COMMENTS ON THE CLOSE SIMILARITY BETWEEN INDIAN POPULATION PROJECTIONS FROM THE CONSTRAINED COALITION AND LOGISTIC MODEL AND THE CENSUS, GOVERNMENT OF INDIA AND UN ESTIMATES

V.K.C. Sanghi
National Institute of Science, Technology
and Development Studies
New Delhi - 110 012, India.

Abstract

The close similarity between the Indian census, Government of India and UN population estimates and those from the Constrained Coalition and Logistic Model (CCLM) has been demonstrated which enhances the usage of differential equation modelling for studies on population growth processes. The CCLM incorporates the legitimate requirement of an upper bound for the aggregate population thereby implying the rate of natural increase to reach the zero level. The numerical value assumed for the upper bound is based on food supply - arable land availability, and accounts for advances in agriculture productivity. However, other factors such as quality of life, environmental degradation, per capita income, etc. can also be used to arrive at an upper bound. The model holds good promise for usage for other developing countries.

Key words: Differential Equation Models, Logistic, Indian Population Dynamics, Less Developed Regions, UN Estimates, Validation.

COMMENTS ON THE CLOSE SIMILARITY BETWEEN INDIAN POPULATION PROJECTIONS FROM THE CONSTRAINED COALITION AND LOGISTIC MODEL AND THE CENSUS, GOVERNMENT OF INDIA AND UN ESTIMATES

V.K.C. Sanghi

National Institute of Science, Technology and Development Studies

New Delhi - 110 012, India.

In a paper[1] different types of differential equation models have been examined to represent the dynamics of population growth in India. The solutions of these models have been obtained using analytical and grapho-analytical techniques. The comparative analysis of the projections from the different models points to a particular model designated as the Constrained Coalition and Logistic Model (CCLM) as the best and this is given by

$$\frac{dN}{dt} = rN = A\left[1 - e^{-\left(\frac{a}{A}\right)N}\right]^{\frac{1}{k}}\left(1 - \frac{N}{M}\right)N \qquad (1)$$

where N = aggregate population, r = rate of natural increase, i.e. the difference of birth and death rates, A = saturation value for the rate of natural increase, i.e. 2.88 percent per annum, M = saturation value for the aggregate population, i.e.

2200 million, a and k are parameters, values for which are fixed with reference to the best-fit using census statitics and found to be

$a = .1145197*10^{-8}$ and $k = .3$.

At the outset, it is interesting to bring out that there has been a direct coincidence between the 1981 Indian census figure for the aggregate population, i.e. 685.2 million [2] which really tends to the 700 million mark duly taking into account an under count of 1.7 per cent which is normal for such a huge operation [3] and the projection from the CCLM for the year 1981, which also placed the country's population at 700 million. The 1991 projection of 850 million from the CCLM is also expected to be within close proximity to reality, while the backward projections i.e. those for the period 1921-71 also compare remarkably very well with census data(Table 1).

The model becomes further interesting when the long-term projections obtained from it lead to certain inferences that are very closely similar to the United Nations estimates (4-9) as brought out herebelow:

a. The population growth curve represented by the CCLM has been derived by following the trend curve for the rate of natural increase(r) which is thus depicted to stabilize at 2.88% per annum and by fixing an upper bound for the Indian population at 2200 million, argued from food supply-arable land considerations including

advances in agricultural productivity. However, the model structure is such that the rate of natural increase can never attain stabilization because of the constraint offered by the bounded population, whereby it progresses to a peak value of 2.18% per annum only (Fig.1). With this model mechanism and using the graphical method of isoclines, the N-N trajectory is obtained (Fig. 2), the inverse of which (Fig. 3) gives the growth projections for the population (Table 1) by measurement of time in Fig. 3. The projection for the year 2101 works out to 2099 million and for the year 2111 as 2128 million, the growth getting slower for the period ahead. Due to the asymptotic nature of the growth trajectory, the mathematical limit of 2200 million can be realized only at infinite time, and therefore, some period - say, 2-3 decades - ahead of 2101 can thus be seen to be the stabilization period for the Indian population, which is in perfect unison with the stabilization period 2110-2130 identified by the United Nations for the world population which really implies the less developed regions depending on whether fertility decline is modest or moderate [4,6,7,9].

