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POPULATION GROWTH AND CHANGING LAND-USE PATTERN IN MUMBAI METROPOLITAN REGION OF INDIA

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ABSTRACT

The rapid population growth and the process of urbanization have resulted into changing land-uses pattern. Mumbai Metropolitan Region (MMR) is one of the fastest growing region of India. Its population increased from 7.7 million in 1971 to 18.3 million in 2001 and is projected to be increased 22.4 million in 2011. With the saturation of land in the city followed by suburbs, other parts of the metropolitan region plows now experiencing the fast growth. Due to growing population pressure the total built-up and industrial area in Mumbai Metropolitan Region has increased from 4.9 percent in 1971 to 12 percent in 1991 and is projected to constitute 31 percent of the total area in 2011. On the other hand, area under forest cover has declined from 30 percent in 1971 to 27 percent in 1991 and is expected to it declines further to 22 percent by 2011. Using various demographic and spatial analysis techniques, this paper attempts to shows the effect of population growth on land-uses and subsequently on the regional environment. It also evaluates critically the development plan of the region. The dates it goes the study have obtained from the Mumbai Metropolitan Region Development Authority and Census of India.

Keywords: *Population growth, Population density, Lan-use change, Mumbai, India.*

CRESCIMENTO POPULACIONAL E MUDANÇAS NO PADRÃO DO USO DO SOLO NA REGIÃO METROPOLITANA DE MUMBAI NA INDIA

RESUMO

O rápido crescimento da população e o processo de urbanização resultaram em mudanças do padrão de uso da terra. A Região Metropolitana de Mumbai (MMR) é um das regiões de crescimento mais rápido da Índia. Sua população aumentou de 7,7 milhões em 1971 para 18,3 milhões em 2001 e é projetado para o ano 2011 uma população de 22,4 milhões de habitantes. Com a total ocupação da cidade seguida por subúrbios, outras partes da região metropolitana estão experimentando um crescimento rápido agora. Devido a pressão da crescente população, a área urbana total da Região Metropolitana de Mumbai aumentou de 4,9 por cento em 1971 para 12 por cento em 1991, com uma projeção para chegar a 31 por cento da área total em 2011. Por outro lado,a área sob cobertura de floresta foi reduzida de 30 por cento em 1971 para 27 por cento em 1991 e espera-se uma redução

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para 22 por cento em 2011. Usando várias técnicas de análise demográficas e de espaço este artigo tenta apresentar os efeitos do crescimento da população no uso da terra e conseqüentemente no ambiente regional. Também avalia criticamente o plano de desenvolvimento da região. Os dados para o estudo foram obtidos das Autoridades de Desenvolvimento de Região Metropolitana de Mumbai e do Censo da Índia.

Palavras chaves: *crescimento de População, densidade de População, uso da terra, Mumbai, Índia.*

The rapid growth of population and the process of urbanization have resulted in an increasing demand for land in urban settlements. A city grows not only by population but also by changes in spatial dimensions. The prime factors of increasing spatial dimension of the city are also the population growth and related requirements of urban life, such as development of transport and communication and others infrastructure facilities. The mismatch between the supply and demand of land leads to the degradation of environmentally fragile land, occupation of hazard prone areas, and loss of cultural resources, open space and prime agricultural land. Within the existing built-up areas of cities uncontrolled growth of population and inadequate infrastructure may cause irreversible losses of cultural resources and open space. Poorly managed development may also cause excessive urban sprawl and negative impact on air quality, energy consumption and aesthetic quality. The conversion of prime agricultural land to urban use may increase costs for locating, storing and purchasing food (Bernstein: 1994).

The pattern of city growth and its spatial structure are determined by various historical, economic, social and ecological forces that influence urban land-use. The improper use of urban land poses serious problems in all countries simply because the supply of surplus land is limited and subject to many competing claims. Dissatisfaction with the emerging urban forms is almost universal. Therefore, proper planning of urban land-use is most essential for an orderly and efficient growth of urban areas.

A variety of factors affect the supply and demand of land and its uses in a city. The supply of urban land is affected by such factors as location of city, laws related to land-use, structure of land markets and urban management. Nevertheless, increasing population size of cities and physical expansion of the

built-up area beyond the city limits as well as rising demand for more land for various purposes induce changes in urban land-use.

It is observed that in developing countries cities are growing very rapidly. The land related problems are impounded in these cities because of the distorted land markets and ineffective urban land management (Bernstein: 1994). Since 1950, the urban population in third world cities has risen from 300 million to 1.3 billion and by the year 2030, the cities in the developing countries are expected to grow by 160 per cent (World Bank: 1991). In most developing countries, the expansion of urban population has resulted into a rapid rise in the demand for housing, land for industry and commerce, and public buildings and infrastructure. Due to many competing claims for urban land and the consequent rise in land prices, supplying land which can be developed at the pace and scale required is a challenge for authorities in most of the cities in the developing countries.

