Assessment of Population at Hazard Risk in India using LandScan Global Population Dataset 2008

Tarun Prakash Meena; Research Scholar, PhD Geography, Jawaharlal Nehru University, New Delhi

Vikas Khatik; Research Scholar, PhD Geography, Jawaharlal Nehru University, New Delhi

Abstract

'History' of geography has witnessed that no area is immune to Natural Hazard and Disaster. But increasing interference of anthropogenic activities have increased the frequency and magnitude of these hazards. Hazards turns into disasters not only due to change in global climate but also due to increasing population pressure on land and lack of knowledge related to their spatial location. Thereby, study focuses on how effectively one can recognize the spatial location, its impact and awareness about it, which can be utilize as an alternative to reduce the impact and adversity of hazards. Case study on Delhi depicts that at present there are 16 million persons residing in Delhi NCT out of which 1.4 million persons are living in those areas which are highly prone to flood i.e. 11.64 percent of total population. And the situation is going to be worse with more in-migration. This study using Remote Sensing and Geographic Information System (GIS) methods extract information regarding the spatiality of population spread in vulnerable zones to hazards. Away from the tradition, in place of census data, which is not available in a continuos pattern, LandScan data (2008) of Oak Ridge National Laboratory's (ORNL) have been used to cover the minimum variation for estimating the population of an area, where area is a pixel of 1x1 km. Case study covers three very different regions which are; coastal regions of India, flood plains of Bihar and Delhi. With the help of SRTM data contour line of 20 metres have been used as a landmark for the vulnerability to sea level rise. Whole population residing below this height have been demarcated as vulnerable in coastal regions of India. To estimate the flood prone population hazard year's images provided by NRSC (RadarSat 2) have been used to assess the population affected by change in course of river in Bihar and Delhi. Result of this study reveals that the LandScan data can be used effectively for further studies, as estimated figures does not show much variation from census figures (only 4 persons per square Kilometre). Data is greatly useful for effective rescue exercise in hazard conditions as exact population of a small area is easy to get.

Key Words: Population, Risk, LandScan, Sea level change, flood.

1. Introduction

Increasing population and in turn increasing natural hazards have compelled the policy makers and researchers to find out the effective ways to mitigate the adverse impacts of hazards. Today the Population growth and climate change is experiencing rapid change which leads to receiving increasing attention, not only from the scientists but also from policy makers. They are growing in area, population and at the same time they are acquiring a new character as their people perform new tasks in the physical environment, that increasingly reflect the use of new technology (Allefsen 1962).[1] As research progresses, it is becoming clear that large-scale changes of the global climate system would seriously affect large numbers of people in various ways. Fundamental for the estimation of the extent of such impacts is population forecasts and predictions of changes in human habitation patterns. Demographic changes are also of prime concern for studies of human impacts on their local environments. The impact of large-scale climatic changes on humans (Sea level Change) and the impact of humans on the local and regional hydrology (Flood). Population changes, including the spatial distribution of people, are therefore essential for assessments of future water resources, in addition to climatic and hydrological parameters (Magnus Bengtsson, Yanjun Shen, Taikan Oki, 2006).[2]

India's average population density is of 382 people per square kilometre as. On an average, 57 more people inhibit every square kilometre in the country as compared to a decade ago (Census of India, 2011).[3] Population maps have a long history, but the recent development of powerful computers and softwares in combination with the increasing availability of various kinds of remote sensing data has led to a growing research activity in this area. In the last few decades several efforts to generate grid maps of population have thus been seen.

The world's populations are not evenly distributed, nor are the risks and hazards to which they are exposed. The World Bank produced a set of maps ("Hotspots" maps) that spatially delimit the populations of the world that are at risk from selected natural hazards such as cyclones/or tornadoes, earthquakes, floods, drought, volcanoes, and landslides (Dilley 2005).[4] These maps use LandScan to calculate disaster risk at the subnational level in order to contribute to development planning and disaster prevention. Some populations are at risk from more than one of these hazards, so their overall exposure to natural hazards is additive. This type of a vulnerability analysis requires the existence of subnational population attribute data and hazard data for each area of interest,

[1] Allefsen, R.A. (1962). City hinterland relationship in India. University of California Press.
[2] Magnus Bengtsson, Yanjun Shen, Taikan Oki; (2006), SRES-based gridded global population dataset for 1990-2100, Population and Environment, Vol. 28, No. 2 (Nov., 2006), pp. 113-131
[3] censusindia.gov.in (accessed on 02 April 2011).
[4] Dilley, M., R.S. Chen, U. Deichmann, A.L. Lerner-Lam, and M. Arnold, 2005. Natural Disaster Hotspots: A Global Risk Analysis. Washington, D.C.: The World Bank, 145 pp.

whether at a county level (Cutter 2006)[5], city level (Pelling 2003), or for a small island nation (Pelling and Uitto 2002)[6].