b. With the Indian population stabilizing at 2200 million during the period 2101-2131 against the 1981 population of 700 million as projected by the CCLM, thereby meaning a 3-fold increase and more, an analogy can be drawn with

the United Nations assessment for the less developed regions, wherein a stable population exceeding 9 billion has been estimated during the stabilization period 2110-2130 [4,6,7,9] against the 1980 population of 3313 million [8], which also represents an increase approaching 3-fold. The saturation value of 2200 million as taken for India, as such corresponds to the overall dynamism of the less developed regions system with regard to growth of population.

c. Further, the average annual growth rate for the decade 1971-81 obtained from the projections given by the CCLM is found to be 2.10% per annum which is synchronous with the UN estimate for the period 1975-80 for the less developed regions [5,6,8]. Interestingly, the parallel monotonic declination in the growth rate as projected for all times henceforth in both the cases as well as the UN estimate for India, medium variant [8], as shown in Table 2, further confirms the probably irreversible downward trend in global population growth and the anticipated acceleration of this trend.

d. The annual increments in the aggregate population as obtained from the CCLM continue to rise uptill the decade 2001 - 2011 inspite of the fact that the average annual growth rate as projected by the CCLM is already declining since 1971-81 - which is followed by continual

declination as anticipated almost alike the situation for the less developed regions as assessed by the United Nations [8], wherein the annual increments reach a peak during 1995-2000 and start monotonically declining thereafter (Table 3). The UN medium variant estimate for India also follows a similar tendency [8], excepting for a slight undulation during 2015-2020, which appears to be inconsistent, however, the UN estimates a somewhat steeper decline in comparison to the CCLM. Due to the higher peak value of these annual increments for India, the UN estimates for the aggregate population for India medium variant [8] as shown in Table 1, project a faster growth for the period 1990-2010 and appear to be coinciding with the CCLM projections by the period 2021-2031.

The current Government of India estimates for population by the turn of the century (year 2001) are high 1021.9, medium 986.1 and low 966.6 million [2]. On comparing these estimates with the projection of 1012 million for the year 2001 from the CCLM, it is seen that this figure falls in between the medium and high values and as such thus reinforces the high possibility of crossing the one billion mark in the first census count of the next century. Of course, with speedier and more extensive direct and indirect efforts over fertility control - possibly, signifying the 'low variant' as envisaged in the UN estimates [4,6] - it could be

possible to restrain the population at the low projection level of 966.6 million and thus bring about stabilization by the year 2070 or so. Of course, the accelerating pattern of decline in fertility as observed for the industrialized regions of the globe, does convey a certain degree of optimism about the same, in the light of a gradual furtherance of urbanization and industrialization all over the country, although other relevant areas such as assured maternal and child health care, supplementary nutritional programmes, extensive medical care facilities and the like have certainly a long way to go.

The keen comparability and accuracy of projections from the CCLM as brought out herein, promote a high degree of validity to the dynamic model which could thus describe the population growth phenomenon in other developing countries as well, besides bringing out the powerful tool contained in mathematical modelling for studies on population growth processes.

References

1. K.K. Murthy and V.K.C. Sanghi, Predictive Model Studies for Indian Population Growth and Energy Demand, in J.M.L. Janssen, L.F. Pau and A. Straszak (editors), Models and Decision-Making in National Economies, North Holland, 281-288 (1979). Proceedings of the Second International Conference on Dynamic Modelling and

Control of National Economies, Vienna(Austria), January 1977.

2. Government of India, Office of the Registrar-General, Demography Division, Report of the Expert Committee on Population Projections, Census of India 1981, Occasional Papers No. 4 of 1988, New Delni, (1988).