Although urbanization process often means accelerated economic performance for a country, the accompanying rise in prices of urban land and its conversion from one form to another affects the natural and cultural resources of the city. It may also have negative implications for the urban poor.

The metropolitan cities in India have experienced rapid growth of population, particularly in the post independence era. Many of them have also experienced tremendous expansion of their statutory limits (Ravindra: 1996). For every metropolitan area growth has spilled beyond the city boundary, which is expected to bring many undesirable changes in the land-use pattern within the city as well as its surrounding areas. But not enough is known about the magnitude of these land-use changes and the relationship of these changes to population growth. This study is an attempt in this direction and focuses on Mumbai Metropolitan Region (MMR). The purpose of this study is to see the population distribution and its growth trends in different constituent units of MMR during 1971, 1991 and 2011. The study is also aimed at finding the land-use changes in MMR during this period. In addition, it attempts to find out what kind of land has been converted into built-up area.

Sources of Data, Limitations and Methodology

The data for this study have been obtained from the following secondary sources.

1. Draft Regional Plan of Mumbai Metropolitan Region (Part I, II and III), 1971-91.
2. Draft Regional Plan of Mumbai Metropolitan Region (Part I and II), 1996-2011.
3. Regional Plan for Mumbai Metropolitan Region, 1971-1991, Vol. 1.
4. Census of India, 1971 through 2001.

There have been changes in the boundary of MMR during the two plan periods. In 1991, the boundary of the MMR was extended to include Alibagh and Pen regions. Apart from that the sub-regions of MMR were also reclassified at that time. Similarly, the land-use categories were also expanded in the second plan period. For instance, in 1971 there was no sub-classification of forests, but in 1991 forests were classified as dense forest, sparse forest and scrubland. Therefore, it is difficult to compare the land-use pattern of 1971 with that of 1991 and 2011. But, for the comparison purposes, the 1971 metropolitan region taken into consideration. The land-use data presented in the 1971draft plan have been generated from the land-use maps, whereas, the data presented in the draft plan for 1996-2011 have been collected through more sophisticated techniques like remote sensing and GIS. Therefore, for comparative purposes, in this paper land-use data have been reclassified in the following broad categories.

1. Built-up area: residential, commercial, and institutional.
2. Industrial.
3. Agricultural.
4. Forest: dense forest, sparse forest, scrub land.
5. Wet land.
6. Water bodies
7. Other areas: airport, harbour, beach/grooney, recreational zone (RTZ) and rocky out crops.

Using the square graph technique, area was calculated in each of the above-mentioned categories directly from the maps given in the two draft reports (details of the technique are given in Appendix No. 1). To see what kind of land has been converted into built-up area, the land-use maps for three time periods were superimposed and areas were calculated. This also gives us some idea of land-use changes due to urban sprawl as well as population growth. To look into the relationship between population growth and land-use change spatially, isopleth maps prepared for 1971, 1991 and 2011 have been superimposed (details of the technique are given in Appendix No. 2).

Population Growth in Mumbai Metropolitan Region:

The MMR is the largest metropolitan region in India. It was notified by the government in 1967 on the recommendations of the Gadgil committee, which was appointed to look into the problems of Mumbai city and suggest the policy measures to overcome these problems. The committee felt planning within the narrow limits of the city could not solve the problems of Mumbai. Regional development was considered a necessity to solve a multitude of the problems faced by Mumbai. Therefore, a much larger region was considered for planning. The MMR includes within its folds the Municipal Corporations of Greater Mumbai, Thane, Kalyan, and Navi Mumbai, 16 municipal towns, 7 non-municipal urban centers and 995 villages. Its administrative region includes entire district of Greater Mumbai, and parts of Thane and Raigad districts.

Table 1 presents the size and proportion of population and density in different constituent units of MMR for the periods from 1971 to 2011. It also shows how population growth is distributed in each constituent unit of MMR. The overall population size of MMR has increased from 7.7 million in 1971 to 14.4 million in 1991, almost doubled in a short span of 20 years. It is expected to increase further to 22.2 million by 2011. As expected, the greatest concentration of population in MMR is in the Greater Mumbai region (Island city and Suburbs) followed by Kalyan.

In 1971, more than three-fourths of the population in MMR lived in Greater Mumbai (Island city and Suburbs). In 1991, the share of population in this region has come down to 69 per cent, which is expected to decline further to 58 per cent by 2011. On the other hand, Thane, Kalyan, Uran, Bhiwandi, and Bassain are growing fast and the share of population in this region has increased from 4.1 per cent, 6.5 per cent, 1.2 per cent, 3.2 per cent and 2.6 per cent respectively in 1971 to 7.7 per cent, 9.5 per cent, 2.7 per cent, 4.3 per cent and 2.9 per cent, respectively in 1991, and is expected to increase to 10 per cent, 11.4 per cent, 7.3 per cent, 5 per cent and 4.5 per cent, respectively in 2011.