1.1 LandScan Data

On the global scale, Dobson, Bright, Coleman, Durfee, and Worley (2000) developed a global population dataset in 30 arc-seconds resolution (LandScan). The LandScan dataset is made by a model, which distributes sub national census data to grids by using various remote sensing data. In recent years it has been found that remote sensing is a cost effective, technologically sound and an increasingly used technique for the analysis of population growth (Yeh and Li 2001).[7] LandScan was developed in 1997 at ORNL, with the explicit intention of modeling populations at risk (Dobson 2007).[8] LandScan starts with subnational population estimates provided by the Population Division of the U.S. Census Bureau and then uses ancillary data sources such as *elevation, slope*, *land cover*, *and road networks* to reallocate persons within administrative areas (Dobson 2003)[9]. LandScan is an explicit model to measure population at an individual "average" or ambient location. LandScan has utility in helping estimate populations at risk, and improvements in the program could improve its utility further. Census is the procedure of systematically acquiring and recording information about the members of a given population. It is a regularly occurring and official count of a particular population. Census provides the information about their households, social, economic status as well as the total population is counted and statistics related to individuals are collected. The decennial census of India is the primary source of information about the demographic characteristics of the population of India. LandScan is grids, they are not geographic features, and have to be used with this understanding when dealing with specific locations in space such as a village or town. Further, the only aspect of population captured by these approaches is total population size. ***No other demographic information can be obtained from this source*** such as age, gender, or race or ethnicity.

Statement of problem

Census provides data on the basis of administrative boundaries and that too over a decade period. Continuos data over time and space is not available. For mitigating the impact of natural hazards, spatial variation of population at risk is needed to be assessed. In light of above problem, attention is being directed to the mapping and assessment of vulnerable population using remote sensing and GIS techniques. With the help of LandScan data it is easy to identify spatial changes of population which have occurred over the space. This study attempts to evaluate the relevance of raster population datasets in the events of natural hazards. Since,

[5] Cutter, S.L., and C.T. Emrich, 2006. Moral hazard, social catastrophe: The changing face of vulnerability along the hurricane coasts. Annals of the American Academy of Political and Social Science 604:102-112.
[6] Pelling, M., and J. Uitto, 2002. Small island developing states: Natural disaster vulnerability and global change. Environmental Hazards 3:49-62.
[7] Yeh, A. G. O., & Li, X. (2001). Measurement and monitoring of urban sprawl in a rapidly growing region using entropy. Photogrammetric Engineering and Remote Sensing, 67, 83–90.
[8] Dobson, J. E., E. A. Bright, P. R. Coleman, and B.L. Bhaduri. "LandScan: a global population database for estimating populations at risk." Remotely Sensed Cities Ed. V. Mesev, London: Taylor & Francis. 2003. 267-281.
[9] Dobson, J.E., E.A. Bright, P.R. Coleman, and B.L. Bhaduri, 2003. LandScan2000: A new global population geography. In V. Mesev (ed.), Remotely Sensed Cities. London: Taylor & Francis, pp. 267-279.

there is hardly any study on India, so evaluation of raster population data is first attempted at various levels, namely state, districts and wards. Further, population living in risk prone areas (Population at Risk) not only coastal areas which are exposed to sea level rise but also flood plains in great plains region of India have been taken.

2. Objective:

The major objective of this study is to assess population at hazard risk by using LandScan data in coastal zone of India and interior flood plains of Bihar and NCT of Delhi.

3. Database:

The study is mainly based on secondary data information and facts available from different sources. The major required sources are as follows:

- Census of India, district census handbook, and Census provisional results* for various census years (2001, 2011*).
- The satellite data of Delhi 08.03.1977 (Landsat MSS), 22.10.1999 (Landsat ETM+), 10.10.2006 (IRS p6 LiSS III); Calcutta 22.02 1973 (Landsat MSS), 17.11.2000 (Landsat ETM+), 24.02. 2006 (IRS P6 LiSS III); Mumbai 09.01.1973 (Landsat MSS), 25.10.2001 (Landsat ETM+); and Chennai 28.10.2000 (Landsat ETM+), 07.02.2006 (Landsat TM) from Earth Science Data Interface at the Global Land Cover Facility (GLCF) and Digital elevation model dataset will be from U.S. Geological Survey‘s (USGS) Earth Resources Observation System (EROS) Data Center.
- NRSC (National Remote Sensing Center, RadarSat 2, August 2008).
- DEM: Digital Elevation Modal: from Shuttle Radar Topography Mission (SRTM).
- LandScan and Geospatial data: Global Population Database by ORNL Technology of LandScan (2008).

