291
ELDORET	8	20	18	42	7.7	4.0	90	244
TOTAL: 6 Towns (Main Urban Centres)	235	623	870	1863	6.9	-	4263	12906
Other 11 Towns (+ 2000 people)	41	48	212	337	4.2	-	807	7723

*Source: 1974 - 78 Development Plan, Republic of Kenya and Scenario 1 Projections

FIG. 1: INTEGRATED URBAN AND RURAL DEVELOPMENT

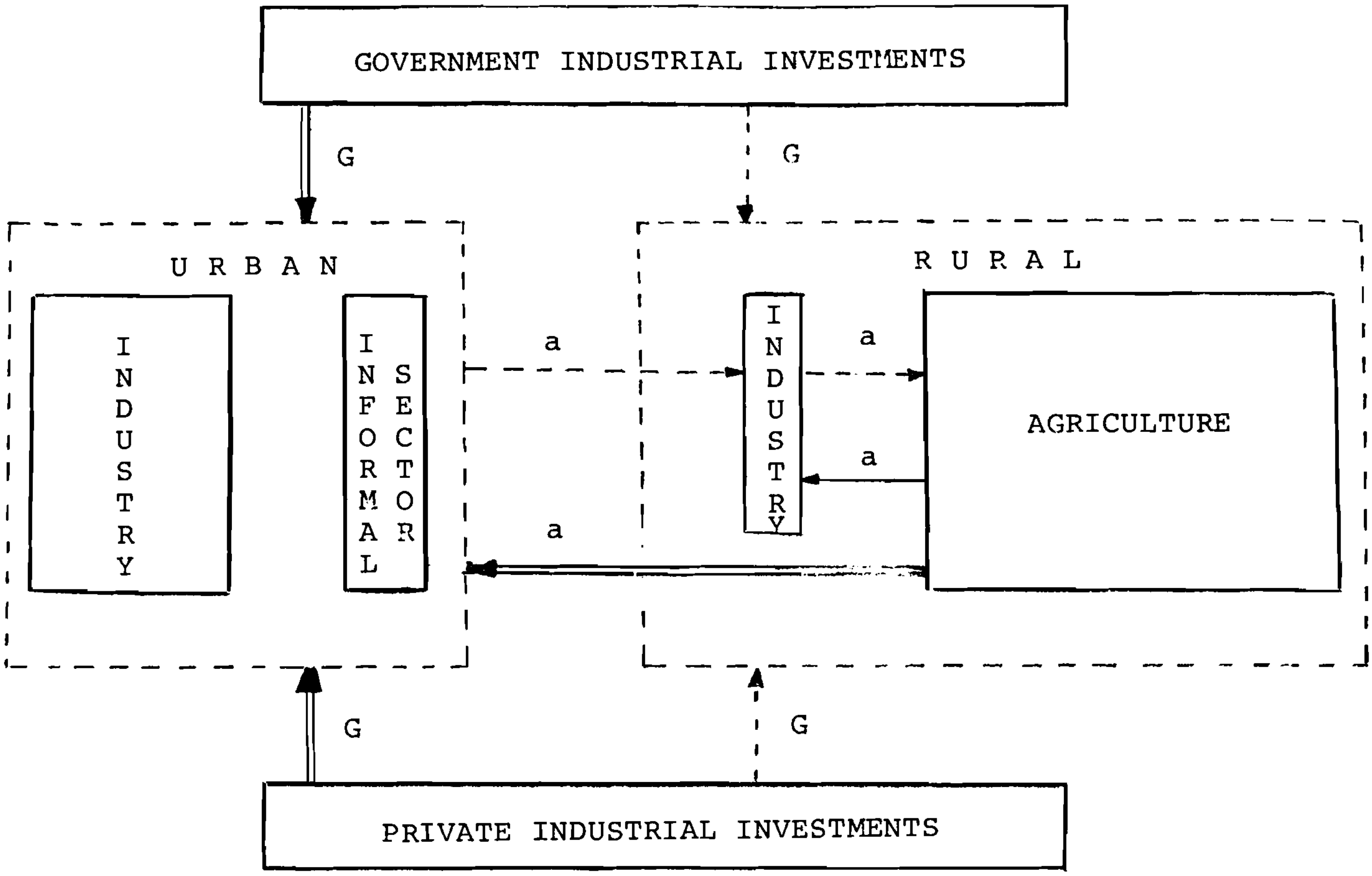

FIG. 1A: CONCENTRATED URBANIZATION

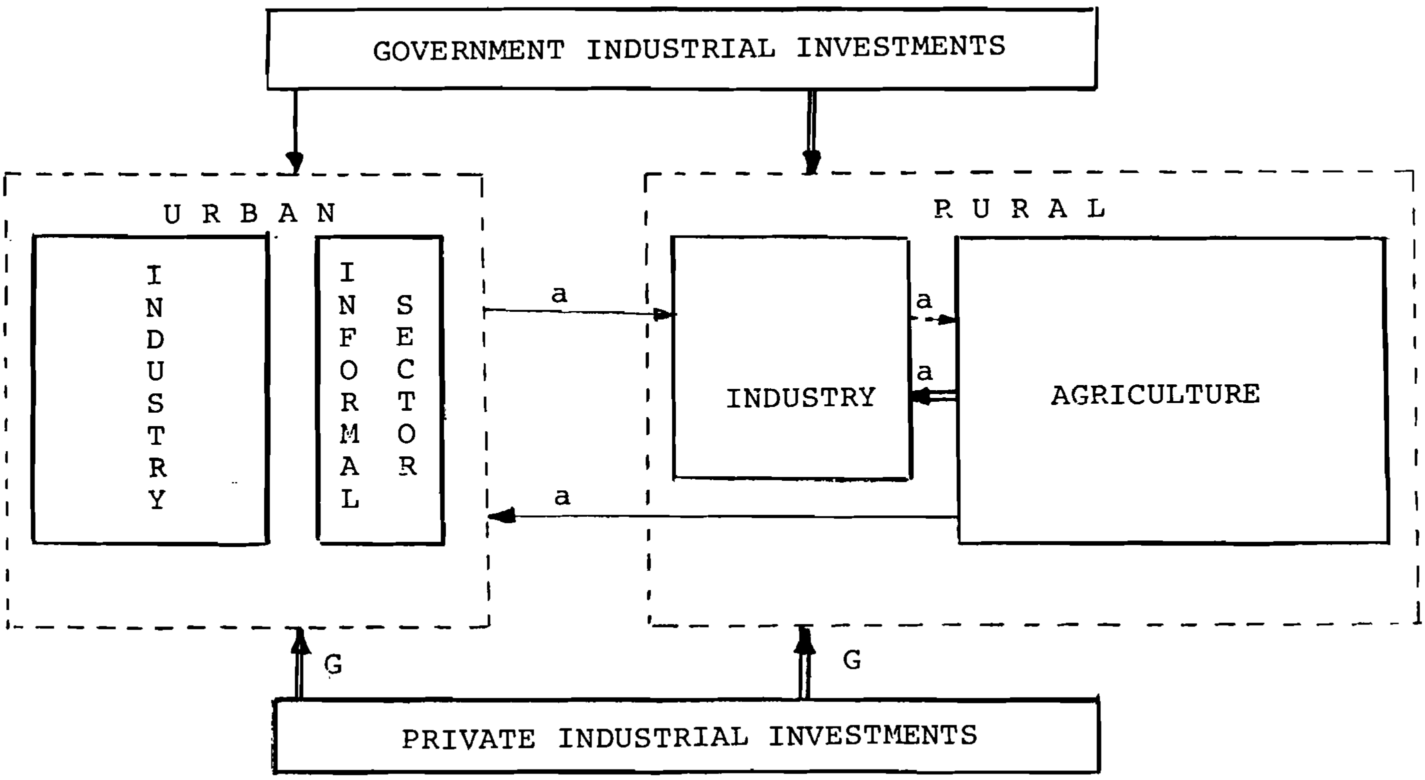

FIG. 1b: DECONCENTRATED URBANIZATION

Major Flow
Intermediate Flow
Minor Flow

a: Population Flow
G: Investment Flow

marketing of agricultural products etc). This decentralized urban development is extremely important in that these centres could supply the services (employment, health, education, marketing etc.) for the surrounding rural population.

In many countries in Africa and Latin America there has been a phenomenal growth in urban population in recent years and typically this urbanization has meant the growth of a limited number of urban centres. In contrast, the past urbanization in Europe was characterized by growth rates lower than are being encountered in many developing countries but also the urbanization was very much deconcentrated. In most developing countries the high growth in the urban population is due to the very high rates of rural to urban migration which is not only leading to serious socio-economic problems in the urban areas but it is also draining a significant part of the more able population in the rural areas. The gap in the living standards in the rural and urban areas is ever widening. At present the level of urbanization in many countries in Africa is below 20% and hence if development is to reach the mass of the population then an integrated rural development (including development of urban centres in predominantly rural areas) strategy is crucial.

In Kenya in 1999 the urban population is expected to be between 5.07 million (scenario 1) and 6.87 million (Scenaria 6) people. Of this, about 72% will reside in Nairobi and Mombasa if the current trend continues. Less than 30% will live in the many other urban centres of population above 2,000. The government policy in Kenya is aimed at decentralized urbanization and here two basic questions are relevant,

