Free and Open Source Geographic Information System for Urban Planning

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With the availability of freely downloadable Geographic Information System (GIS) namely Geographic Resource Analysis Support System (GRASS) and numerous related software the bottle neck of costly proprietary GIS software is solved for the developing world. Further free availability of satellite imagery on the World Wide Web added impetus to creating GRASS database of any chosen area The imagery of parts of the Hyderabad city are imported into GRASS GIS. These are geo-referenced with WGS-84 geographic coordinates acquired using a hand held Geographic Position System (GPS) at the reference points, like traffic junctions, bridges and road-rail crossing points. The ensuing GRASS raster is then vectorised with suitable attribute information. Features as important road traffic junctions, suburban railway stations, educational Institutes, hospitals and spots popular with tourists are added as sites (points) information. Roads and rail roads are added as lines with road-name as attribute information. Drainage is also added as lines with attribute information. Different localities of the city, water bodies and larger landmarks like parks; shopping malls etc are added as areas (polygons). This forms the area specific (region) GRASS dataset for data attribution and analysis.

Value addition to this GRASS database is done by reality mapping using a GPS. The sites data is added with tourist spots like historical monuments, museums and Hotels. Traffic junctions are classified as, 'Busy', 'Traffic jam prone', and' commercial' etc. The line data is added with information like, 'One way', 'Highway', 'City road', 'Local road' , 'Dense traffic' (with approximate times of traffic jams) 'Residential', and 'Commercial' etc. The areas are added with information like, 'Name', 'Residential', 'Commercial', 'Educational', 'Hospital' and 'Office Zone'. The GRASS data set thus generated is of help to the city population and visitors alike. The resultant GRASS data set can be placed on a website, government computer kiosks. and with touch screens (computers) at Airport, Railway station and Bus stations. Urban planning can take this GRASS dataset as a basis for a plethora of tasks.

Creation of GRASS GIS dataset for the city of Hyderabad:

Freely available satellite imagery, maps of Hyderabad, SRTM height data and ground control points collected with portable GPS system are the inputs for creation of the database. Scanned maps are vectorised, and the imagery are geo-referenced using a combination of map data and portable 'GPS', location data depending on the suitability. On these basic inputs GRASS dataset are generated for parts of the Indian city of Hyderabad with development of thematic vector content and crunching of attribute information for urban planning. An accounts of advantages of various vector themes and their importance along with simulation of flood in River Musi is dealt at length as an example.

Urban roads:

Roads that are prone to traffic jams may be marked, and road accidents can be planted as point information, to identify areas for development planning like building road flyovers etc. Hourly information of traffic flow on each important road during peak traffic hours can help in planning traffic distribution, with avoidance of traffic jams. Even road maintenance work can be planned with field observation for damaged roads and roads prone to water logging.

Urban housing and tax collection:
Marking housing complexes and problem areas of urban slums with suitable attribute information can help the urban planner. Areas that are prone to water logging can be marked with suitable attribute information by overlaying the drainage information. Tax collection can be marked as attribute information, for proper tax collection endeavours.

Urban drainage:
Urban areas are frequently flooded after heavy rains, due improper maintenance of drains, and a lack of garbage disposal planning. Choke points of drainage can be marked that warrant urgent civic planner's action. Simulating floods on a digital elevation model can give an early warning averting disasters. This can be accomplished by surveying the area with collection of elevation data in the most flood affected areas.

Urban civic amenities:
Cities of the developing world face problems of sanitation and spread of slums which go together. Frequent inputs from field workers in the city armed with hand held GPS can enrich attribute information and the resultant datasets provide valuable information for the urban planner. Outbreak of seasonal fevers and other medical emergencies also can be added as attribute information to help planners.