4. Methodology:

This study is based on quantitative and qualitative data collection, for which various statistical and visualisation techniques have been used-

- To make the comparisons possible, population datasets were adjusted to the same year calculating Exponential Growth Rate (2008) meters spatial resolution. E*xponential growth rate* method has been used to estimate population for each state for the year 2008, by census of India 2001 data;

  Exponential Growth Rate: $\boldsymbol{x_t = x_0(1 + r)^t}$

  x_0 is the value of x at time 0. For example, with a growth rate of r = 5% = 0.05, going from *any* integer value of time to the next integer causes x at the second time to be 1.05 times (i.e., 5% larger than) what it was at the previous time.

- LandScan data are numerical population estimates per cell, and cell size changes with latitude. The formula for calculating the area (in sq km) of each LandScan cell is:

Calculating Population Density: **Area = R^2 (sin (lat2)-sin (lat1)) * DeltaLong**

Where: *R* = Radius of the earth in Kilometers; *lat2* = Upper Latitude in radians (radians = decimal degrees * π/180); *lat1* = Lower Latitude in radians; *deltaLon*g = Longitudinal width of cell in radians. *To calculate density, simply divide each cell value by the resulting cell area.* [10]

- The various districts along with the coastal boundary of India have been mosaic for the purpose of population estimation in these districts using LandScan data. Further this data have been imposed on SRTM data for the purpose of risk estimation along the coast for the population living in these regions. on the basis of SRTM data contour line at the interval of 10 meters were demarcated for coastal regions of India. On the basis of avalible literature and estimation, 20 meter contour line have been used as risk line for estimating vulnerable population towards sea level rise.

5. Results and Discussion

Initially there is need to look at the reliability of LandScan data over the available census data. Comparision depicts the fact that majority of the area is showing LandScan population estimation to be lower than census population[11]. There are only 4 People per 1×1 Kilometre grid square difference between Census and LandScan. The Percentage difference between census population and LandScan Population is just -1.09%. Figure 1 portray that at the state level difference is very less or almost nil, between Census population and LandScan Counts except West Bengal and Bihar. An in-depth observation at district level depicts a very perceptible fact that in all the coastal districts population estimated by LandScan is less than the census population. This pattern is opposite to the pattern which has been observed in Megacities where LandScan. Population estimation is more than the census population. There are variations within districts in terms of the difference between two measures of population. Overall the difference between two population measures is very minute, thereby this study have further used Landscan data for assessing the risks and burden of Sea Level change and for assessing the vulnerable population at flood risk in Bihar and Delhi.

---

[10] Dobson, J. E., E. A. Bright, P. R. Coleman, R.C. Durfee, B. A. Worley. 2000. "LandScan: A Global Population Database for Estimating Populations at Risk," Photogrammetric Engineering & Remote Sensing (inc. front cover of journal) 66(7):849-857.

[11] Bhaduri, Budhendra et el. 2007. Urban, LandScan USA: a high-resolution geospatial and temporal modelling approach for population distribution and dynamics. GeoJournal (2007) 69:pp. 103–117.

