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Application of Geospatial Technology to Municipal Waste Generation Estimation: A case Study of Rohtak, India

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Abstract—*Urban populations are experiencing a very rapid increase. In the face of this rapid urbanization pose challenges for the management of MSW of expanding cities. For the efficient management of MSW, the dynamic change in the quantity and spatial distribution of MSW has to be updated regularly. As waste generation is a product of population, the trend in waste generation follows the growth and distribution of population, so it important to know the updated population. Newer methods for estimation of population in near real time are now available through advance in satellite remote sensing. Because of its synoptic view and multispectral characteristics, satellite imagery allows measurements related to population and the identification of its spatial concentration in an efficient manner. The technique is inexpensive, fast and accurate enough. The paper discusses a methodology for urban population and waste generation estimation for Rohtak city. The city was made up of two types of area- Rural and urban. The blocks of rural areas showed the negative error whereas blocks of urban area had shown the positive error.*

Keywords: *Geographical Information System, Housing Units, Population estimation, waste generation estimation.*

1. INTRODUCTION

Urban populations are experiencing a very rapid increase. Globally 54 per cent of the world's population was residing in urban areas in 2014. In 1950, 30 per cent of the world's population was urban, and by 2050, 66 per cent of the world's population is projected to be urban [2]. This rapid expansion of cities poses a challenge for the management of various services, including the management of solid waste. As waste generation is a product of population, so it is important to know the updated population. The method of population registration through conventional census is slow, expensive, and complex and thus is only conducted in most countries once every decade [3] [4]. Consequently, no accurate population information is available for the inter-census period. Accurate and current population information is of great interest in growing urban and suburban areas for such diverse purposes as urban planning, resource management, marketing analysis, service allocation, etc. Knowledge of the size and distribution of human population is also essential for understanding and responding to many social, political, economical and environmental problems. Newer methods for estimation of population in near real time are now available through advance in satellite remote sensing. Because of its synoptic view and multispectral characteristics, satellite imagery allows measurements related to population and the identification of its spatial concentration in an efficient manner. The technique is inexpensive, fast and accurate enough. The approach advocated in this paper is founded on the use of satellite imagery. Satellite imagery has been used with respect to population estimation. Google earth satellite images have been used to estimate the horizontal distribution of dwelling units (DUs) [5]. By identifying DUs, population of the Area of Interest (AOI) was estimated [1]. The solid waste generate in AOI can be calculated from the per capita waste generation volume.

2. STUDY AREA

Rohtak city lies between longitude $76^0$32'01.59" to $76^0$41'47.24" and Latitude $28^0$50'36.69" to $28^0$56'35.81" (Fig.1). It is located at 250 km south of the state capital Chandigarh and 70 km northwest of New Delhi, the national capital of India. It is one of the eight regional centers of National Capital region. The population of Rohtak city is 484,382 and it covers area of 139.4 Square Km. The city is divided into 488 blocks by the Municipal corporation of Rohtak (MCR).

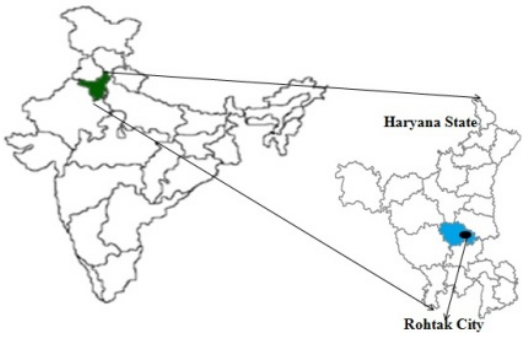

Fig. 1: Study area

3. MATERIALS AND METHODS

The methodology adopted has two parts-1. Estimation of number of DUs from high resolution remote sensing data and 2. Ground survey to obtain number of persons per DU, per capita waste generation, number of vertical DUs and percentage of occupancy of vertical DUs (Fig.2).

1. **Ground survey to obtain attribution data**- Two sets of sample blocks were selected for the survey. Set A Blocks with high economic status and set B Blocks for low economic status (Fig.3). Economic status of colony was differentiated on the basis of size of the plots, colony infrastructure, building structure and the type and number of vehicles. Ten representative colonies each, from both the classes were selected and ten housing units from each colony class were randomly selected for the first level sampling. For estimating persons per housing unit a questionnaire survey was conducted in the selected colonies and per capita waste generation was estimated through experimental setup in which waste was sampled from each housing unit for one month.
2. **Applied formula**-

$P_{VDU} = N_{VF}/H_{HU} \times 100$

$T_{DU} = HU + (P_{VDU} \times P_{ODU})$

$T_{WG} = T_{DU} \times P_{PDU} \times P_{CWG}$

P_{VDU} = Percentage of HU having vertical

Dwelling units.

