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Flood damage assessment of an urban area in Chennai, India, part I: methodology

S. Suriya · B. V. Mudgal · Prakash Nelliyat

Abstract Floods are random phenomena that not only cause damage to the lives, natural resources and the environment, but also affect the health of people. The severity of flooding tends to increase with urbanization. Socio-economic impacts of floods depend on the area, duration and depth of inundation, population density, housing typology, construction materials of dwellings, etc. This article examines the different available methods to trace the flood damage and illustrates the methodology to explore the economic loss through social investigation in Velachery, a part of urban Chennai in India. This paper is Part I of a two-part series in which the objectives and methodology are discussed. Based on the objectives and methodology developed for the study, a comprehensive flood management strategy can be proposed for the efficient management of future flood disasters. The results of the study are discussed in Part II.

Keywords Urban flood · Economic loss · Flood damage assessment

1 Introduction

Asia is struck by 70% of all floods in the world, and the average annual cost of floods over the past decade is approximately 15 billion USD in which the average annual infrastructure loss accounts approximately to 12 billion USD for the past decade (Hansson et al. 2008). Around the world, during the period of 1963–1992, it has been found that floods cause maximum damage when compared with other natural calamities (Dhar and Nandargi 2003). Floods are extreme hydrologic events, which are non-deterministic both in space and in time. Flood disasters result from the interaction between hydrologic, environmental, social and economic processes. 'Flood issues are influenced not only by the physical causes of flooding but also the overall social, economic and political setting of the area concerned'

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(WMO 2006). Different types of floods include riverine floods, coastal floods and urban floods. Coastal cities all over the world are vulnerable to urban flooding. Urbanization due to population growth, migration and industrialization often lead to unplanned changes in land use. Floods get magnified in urban areas due to the conversion of agricultural fields and water bodies to roads, parking lots and dwellings. This transformation from permeable area to impermeable area decreases the infiltration capacity of the soil and increases runoff to two to six times over and above what would occur on natural terrain. Floods not only have negative consequences but also have positive impacts such as recharge of water sources, enrichment of flood plains by carrying sediments rich in nutrients and rejuvenation of the riverine ecosystem. The negative impacts of flooding are loss of life and property, loss of livelihood, disruptions to clean water, transportation, communication and health care, mass migration, psychological effects and political implications. The severity of flood impact depends on the vulnerability of activities of the population and the frequency, intensity and extent of flooding.

Flooding cannot be avoided but their impacts can be mitigated. Flood damage assessment is an important part for mitigating, controlling and preventing flood problems, intervention and relief operations. 'Flood damages depend on the characteristics of flood event including the area covered, the depth and duration of flooding, the velocity of flood water, sediment content of the water, season of the occurrence and the nature of the development' (Soetanto and Proverbs 2004). Flood damages can be both tangible and intangible. The tangible damages can be further subdivided into direct and indirect damages. Direct damages result from direct contact of flood water with damageable property, and the extent of damage is assumed to be the cost of restoration of that property to its pre-flood condition or to its current market value if restoration is impracticable. Indirect damages are the losses caused by the disruption of physical and economic linkages including the loss of production, loss of income, loss of business and delays in transportation of goods. Intangible damages include fear, anxiety, annoyance, ill health and ultimate loss of life.

2 Literature review: methodologies adopted for damage analysis

Smith (1981) stated that data based on stage damage curve combined with hydrologic and land use information would help in estimating the flood losses. Joy (1993) assessed the cost of direct and indirect flood damages of New South Wales town of Nyngan by conducting property damage survey, public authority survey, survey of volunteer effort and survey of donated goods and money. A computer model 'FLDAMAGE' was used to estimate damage to all residential and commercial properties. Stage damage curves were also drawn based on the results of the survey.

Betts (2002) analyzed the flood damage using GIS. The property damage was calculated on a property-by-property basis, and the data were analyzed on suburb-by-suburb basis. Zhang et al. (2002) present the methodology and procedure for risk assessment and zoning of flood damage caused by heavy rainfall based on the 'macrozonation concept' in which regional macroinformation such as meteorological triggering factor, natural and socio-economic factors contributing to flood damage is considered. Mohit and Akther (2002) attempted to delineate the 1998 flood-affected city wards in Bangladesh into three flood damage zones based on composite damage value derived from five sectors of the city. A questionnaire was prepared for collecting wardwise damage data covering five sectors—housing, educational institutions, commerce, industry and roads. The extent of damage was

measured using percentage of units damaged and its monetary value in local currency. The sectoral damage maps were prepared. The monetary value of flood damage was calculated in these five sectors using Statistical Package for Social Science (SPSS). Three damage zones—low, moderate and high—were identified to help in several planning strategies.