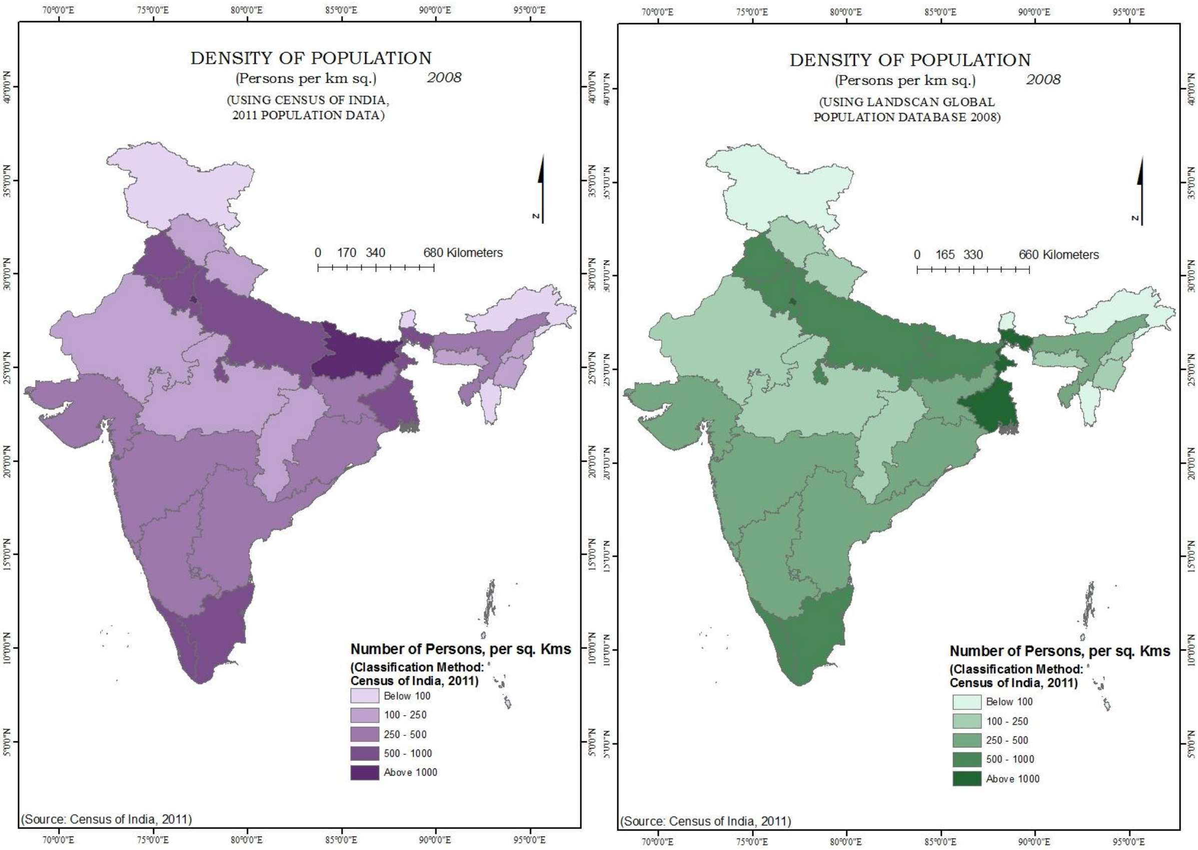

Figure 1:

1) Census of India, 2011 population data: Density of Population in India, 2008
2) LandScan population database 2008: Density of Population in India, 2008

5.2 Vulnerability Assessment

Mean sea level is rising along the Indian coast. Among these states, the estimates for coastal states Maharashtra, Kerala, and Orissa showed a sea level rise of 0.78, 1.14 and 0.75 mm/year respectively, whereas the estimate for Tamilnadu showed a decrease in sea level (– 0.65 mm/year). The present estimates do not significantly differ from those in the earlier study, except for Tamil Nadu.[12]

Vulnerability of Indian Coastal Region to damage from Sea Level Rise: One indicator of vulnerability of a coastal region to inundation is the topographic slop. The slop is generally high in central western coast. The east coast slopes are usually smaller than those on the west coast.

According to the IPCC, even the best-case scenarios indicate that a rising sea level would have a wide range of impacts on coastal environments and infrastructure. Effects are likely to include coastal erosion, wetland and coastal plain flooding, salinization of aquifers and soils, and a loss of habitats for fish, birds, and other wildlife and plants[13]. The Environmental Protection Agency estimates that 26,000 square kilometers of land would be

---

[12] Emery, K. O. and Aubrey, D. G., Tide gauges of India. *J. Coast.Res.*, 1989, **5(3)**, 489–501.

[13] IPCC, 2007: Climate Change 2007: Impacts, Adaptation, and Vulnerability . Contribution of Working group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

lost should sea level rise by 0.66 meters, while the IPCC notes that as much as 33% of coastal land and wetland habitats are likely to be lost in the next hundred years if the level of the ocean continues to rise at its present rate. Even more land would be lost if the increase is significantly greater, and this is quite possible. As a result, very large numbers of wetland and swamp species are likely at serious risk.

Population at Risk due to Sea Level Rise shows that at the application point of view, as if the sea level around Indian coastal region is increased by 20 meter the affected population will be 30 million, out of total population 488 million which is 6.35 percent of total population living in coastal region of India. Regional Variation is also there in the Population at risk due to sea level rise which can be seen in table 1.