1. How to allocate the urban population to the urban centres of various sizes? Which system of cities or urban hierarchy is optimal? (the urban policy problem).
2. Is the projected rate of urban growth desirable? If not, how can the urbanization process be curtailed? As mentioned before, this would require a greater emphasis on rural development (the rural policy problem).

The rural and urban policy problems are not independent. Rural development may be enhanced by the creation of small towns with an industrial sector based on the existing agricultural activity. These small centers may on the other hand contain public facilities serving the population of the surrounding rural area. Therefore, integrated rural development and decentralized urbanization or deconcentration (concentration of urban development in regional and local centres) are closely related.

This interdependence is illustrated in Figure 1. The rural areas contain agricultural and industrial activities. The urban areas contain industry and an informal sector. The diagram shows two types of mobility. Geographical mobility or migration between rural and urban areas and sectoral mobility between agriculture and industry. The relatively undeveloped nonagricultural sector in rural areas explains the fact that most off-farm migration (sectoral mobility) conincides with leaving the rural areas (geographical mobility). To find alternative employment opportunities, people must move to urban areas and, as a consequence, they aggrevate the urban problem. The development of a broader industrial basis in rural areas may relieve the urban problem by limiting rural outmigration. This may be associated with decentralized urbanization. It could even induce a flow in the opposite direction, from urban to rural areas (return migration). However, this development process can only materialize if both government and private industrial investments stop being urban-biased and open up nonagricultural opportunities in rural areas. This also implies a greater emphasis on sectoral mobility within rural areas, than could be found in the development literature of the past two decades.