Zhang et al. (2005) classified the disaster assessment into Pre-disaster assessment, Mid-disaster assessment (assessment belongs to predictive assessment) and Sith disaster assessment (assessment belongs to actual losses data). In order to determine flood control standard and disaster reduction measures in a given region, flood damage assessment model was used, which predicts possible economic losses (on the basis of inundation, water level of various schemes and combining them with social and economic information) resulting from flood with various frequencies. Kang et al. (2005) focus on the use of spatial data to capture spatial characteristics of damages during natural calamities. Stage damage curve was built for the residential sector in this study based on socio-economic data such as persons per household, building characteristics, living styles and common indoor decorations, furniture and appliances. This study demonstrates the use of geographic database and spatial analysis in regional flood damage assessments to capture spatial variations within the region. Huang et al. (2008) carried out a retrospective study in areas that suffered from floods during 2000 in China and explored the total economic loss, components of economic loss and factors influencing economic loss during flooding. The economic loss was calculated based on the property damage, income loss and increased medical cost. They found that the economic loss was significantly related to a family's pre-flood income, duration of the flood, severity of flood and type of flood.

The above literature review provides a broader overview about flood damage assessment studies carried out in different parts of the world. Most of the literature on flood damages concerns with direct tangible damage. Different authors use different methodologies to calculate the monetary value of flood loss, which are more appropriate in different geographic area considering land use, hydrologic and social conditions. The purposes of this paper were to present a simple methodology to assess the magnitude of flooding in the study area and to conduct a socio-economic impact analysis using questionnaire survey.

3 Study area description

The two rivers namely Adyar and Cooum divides the Chennai Metropolitan Area (CMA) into three parts, the northern part is above the Cooum river, middle region is between Cooum and Adyar rivers and southern portion is below Adyar river. The growth in infrastructure development, especially in southern part of Chennai including the Information Technology (IT) corridor and industries, may have had implications for the problem of flooding noticed in recent years. The drainage of storm water has been a real problem for many of the newly emerging habitations in this part of the city. The impacts of flooding on the growth of IT industry and sustainability of housing sector may be significant in the years to come.

Velachery, a rapidly growing region in southern CMA, is located between latitude $12°58'20''$N and longitude $80°13'35''$E. It is well connected by roads and metro railway network, MRTS (Mass Rapid Transit System). The lithology in Velachery is generally of hard rock type. Also, a large marshland known as Pallikaranai marsh is located in the southern region. The marshland plays a major role in absorbing the flood waters. Rapid urbanization along with encroachment and real estate development boom has affected the water bodies in the region. Almost every year, Velachery is flooded due to cyclonic rains.

Flood waters from Velachery eventually flow into the Pallikaranai marsh through the culverts on the Velachery main road. The capacity of the culvert and storm water drain that connects the Velachery tank and Pallikaranai marsh is not sufficient to drain the flood water quickly; as a result, the entire area is inundated for several days. It is experienced that the flooding is severe as observed during the floods of 2002, 2005 and 2008. In the present study, the flood of December 2005, which corresponds to a rainfall return period of 100 years, is chosen.

4 Materials and Methods

Figure 2 represents the overall methodology followed in the study. The methodology consists of

– Problem identification tasks comprising

  • Focus Group Discussion
  • Stakeholder meeting
  • Questionnaire Survey

– Dataset preparation
– Flood damage assessment

4.1 Problem identification tasks

4.1.1 Focus Group Discussion (FGD)

'The hallmark of focus groups is the explicit use of the group interaction to produce data and insights that would be less accessible without the interaction found in a group' (Morgan 1988). FGD technique is a tool for studying ideas in group context. The optimal size of the group is 6–8 respondents. It is a carefully planned discussion designed to obtain perceptions on a defined area of interest in order to solve a problem. They can produce a lot of information quickly at a relatively less cost than individual interviews. They can indicate the range of beliefs, ideas or opinions in a community.

4.1.2 Stakeholder meeting

The purpose of the stakeholder meeting is to deliberate on the current situation in the field, to identify the problems and areas that require attention. According to WMO (2006), the objectives of stakeholder participation are to

  • Provide all stakeholders, including the public, with full opportunities to share their views and influence the outcome
  • Build consensus and public support for the outcomes
  • Build stakeholders commitment
  • Ensure sustainability of plans and associated decisions

Flood-prone communities in the study area are selected as stakeholders. The perception of risks by stakeholder differs significantly depending on their experience and knowledge.

Stakeholders' meeting was conducted in order to cross-check the information collected and also to record their suggestions about flood mitigation measures.

4.1.3 Questionnaire Survey (QS)

Questionnaire is a collection of questions in a written form. It can be subdivided into two types: (a) closed end and (b) open end. Closed-end questions limit respondent's answers to the survey. They can be answered in a single word or a short phrase, i.e., the respondents are allowed to choose from a pre-existing set of dichotomous answers such as yes/no, true/false or multiple choice with an option or ranking scale response options. The main advantage of closed-end questions is that they are more specific and can be easily analyzed. In open-ended questions, the answers are not pre-determined and fixed; they are left to the choice of the respondent. In our survey, closed-end questions are used.