N_{VF} = Number of vertical floors.

H_{HU} = Horizontal HU.

T_{DU} = Total number of Dwelling units.

HU = Housing Units.

P_{ODU} = Percentage of occupancy of vertical

Dwelling units.

T_{WG} = Total waste generation.

P_{PDU} = Persons per dwelling unit.

P_{CWG} = Per capita waste generation.

The value of N_{VF}, P_{ODU}, P_{PDU} and P_{CWG} was estimated by survey and H_{HU} from high resolution satellite imagery. In survey the HU with vertical flooring and its occupancy was randomly selected. In study area the mean value of vertical floors was 2. So in all blocks it was taken as constant. The product of P_{VDU} and P_{ODU} gave the number of 2nd floor. By the addition of number of 2nd floor and total number of HU, T_{DU} was identified. The value of P_{PDU} and P_{CWG} had different value on the bases of economic status (ES) of the blocks. For high ES the value estimated for P_{PDU} was 4 Person per HU and P_{CWG} was 0.5 Kg/day. In low ES the value of P_{PDU} was 5 Person Per HU and P_{CWG} was 0.49 Kg/day.

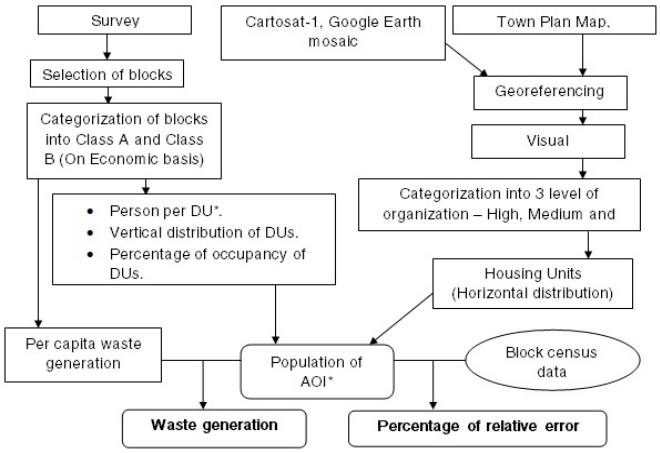

Fig. 2: General methodological flow chart.

*AOI- Area of Interest, *DU- Dwelling Units.

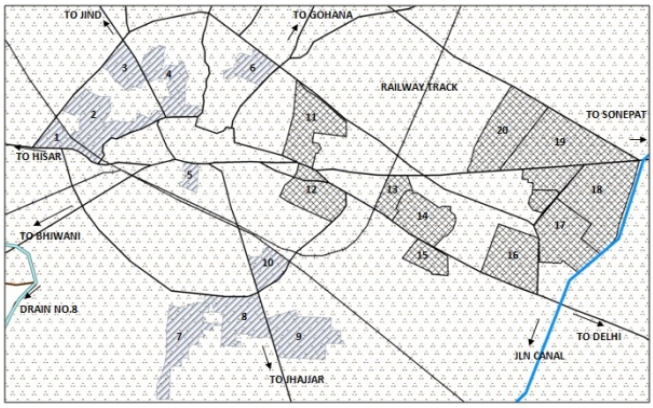

Fig. 3: Demarcation of class A (No.-1 to 10) and B (No.-11 to 20) colonies selected for sampling.

Legend- 1- Shyam Colony, 2- Indra Colony, 3- Nehru Colony, 4- Kabir Colony, 5- Dairy Mohalla, 6- Hanuman Colony, 7- Amrit Colony, 8- Vijay Nagar, 9- Ekta Colony, 10- Shivaji Colony, 11- Prem Nagar, 12- DLF Colony, 13- Subhash Colony, 14- Modal Town, 15- Dev Colony, 16- Sector-14, 17- Sector-1, 18- Sector-2, 19-Sector-3, 20- Sector-4.

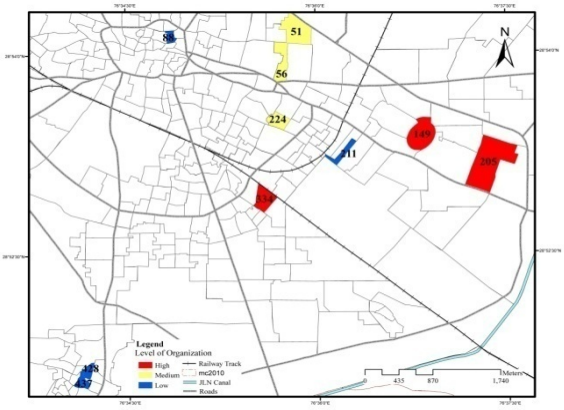

Fig. 4: Sampling sites for DUs estimation.