3. United Nations Fund for Population Activities (UNFPA), The Subcontinent Takes Stock, Population, UNFPA Newsletter, Vol. 7, No.5, 2-3, New York (May 1981).

4. United Nations, Department of International Economic and Social Affairs (DIESA), Long-range Global Population Projections, Population Division Working Paper, ESA/P/WP. 75, New York (August 1981).

5. United Nations, DIESA, World Population Prospects As Assessed in 1980, New York (January 1981).

6. Rafael M. Salas, State of World Population 1981:Beyond 2000, Populi, UNFPA Journal, Vol.8, No.2, 3-11, New York (1981).

7. Nafis Sadik, Safeguarding the Future, Populi, Vol.15, No.2, 4-37, New York (1988), also in UNFPA Annual Report 1987, 7-44, United Nations Population Fund, New York,

(1988).

8. United Nations, DIESA, World Population Prospects 1988, Population Studies No. 106, Population Division, New York (1989).

9. United Nations Population Fund, State of World Population 1989, UNFPA, New York (1989).

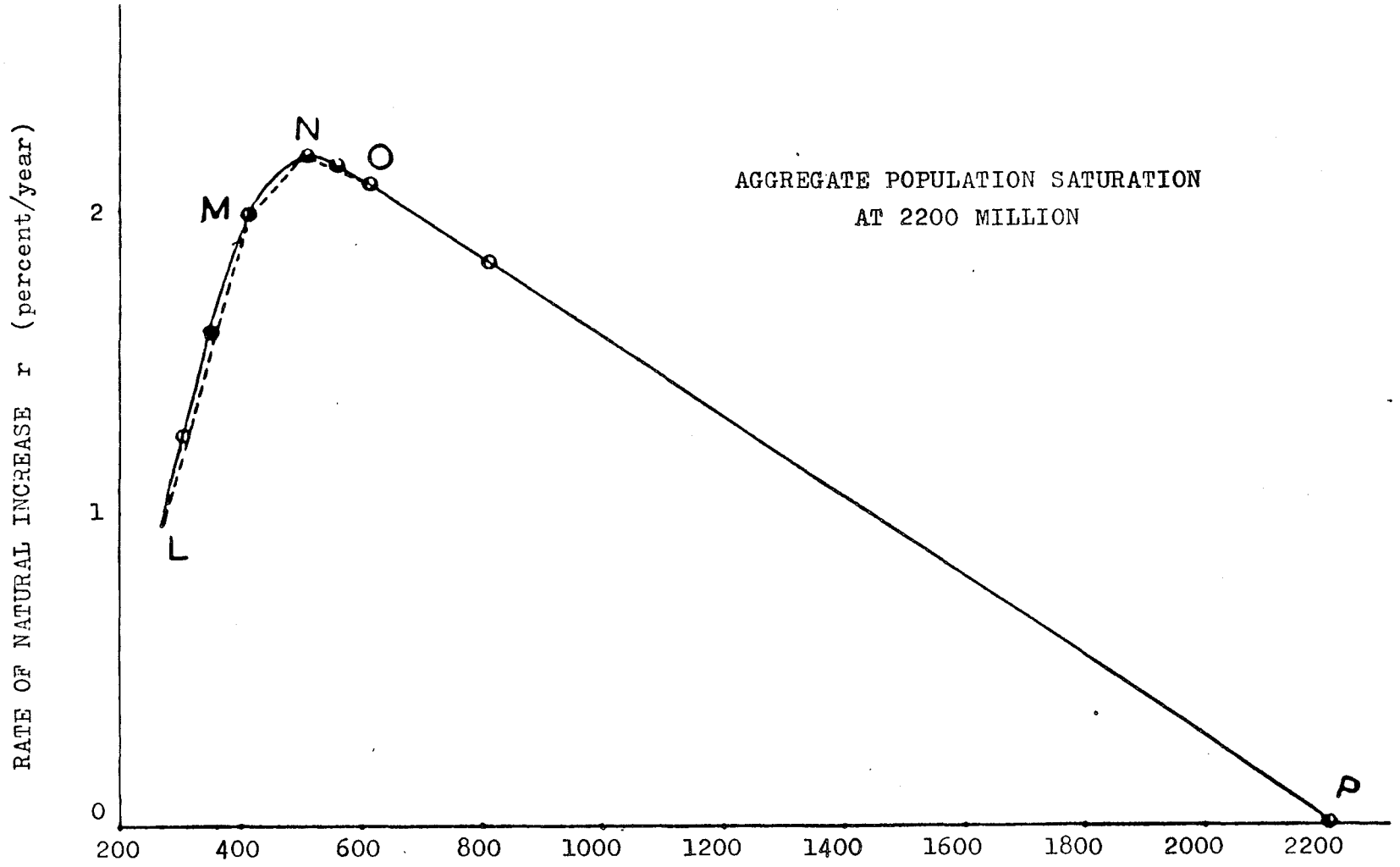

Fig.1 PIECEWISE-LINEARIZATION OF r & N

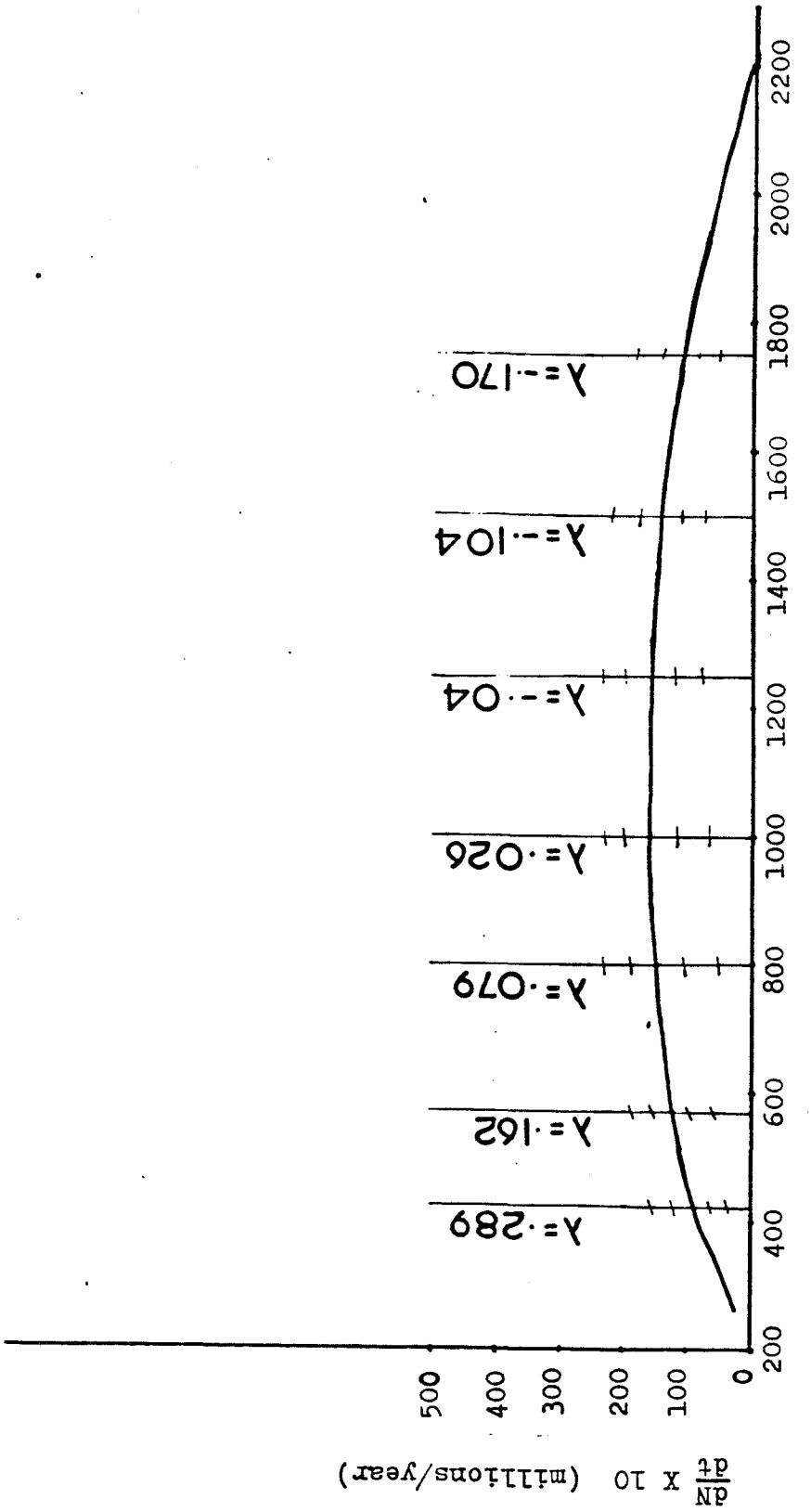

Fig.2 RESPONSE TRAJECTORY FROM ISOCLINES IN THE PHASE PLANE

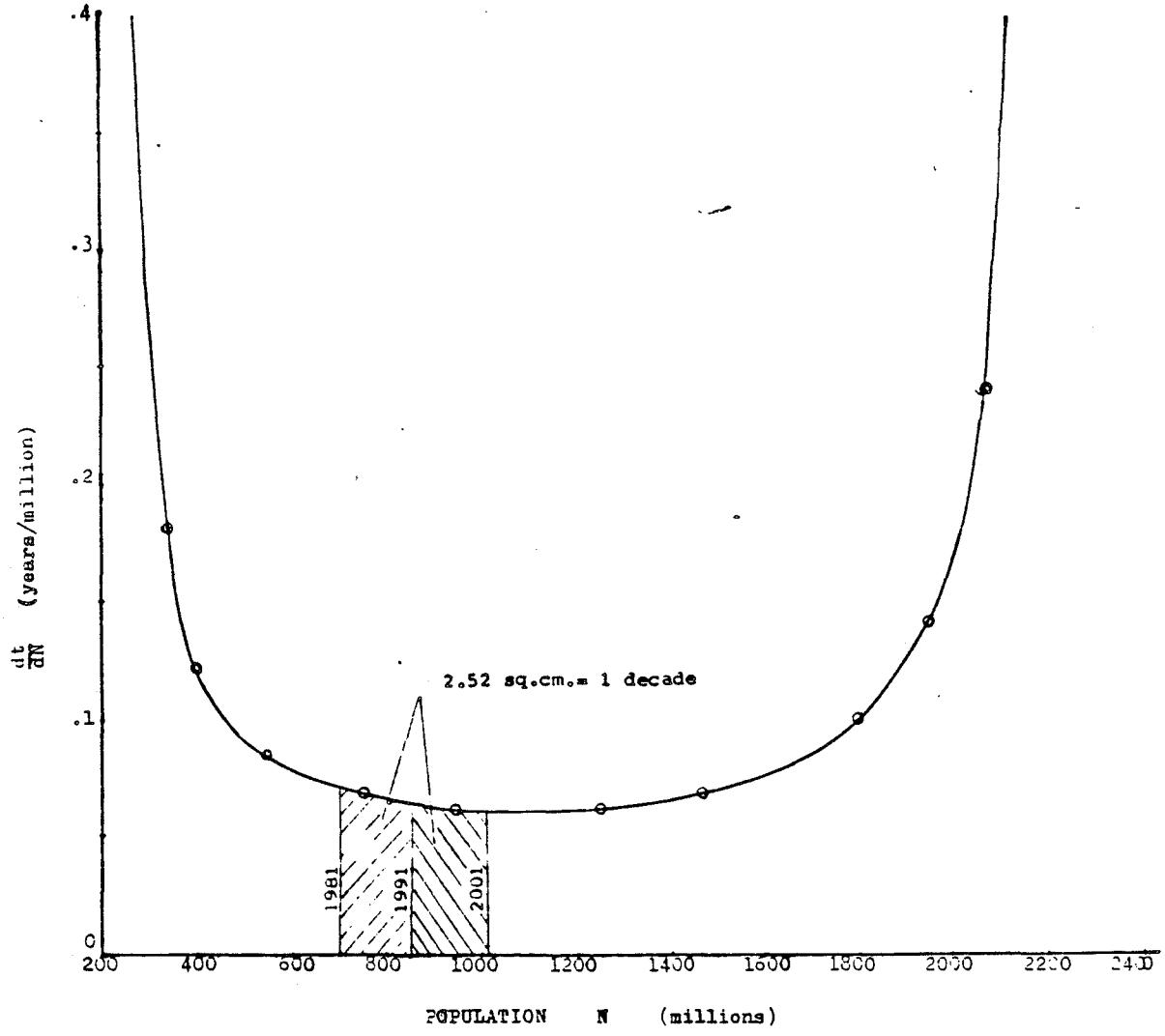

Fig.3 POPULATION PROJECTION BY MEASUREMENT OF TIME

Table 1 : Comparison of Population Projections for India from the Constrained Coalition and Logistic Model (CCLM) with Census Population, Govt. of India Projections & UN Estimates for India

millions

Census/ Decennial Year	Census Population	CCLM Projections	Govt. of India Projections			UN Estimates for India			Decennial Year
			High	Med	Low	High	Med	Low	
	B A C K W A R D		**P R O J E C T I O N S**						
1921	251.3	251.3							
1931	279.0	278.0							
1941	318.7	314.0							
1951	361.1	370.0							