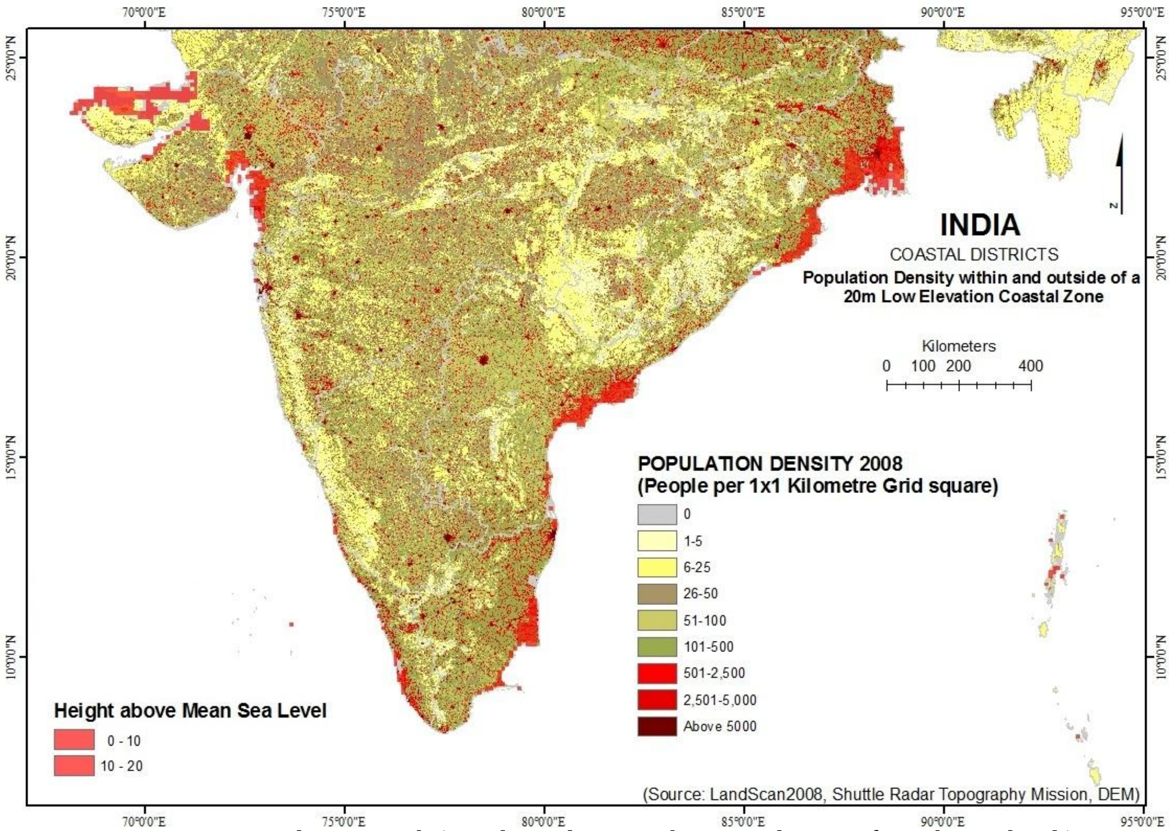

Figure No.4 : Population at risk (Population living within 20m elevation from the sea level.)

Table No. 1 Population at Risk : Sea level Rise upto 20 meters

Sea level Rise (20 meters)	*Population at Risk*	*State Population*	*Percentage Share of State*
Gujarat	4037192	50596992	7.98
Maharashtra	227199	96752247	0.23
Goa	0	1343998	0.00
Karnataka	177827	52733958	0.34
Kerala	4124243	31838619	12.95
Tamil Nadu	1403867	62110839	2.26
Andhra Pradesh	3400794	75727541	4.49
Orissa	1617383	36706920	4.41
West Bengal	15993835	80221171	19.94
Coastal India	**30982340**	**488032285**	**6.35**

West Bengal is the worst affected state due to sea level rise because of its low delta plains of Hooghly. With the rise in sea level by 20 meters 19.94 percent of population of west Bengal living in these areas will displace. Kerala and Gujarat are the most affected states after West Bengal with the population affected of 12.95 and 7.98 respectively. Goa, Maharashtra and Karnataka are the least affected states with change in sea level with a smallest amount of population share 0.00, 0.23, 0.34 respectively.

Case Study on Bihar- In India, the monsoon season generally lasts from June to September. According to Government of India, Ministry of Home Affairs's disaster management unit, countrywide death toll from floods in various state was 2,404 between June to September in 2008. Flood in Bihar in the same year was one of the most disastrous floods in the history of Bihar, an impoverished and densely populated state in India. A *breach* in the *Kosi embankment* near the Indo-Nepal border (at Kusha in Nepal) occurred on 18 August 2008. The river changed course and inundated areas which hadn't experienced floods in many decades. The flood affected over 2.3 million people in the northern part of Bihar. Flooding occurred throughout the Kosi River valley in northern Bihar, in the districts of Supaul, Araria, Purunia, and Madhepura,. The southeast Tarai ecoregion of Nepal was also affected. The flood killed 250 people and forced nearly 1253714 people from their homes in Bihar. More than 300,000 houses were destroyed and at least 340,000 hectares (840,000 acres) of crops were damaged. Villagers in Bihar ate raw rice and flour mixed with polluted water. Hunger and disease were widespread. The Supaul district was the worst-hit; surging waters swamped 1,000 square kilometres (247,000 acres) of farmlands, destroying crops.