A questionnaire survey is prepared for collecting damage data covering four aspects—general information, information about flood, flood damage assessment and flood management. In the general information, the demographic details, annual income and housing typology were collected. Cause of flooding, problems faced by people due to flooding, outflows of flood water, water stagnation period and area of inundation in their house were the information collected pertaining to flooding. Information on property damage and the recovery cost, daily wage loss and the additional amount spent during flooding was collected to assess the flood damage. For flood management, coping strategy, measures taken by them to limit future flood loss and their suggestions to minimize the effect of flooding were collected. For urban floods, streetwise damage data were collected. One household in each street was identified for Questionnaire Survey, and a total of 54 streets (and households) were surveyed in East Velachery. Every 5th house on one side of the street is chosen for the survey. This technique is called systematic sampling technique, and this procedure is used because the sampling frame is available in the form of streets. The format used for questionnaire survey conducted is given in Appendix 1.

4.2 Dataset preparation

A reconnaissance survey is carried out to gather preliminary information about the flood-affected areas of Velachery. The information about areas prone to inundation in Velachery is collected from the Chennai City Corporation Office. It is found that the areas south of the Velachery Lake namely West Velachery (A in Fig. 1) and Velachery—Taramani Road namely East Velachery (B in Fig. 2)—were badly affected due to floods. There are about 54 streets in East Velachery that were inundated due to floods. All the 54 streets are taken into consideration for the Questionnaire Survey. In order to handle and analyze the huge volume of spatial and non-spatial data, GIS (geographic information system)-based software applications were used. The QuickBird Imagery of the study area was digitized and the contour map of the study area was overlaid. Non-source flood ('Non-source flood corresponds to the case with well-distributed and large-area rainfall where all the low-lying land may have a flood disaster, and in this case all the points with elevations below the given water level should be included in the flood area' (Renyi and Nan 2002)) caused by a well-distributed rainstorm in large area where all low-lying lands may have a flood disaster is considered for determining flood spread area. The information about flood spread area is collected from Questionnaire Survey.
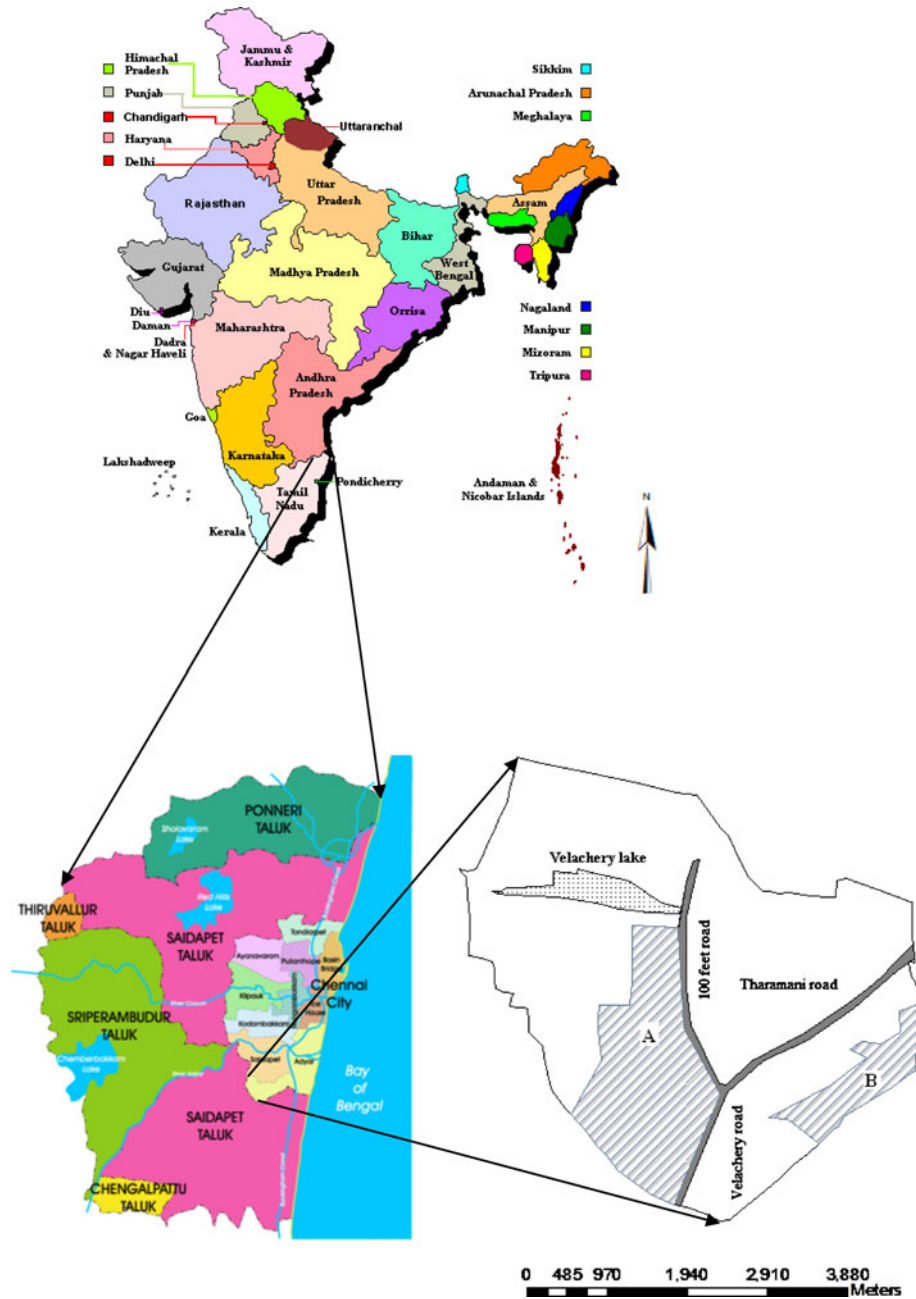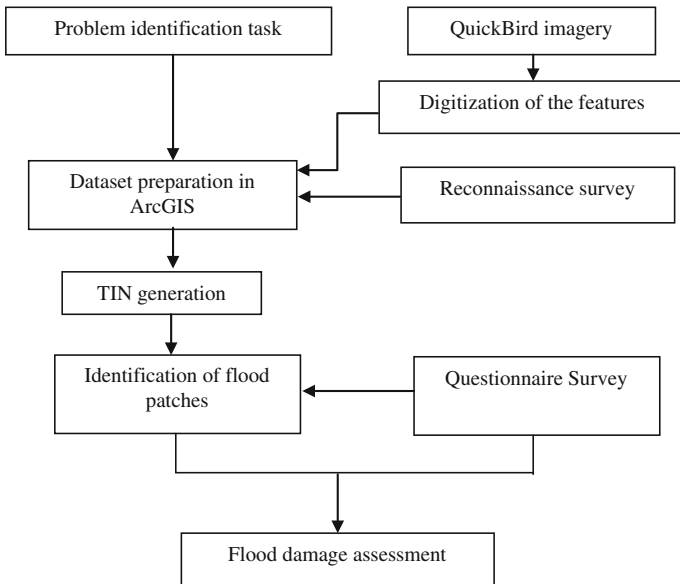
Fig. 1 Study area map