7. CONCLUSION

The objective of this paper was to provide alternative projections of rural and urban populations of Kenya and to trace the impact of alternative population growth paths on education, employment and demand for health services. Rural and urban areas are treated as components of an interconnected two-region population system. Demographic projections for both areas are performed simultaneously, by applying the methodology of multiregional demography. However, lack of data, in particular migration data, did not permit us to make full use of this recent methodology. For example, net migration rates were used in this report, although gross migration rates would yield better results. The estimation of gross migration rates from survey and census data and a more detailed treatment of fertility and mortality data will be considered at a later date.

Although the focus of this paper has been on alternative demographic projections, the place of these projections in overall development planning has been discussed. Section 6 of the paper addressed some important issues which have to be dealt with in order to solve the urban problem and to promote a self-sustaining rural development in developing countries. However, much more research is needed to prepare consistent policies. Some suggestions for priority research are listed below:

1. Migration: Analysis of sectoral and geographical mobility for integrated rural development with particular emphasis on:

    a. Agricultural development (rural to rural migration)

    b. Deconcentrated urban development (rural to local urban centres-migration).

2. The economics of urbanization in a developing country where the level of urbanization is still low (<20%) with reference to:

   a. Economics of agglomeration (optimal city size).

   b. The effect of the development of local urban centres on surrounding rural areas.

3. The relevance of industrial development in rural areas. The main issues are:

   a. The Composition of Industry: Should industry in the rural areas be primarily to serve the agricultural sector or not? Should it be small scale, labour intensive, etc?

   b. The attraction of Industry: Incentives and facilities to attract private investments into new industrial centres located in the rural areas.

The above mentioned topics are relevant to the issues of development and in particular rural development and urbanization. An integrated interdisciplinary approach is crucial, not only for understanding the dynamics of the above mentioned topics, but also for planning in these areas.

Appendix

PROJECTION PROCEDURE

The urban and rural populations are projected simultaneously. The multiregional demographic growth model has been developed by Rogers (1973, 1975) as a generalization of the Leslie (1945) model or cohort-survival model. This generalization is simplified by using matrix notations.

Denote the number of people in urban and rural areas at time t and aged x to x + h by $\{\underset{\sim}{K}^{(t)}(x)\}$:

$$\{\underset{\sim}{K}^{(t)}(x)\} = \begin{bmatrix} K_u^{(t)}(x) \\ K_r^{(t)}(x) \end{bmatrix} \qquad \text{(B1)}$$

In this paper we consider 5-year age groups, i.e. h = 5. The multiregional population projection is to determine how $\{\underset{\sim}{K}^{(t)}(x)\}$ for all x, changes over time. We consider first the projection of the population already alive at time t, and next the projection of the births and the subsequent children in the 0-4 year age group.

a. Population alive at time t.

The people aged x to x + 4 at time t can survive, migrate within the country, emigrate or die in the unit interval*. Denote by $s_{ru}^{(t)}(x)$ the proportion of the people in rural areas and x to x + 4 years old at time t, who survive and to be x + 5 to x + 9 years old five years later at time t + 1 and are then in the urban areas. Equivalently, $s_{uu}^{(t)}(x)$ denotes the proportion of the people x to x + 4 years old who remain in the urban areas. Ignoring immigration, the number of people of age x + 5 to x + 9 in urban areas at time t + 1 is given by

$$K_u^{(t+1)}(x+5) = s_{uu}^{(t)}(x)\ K_u^{(t)}(x) + s_{ru}^{(t)}(x)\ K_r^{(t)}(x) \qquad \text{(B2)}$$

---

*The projection interval is assumed to be the same as the age interval, i.e. five years. The superscript t refers to the time period and not to the exact year.

Note that $s_{uu}^{(t)}(x)$ includes in principle the persons who left urban areas but returned in the same time interval. Important for projection purposes is not the complete migration history of an individual but the places of residence at the beginning and at the end of the projection interval. Equation (B2), written for the rural areas yields

$$K_r^{(t+1)}(x+5) = s_{ur}^{(t)}(x)\ K_u^{(t)}(x) + s_{rr}^{(t)}(x)\ K_r^{(t)}(x) \qquad \text{(B3)}$$

Expressions (B2) and (B3) may be combined in the matrix operation:

$$\begin{bmatrix} K_u^{(t+1)}(x+5) \\ K_r^{(t+1)}(x+5) \end{bmatrix} = \begin{bmatrix} s_{uu}^{(t)}(x) & s_{ru}^{(t)}(x) \\ s_{ur}^{(t)}(x) & s_{rr}^{(t)}(x) \end{bmatrix} \begin{bmatrix} K_u^{(t)}(x) \\ K_r^{(t)}(x) \end{bmatrix}$$

$$\{\underset{\sim}{K}^{(t+1)}(x+5)\} = \underset{\sim}{S}^{(t)}(x)\ \{\underset{\sim}{K}^{(t)}(x)\} \qquad \text{(B4)}$$

The matrix of survivorship proportions $\underset{\sim}{S}^{(t)}(x)$ may be derived directly from observed age-specific mortality and migration rates. In general, however, it is derived from the multiregional life table. The computation procedure will be discussed later.

b. Births

The children of 0 - 4 years at time t+1 are born during the unit projection interval. Let $F_u^{(t)}(x)$ and $F_r^{(t)}(x)$ be the annual birth rate of people aged x to x + 4 in urban and rural areas respectively. It is assumed that children, born in the unit time interval (t, t+1), are born in the region of residence of the parents at time t. The number of births in urban areas at t to people aged x to x + 4 is

$$B_u^{(t)}(x) = F_u^{(t)}(x)\ K_u^{(t)}(x) \qquad \text{(B5)}$$

The multiregional distribution of births is

$$\{\underset{\sim}{B}^{(t)}(x)\} = \underset{\sim}{F}^{(t)}(x)\ \{\underset{\sim}{K}^{(t)}(x)\}$$

where

$$\{\underset{\sim}{B}^{(t)}(x)\} = \begin{bmatrix} B_u^{(t)}(x) \\ B_r^{(t)}(x) \end{bmatrix} \quad \text{and } F^{(t)}(x) = \begin{bmatrix} F_u^{(t)}(x) & 0 \\ 0 & F_r^{(t)}(x) \end{bmatrix}$$