In 1971, the overall density of MMR was 1,989 persons per square kilometer. The population density of

Island city was exceptionally high at a level of 42,060 persons per square km. In contrast, suburban areas had a density of 7,340 persons per square km. But in 1991, the overall density of MMR increased to 3,743 and in 2011 it is expected to be 5,774 persons per square km. The population density of Island city in 1991 was 44,096 persons per sq.km., while in suburbs it was around 17,087. The other regions which had high density (nearly 2000 or more) were Thane, Kalyan and Uran. By 2011, the population density in the Island city is expected to decline to around 39,236 and in the suburbs it is expected to go up to around 25,578. The other regions which are expecting a very high density (more than 2,000) are Thane, Bassain, Kalyan and Uran. Very soon Uran is going to be the next most congested place after Suburbs, with a density of more than 7,500.

Table 1

Population distribution and density in MMR, 1971-2011

	Population			Percent of population			Density		
Region/Sub Region	**1971**	**1991**	**2011**	**1971**	**1991**	**2011**	**1971**	**1991**	**2011**
Island city	3070378	3174889	2825000	40.1	22.0	12.7	42060	44096	39236
Suburbs	2900197	6751002	10106000	37.8	46.8	45.4	7340	17087	25578
Thane	312348	1104795	2238934	4.1	7.7	10.1	903	3193	6471
Bassain	200799	420263	1002031	2.6	2.9	4.5	461	964	2298
Bhiwandi	241424	626056	1115319	3.2	4.3	5.0	351	911	1623
Kalyan	500435	1365926	2545924	6.5	9.5	11.4	772	2108	3928
Panvel	234415	427487	625645	3.1	3.0	2.8	408	745	1090
Uran	91557	390114	1616751	1.2	2.7	7.3	427	1821	7548
Khalapur	36577	72392	93167	0.5	0.5	0.4	213	421	542
Karjat	75939	93629	84141	1.0	0.6	0.4	246	303	272
Total	**7664069**	**14426553**	**22252912**	**100**	**100**	**100**	**1989**	**3743**	**5774**

Source: Draft Regional Plan for MMR, 1971-1991 and 1996-2011, MMRDA

Table 2 presents the distribution of population growth and annual growth rate in different constituent units. The population growth rate in MMR declines from 4.4 per cent during 1971-1991 to 2.7 per cent during 1991-2011. It may be noted that Greater Mumbai (Island city and Suburbs) observes a decline in its growth rate from 3.3 per cent in 1971-91 to 1.5 per cent during 1991-2011. The growth rate of the Island city becomes negative during the later period. Some of the areas of the region are growing at a dramatic rate.

The annual population growth rate of Thane was 12.7 per cent during 1971-91, which is reduced to 5.1 per cent during 1991-2011. Similarly, Bhinwadi and Kalyan had a growth rate of 8 per cent and 8.6 per cent in 1971-91, which is reduced to 3.9 per cent and 4.3 per cent, respectively in 1991-2011. The other area, which experienced an increased growth rate is Bassain. The annual growth rate of Bassain grew from 5.5 per cent in 1971-91 to 6.9 per cent in 1991-2011.

Of the total population growth in MMR during 1971 to 1991, 57 per cent population has been added only in the suburban areas of Greater Mumbai compared to only 1.5 per cent in the Island city. During this period 12 per cent and 13 per cent of the additional population has gone to Thane and Kalyan. For the period 1991-2011, share of population growth is expected to decline to 43 per cent in suburbs and increase to 15 per cent in Thane and Kalyan. The overall population of the Island city is declining during this period. However, the contribution of Uran goes up in population growth from 4.4 per cent in 1971-91 to 15.7 per cent in 1991-2011.

Table 2

Population growth in MMR, 1971-2011

	Population growth		Distribution of population growth		Annual growth rate	
Region/Sub Region	**1971-91**	**1991-2011**	**1971-91**	**1991-2011**	**1971-91**	**1991-2011**
Island city	104511	-349889	1.5	-4.5	0.2	-0.6
Suburbs	3850805	3354998	56.9	42.9	6.6	2.5
Thane	792447	1134139	11.7	14.5	12.7	5.1
Bassain	219464	581768	3.2	7.4	5.5	6.9
Bhiwandi	384632	489263	5.7	6.3	8.0	3.9
Kalyan	865491	1179998	12.8	15.1	8.6	4.3
Panvel	193072	198158	2.9	2.5	4.1	2.3
Uran	298557	1226637	4.4	15.7	16.3	15.7
Khalapur	35815	20775	0.5	0.3	4.9	1.4
Karjat	17690	-9488	0.3	-0.1	1.2	-0.5
Total	**6762484**	**7826359**	**100**	**100**	**4.4**	**2.7**