Table No. 3 Population at Risk : Kosi Flood 2008

District	*Population at Risk*	*Population 2001*	*Percentage Share of District*
Supaul	350976	1745069	20.11
Araria	274237	2124831	12.91
Purnia	85364	25,40,788	3.36
Madhepura	543137	15,24,596	35.62
Kosi affected District	***1253714***	***7935284***	15.80

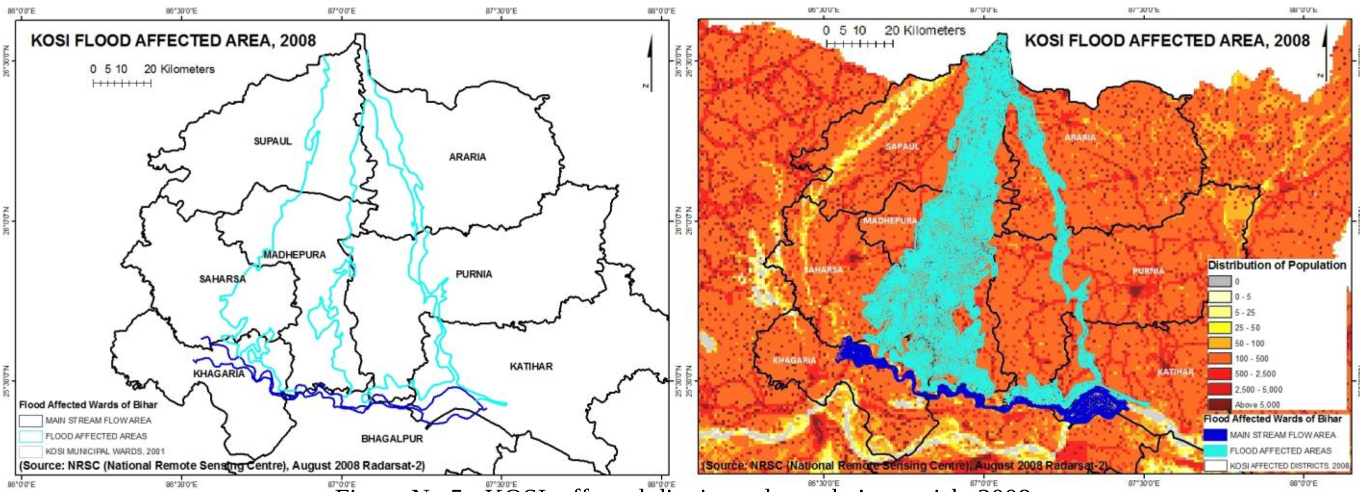

Figure No.5 : KOSI, affected district and population at risk, 2008

Population Risk Assessment using LandScan 2008 data shows that the affected population due to flood breach in the Kosi embankment near the Indo-Nepal border is about ***1.4 million** (Using LandScan 2008)* in 5 districts of north Bihar Supaul, Madhepura, Araria, Khegaria are four most affected districts including more than 50 percent of district area as well as population. Overall, more than 1.4 million people in 13 districts of Bihar are flood affected. More than 225,000 houses have been destroyed.[14] Thereby, on the basis of LandScan estimation, population at the risk of flood can be spatially located and this prediction can lead to mitigation of adverse impacts. Sorrow of Bihar 'Kosi river' every years this region experience flood still in 2008 it is because of sudden breach a large number of persons got affected. Flood affected four districts in which 1.2 million people got affected which is 15.80 percent of the population living in these four districts which is estimated on the basis of LandScan dataset 2008.

Case study on Delhi - When the Flood occurs in Yamuna river, water level in surrounding region increased by several meters and affected the population in Delhi in 2010. On the basis of estimation by LandScan data 2008 affected population by increased water level was 1.73 lakh out of total population of 1.4 million, which is 11.64 percent of total population living in Flood Plain area of Yamuna in Delhi.

With in Delhi a ward level study reflects regional variation with in wards. Ward number 71 was the most affected state because of its low elevation. Total affected population is 48.46 percent of total population of this ward. Ward number 75, 94, 102 and 104 were most affected wards after Ward number 71 with the population affected of 22.21, 15.90, 14.50 and 13.26 respectively. Ward no. 115 and 65 is the least affected of flood in the year 2010 with only 0.12 and 0.98 percent of their population. Ward number 74, 2 , 91 and 7 were other affected wards with the rise in water level with a small amount of population share 9.09, 6.76, 6.73 and 5.60 respectively.