The number of births during the 5-year period starting at t to people aged x to x + 4 is

$$\{\underset{\sim}{B}^{(t,t+1)}(x)\} = \int_0^h \underset{\sim}{F}^{(t)}(x+t)\ \{\underset{\sim}{K}^{(t)}(x+t)\}dt.$$

The integral equation may be approximated by the linear interpolation:

$$\{\underset{\sim}{B}^{(t,t+1)}(x)\} = \frac{5}{2}\ [\underset{\sim}{F}^{(t)}(x)\{\underset{\sim}{K}^{(t)}(x)\} + \underset{\sim}{F}^{(t+1)}(x+5)\{\underset{\sim}{K}^{(t+1)}(x+5)\}]$$

$$= \frac{5}{2}\ [\underset{\sim}{F}^{(t)}(x) + \underset{\sim}{F}^{(t+1)}(x+5)\ \underset{\sim}{S}^{(t)}(x)]\ \{\underset{\sim}{K}^{(t)}(x)\}.$$

Of these births, only a fraction will be in urban and rural areas at the end of the time interval, i.e. at t+1, and then be members of the first age group. Denote these fractions by the matrix

$$\hat{\underset{\sim}{P}}^{(t)} = \begin{bmatrix} \hat{p}_{uu}^{(t)} & \hat{p}_{ru}^{(t)} \\ \hat{p}_{ur}^{(t)} & \hat{p}_{rr}^{(t)} \end{bmatrix} \qquad \text{(B6)}$$

where an element $\hat{p}_{ij}^{(t)}$ is the proportion of babies born in region i during time interval (t, t+1), who survive and are in region j at the end of the time interval. This matrix takes into account the migration of children in the first age group.

Writing

$$\underset{\sim}{B}^{(t)}(x) = \frac{5}{2}\,\hat{\underset{\sim}{P}}^{(t)}\left[\underset{\sim}{F}^{(t)}(x) + \underset{\sim}{F}^{(t+1)}(x+5)\ \underset{\sim}{S}^{(t)}(x)\right] ,$$

the population in the first age group at time t+1 is

$$\{\underset{\sim}{K}^{(t+1)}(0)\} = \sum_{x} \underset{\sim}{B}^{(t)}(x)\ \{\underset{\sim}{K}^{(t)}(x)\} . \tag{B7}$$

The summation is over all the fertile age groups. If $\bar{\alpha}$ and $\bar{\beta}$ are respectively the lowest and the highest age group of the reproductive period, then the summation is from $\bar{\alpha}$ to $\bar{\beta}$.

c. The complete growth model

The two equation systems (B4) and (B7) describe the growth of a multiregional population. Both systems may be combined into a single matrix expression of an extremely simple form:

$$\{\underset{\sim}{K}(t+1)\} = \underset{\sim}{G}(t)\ \{\underset{\sim}{K}(t)\} , \tag{B8}$$

where

$$\{\underset{\sim}{K}(t)\} = \begin{bmatrix} \{K^{(t)}(0)\} \\ \{K^{(t)}(5)\} \\ \vdots \\ \{K^{(t)}(x)\} \\ \vdots \\ \{K^{(t)}(z)\} \end{bmatrix}$$

and

$$\underset{\sim}{G}(t) = \begin{bmatrix} \underset{\sim}{0} & \underset{\sim}{0} & \underset{\sim}{B}^{(t)}(\bar{\alpha}) & \cdots & \underset{\sim}{B}^{(t)}(\bar{\beta}) & \underset{\sim}{0} & \cdots & \underset{\sim}{0} & \underset{\sim}{0} \\ \underset{\sim}{S}^{(t)}(\underset{\sim}{0}) & \underset{\sim}{0} & & & & & & \vdots & \vdots \\ \underset{\sim}{0} & \underset{\sim}{S}^{(t)}(5) & \ddots & & & & & \vdots & \vdots \\ \vdots & & & \ddots & & & & & \\ \underset{\sim}{0} & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \underset{\sim}{S}^{(t)}(z-5) & \underset{\sim}{0} \end{bmatrix} \tag{B8'}$$

with z being the last age group. The matrix $\underset{\sim}{G}(t)$ is called the generalized Leslie matrix (Feeney, 1973, p. 36; Rogers, 1975, p. 123).

If the growth matrix is constant in time, then the population growth model may be written as:

$$\{\underset{\sim}{K}^{(t)}\} = \underset{\sim}{G}^{t} \{\underset{\sim}{K}^{(0)}\}, \tag{B9}$$

with $\{\underset{\sim}{K}^{(0)}\}$ the base year population.

d. Estimation of the survivorship proportions: the multiregional life table.

The multiregional life table is a table expressing the mortality and migration history of hypothetical regional populations (birth cohorts), as they age. The multiregional life table was developed by Rogers (1975), Chapter 2) and is a fundamental concept of multiregional demography. It contains several interesting demographic statistics derived from observed age-specific rates of mortality and migration. The most important life table statistic is the life expectancy. For projections, the relevant statistics consist of the survivorship proportions. In this section, we will describe in general terms the multiregional life table and the derivation of $\underset{\sim}{S}(x)$. We drop the time-superscript for convenience.