Source: Draft Regional Plan for MMR, 1971-1991 and 1996-2011, MMRDA

Land-use Pattern in Mumbai Metropolitan Region

Table 3 presents the land-use pattern for different regions of MMR in 1971. At that time nearly 4 per cent area of the region was used as built-up area, more than one-fourth was under forest cover and more than half was used for

agricultural purposes. In the Island city three-fifths of the land was used as built-up area and 6 per cent for industrial purposes. But in the suburbs less than one-fifth area was used as built-up and 4 per cent as industrial land. In suburbs nearly two-fifths of the land was used for agricultural purposes or was under the forest cover. Built-up area had a very small proportion (less than 3 per cent) in all the other regions. In Thane about 4 per cent area was under industrial use. In Bassain, Khalapur, Karjat and Bhiwandi one-third or more area was under forest cover. In Bhiwandi, Kalyan, Panvel, and Karjat more than three-fifths of the land was used for agricultural purposes (see figure 1).

Table 3

Existing land-use distribution in MMR in 1971 (Area in sq. km)

Region/Sub Region	Built-up	Industry	Agriculture	Forest	Wet land	Water body	Others	Total area
Island city	45.2	4.8	0	0	8.9	0	15	73.9
Suburbs	71	16	47.9	103	126.1	9.5	21.5	395
Thane	9.5	15	143	98	75.5	3.5	1.5	346
Bassain	1.3	0	206.3	180	44.3	4.3	0	436.2
Bhiwandi	1.6	1.5	443	200	25	16	0	687.1
Kalyan	13.2	1	421	171.2	1	24.6	16	648
Panvel	2	2.4	423.6	102	32	12	0	574
Uran	0.5	1	127.5	20	58	1.5	5.5	214
Khalapur	0.5	3.5	95	66	3	4	0	172
Karjat	4.3	0	191	105.2	0.5	8	0	309
Total	**149.1**	**45.2**	**2098.3**	**1045.4**	**374.3**	**83.4**	**59.5**	**3855**

Source: Draft Regional Plan for MMR, 1971-1991, MMRDA

Table 4 shows the land-use pattern for 1991. Nearly one-tenth of the area of MMR was used as built-up area and less than 3 per cent as industrial area. Two-fifths of the land was used for agricultural purposes and more than one-third was under the forest cover. In the Island city, built-up area was 71 per cent and industrial area was 8 per cent. In the suburbs, 33 per cent area was built-up and 4 per cent was used for industries. In Bhinwadi, more than half of the land was under the agriculture. In all the other regions between 30 to 50 per cent of the land was used for agricultural purposes. In Khalapur and Karjat more than half of the land was under forest cover. While in Bassain, Bhinwadi, Kalyan and Panvel between 30 to 45 per cent of the land was under the forest cover (see figure 1).