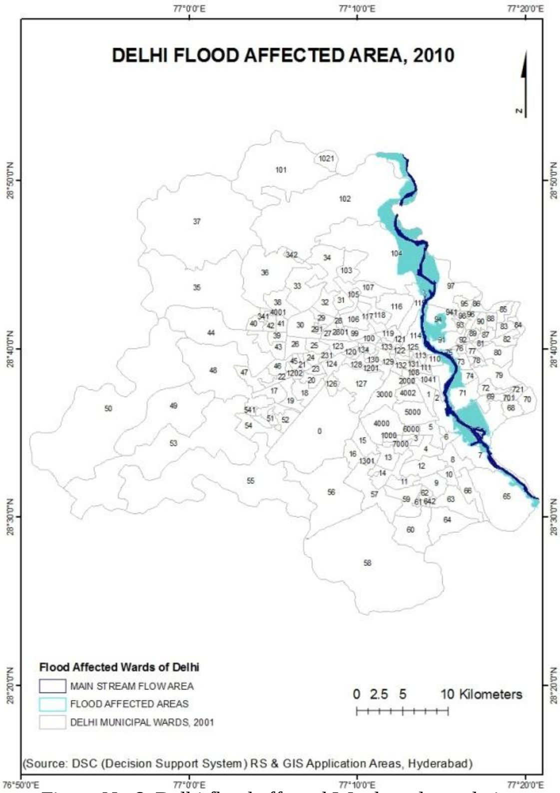

Figure No.6 :Delhi flood affected Wards and population at risk, 2010

Table No. 4 Population at Risk : Delhi Flood 2010

Delhi Ward No.	Population at Risk	Population 2001	Percentage Share of Wards
2	9629	142413	6.76
7	11404	203492	5.60
65	1682	170792	0.98
71	58577	120882	48.46
74	13225	145540	9.09
75	21570	97127	22.21
91	10403	154666	6.73
94	23102	145276	15.90
102	5964	41120	14.50
104	17704	133526	13.26
115	164	135222	0.12

[14] Indian Meteorological Department (IMD), UNICEF- "Situation Report Bihar Floods 2008 Overall Situation Flood Forecast"

Delhi	**173424**	**1490056**	**11.64**

The study began with an overview of the data required to prepare estimates of populations at risk. Since it is impossible to know in advance what events people might confront, the estimates for planning purposes need to be spatially explicit and sufficiently detailed in demographic terms so that they have broad applicability to a number of emergencies. Ideally, population registries would be universally accessible as sources of data at all geographic levels. In reality, censuses of population tend to be the best single source of data because they maximize the geographic coverage of populations and typically have enough detailed characteristics about each person in each household to permit the calculation of estimates of vulnerability. In theory, censuses are also ideal geographically because each household's location had to be known to the statistical agency undertaking the census, so the characteristics of people should be capable of being spatially identified with considerable precision. In practice, the exact location may not be recorded and so is lost immediately after the data are collected; even if the location is known, it may not be converted to a digital format that can be mapped easily. Therefore, the real issue is not the collection of data per se, but rather what happens to the data after being collected. Census and other data about households and individuals need to be georeferenced (with proper privacy safeguards), linked to accurate maps, and then analyzed by individuals with the appropriate training to undertake tasks.

A major shortcoming of census data (and most population registers as well) is that they are universally collected at places of residence, yet people are often at risk outside of their home. There is no simple answer to this dilemma of estimating the "daytime" populations (assuming that being away from homes is essentially a daytime activity), but modeling based on the results of survey data about out-of-home activities is the most common approach. Most other problems in creating estimates of the population at risk are related to the fact that censuses are not conducted everywhere on a regular basis, and even where they are conducted, the national statistical agency may not have the resources to provide data at a local level, to prepare local-level maps coinciding with the census geography. To work around some of these issues, global population databases such as LandScan were developed to create population "surfaces" for the globe, but at the moment they lack the breadth of demographic characteristics that would allow users to create estimates of vulnerability beyond population counts and density in a given area.

6. Conclusion:

This study makes use of a derived population distribution dataset to draw inferences about the distribution of local population density. Results comes out with a suggestion that applying a population density threshold to this distribution can provide an indicator of population pressure on the land that is traditionally measured with more comparability across regions. In the meantime, our ''People and Pixels''[15] approach can take advantage of current remote sensing data, particularly if the data and tools are made widely available and a research community develops around their use.

[15] Dobson, J.E., E.A. Bright, P.R. Coleman, and B.L. Bhaduri, 2003. LandScan2000: A new global population geography. In V. Mesev (ed.), Remotely Sensed Cities. London: Taylor & Francis, pp. 267-279.