The life table functions are derived from a set of age-specific mortality and migration rates. These rates are arranged in a particular matrix $\underset{\sim}{M}(x)$. Let $M_{ij}(x)$ denote the annual rate of migration from i to j of age group x to x + 4, and let $M_{i\delta}(x)$ be the annual age-specific death rate in region i. Then

$$\underset{\sim}{M}(x) = \begin{bmatrix} (M_{u\delta}(x) + M_{ur}(x)) & -M_{ru}(x) \\ & \\ - M_{ur}(x) & (M_{r\delta}(x) + M_{ru}(x)) \end{bmatrix} \tag{B10}$$

The mortality and migration experience of a birth cohort in the life table are expressed in terms of probabilities. Let ${}_i\hat{\ell}_j(x)$ denote the probability that a person born in region i will be in region j at exact age x. The set of possible probabilities in a two-region system (urban-rural) is contained in the matrix $\hat{\underset{\sim}{\ell}}(x)$:

$$\hat{\underset{\sim}{\ell}}(x) = \begin{bmatrix} {}_u\hat{\ell}_u(x) & {}_r\hat{\ell}_u(x) \\ {}_u\hat{\ell}_r(x) & {}_r\hat{\ell}_r(x) \end{bmatrix}$$

For example, ${}_u\hat{\ell}_r(x)$ denotes the probability that a person born in the urban area will be in the rural area at age x. The diagonal element ${}_u\hat{\ell}_u(x)$ is the probability that he is born in the urban area and is there at age x. Note that this does not imply that he has always been in the urban area. He may have spent some time in rural areas before reaching age x. The matrix $\hat{\underset{\sim}{\ell}}(x)$ tells something about the regions of residence of a person at two points in time.

Assuming that the probabilities of survival and of migrating at a certain age only depend on the region of residence at that age and are independent of previous residences, then $\hat{\underset{\sim}{\ell}}(x)$ may be written as the product of conditional probabilities:

$$\hat{\underset{\sim}{\ell}}(x) = \underset{\sim}{P}(x-5)\ \underset{\sim}{P}(x-10)\ldots.\underset{\sim}{P}(y),\ldots.\underset{\sim}{P}(0) \quad ,$$

where

$$\underset{\sim}{P}(y) = \begin{bmatrix} p_{uu}(y) & p_{ru}(y) \\ p_{ur}(y) & p_{rr}(y) \end{bmatrix}$$

and an element $p_{ij}(y)$ denotes the probability that a person of region i and y years old will survive and be in region j five years later (age interval). Note that $p_{ij}(y)$ is a conditional probability.

The matrix of conditional probabilities $\underset{\sim}{P}(y)$ is computed from observed or estimated age-specific rates (Rogers and Ledent, 1976)

$$\underset{\sim}{P}(y) = [\underset{\sim}{I} + \frac{5}{2}\underset{\sim}{M}(y)]^{-1} [\underset{\sim}{I} - \frac{5}{2}\underset{\sim}{M}(y)]. \qquad \text{(B11)}$$

Therefore, the matrix $\hat{\underset{\sim}{\ell}}(x)$, in terms of the observed rates is:

$$\hat{\underset{\sim}{\ell}}(x) = \prod_{y=x-5}^{0} [I + \frac{5}{2} M(y)]^{-1} [\underset{\sim}{I} - \frac{5}{2}\underset{\sim}{M}(y)].$$

The number of people at exact age x and their regional distribution is easily derived. If the regional birth cohorts are contained in the diagonal of the diagonal matrix $\underset{\sim}{\ell}(0)$, then the number of people of age x by place of birth and place of residence is

$$\underset{\sim}{\ell}(x) = \hat{\underset{\sim}{\ell}}(x)\ \underset{\sim}{\ell}(0).$$

The definition of $\underset{\sim}{\ell}(x)$ leads to the problem of computing the number of people in age group x to x + 4, by place of birth and place of residence $\underset{\sim}{L}(x)$:

$$\underset{\sim}{L}(x) = \begin{bmatrix} {}_uL_u(x) & {}_rL_u(x) \\ {}_uL_r(x) & {}_rL_r(x) \end{bmatrix},$$

where an element ${}_iL_j(x)$ denotes the number of people in region j and aged x to x + 4, who were born in region i. The matrix $\underset{\sim}{L}(x)$ is given by

$$\underset{\sim}{L}(x) = \int_0^5 \underset{\sim}{\ell}(x+t)dt = [\int_0^5 \hat{\underset{\sim}{\ell}}(x+t)dt]\underset{\sim}{\ell}(0).$$

Assuming a uniform distribution of outmigrations and deaths over the five-year age interval, we may evaluate the integral by linear interpolation:

$$L(x) = \frac{5}{2}\,[\ell(x) + \ell(x+5)].$$

This formula is of course equivalent to $L(x) = \frac{5}{2}[I + P(x)]\hat{\ell}(x)\ell(0)$. Aggregating $L(x)$ over all ages gives the total number of people that would evolve if the mortality and migration rates of an observed population are applied to regional birth cohorts. This population is called the life table population. It is a stationary (zero growth) population, since deaths are equal to births. The age distribution of this stationary population is given by $L(x)$. Expressing this distribution in relative terms; namely, in unit births, we have $\hat{L}(x) = L(x)\,\ell^{-1}(0)$.