Figure 1

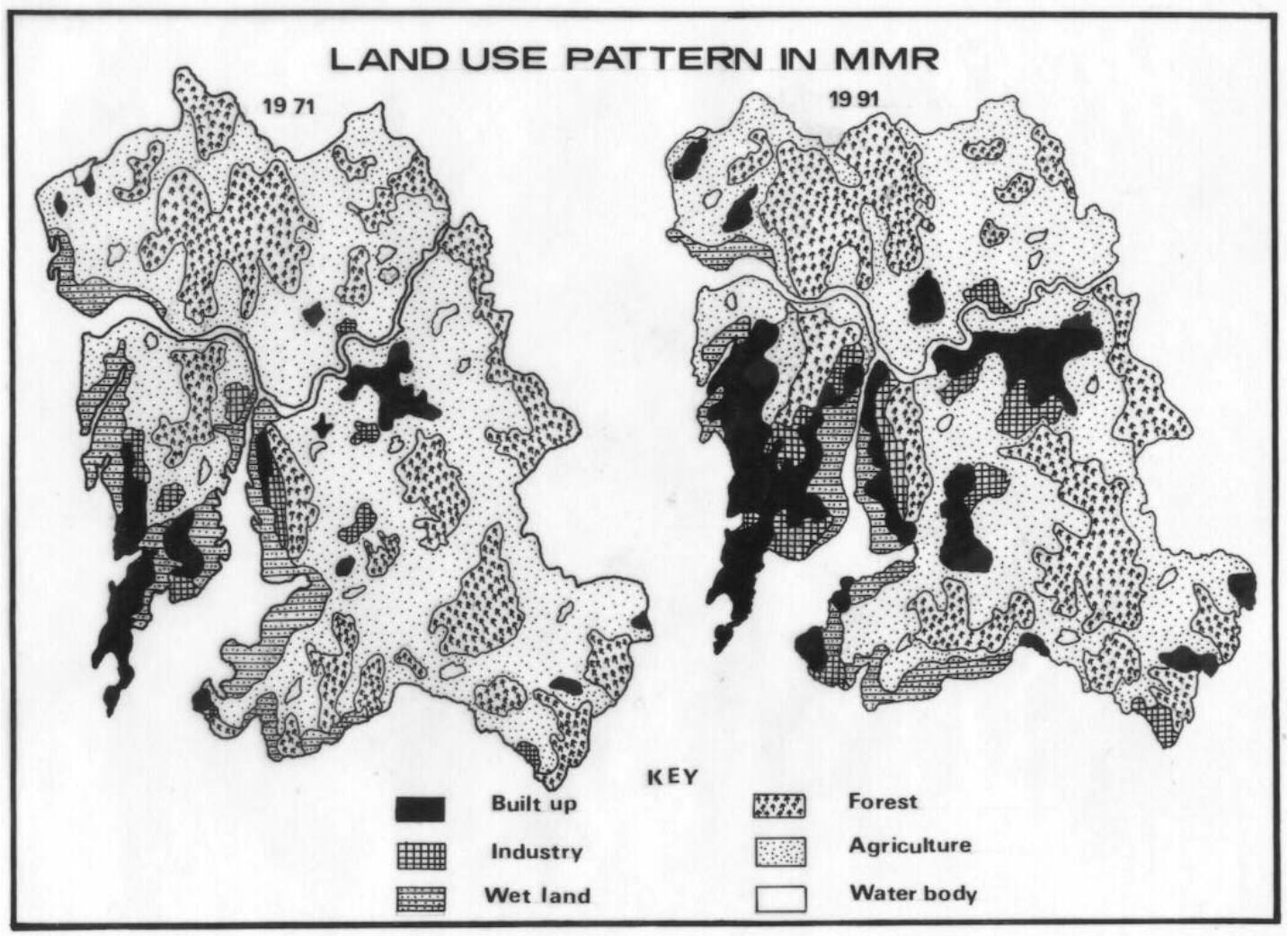

LAND USE PATTERN IN MMR
19 71
19 91
KEY
Built up
Industry
Wet land
Forest
Agriculture
Water body

Table 4

Existing land-use distribution in MMR in 1991 (Area in sq. km)

Region/Sub Region	Built-up	Industry	Agriculture	Forest	Wet land	Water body	Others	Total area
Island city	51.8	6.3	0	0	5.9	0	9.9	73.9
Suburbs	130.1	16.3	24.6	95.8	98.1	8.8	21.4	395.1
Thane	46.4	40.9	83.8	98	72.1	3.4	1.5	346.2
Bassain	26.6	1.7	160.7	200	43.8	3.2	0	436
Bhiwandi	17.9	0.4	388.7	232	37.6	10.4	0	687
Kalyan	38.1	17.4	277.5	274.5	7.3	16.8	16.5	648.1
Panvel	25.6	14.3	250.4	236.8	35	12	0	574.1
Uran	6.8	1.3	71.2	70.2	57.7	1.5	5.5	214.2
Khalapur	3.2	3.5	40.7	117	4.3	3.3	0	172
Karjat	4.8	0	148.4	147.5	0.5	7.9	0	309.1
Total	**351**	**101.7**	**1445.9**	**1471.6**	**362.0**	**67.1**	**54.7**	**3855**

Source: Draft Regional Plan for MMR, 1996-2011, MMRDA

Table 5 shows the proposed land-use plan for 2011. Mumbai Metropolitan Regional Development Authority modified the zoning plan for the plan period 1996-2011. The new land-use categories are given below:

- ⇒ Urbanisable Zone U1
- ⇒ Urbanisable Zone U2
- ⇒ Industrial Zone
- ⇒ Forest
- ⇒ Agriculture
- ⇒ Wet land
- ⇒ Water body
- ⇒ Others (Airport, Quarry zone, RTZ, etc.)

Table 5

Proposed land-use distribution in MMR in 2011 (Area in sq. km)

Region/Sub Region	Built-up	Industry	Agriculture	Forest	Wet land	Water body	Others	Total area
Island city	56.8	5.5	0	0	0	0	11.5	73.9
Suburbs	180.2	27.9	100.5	0	0	7.6	79.2	395
Thane	176	25.8	73.3	23.5	13.7	4.2	29.5	346
Bassain	93.8	4.2	176.5	129.4	5.2	2.2	24.7	436
Bhiwandi	92.4	2.8	342.4	215.1	2.1	7.4	25.5	687
Kalyan	138	24.9	300	157	0.2	14.8	13.4	648
Panvel	170.5	4.52	180.4	160.23	8.3	16.46	33.64	574
Uran	76.7	41.1	18.4	23.2	32.4	1.4	21.4	214
Khalapur	34.36	3.3	51.3	64.7	0	8.2	10.4	172
Karjat	55.28	0	138.5	106.1	0	5.8	3.4	309
Total	**1074.04**	**140.02**	**1381.3**	**879.23**	**61.9**	**68.06**	**252.64**	**3855**

Source: Draft Regional Plan for MMR, 1996-2011, MMRDA

According to this plan, built–up area is divided into two categories - U1 and U2. Zone U1 includes those areas, which are primarily built-up and intensively used for residential and economic activities. While Zone U2 includes the land within 1 km on either side of important roads and within 1.5 km radius from railways stations subjects to other physical and statutory constraints.