4.3 Flood damage assessment

Triangulated Irregular Network (TIN), a vector-based representation of the land surface or submerged areas made up of irregularly distributed nodes and lines with three-dimensional

Fig. 2 Methodology flow chart

coordinates (x, y and z) arranged in a network of non-overlapping triangle, was generated. Based on the information collected from the survey, the extent of flood is identified and digitized. Statistical Package for Social Sciences (SPSS) version 15 is used to analyze both qualitative and quantitative data collected from the survey. SPSS has three basic files: the data, syntax and output file. The data window contains the SPSS system files and displays the data in spreadsheet format. Excel spreadsheet was used to prepare the Master Table. In Master table, the rows are considered to be the observational units and the columns are considered to be variables for the observational units. Simple statistical tools such as mean, median, mode and min/max values are performed using the Master table to make the data meaningful. Then, the stage damage curve is drawn based on the information collected from the questionnaire survey. 'A stage damage curve also referred as "flood loss function" depicts the relationship of damage varied with flood depth' (Kang et al. 2005). There are two typical approaches for the construction of stage damage curves. The first one is to use the flood damage data from field survey to derive the relationship of the flood damage with the flood depths. The second one is to synthesize the curve using a hypothetical model family that can represent a typical household in the region. The stage damage curve can be used for the estimation of single building damage under different flood depth.

The flood hazard and risk increases with urbanization. In order to evaluate the changes in risk, it is necessary to examine the increasing exposure to floods and the damage potential losses resulting from these floods. The following are the different approaches (WMO 2007) adopted, reflecting different purposes and the availability of data. Real flood damage data try to incorporate as much actual flood data as possible from recent floods into a database. Unit area approach looks at individual properties and assesses damage per square meter of floor space. Percentage of property value approach uses the market value of the property concerned, preferably just for the building rather than the land the building occupies, and expresses the flood damage potential as percentages of that value. The probabilities of flooding of particular depths taken from a range of project appraisals are

expressed in terms of annual flood damage potential. Then, the damage is weighted by the frequency of returning which results in the weighted average. Synthetic approach involves a synthesis of all available data, from both secondary sources and the real experience of floods. In the present study, synthetic approach is adopted to assess the flood damage.

After completing the questionnaire surveys, the samples are categorized into two groups, namely Group I (households with property damage) and Group II (households without property damage) based on the experience of flood impact.

Total cost spent during flood for Group I = Additional amount spent during flood (transport, consumable items, etc.) + Replacement cost
Total cost spent during flood for Group II = Additional amount spent during flood

Thus, the total cost spent by Group I and Group II is found out.

5 Concluding comments

In this paper, we have discussed the different methods adopted to calculate the damage cost, and a methodology to perform a damage analysis through social survey in an urban area is presented. The social survey involved extensive field visits, stakeholder meeting and questionnaire survey in the affected area. The methodology presented here is purely based on the information collected from the victims and stakeholders. This methodology can be adopted when there are technical data constraints. The quality of data assessment depends on the quality of data collected from questionnaire survey. Flood damage costs are determined using the information gathered from residents, sometimes may be exaggerated, but this type of field surveys helps us to understand the real-life situations.