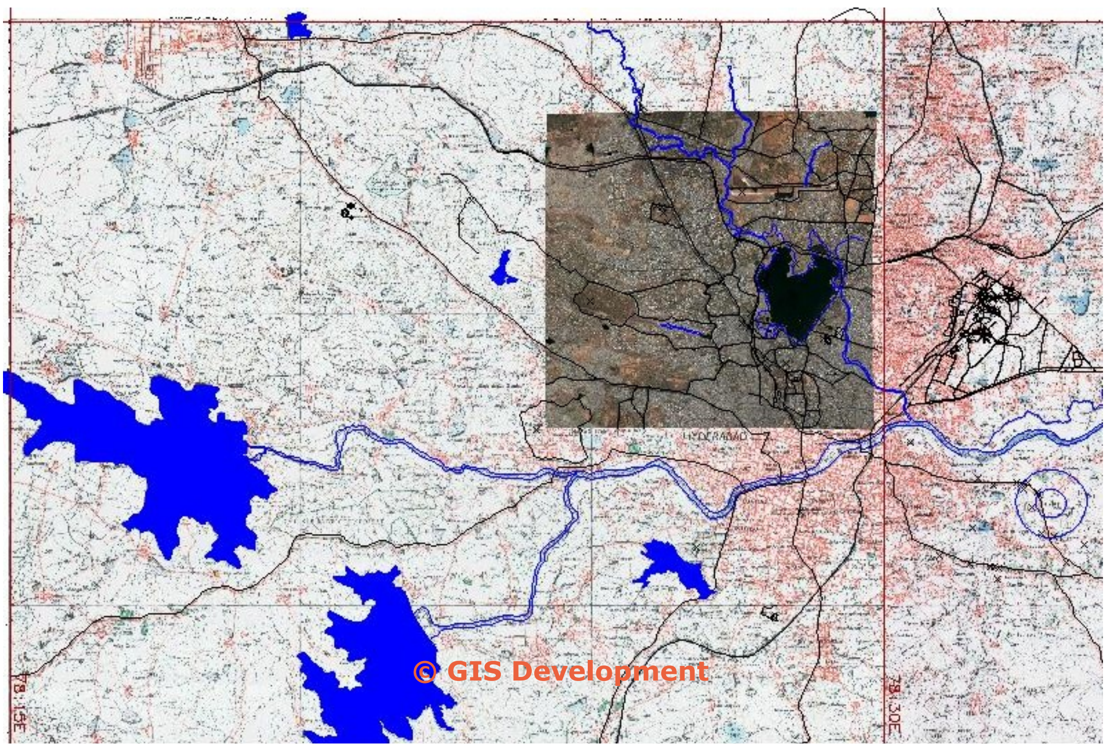


Fig.1: Road, rail and drainage, water-bodies, GPS read location points over-plotted on GRASS georeferenced maps and image

Urban tourism:
A tourist or visitor to the city can plan his trip and decide where to stay and visit areas of interest. A computer with touch screen (for inputs) showing the GRASS GIS data set, can help the tourist with information on Hotel accommodation, city transport and locations of interest.

Simulation of flood and acquisition of information:

Flooding due to excessive precipitation in highly populated Indian cities creates regular havoc and loss of life. Free and Open source GIS can help modeling floods for planning effective disaster management.

Musi river watershed of Hyderabad:
River Musi flows through Hyderabad. The river has assumed a shape of a lean and narrow channel in dry seasons. Landuse thematic map developed from LISS bands indicates that the valley is full of vegetation. But ground reality is that the damp ground along the river supports only bushes and tall grasses. Contours developed on SRTM surface data indicate that there is a natural barrier in the valley at the easternmost limit of the city (classification of LISS bands into Landuse by Maximum Likelihood Method method in GRASS). Behind the barrier, Musi drains a watershed area of 880 sq.km. Three fourth area of the catchment is occupied by built-ups (of Landuse) of concrete and tar.