The proposed land-use plan shows that by 2011 more than one-fourth area of the MMR will be built-up in the U1 and U2 categories. About 4 per cent of the land will be for industrial use and 23 per cent under forest cover. The proportion of agricultural land remains almost at the same level of slightly less than 40 per cent. In the Island city three-fourths of the land is built-up and 8 per cent is used for industries. In the suburbs 46 per cent of the land is built-up and 7 per cent is used for industries. Only in Bhiwandi and Karjat region more than 30 per cent area is under forests cover. In all the other regions less than 30 per cent area is under forests. Out of all the regions Bhinwadi and Kalyan have the highest proportion of land for agricultural use (nearly 50 per cent), followed by Karjat where 45 per cent land is used for agriculture. In all the other regions less than 40 per cent land is used for agriculture. It is as low as 10 per cent in Uran (see figure 1).

Due to peculiar geographical location of the MMR urban sprawl has taken place only in one direction. Till 1971 urban built-up area of MMR was 149.1 sq.km, out of which 116.2 sq.km area was located in Greater Mumbai (Island city and suburbs). Until that time urban expansion was confined to the Island city and its suburbs. In the later period growth took place along the transport network beyond Greater Mumbai and on the main land mainly towards Bassain, Bhiwandi, Thane, Kalyan, Panvel, Uran, Khalapur and Karjat. In these regions large parts of agricultural and forest land were brought under built-up area.

Land-use Change in Mumbai Metropolitan Region

Table 6 shows the land-use distribution in the constituent units of MMR. It focuses only on the built-up area, agricultural area, forest area and wet land. A comparison of this table with Table 1 reflects upon the inequality in the distribution of population and built-up area. The share of Island city in overall built-up area of MMR is declining with time, which is in congruity with share of

population distribution. But the share of built-up area in Suburbs has decreased substantially, whereas share of population has increased during 1971-91 and has remained almost at the same level during 1991-2011. In most of the places the proportion of population and built-up area has gone up during the study period. In some areas the inequality has increased sharply. For example, in 1971 Panvel had 3 percent of population and 1 percent of built-up area, but in 2011 although the share of population remains the same the proportion of built-up area increases to 16 percent.

Table 7 presents the changes in land-use pattern in MMR during 1971 to 2011. In 1971 more than half of the land (54 per cent) in MMR was under agriculture and more than one-fourth was covered by forests. Only a small part of the region (4 per cent) was built-up area.

Table 6

Land-use distribution in MMR in 1971-2011 (in %)

	Proportion of Built-up area			Proportion of Agriculture area			Proportion of Forest area			Proportion of Wet land area		
Region/Sub Region	**1971**	**1991**	**2011**	**1971**	**1991**	**2011**	**1971**	**1991**	**2011**	**1971**	**1991**	**2011**
Island city	30.3	14.7	5.3	0	0	0	0	0	0	2.4	1.6	0
Suburbs	47.6	37.1	16.8	4.9	1.7	7.3	9.9	6.5	0	33.7	27.1	0
Thane	6.4	13.2	16.4	6.8	5.8	5.3	9.4	6.7	2.7	20.2	19.9	22.1
Bassain	0.9	7.6	8.7	9.8	11.1	12.8	17.2	13.6	14.7	11.8	12.1	8.4
Bhiwandi	1.1	5.1	8.6	21.1	26.9	24.8	19.1	15.8	24.5	6.7	10.4	3.4
Kalyan	8.9	10.9	12.8	20.1	19.2	21.7	16.4	18.7	17.9	0.3	2	0.3
Panvel	1.3	7.3	1.6	20.2	17.3	13.1	6.8	16.1	18.2	8.5	9.6	13.4
Uran	0.4	1.9	7.1	6.1	4.9	1.3	1.9	4.8	2.6	15.5	15.9	52.3
Khalapur	0.4	0.9	3.2	4.5	2.8	3.7	6.3	7.9	7.4	0.8	1.1	0
Karjat	2.9	1.4	5.1	9.1	10.3	10	10.1	10	12.1	0.1	0.1	0

Source: Draft Regional Plan for MMR, 1971-1991 and 1996-2011, MMRDA

Table 7

Comparative area of existing and proposed land-use in MMR (Area in sq. km)

	Existing land-use in 1971		Existing land-use in 1991		Proposed land-use in 2011	
	Area	**%**	**Area**	**%**	**Area**	**%**
Built-up	149.1	3.9	351	9.1	1074.04	27.8
Industry	45.2	1.2	101.7	2.6	140.02	3.6
Agriculture	2098.3	54.4	1445.9	37.5	1381.3	35.8
Forest	1045.4	27.1	1471.6	38.2	879.23	22.8
Wet land	374.3	9.7	362.	9.4	91.9	1.6
Water body	83.4	2.2	67.1	1.7	68.06	1.8
Others [1]	59.5	1.5	54.7	1.4	252.64	6.6

Note: Others[1] includes Airport, Harbour, Beach/grooney, RTZ and Rocky out crop.
Source: Calculated from Table 3, 4 and 5.