Applications of the methodology are envisaged in urban planning, both at policy and at development control level.

Appendix 1. Questionnaire used during interview

I. Personal and general information

1. Name of the respondent:
2. Age:
3. Sex:
4. Educational qualification:
5. Occupation
6. Family details

Members	Sex	Age	Occupation	Income/month

7. Annual income
8. Ownership details
9. Housing typology
10. When did you construct/buy this house?
11. How long have you lived in this area?
12. Why did you shift to this area?

II. Information about flood

13. How many times you have experienced floods?
14. How long was this area flooded? (in each flood)
15. What was the cause of flooding?
16. What was the extent of flooding?
17. What was the depth of flooding?
18. What were the outflows of flood water?

III. Flood damage assessment

19. Have you experienced damage to your property from flooding?
20. What was damaged? Fill the estimated cost of damage
21. Was your daily life interrupted by flood effects?
22. If yes, what are the public property which was damaged?
23. What are the problems due to flooding?
24. What was the daily wage loss if you are not going to your work?
25. What was the additional amount spent (during normal times and flooding)?

[] Milk
[] Water
[] Rice
[] Provisions
[] Transportation
[] Health
[] Others

IV. Flood management

26. How will you prepare yourself during flooding?
27. Have you taken any of the following steps to limit your future flood loss and fill the cost you have spent? (flood mitigation cost)
28. Have you got any relief funds?
29. If yes, how many times you have got relief fund?
30. What kind of relief fund you have received?
31. If your answer to the previous question is cash, then how much? Rs
32. Who will support you during floods?
33. What are your suggestions to minimize the effects of flooding?
34. Give your suggestions to improve the quality of life
35. Rank the problems prevailing in your area

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Flood damage assessment of an urban area in Chennai, India, part II: results and discussions

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Abstract   This paper is Part II of a two part series in which the results and discussions are presented after carrying out a detailed flood assessment study in Velachery, an urban area in Chennai. This study focuses on loss due to property damage and on additional amount spent during flooding for essential commodities and evaluates the flood mitigation cost. Focus group discussion and stakeholder meeting are conducted in the study area in order to explore more information about flood damage. The estimated flood cost per hectare in East Velachery is about Indian Rupees (INR) 66,550. Questionnaire Survey (QS), comprising demographic details, extent of flooding, causes of flooding, flood mitigation measures, etc., is conducted to estimate the direct and indirect damages. A stage damage curve is drawn based on the information collected. Optimal and sustainable mitigation measures can be achieved only when the sociological aspects are fully considered. This analysis is designed to estimate the effects of flooding on a community's social and economic welfare. This type of analysis would help to educate the community, including residents and officials, about the impact and magnitude of flooding.

Keywords   Flood damage assessment · Velachery · Stage damage curve · Flood spread area · Tangible damage

1 Introduction

Chennai, a coastal urban city in India, is frequently affected due to cyclones. Due to urbanization and mass migration, flooding tends to be severe and is considered to be one of the important problems. Moreover, the major waterways in south Chennai such as the Adyar, the Buckingham canal and the Velachery-Pallikaranai channel which receive surplus water from several tanks and lakes, small streams and rainwater drains got clogged.

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As a result, there is accumulation of silt and trash at their mouths, which caused stagnation. Several areas were water logged and the local government authorities have identified 36 hot spots in Chennai. East Velachery is one of the 36 hot spots. Therefore, a flood damage assessment is carried out in East Velachery.

When a single flood event is chosen to be studied, flood damage estimation in a fixed area should be carried out based on the information and data regarding historical flood damages in areas with similar social and economic characteristics (Oliveri and Santoro 2000). But such information is rarely available. In these cases, a different approach based on field analysis must be followed. One such approach is adapted in this paper.

2 Results and discussions

Due to non-availability of technical data and lack of information, it is difficult to assess flood damage. Hence, a methodology to carry out a flood damage assessment is identified and presented in Part I of a two-part series. In order to determine the flood damage assessment, it is essential to calculate the flood spread area. GIS and remote sensing platforms such as ArcInfo are adapted to visualize and calculate the flood spread area.

2.1 Flood area calculation

As mentioned in Part I, the QuickBird satellite imagery is used to digitize the features. After carrying out the survey, the flood depth is marked at the corresponding places and a polygon is constructed to visualize the flood spread area. Then, this area is calculated using the raster calculator in ArcGIS 9.3. The total area of flood patches is found to be 422.48 hectares, and the total volume of flood patches is found to be 348.4 ha m. The depth of inundation is varying from 10 cm to 150 cm. The average depth is found to be 80 cm. Figure 1 shows the TIN and flood spread area in Velachery.