1961	439.2	456.0							
1971	547.9	568.5							
	F O R W A R D		**P R O J E C T I O N S**						
1981	685.2	700.0							
1990						865.2	853.3	847.9	1990
1991		850.0	841.7	837.2	834.8		871.5		
2000						1080.2	1042.5	1010.9	2000
2001		1012.0	1021.9	987.1	966.6				
2010						1299.3	1225.3	1159.6	2010
2011		1180.0							
2020						1513.4	1374.4	1257.8	2020
2021		1340.0							
2031		1490.0							
2041		1627.0							
2051		1767.0							
2061		1864.0							
2071		1944.0							
2081		2010.0							
2091		2061.0							
2101		2099.0							
2111		2128.0							
2121		Approaching							
2131		stabilization at							
:		2200.0							

Table 2 : Comparison of average annual population growth rate for India from the CCLM with UN Estimates, medium variant, 1971-2031

percent per annum

Quinquennial/ Decennial Period	UN Estimates for Less Developed Regions	UN Estimates for India	CCLM Projections
1975-1980	2.10	2.08	
1971-1981			2.10
1980-1985	2.10	2.21	
1985-1990	2.10	2.08	
1981-1991			1.96
1990-1995	2.06	2.09	
1995-2000	1.92	1.92	
1991-2001			1.76
2000-2005	1.74	1.72	
2005-2010	1.56	1.51	
2001-2011			1.55
2010-2015	1.41	1.28	
2015-2020	1.25	1.02	
2011-2021			1.28
2020-2025	1.13	1.01	
2021-2031			1.07

Table 3: Comparison of annual population increments for India from the CCLM with UN Estimates, medium variant, 1971-2031.

millions

Quinquennial/ Decennial Period	UN increments for Less Developed Regions	UN increments for India	CCLM increments
1975-1980	65.9	13.6	
1971-1981			13.1
1980-1985	73.3	16.1	
1985-1990	81.4	16.8	
1981-1991			15.0
1990-1995	88.9	18.8	
1995-2000	91.5	19.0	
1991-2001			16.2
2000-2005	90.7	18.7	
2005-2010	88.3	17.8	
2001-2011			16.8
2010-2015	86.2	16.2	
2015-2020	81.6	13.6	
2011-2021			16.0
2020-2025	78.4	14.2	
2021-2031			15.0