In 1991 the proportion of area under agriculture declined to 38 per cent. On the other hand, built-up area increased to 9 per cent. In all the other land-use categories there was hardly any change. The proportion of area under forest and green land also increased from 27 to 38 percent. In the proposed land-use plan there is a much greater emphasis on increasing the built-up area. More than one-fourth of the land in the metropolitan region will be built-up by 2011. For this purpose mainly forest land is being used as its proportion declines from 38 to 23 per cent during 1991 to 2011. The proportion of wetland also declines substantially during this period from 9 per cent to less than 2 per cent.

Table 8 shows the changes in the actual area under different uses during the two time periods. The areas in different categories of land-use have been calculated by superimposing map of 2011 on the map of 1991 and 1971. Nearly 202 sq. km of land under different uses was converted to built-up area during 1971-1991, but during 1991-2011 the area of such conversion increases to 717 sq. km. While during 1971-1991 57 square km of land was added to industrial use, in the later period only 24 sq. km land is added for such use. During 1991-2011 agricultural land declines by 43 square km, forest land by 593 square km and wetland by 300 square km.

Table 8

Land-use changes in MMR (Area in sq. km)

	Land-use change in 1971-2011	
	1971-91	**1991-2011**
Built-up	202	723
Industry	57	38
Agriculture	-652	-65
Forest	426	-592
Wet land	-12	-300
Water body	-16	1
Others [1]	-5	198

Note: Others[1] includes Airport, Harbour, Beach/grooney, RTZ and Rocky out crop.
Source: Calculated from Table 3, 4 and 5.

Table 9 shows details of different types of land that were converted into built-up area during the two time periods. During 1971-91 nearly two-thirds of the land that was converted into built-up area was under agricultural use earlier.

Nearly one-fifth was wetland and little more than one-tenth was under forest cover. But in 1991-2011 little more than half the land that was converted into built-up area was under forest use earlier and one-third of the land was converted into built-up area was wet land earlier.

Table 9

Conversion of different land-uses to built-up area in MMR during 1971-91 and 1991-2011
(Area in sq.km)

	Conversion of land during 1971-91		Conversion of land during 1991-2011	
	Area	**%**	**Area**	**%**
Industry	1	0.5	2	0.3
Agriculture	137	63.9	57	7.9
Forest	28	13.1	388	54.1
Wet land	41	18.9	244	33.9
Water body	4	1.4	6	0.8
Others [1]	5	2.2	22	3

Note: Others[1] includes Airport, Harbour, Beach/gooney, RTZ and Rocky out crop.
Source: Calculated from Land-Use Map of Draft Regional Plan for MMR, 1971 to 1991 and 1996-2011, MMRDA.

Relationship Between Population Growth and Land-use Change:

To see the relationship between population growth and land-use change, isopleth maps prepared for 1971, 1991 and 2011 and have been superimposed. The 1971-91 isopleth map showing a strong relationship between population growth and land-use change in Island city, Suburbs, central part of Thane and central part of Kalyan. The relationship is medium in southern part of Bhiwandi, western part of Bassin, central part of Panvel and Uran. It is weak in Khalapur and Karjat (see figure 2).