### 2.2 Stakeholder meeting and Focus group discussion

The issues discussed in stakeholder meeting are provided in Table 1. The issues are broadly classified as causes for flooding, problems due to flooding, damages due to flooding, coping strategies and suggestions to minimize the effect of flooding. The list of participants is provided in Appendix I

2.3 Respondents' opinion of flood problems

All respondents in the study area experienced the flooding in their personal property and their surroundings. Several questions were asked to the respondents in order to gather their assessment of flood problem. Tables 2 and 3 present the socio-economic characteristics of the community and the respondents' estimates to flood problems, respectively.

2.4 Flooding and flood damage assessment

The study area has experienced increasing anthropogenic activities in the past three decades. The intensity of land use and development has increased rapidly. After analyzing the responses to the questionnaire survey in SPSS, it is found that the majority of the people
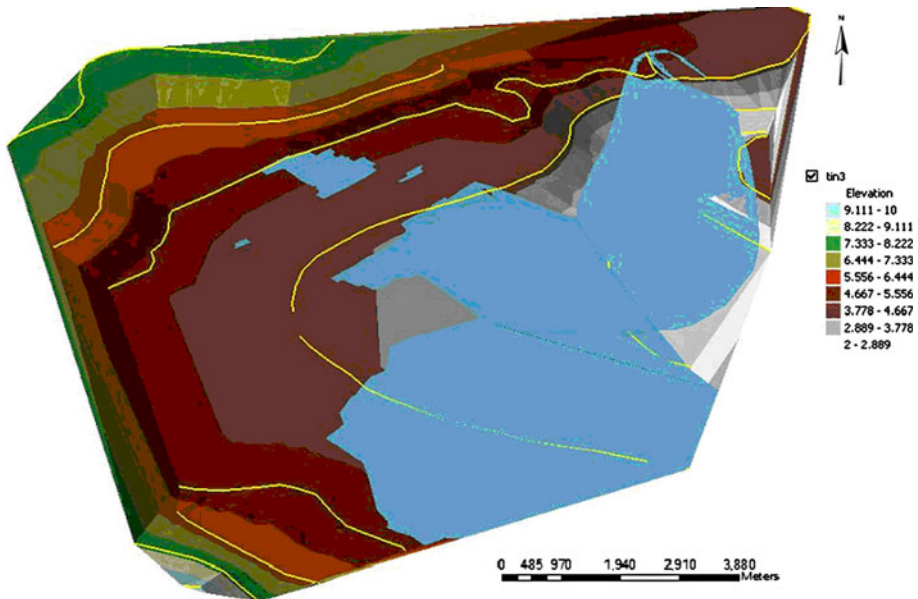
Fig. 1 Flood spread in the study area

live in individual dwellings and the annual average income of the people varied from Rs 50,000 to 100,000 (1 US\$ = Rs 47 approx.). From the survey, it is found that 31 households fall under Group I and the remaining 23 households fall under Group II. The property losses for Group I are in the form of furniture, TV, house, garage and vehicle. Of the 54 house surveyed, 31 houses were flooded above the floor level. All the people living in this area face some intangible damages such as difficulty to access to schools, colleges and workplaces, hardship in getting essential things, mental agony and physical stress, which cannot be expressed in terms of monetary value.

The stage damage curve shown in the Fig. 2 is constructed to derive the relationship between flood damage and flood depth which is collected from the field survey. It can be used for the estimation of damage/household under different flood depth in the study area. The information about damages to the assets under different flood depths is collected from the survey. It is observed from the graph that flooding extends inside the house only if the depth of flooding is greater than 0.6 m.

The total replacement cost for the flood in 2005 is found to be Rs 1,62,000. The details are provided in the Table 4.

The details of the amount spent by the people during floods for transportation and health are tabulated in the Table 5. Flood cost (health and transportation without considering the expenses during normal period) for Group I is Rs 92,160. Flood cost (health and transportation) for Group II is Rs 67,340.

From the survey, it is found that certain mitigation measures were adapted to minimize the effect of flooding. The details are given in Table 6. Flood mitigation cost spent by Group I is Rs 1,35,500 and by Group II is Rs 58,500.

The summary of Tables 4, 5 and 6 is provided in Table 7, which is the aggregated flood (damage) cost.

Table 1 Issues discussed in the meeting

Classifications	Responses
Causes of flooding	Encroachment
	Urbanization
	MRTS construction (mass rapid transit system)
	Roads were built against the natural slope
	Bifurcation of Pallikaranai marsh (inner ring road)
	Water is not allowed to flow in its natural path (diversion of water)
	Accumulation of silt and trash in the storm water drains
	The number of culverts is insufficient
Problems due to flooding	People do not have access to essential services, such as water and milk
	Power supply and telephone lines are badly disrupted
	Transportation is affected
	Mental and physical stress
	Water quality gets affected
	Mosquito problem due to stagnation of water
	Reptiles move freely inside the house
	People are not going for their office
	Schools and colleges are closed
Damages due to flooding	There is a lot of damage (TV, fridge, washing machine and furniture)
	Loss of livelihood (construction activities are disturbed)
	Plants die due to stagnation of water
	Health problems
Coping strategies	During flooding, people stay at their relatives' house or at first floor
	People were forced to build first floor
	By moving the valuable things to first floor, the damage cost is reduced
	Mentally prepared (buying candles and necessary things)
Suggestions	Adambakkam lake, Madipakkam lake, Chitteri lake and Velachery lake have to be cleaned periodically
	In order to improve the flow pattern, aquatic weeds have to be removed partially. They should not be cleaned completely because they feed animals and biogas can be generated from them
	Sand bar formation in Adyar river and Muthukadu has to be removed
	Buckingham canal has to be widened.
	Check dams must be built wherever it is necessary to store the rainwater
	Removing encroachments
	Cleaning the inlet and outlet channels of Pallikaranai marsh