Detailed and contemporary spatial population data are valuable for assessing the risks and burden of Sea Level change, for planning humanitarian assistance, resource allocation, or public health strategies. The construction of a detailed population database for India has been attempted here using LandScan and Census data. Losses due to natural and man-made disasters will continue to increase because of our continuing population growth and the increase of the concentration of growth in risk prone areas such as coastal regions, flood plains. On an average more than 1000 people died every year due to floods in India. As in 2008 Kosi flood hit four districts of Bihar about 1.2 million people got affected (15.80 %) in four districts. In 2010 Delhi, along Yamuna river floodplain about 11 municipal wards were affected. Thus, LandScan estimates are useful enough to locate and estimate the persons under risk of flood as well as due to change in sea level. Sea level rise is a great threat to the *30.9 million people of India*, who are projected to be environmental refugees if the sea level rises to the level of 20m above of now. Out of nine coastal states there are five most risk prone, thus about 6 percent population might be affected with this change. It is threatening to the basic human right of large number of population. Based on above it can be said that LandScan is comparatively more accurate and reliable, geographically based, time-of-day population distribution model and databases which allows quick and easy assessment, estimation and visualization of population at risk with a high resolution population distributions datasets. It can act as critical component of emergency planning and management, rapid risk assessment, evacuation planning, consequence assessment, mitigation planning and implementation.

7. References:

Allefsen, R.A. (1962). City hinterland relationship in India. University of California Press.

Bhaduri, Budhendra et el. 2007. Urban, LandScan USA: a high-resolution geospatial and temporal modelling approach for population distribution and dynamics. GeoJournal (2007) 69:pp. 103–117.

Catherine Linard, Victor A Alegan, Abdisalan M Noor, Robert W Snow, Andrew J Tatem;(2010); A high resolution spatial population database of Somalia for disease risk mapping; Linard et al. International Journal of Health Geographics 2010, http://www.ij-healthgeographics.com/content/9/1/45

Clark, J.I. & Rhind, D.W. 1992. Population Data and Global Environmental Change. Paris, IISC/UNESCO.

Cutter, S.L., and C.T. Emrich, 2006. Moral hazard, social catastrophe: The changing face of vulnerability along the hurricane coasts. Annals of the American Academy of Political and Social Science 604:102-112.

Dilley, M., R.S. Chen, U. Deichmann, A.L. Lerner-Lam, and M. Arnold, 2005. Natural Disaster Hotspots: A Global Risk Analysis. Washington, D.C.: The World Bank, 145 pp.

Dobson, J. E., E. A. Bright, P. R. Coleman, and B.L. Bhaduri. "LandScan: a global population database for estimating populations at risk." Remotely Sensed Cities Ed. V. Mesev, London: Taylor & Francis. 2003. 267-281.

Dobson, J. E., E. A. Bright, P. R. Coleman, R.C. Durfee, B. A. Worley. 2000. “LandScan: A Global Population Database for Estimating Populations at Risk,” Photogrammetric Engineering & Remote Sensing (inc. front cover of journal) 66(7):849-857.

Dobson, J.E., E.A. Bright, P.R. Coleman, and B.L. Bhaduri, 2003. LandScan2000: A new global population geography. In V. Mesev (ed.), Remotely Sensed Cities. London: Taylor & Francis, pp. 267-279.

Dobson, J.E., E.A. Bright, P.R. Coleman, and B.L. Bhaduri, 2003. LandScan2000: A new global population geography. In V. Mesev (ed.), Remotely Sensed Cities. London: Taylor & Francis, pp. 267-279.

Emery, K. O. and Aubrey, D. G., Tide gauges of India. J. Coast.Res., 1989, 5(3), 489–501.

Indian Meteorological Department (IMD), UNICEF- "SITUATION REPORT BIHAR FLOODS 2008 OVERALL SITUATION FLOOD FORECAST"

IPCC, 2007: Climate Change 2007: Impacts, Adaptation, and Vulnerability . Contribution of Working group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

Jeffrey B. Tschirley, 2005, FAO; Mapping global urban and rural population distributions http://www.fao.org/docrep/009/a0310e/A0310E04.html.

Joshua Comenetz (2007); Tools and Methods for Estimating Populations at Risk from Natural Disasters and Complex Humanitarian Crises, U.S. Census Bureau

Lawrence A. Hoffman; (1948) India: Main Population Concentrations; The Geographical Journal, Vol. 111, No. 1/3 (Jan. - Mar., 1948), pp. 89-100.

Magnus Bengtsson, Yanjun Shen, Taikan Oki; (2006), SRES-based gridded global population dataset for 1990-2100, Population and Environment, Vol. 28, No. 2 (Nov., 2006), pp. 113-131

Pelling, M., and J. Uitto, 2002. Small island developing states: Natural disaster vulnerability and global change. Environmental Hazards 3:49-62.

Tobler, W., 1992. Preliminary representation of world population by spherical harmonics. Proceedings of the National Academy of Sciences 89:6262-6284.

Yeh, A. G. O., & Li, X. (2001). Measurement and monitoring of urban sprawl in a rapidly growing region using entropy. Photogrammetric Engineering and Remote Sensing, 67, 83–90. censusindia.gov.in (accessed on 02 April 2011).

*Census Provision Results released on 02 April 2011 (.pdf)