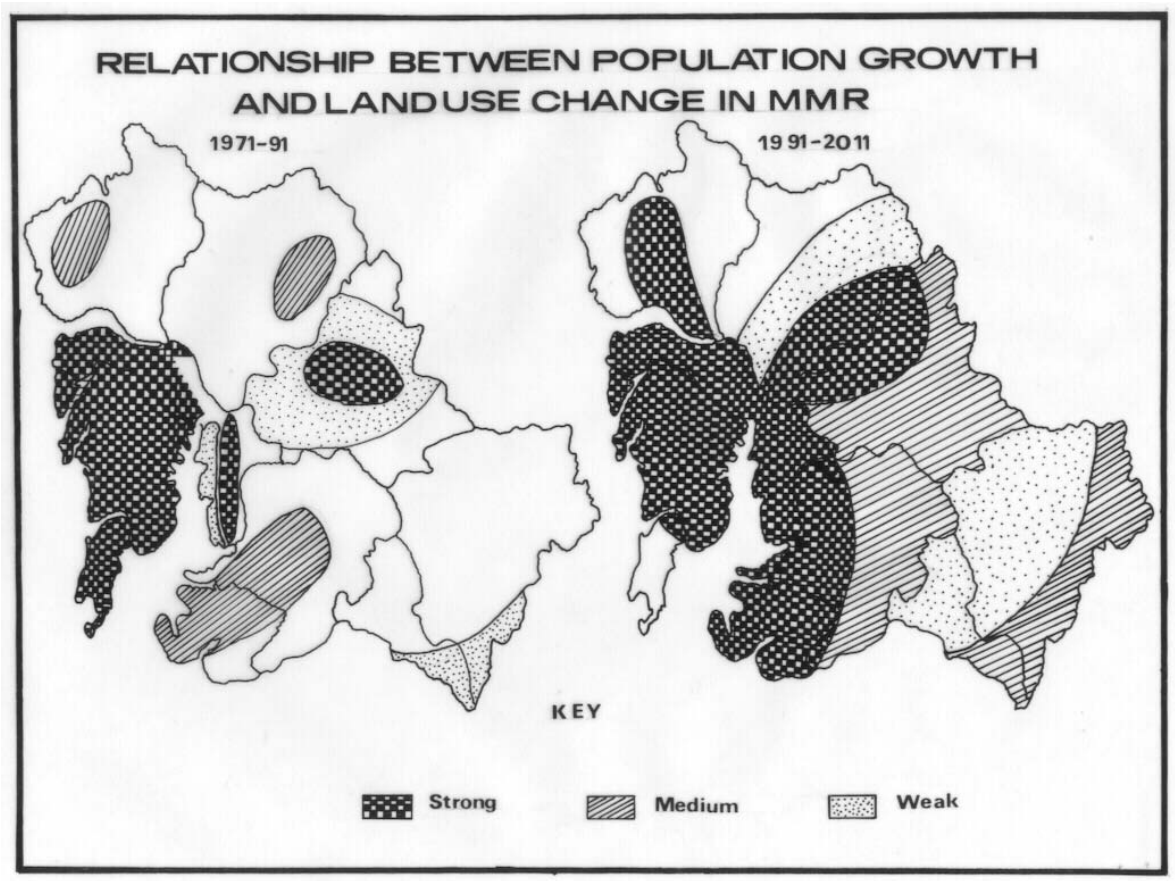
The 1991-2011 isopleth map showing a strong relationship between population growth and land-use change in suburbs, central part of Bassin, southern Bhiwandi, northern and central part of Kalyan, Uran, Thane and western part of Panvel regions. The relationship is medium in southern Kalyan, south eastern Panvel and southern part of Karjat and Khalapur. It is weak in central Bhiwandi and northern part of Karjat and Khalapur (see figure 2).

Summary:

Population in MMR has grown very fast in the past but the growth rate shows a declining trend. The Island city, which supports one-thirds of the population, has

started loosing population. The three regions, which have been growing very fast, are Thane, Kalyan and Uran. The Uran region has experienced a dramatic growth rate of 15 per cent per year during 1991-2011 because the new port of Nhava Sheva has started attracting other commercial activities. Its growth rate was 4 per cent during 1971-91. A significant growth in population in Thane, Kalyan and Panvel regions can be attributed to industrialization.

Figure 2



Along with population growth built-up area has also increased, from 4 per cent in 1971 to 9 per cent in 1991. Nevertheless, in 2011 more than one-fourth of the land in MMR will be used as built-up area. The increase in built-up area is at the cost of agricultural land, forest land and wetland. The MMR was developed with the idea of decongesting Mumbai city and its suburbs, but the plan has not been successful because the density of population is very high in this part of the region. Although population density in the Island city shows a

declining trend the suburbs still experience an increase in density during 1991-2011.

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Appendix:

1. The square graph technique is used to calculate the area of different smaller units on the map having similar characteristics. A graph paper is used to calculate the area according to the scale of the map.

2. Isopleth map is prepared by drawing isolines. Isolines are lines on map joining places with same value for selected variables. The area between two isolines is shaded according to the ranges of higher to lower values. Here administrative boundaries are not taken into consideration for showing the distribution of selected characteristics.

3. The spatial variation of relationship between two different variables can be seen by superimposing the isopleth maps of those variables. If the pattern of isolines are similar then the relationship is strong. If the isolines of higher values of one variables coincide with the isolines of higher value of another variables the relationship is positive, but if the isolines of lower value of one variable coincide with the higher

value of another variable, the relationship is negative. If the isolines of two variables intersect at right angle, there is no relationship between the two variables in that area. If the isolines of two variables intersect at low angle the relationships is weak and if the isolines of two variables are parallel to each other the relationship is strong (see figure 3).

Figure 3

VARIABLES OF ISOLINES AND THERE RELATIONSHIPS