Digitisation of **Musi River Catchment** in
the area of interest **behind the choke point**
Raster > Develop Map > Digitize Raster >

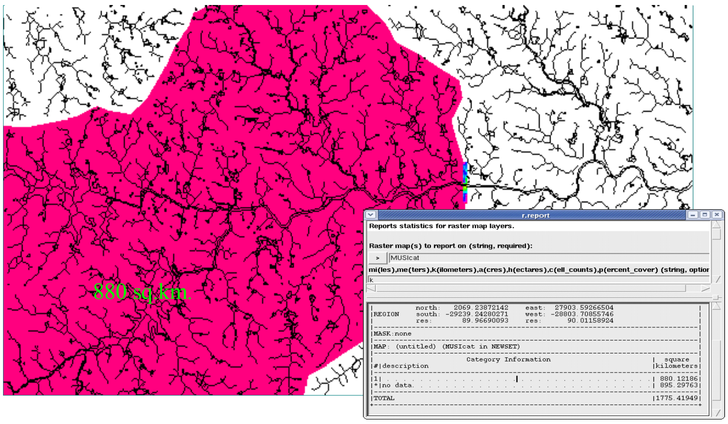


Fig.2 : Extarcted drainage line and digitized watershed area.

Human interference in the domain of nature leads the precipitated water driven as thick surface flow at a cost of lowest resistance and without any percolation down into the impervious concrete and tarry surface of the built-up. The surface flow drives the waste material, kept in unorganized manner all through the dry months, down to the stream lines – which finally pours into Musi. Sizable particles of the waste and plastic sheets got struck to the base of tall grasses and bushes on the river bed and obstructs the out flow rate. Ground reality is that the thick pillars erected on the river bed to bridge the valley for road and railway transport system play its final role in posing the obstruction in the flow regime. These complete the chain of obstructions resulting into a flash flood in the valley submerging the human settlements.

Simulation of floods, GRASS steps :

For the present study SRTM (90 m resolution) data pertaining to a major part of Hyderabad city and Musi catchment were downloaded from World Wide Web and the digital surface model (DSM) was studied in GRASS software to extract flash flood related information. In process to arrive final picture, the mosaicked *(Raster > Overlaymaps >Patchmaps)* imageries were to pas through following steps:

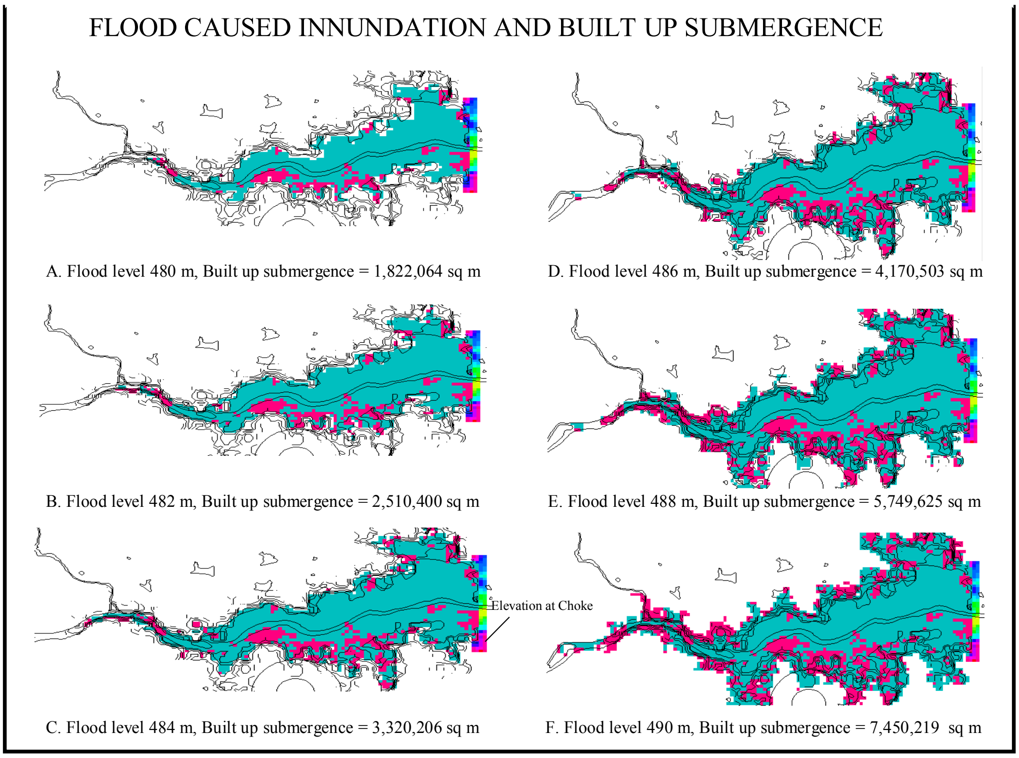


Fig. 3: Six simulation of flood and affected builtup

1. Extraction of drainage line map from SRTM (*Raster > Hydrological Modelling > Watershed analysis*; a conditional statement was issued to extract the drainage line from flow accumulation picture map; output = RIVERLINES),
2. Preparation of contour map from SRTM (*Raster > Generate Contour Lines; Output = CONTOUR*),
3. Overplotted visualization of RIVERLINES and CONTOURS. Identification of a choke point / location of natural barrier in Musi river valley.
4. Digitisation of a line for the natural barrier across the valley (*Raster > Developmap > Digitise raster*; output = BARRIER).
5. Extraction of height on raster cells for BARRIER using a conditional statement on A. SRTM , B. BARRIER [*Raster > Map Calculater; if (B>=0, A, null())*; output = HGTonBARRIER for heights on BARRIER cells].
6. Collection of map information for the minimum and maximum of height values in HGTonBARRIER cells (*Raster > Reports and Statistics > Report basic file*

information).

7. Digitisation of watershed behind BARRIER (*Raster > Developmap > Digitise raster*; output = WATERSHED).
8. Conditional statement on A. SRTM map to extract the band bounded between lowest BARRIER height and a level between 480m to 490m [Raster > Map Calculater; *if (A>= <min cell value in BARRIER> && A <= 480, 1, null()*); output = BAND480].
9. Flood zone: Extraction of a portion of the A.BAND480 (482 || 484 || ...) falling exclusively within the B.WATERSHED using a conditional statement in map calculator [*Raster > Map Calculater; if (A>= 1 && B == 1, 1, null())*; output = FLOOD480]..
10. Transfer of height data from A. SRTM to the flooded area (B. FLOOD480) by making a conditional statement in map calculator [*if (B>=0 , A, null())*; output = TOPOofFLOODzone480].
11. Operation to acquire height of water column in each cell from A. TOPOofFLOODzone480 [Formula in map calculator : *480 – TOPOofFLOODzone480*; output = WATER_CLM480].
12. Computation of area of inundation and volume of water accumulated behind the barrier for a case of flood (to extract area figure: *Raster > Reports and statistics > Sum area by map and category*; to extract volume from map calculator using A. FLOOD480 and B. WATER_CLM480 on formula: *if (A>=0, <EW resolution>*<NS resolution> * B, null()*; output = WATERvol480, Total volume is computed on WATERvol480 using r.sum tool at *Raster > Reports and statistics > Sum all cell category value*.)

This way, computation of area under inundation and volume of water logged behind the barrier is computed for an artificial flood affecting an MSL 480 m the other flood zones for levels 482m, 484m, 486m, 488m and 490m were also computed following step 9 to 12 as above.

Extracted information:

For each case of floods with known volume of waters accumulated behind the natural barrier computation of least precipitation in the watershed (880 sq. km) which could cause the supply was computed. The figures are presented in the table below:

Table 1: Information generated from the analysis

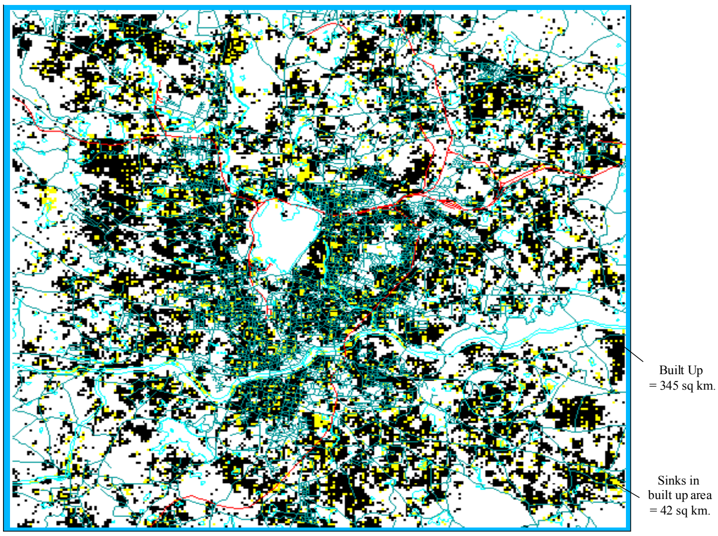
Flood level	***Submergence area***	***Volume of water accumulated behind the barrier***	***Precipitation in the watershed (880 sq.km.)***
480 m	11.126,368 sq.km.	67,821,300 cu.m.	7.70 mm
482 m	14.155,12 sq.km.	94,810,500 cu.m.	10.80 mm
484 m	17.127,11 sq.km.	127,550,500 cu.m.	14.49 mm
486 m	19.759,28 sq.km.	165,353,400 cu.m.	18.79 mm
488 m	23.654,444 sq. km.	210,753,900 cu.m.	23.95 mm

Flood level	*Submergence area*	*Volume of water accumulated behind the barrier*	*Precipitation in the watershed (880 sq.km.)*
490 m	28.446,177 sq. km.	246,610,800 cu.m.	30.06 mm

In short, if Musi watershed receives 7.70 mm to 30.06 mm incessant rain in an area of 11.126sq.km. to 28 sq.km then it can submerge the area with 67,821,300 cu m to 264,610,800 cu m of accumulated water, behind the natural obstruction. Submerged Builtups can also be extracted and a combined pictures / figures of submerged builtup areas can be worked out.

Floods of a different kind can be obtained for those areas of cities where sinks / low grounds are surrounded by higher elevation (could be a natural high grounds or human buildups) in the neighborhood. Using a neighborhood statement run from map calculator on, A. SRTM and B. BUILTUP: *if (A[0,0])<=(min(A[-1,-1],A[-1,0] ,A[-1,1], A[0,1],A[1,1], A[1,-1], A[0,-1])+1), 1, B)*. This is an expression of 3x3 cells in neighbourhood. Which means that if central cell of a neighborhood of the DSM has height equal to or less than minimum + 1m height reports, such cell by assigning them 1 as value otherwise assign the value what is there in BUILTUP map. It is assumed that if the surroundings have higher heights and central locales have minimum or minimum + 1m height such zones will be under effect of water logging in case of incessant rain.

SINK CAUSED FLOOD ZONE OF HYDERABAD



Terrain ruggedness causes other type of flood in Hyderabad.
This is caused by sinks amids elevated neighbourhood.

Fig. 4 : Sinks amidst elevated neighbouhood

This work was carried out on a 90m DSM resolution. More accurate picture can be obtained by use of high resolution DSM. Organisation / community/ municipality would have to spend on reality depicting databases to obtain dependable information for forecasting disasters.

Conclusion

Usage of Geographic Information System can help planners in various ways. Using a Free and Open Source GIS can make it happen with almost no expense for acquiring the otherwise very costly software. Grass is not just a GIS, it is a capable image processor also. It can capture, manipulate and analyse efficiently on the thematic / criteria maps in favour of a proposition of analysis, both in vector and raster approaches. GRASS, as an assembly of spatial data handling tools, is a front runner among the Free and Open Source Software with a GNU license. Countries like India characterised by large population of educated youth are human resource waiting to trigger a GIS revolution to happen. With proper capacity building in GRASS GIS not only for urban planning but planning in general can be achieved, where ever hitherto a paper map forms the basis. GRASS GIS can benefit the entire ambit of civil society from the agriculture farmer by planning better land use and crop rotation vis a vis market, to the city dweller alike.

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