Now we are able to derive the matrix of survivorship proportions, defined in (B4) and to define $\hat{P}$ of (B6) in terms of life table statistics. Recall that an element $s_{ij}(x)$ of $S(x)$ denotes the proportion of individuals aged x to x + 4 in region i, that survives to be x + 5 to x + 9 years old 5 years later and are then in region j. The matrix $S(x)$ relates the population in one <u>age group</u> to the population in the previous <u>age group</u>:

$$S(x) = L(x+5)\,L^{-1}(x)\ . \qquad \text{(B12)}$$

Recently, it has been shown that $S(x)$ may be expressed directly in terms of the matrices of observed age-specific rates (Ledent, 1978):

$$S(x) = [I + \frac{5}{2}M(x+5)]^{-1}\,[I - \frac{5}{2}M(x)] \qquad \text{(B13)}$$

for $x < z-5$.

and for, $x = z-5$

$$S(z-5) = \frac{1}{5}M^{-1}(z)\,[I - \frac{5}{2}M(z-5)]. \qquad \text{(B14)}$$

Recall that the matrix $\hat{\underset{\sim}{P}}$ of (B6) contains the proportions of children born in the unit time interval that survives till the end of the interval or beginning of the next interval. In the life table population $\underset{\sim}{L}(0)$ is the number of children in the first age group and $\underset{\sim}{\ell}(0)$ is the number of births. Hence the proportion of the births that survives to become members of the first age group is

$$\hat{\underset{\sim}{P}} = \frac{1}{5}\,\underset{\sim}{L}(0)\;\underset{\sim}{\ell}^{-1}(0) = \frac{1}{2}[\underset{\sim}{I} + \underset{\sim}{P}(0)]\,\underset{\sim}{\ell}(0)\;\underset{\sim}{\ell}^{-1}(0)$$

$$= \frac{1}{2}[\underset{\sim}{I} + \underset{\sim}{P}(0)] \tag{B15}$$

Finally, we derive a most interesting life table statistic; namely, the expectation of life. The life expectancy at age x is the average number of years remaining to a person of exact age x. In multiregional demography, the life expectancy is disaggregated by place of residence. It is the sum of conditional probabilities:

$$^{r}\underset{\sim}{e}(x) = [\int_{x}^{\omega} \hat{\underset{\sim}{\ell}}(t)dt]\,\hat{\underset{\sim}{\ell}}^{-1}(x). \tag{B16}$$

$$^{r}\underset{\sim}{e}(x) = \begin{bmatrix} {}^{r}_{u}e_{u}(x) & {}^{r}_{r}e_{u}(x) \\ {}^{r}_{u}e_{r}(x) & {}^{r}_{r}e_{r}(x) \\ \hline {}^{r}_{u}e_{.}(x) & {}^{r}_{r}e_{.}(x) \end{bmatrix} . \tag{B17}$$

An element ${}^{r}_{i}e_{j}(x)$ denotes the average remaining number of years spent in region j by a person living in region i and x years of age. It denotes the life expectancy by place of current residence and place of future residence. Expression (B16) is evaluated as follows *:

$$^{r}\underset{\sim}{e}(x) = \left[\sum_{y=x}^{z} \underset{\sim}{L}(y)\right] \underset{\sim}{\ell}^{-1}(x). \tag{B18}$$

---

*Note that $\underset{\sim}{L}(y)$ denotes on the one hand the <u>number of people</u> in age group y to y + 4 by place of birth and place of residence and on the other hand the average <u>number of years lived</u> by the birth cohorts between ages x and x + 5 by region of residence and region of birth.

The life expectancy may also be expressed by place of birth instead of place of current residence. Define the diagonal matrix $\bar{\underset{\sim}{\ell}}(x)$ with in the diagonal the elements of the vector $\{\underset{\sim}{1}\}'\ \underset{\sim}{\ell}(x)$, i.e. the total number of people at exact age x by place of birth. The life expectancy matrix by place of birth is

$$^{b}\underset{\sim}{e}(x) = \left[\sum_{y=x}^{z} \underset{\sim}{L}(y)\right] \bar{\underset{\sim}{\ell}}^{-1}(x) \quad . \tag{B19}$$

Note that for age 0, $^{r}\underset{\sim}{e}(0) = {}^{b}\underset{\sim}{e}(0)$

Table A1 gives the multiregional life table for rural-urban Kenya. The total life expectancy of a person born in the urban areas is 47.51 years at the average, whereas this of a rural-born person is 43.59 years. Note that the expectation of life of an urban-born only depends on the age-specific mortality rates of the urban areas since no migration out of these areas is assumed. Therefore, a person born in urban areas will spend his whole lifetime there. The life expectancy of a rural-born person, on the other hand, not only depends on rural mortality rates, but is also affected by urban rates since an average rural-born person spends some time in urban areas*. Table A1 shows that of the total average lifetime of 43.59 years, 6.34 years are expected to be lived in urban areas. This implies a migration level of

$${}_2\Theta_1 = \frac{{}_2e_1(0)}{{}_2e_{.}(0)} = 0.1454 .$$

In other words, about 15% of a rural-born person's lifetime is expected to be lived in urban areas. During this time, he experiences the demographic behavior (age-specific rates) of the urban population.

*Recall the assumption that the mortality, fertility and migration behavior of a person is determined by his place of residence at the time that the event takes place.

e. Related statistics

The multiregional life table pictures the demographic meaning of observed schedules of mortality and migration. It applies the observed age-specific rates to a set of regional cohorts. The interesting feature of the life table is that its statistics only depend on the age-specific rates and are independent of the age and regional distribution of the observed population. From these age-specific rates, a population is generated by age and region. It is distributed according to $\underset{\sim}{L}(x)$ and is uniquely determined by the age-specific rates of mortality and migration. A convenient way of expressing $\underset{\sim}{L}(x)$ in relative terms, is in unit births: $\hat{\underset{\sim}{L}}(x)$. Note that $\sum_x \hat{\underset{\sim}{L}}(x)$ is the life expectancy matrix at birth. It also denotes the number of people in the multiregional population system by place of residence and place of birth in terms of unit births.