Total cost spent during flood by Group I = Rs 3,63,070
Total cost spent during flood by Group II = Rs 1,05,530

On an average, there are about 20 households in a street. From the analysis, it is found that 31 streets have undergone property damage (Group I) and the remaining 24 streets fall under Group II category.

No. of households that come under group I = 620
No. of households that come under group II = 460
Total cost spent during flood by 620 households = Rs 72,61,400
Total cost spent during flood by 460 households = Rs 21,10,600
The total cost spent by 1,080 households is found to be Rs 93,72,000

The inundated area in patch B (Fig. 1 of Part I paper) is found to be 140.83 ha. The total flood cost per hectare is Rs 66,550.

Table 2 Socio-economic details

Sl. No	Category	Percentage
1.	Education levels	
	Primary	4
	Secondary	15
	Higher secondary	24
	Bachelor degree	35
	Master degree	22
	Illiterate	0
2.	Occupation	
	Government	4
	Private	44
	Business	20
	Others	32
3.	Annual income (Rs)	
	<50,000	
	50,001–100,000	91
	100,001–500,000	2
	500,001–1,000,000	2
	>1,000,000	0
4.	Type of dwelling	
	Individual	94
	Apartment	4
	Others	2
5.	Ownership details	
	Owner	54
	Tenant	46
	Lease	0

Table 3 Respondent's estimates of flood problems

Flood characteristics	SD ($N = 54$)	Minimum	Maximum
Frequency of flooding in a year (no. of times)	1.374	1	4
Inundated period in days	14.946	4	90
Depth of flooding in feet	1.065	1	6

The current study deals with the assessment of tangible damage. It concentrates more on quantitative data. The qualitative data (pre-flood arrangements, mental and physical stress) must be incorporated in future to obtain the effective flood cost, because in addition to the monetary loss, there is physical and mental stress to the people. The quality of data assessment depends on the quality of data collected from questionnaire survey. In this study, flood costs are determined by the information gathered from residents, sometimes may be exaggerated, but this type of field surveys helps us to understand the real-life situations.
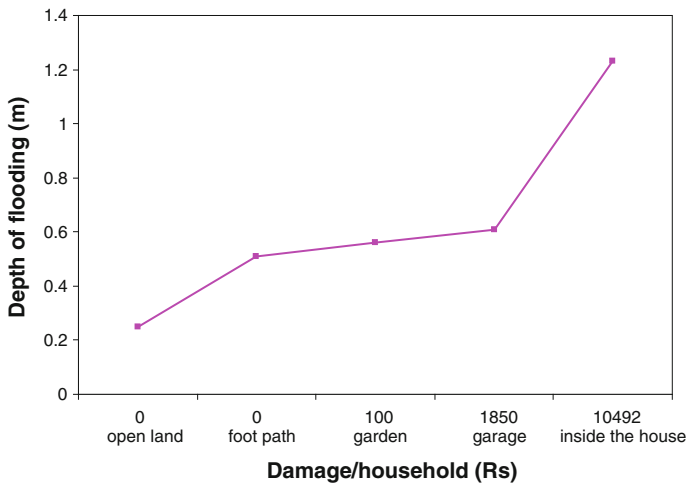
Fig. 2 Stage damage curve

Table 4 Replacement cost for Group I

Property	No. of households	Replacement cost (Rs)
House	7	61,000
Furniture	18	32,000
TV	2	6,000
Garage/shed	10	18,500
Vehicle	4	20,500
Miscellaneous	7	24,000
Total replacement cost		1,62,000

Table 5 Comparative table for the amount spent normally and during flood

Content		No. of households		Amount spent (Rs)	
		Group I	Group II	Group I	Group II
Transportation	Normal	26	18	10,520	8,350
	Flood	26	18	38,530	27,550
Health	Normal	31	23	16,070	11,900
	Flood	31	23	53,630	39,790

3 Perspectives

3.1 Flood management: Policy recommendations

It is important to describe the sustainable urban development, which involves minimal disturbances to the natural environment. In order to achieve this goal, the effect of urbanization on hydrologic cycle must be understood. Population pressure, demand for

Table 6 Comparative table for the amount spent for mitigation measures

Item (mitigation options)	No. of households		Amount spent (Rs)	
	Group I	Group II	Group I	Group II
Elevated electric box	18	16	28,500	22,000
Elevated appliances	3	2	9,500	8,000
Elevated structure	19	9	61,500	25,500
Improved drain around home	10	1	36,000	3,000