4. RESULTS AND DISCUSSIONS-

The number of HUs detected and identified from high resolution Remote Sensing (RS) data and the number of Hus counted in ground survey in the High, medium and Low HU organization given in Table.1. The relative error in High organized blocks ranges from -7 to +5. The corresponding range of relative error for medium and Low is +9 to +11 and -16 to +15 respectively. The results indicate that the identification of Hus is more accurate in the highly organized blocks due to regular arrangement of HUs, larger size of plots and space between demarking and more demarking space between HUs. In low organization blocks the accuracy of identification of HUs is less due to irregular distribution of the HUs, small size of the plots, irregular shape of the HUs, minimal buffering area of the HUs as well as irregular shape of the streets with narrow and dead ends, and roofs of the small houses are shaded by neighborly placed vertically high HUs.

Table 1: Housing units detected from high resolution satellite imagery .

Block No.	Organiz-ation Level	Housing Units counted	Housing unit surveyed	Relative Error %
334	High	288	279	+9
149	High	345	352	-7
205	High	491	486	+5
224	Medium	204	194	+10
56	Medium	416	407	+9
51	Medium	447	436	+11
88	Low	276	292	-16
211	Low	311	327	-16
437	Low	324	309	+15
428	Low	212	201	+11

Through High resolution RS data the horizontal distribution of HUs can be measured with fair amount of accuracy. However in order to calculate the population of the block additional attribution data of the HUs is required, such as vertical distribution of DUs, occupancy of DUs and Persons per DUs has to be done by ground truthing survey to obtain the additional properties of the horizontal HUs identified [6][7]. Taken into account percentage 2nd floor of the HU and percentage of 2nd floor occupancy is given in Table.2.

Table 2: Total number of DU estimated by survey.

Block No.	% of 2nd floor	% of 2nd floor occupancy	Economic Class	Housing Units	No. of 2nd floor	No. of 2nd floor occupied	Total No. of DUs
334	95	100	High	288	274	274	562
149	85	40	High	345	293	117	462
205	80	50	High	491	393	196	687
224	95	30	High	204	194	58	267
56	80	45	High	416	333	150	566
51	75	60	High	447	335	201	648
88	60	90	Low	276	166	149	425
211	50	95	Low	311	156	148	459
437	10	0	Low	324	32	0	324
428	5	0	Low	212	10.6	0	212

The waste generation in each block presented in Table.3. As high resolution satellite imageries interpretation gives only horizontal survey for vertical DU was conducted to arrive at the total number of DUs in each block. Population of each block was calculated from the person per DU and the solid waste generated was calculated from the per capita waste generation. The data is presented in Table. 3. In order to validate the accuracy of the method the population calculated through the identification of HUs from remote sensing data and total DUs from the field survey was compared with the census population in each block. The relative error in all the blocks sampled was from +1.17 to +16.9 most of the percentage of relative except block number 437 and 428 have positive values indicating in overestimation of the population. However this positive error may be due to time difference between the census data and time of performing this experiment which may be due to increase in number of HU/DU during this period.

Table.3 Total waste generation by the blocks.

Block No.	Per capita waste generation (Kg/day)	Total No. of DUs	Estimates population (EP)	Census population (CP)	Relative error %	Waste generation of EP (Kg/day)
334	0.5	562	2248	2084	+8.9	1124
149	0.5	462	1842	1510	+22	921
205	0.5	687	2748	2350	+16.9	1374
224	0.5	267	1048	1020	+2.75	524
56	0.5	566	2264	2190	+3.38	1132
51	0.5	648	2592	2562	+1.17	1296
88	0.49	425	2127	1865	+14.05	1042
211	0.49	459	2643	2262	+16.84	1295
437	0.49	324	1620	698	-132	794
428	0.49	212	1210	484	-150	593
Total			20342	17025	+19.5	10095

Negative value of blocks number 437 and 428 are on city parameter in the villages are due to very low percentage of occupancy of the HU. As many of the identified HUs were used for storing of the hay, stable for cattle's and tractor sheds.

5. CONCLUSION

The counting of housing units (HUs) for high resolution Remote Sensing Imagery is possible and gives accurate results. The estimation of population from the above counted DUs gives a negative error because the vertical distribution of floor of each HUs cannot be estimated through this technique. The number of stories, number of person per housing units, occupancy of HU can only be estimated through field survey.

Addition of field survey data results in a better estimation of the population and a positive error. Housing unit can be identified more accurately in High organized colony as compared to medium and low and error being greatest in lowly organized colony. Positive error which denotes an over estimation is better than a negative error for the better waste management practice. In the present study the accuracy of estimation of amount of solid waste generated per block is proportional to the accuracy with which the population of the block can be estimated.

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