The matrices $\hat{\underset{\sim}{L}}(x)$ of the multiregional life table express a relative age and regional composition of a population that is uniquely determined by the schedules of mortality and migration. It is the life table population, free of the effect of the distribution of the observed population. To this life table population, we may apply the observed fertility schedule. The matrix $\underset{\sim}{\phi}(x) = \underset{\sim}{F}(x)\, \hat{\underset{\sim}{L}}(x)$ is the generalized net maternity function (Rogers, 1975, p. 93). The sum of $\underset{\sim}{\phi}(x)$ over all ages is the net reproduction rate matrix:

$$\underset{\sim}{NRR} = \sum_x \underset{\sim}{\phi}(x) = \sum_x \underset{\sim}{F}(x)\, \underset{\sim}{L}(x) \tag{B20}$$

where

$$\underset{\sim}{NRR} = \begin{bmatrix} {}_u NRR_u & {}_r NRR_u \\ {}_u NRR_r & {}_r NRR_r \end{bmatrix} \tag{B21}$$
$$\qquad\quad {}_u NRR_{.} \qquad\quad {}_r NRR_{.}$$

The total ${}_i NRR_{.}$ denotes the expected number of children to be born to a parent born in region i. Some children, ${}_i NRR_i$, will be born in the region of birth of the parent and some, ${}_i NRR_j$, will be born in region j. The matrix $\underset{\sim}{NRR}$ is the multiregional analogue of the net rate of reproduction. It not only gives the expected number of descendents but also where they will be born.

TABLE AI - MULTIREGIONAL (TWO-REGION) LIFE TABLE: URBAN AND RURAL KENYA

MORTALITY LEVELS $_1e(0) = 47.51$ $_2e(0) = 45.59$ MIGRATION LEVELS $_1\theta_2 = 0.2000$ $_2\theta_1 = 0.1454$

AGE	Q(X,1)	P(X,1,1)	P(X,2,1)	L(X,1,1)	L(X,2,1)	LL(X,1,1)	LL(X,2,1)	M(X,2,1)	MD(X,1)	S(X,1,1)	S(X,2,1)	E(X,1,1)	E(X,2,1)
0	0.224437	0.775563	[illegible]	100000.	0.	4.45891	0.00000	0.000000	0.050561	0.864164	0.000000	47.51	0.00
5	0.021555	0.976475	[illegible]	77556.	0.	3.85595	0.00000	0.000000	0.004366	0.983697	0.000000	55.53	0.00
10	[illegible]	[illegible]	[illegible]	[illegible]	0.	3.77341	0.00000	0.000000	0.002191	0.988347	0.000000	51.70	0.00
15	[illegible]	0.987579	[illegible]	[illegible]	0.	3.72944	0.00000	0.000000	0.002508	[illegible]	[illegible]	47.25	0.00
20	0.016719	[illegible]	[illegible]	74123.	0.	3.67144	0.00000	0.000000	0.003779	[illegible]	[illegible]	42.81	0.00
25	[illegible]	[illegible]	[illegible]	72735.	0.	3.59144	0.00000	0.000000	0.005047	[illegible]	[illegible]	38.58	0.00
30	[illegible]	[illegible]	[illegible]	[illegible]	0.	3.48991	0.00000	0.000000	0.006443	[illegible]	[illegible]	34.50	0.00
35	[illegible]	0.959565	[illegible]	68674.	0.	3.36427	0.00000	0.000000	0.008254	0.954111	0.000000	30.55	0.00
40	0.051573	0.948427	[illegible]	65897.	0.	3.20989	0.00000	0.000000	0.010588	0.939970	0.000000	26.73	0.00
45	[illegible]	[illegible]	[illegible]	62499.	0.	3.01720	0.00000	0.000000	0.014262	0.920632	0.000000	23.05	0.00
50	[illegible]	[illegible]	[illegible]	58169.	0.	2.77773	0.00000	0.000000	0.018971	0.911102	0.000000	19.57	0.00
55	[illegible]	[illegible]	[illegible]	52922.	0.	2.53280	0.00000	0.000000	0.018227	0.676445	0.000000	16.27	0.00
60	0.154329	0.845671	[illegible]	48312.	0.	2.22316	0.00000	0.000000	0.034624	1.734251	0.000000	12.56	0.00
65	1.000000	[illegible]	[illegible]	40615.	0.	3.65552	0.00000	0.000000	0.105341	0.000000	0.000000	9.49	0.00