Table 7 Total damage assessment

Flood cost/problem	Actual no. of households	% of households	Total loss (Rs)
Property damage	31	57	1,62,000
Transportation	44	81	47,210
Health	54	100	65,450
Elevated electric box	34	63	50,500
Elevated appliances	5	9	17,500
Elevated structure	28	52	87,000
Improved drain around home	11	20	39,000
Total flood cost			4,68,660

land and services, the state of urban infrastructure and lack of planning have led to an exponential increase in the risks of flooding (Tucci 2007). As mentioned above, urbanization tends to increase peak discharge, reduce infiltration and increase the runoff volume. Due to encroachments and increasing population, the canals have loss their ability to carry flood water. Therefore, effort should be made to prevent the destruction of canals. Human settlements must be discouraged to settle in flood-prone areas. Existing storm water drains and water bodies must be maintained properly.

The entire city can be divided based on the watershed. A 'Watershed Committee' consisting of representatives from Government agencies, Non-Government Organizations, local residents, policy makers and academicians may be formed and this committee shall be responsible for monitoring the implementation of flood management plans with minimal disruption to natural environments in their corresponding watershed.

There is only one outflow point in Velachery (study area) that connects the storm water drainage to Pallikaranai marsh. Moreover, the capacity of the existing channel is not sufficient to carry the flood water from Velachery. Additional storm water drains may be provided. Kron (2008) states that 'The job of the state or the government is primarily to reduce the underlying risk for society as a whole. It provides access to observation and early-warning systems, builds dykes, deploys flood retention areas, determines the framework for the use of exposed areas by enacting statutory provisions, and prepares emergency plans, including programs to alleviate recovery (temporary housing, financial assistance, tax relief, etc.)'. So, more money may be spent for the installment of permeable paving, erection of barriers and implementation of rainwater harvesting structure in order to minimize the flood damage. During the survey, it is found that there is lack of awareness

about flood insurance among the people and there is a gap in the communication and the support between the residents and administrative bodies. It is the responsibility of the government to educate the people and make the flood insurance mandatory. This will reduce the government spending on reconstruction of damaged property. Coordination between the public and government agencies and other institutions can be strengthened to reduce the flood damage impacts.

4 Conclusions

The flood damage assessment is made using synthetic approach that utilizes the available data collected from the secondary sources and real-field situations. Integrated flood management approach (involving technical, social and economical) is adapted in this study in order to assess the flood damage. Flood volume of the area is calculated using GIS. In addition, the total flood cost spent by affected people in East Velachery is derived for the flood in 2005. The cost comes to around 9.3 million INR, and the flooding extends inside the house only if the depth of flooding is greater than 0.6 m and the maximum depth of inundation is about 2.0 m.

Further work is needed to derive the costs incurred for intangible damage to improve the results. Using the information obtained about the extent of flood patches and the amount spent by the people during flooding, policies and strategies can be developed to evacuate the people quickly and to minimize the cost spent during flooding. The outcome of this study may also help in determining the flood relief to be provided to the flood victims. It is anticipated that proposed policy recommendations can contribute to effective management for future flood events and minimize the flood damage cost. Flooding is one of the major natural hazards causing loss of lives and damage to public property. It cannot be controlled but at best be mitigated.

Appendix 1

See Table 8.

Table 8 List of participants

Sl. no.	Name	Designation
1.	A. Raju	Supdt (Retd) TNPCB
2.	M. V. Gopalan	Engine driver (Retd), Southern railway
3.	S. Chidambaram	Educationist (Retd), Banker
4.	E. Prabakar	Private company (Retd)
5.	S. V. Chari	Custom relation officer
6.	V. Janardhanam	Principal (ILC), Institute of Chemical Technology
7.	S. Vasudevan	President, Federation of south Chennai welfare association
8.	K. Purushothaman	General secretary, Federation of south Chennai welfare association

Table 8 continued

Sl. no.	Name	Designation
9.	K. Swamiraj	Srinivasa Nagar welfare association
10.	S. Swaminathan	Correspondent, Sri Sankara Vidhayalaya, Madipakkam
11.	Mr. Thirunavukkarasu	PWD officer (Retd)
12.	Prof. N. K. Ambujam	Professor, Centre for water resources, Anna University
13.	Mr. Anuthaman	Senior Lecturer, Centre for water resources, Anna University
14.	Dr. Prakash Nelliyat	Project Coordinator, Centre for water resources, Anna University
15.	S. Suriya	Research Scholar, Centre for water resources, Anna University
16.	K. Parameswari	Research Scholar, Centre for water resources, Anna University
17.	S. Packialakshmi	Research Scholar, Centre for water resources, Anna University
18.	M. Chaitanya Sudha	Research Scholar, Centre for water resources, Anna University
19.	Dharani	M. E Student, Centre for water resources, Anna University
20.	Saranya	M. E Student, Centre for water resources, Anna University
21.	Residents	Velachery

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