AGE	Q(X,2)	P(X,2,2)	P(X,1,2)	L(X,2,2)	L(X,1,2)	LL(X,2,2)	LL(X,1,2)	M(X,1,2)	MD(X,2)	S(X,2,2)	S(X,1,2)	E(X,2,2)	E(X,1,2)
0	[illegible]	[illegible]	[illegible]	100000.	0.	4.23218	0.11291	0.012020	0.060549	[illegible]	0.051864	37.26	6.34
5	[illegible]	[illegible]	[illegible]	69287.	4516.	3.41366	0.23242	0.001073	0.005226	0.975252	0.005270	44.75	8.43
10	[illegible]	0.981713	[illegible]	67139.	4741.	3.32625	0.24661	0.001073	0.002618	0.974724	0.011393	41.18	6.33
15	0.014819	0.947565	0.037616	65911.	5084.	3.24211	0.28163	0.003604	0.002990	0.944455	0.037241	37.03	8.09
20	0.022255	[illegible]	0.057176	63773.	6182.	3.06202	0.39734	0.012021	0.004523	0.923962	0.052133	32.94	7.81
25	[illegible]	0.927643	0.042677	[illegible]	9712.	2.82919	0.54219	0.008968	0.006047	0.941563	0.024738	29.21	7.40
30	0.037832	[illegible]	[illegible]	[illegible]	11976.	2.66391	0.59685	0.001155	0.007716	0.951572	0.005524	25.82	6.81
35	[illegible]	[illegible]	0.005513	52297.	11299.	2.55491	0.59008	0.001156	0.009879	0.939906	0.005444	22.64	6.14
40	[illegible]	0.933143	[illegible]	49299.	11745.	2.36257	0.57685	0.001156	0.012677	[illegible]	0.005366	19.60	5.47
45	[illegible]	0.912711	0.005333	[illegible]	11369.	2.19978	0.55501	0.001155	0.017099	[illegible]	0.005241	16.66	4.81
50	.107540	0.887254	[illegible]	41968.	10831.	1.98104	0.52249	0.001156	0.022741	0.889232	0.005225	13.96	4.18
55	[illegible]	0.891461	0.005235	37254.	10069.	1.76161	0.48639	0.001157	0.021796	0.852362	0.004495	11.39	3.56
60	0.187669	[illegible]	[illegible]	33210.	9387.	1.50153	0.43519	0.000934	0.041420	1.417477	0.004435	8.52	2.81
65	1.000000	[illegible]	[illegible]	[illegible]	8022.	2.12838	0.76138	0.002000	0.126156	0.000000	0.000000	6.10	2.18

1 = urban

2 = rural

Table A1 (continued)

Q(x,i):	probability of dying in region i for an individual at exact age x, before reaching age x + 5.
P(x,j,i):	probability that an individual at age x in region i will be in region j at age x + 5, 5 years later.
L(x,j,i):	number surviving at exact age x in region j, of 100,000 born in region i. This is also the probability that a baby born in region i, will survive and be in region j at exact age x, multiplied by 100,000.
LL(x,j,i):	total years lived between ages x to x + 5 in region j, per unit born in region i.
M(x,j,i):	age-specific migration rate from region i to j (equal to observed value).
MD(x,i):	age-specific death rate in region i (equal to observed value).
S(x,j,i):	proportion of people in region i and aged x to x + 4, who will survive to be in region j and aged x + 5 to x + 9, five years later.
e(x,j,i):	part of expectation of life of i-born people at age x, that will be lived in region j, i.e. the average number of years lived in region j by i-born people, subsequent to age x, (life expectancy by place of birth).

The NRR for Kenya is:

Table A2

Net Reproduction Rate Matrix for Kenya

Place of Birth of Children	Place of birth of Parents Urban	Rural
Urban	1.960224	0.261599
Rural	0.000000	2.212129
Total	1.960224	2.473727

The table shows that of the average of 2.47 children born per rural-born person, 0.26 or 10.6% are born in urban areas.

The growth matrix (B8'), derived from the multiregional life table and the observed fertility rates is illustrated in Table A3. Note that the survivorship proportions are identical as those in Table A1.

Table A3

The Multiregional Growth Matrix

AGE	REGION URBAN FIRST ROW URBAN b_{11}	REGION URBAN FIRST ROW RURAL b_{12}	REGION RURAL FIRST ROW URBAN b_{21}	REGION RURAL FIRST ROW RURAL b_{22}
0	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000
10	0.190954	0.000000	0.000000	0.000000
15	0.527333	0.000000	0.025291	0.476774
20	0.625811	0.000000	0.033691	0.712679
25	0.467406	0.000000	0.023029	0.696583
30	0.300814	0.000000	0.015765	0.564931
35	0.181270	0.000000	0.010718	0.389814
40	0.088051	0.000000	0.006426	0.234498
45	0.031641	0.000000	0.002139	0.080196
50	0.000000	0.000000	0.000000	0.000000
55	0.000000	0.000000	0.000000	0.000000
60	0.000000	0.000000	0.000000	0.000000

AGE	SURVIVORSHIP PROPORTIONS URBAN s_{11}	SURVIVORSHIP PROPORTIONS RURAL s_{12}	SURVIVORSHIP PROPORTIONS URBAN s_{21}	SURVIVORSHIP PROPORTIONS RURAL s_{22}
0	0.864164	0.000000	0.031864	0.805886
5	0.983697	0.000000	0.005270	0.975252
10	0.988347	0.000000	0.011393	0.974704
15	0.984449	0.000000	0.037041	0.944455
20	0.978209	0.000000	0.050133	0.923960
25	0.971730	0.000000	0.024738	0.941583
30	0.964001	0.000000	0.005524	0.951572
35	0.954111	0.000000	0.005464	0.939906
40	0.939970	0.000000	0.005366	0.923280
45	0.920632	0.000000	0.005241	0.900563
50	0.911102	0.000000	0.005225	0.889232
55	0.878445	0.000000	0.004495	0.852362
60	1.734251	0.000000	0.004435	1.417477

$b_{ij}(x)$: proportion of babies born in region i to mothers of x to x + 4 years old, that survives and that is in region j at the end of the time interval.

$s_{ij}(x)$: proportion of people in region i and x to x + 4 years old at time t, that survives to be x + 5 to x + 9 years old five years late at time t + 1 and is then in region j.

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