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Urbanisation Effect on Hydrological Response: A Case Study of Asan River Watershed, India

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Abstract

Human being keeps on modifying the environment especially land use/land cover (LULC), in pursuance of excel, comfort and development. The subsequent impact of urbanization to the environment, especially land cover change, now occurs on scales that significantly affect hydrologic variations. The altering environment makes it necessary to understand and quantify various hydrological components for efficient water resource management. Therefore, in the present study, an attempt was made to study the impact of LULC change on runoff generation potential. Asan River watershed, which lies in Dehradun, capital of newly created Uttarakhand State, India, is selected as study region. A huge industrialization is been taken place within this watershed immediately after declaration of state in year 2000. Initially, LULC change detection analysis was carried out by simple LULC class area difference between two years under consideration i.e. 2000 and 2010. The hydrological simulation using variable infiltration capacity macro-scale hydrological model depicted increase in runoff after urbanization took place.

Keywords: Land use land cover change, Urbanization, Impact assessment, hydrological modeling, variable infiltration capacity model, runoff potential

1. Introduction

In pursuance of excel, comfort and development, human being keeps on modifying the environment especially land use land cover (LULC) resulting in huge urbanization that significantly affect hydrologic variations. According to Leopold (1968), among all land use changes affecting the hydrology of an area, urbanization is by far the most forceful. It was reported that there are four interrelated but separable effects of land use changes on the hydrology such as changes in peak flow characteristics, changes in total runoff, changes in quality of water and changes in the hydrologic amenities. The foremost observation, when a watershed in its natural state is being transformed as a result of urbanization, is increase in runoff volume. (Carlson and Arthur 2000; Rose and Peter 2001; Cheng and Wang 2002; DeFries and Eshleman 2004; Tang et al. 2005; Cowden et al. 2006; Li et al. 2007; Olivera and DeFee 2007; Ahn et al. 2008; Roy et al. 2009; Kjeldsen 2009; O'Driscoll et al. 2010; Sung and Li 2010; Suriya and Mudgal 2012). Therefore, now it become necessary to understand and quantify various hydrological components for efficient water resource management for this altering environment. A thorough knowledge and understanding of the different hydrological phenomena and their components are required to implicate these changes. In this regard, the hydrological modeling technique can help to gain an understanding of the hydrological system in order to provide reliable information for managing water resources in a sustained manner at larger scale.

The hydrological model should consider all of the hydrological components; and links, relations, interactions, consequences, implications among those components. Recently, a large number of soil-vegetation-atmosphere transfer schemes (SVATS) models have been developed by researchers. These models have been developed explicitly to represent the land surface partitioning of net radiation into latent, sensible and ground heat fluxes in climate and weather forecast models. These models consider the role of vegetation in estimation of ET and carry out surface energy balance by iterating on one or more effective temperatures (Lettenmaier 2001). However, the major disadvantage of SVATS is they generally emphasis on column processes such as extraction of soil moisture by vegetation, and feedback between vegetation, soil moisture and surface atmospheric conditions those control transpiration. The horizontal complexity/spatial heterogeneity of soil, vegetation, and topography has not been considered in these model which governs the runoff generation (Wood 1991; Abdulla et al. 1996). Therefore, in the present study, two-layer variable infiltration capacity (VIC-2L) semi-distributed hydrological model has been used for hydrological simulation which was also developed as a SVATS for general circulation models by Liang et al. (1994). It is a grid based macro-scale model, but, its takes in account the sub-grid variability in soil infiltration capacity and vegetation classes.

In Dehradun, being a capital as well as plane region of newly born Uttarakhand hilly state of India, a huge industrialization has been taken place on the outskirts of the city to meet the economic growth. Therefore, a study has been taken up to study the impact of urbanization on hydrological regime of Asan River watershed which falls in surroundings of Dehradun city.

2. Asan River Watershed

The Asan River watershed is located between latitudes 30° 14' 14" N to 30° 29' 54" N and longitudes 77° 39' 42" E to 78° 05' 30" E, Dehradun district, Uttarakhand State, India as shown in Figure 1. It covers an area of approximately 654.47 km^2. It is bound in the north by the Lesser Himalayan range and in south by the Siwaliks. It forms an asymmetrical synclinal valley. The study area is a part of the intermountain valley situate in the foot hill of lesser Himalaya. Pysiographically, the area can be broadly divide into three regions Northernmost part of the area is occupied by the Himalayan Mountainous Ranges, and high denudation processes are occurred in it. Geomorphologically it can be classified as a denudation hill. Northern Siwalik ranges can be found between the Himalayan ranges and alluvial plain as a structural hill. In Southernmost part of area, Siwalik ranges are highly dissected by the streams due to lesser compaction of Upper Siwalik rocks and formed as highly dissected structural hill.

Asan river is flowing in central portion of the area from south-west to north-east direction and flow into the Yamuna river which as a western margin of the area. The tributaries of these two rivers made gentle slopping piedmont plain on both side of the Asan river. The river terraces can be seen in the area. Due to neotectonic activities of the area alluvial material underlain by the Siwalik rocks are uplifted and formed as residual hills near the northern margin of piedmont zone with the structural hill.

The major drainage present in the area are parallel to sub-parallel, sub-dendritic, trellis, angular, rectangular, intermittent and braided. The drainage of the area results from the climatic condition, tectonic structures, unlying geologic formation and geomorphology. The major tributaries of Asan river are Koti, Nun, Suarana, Tons and Sitla Rao. These tributaries emerge from south slope of Mussoorie hills flowing S-SW and joining the NW flowing main river. And also many other minor ephemeral tributaries are accompanied during monsoon season. Sub-dendratic pattern and structurally controlled drainage is normally seen in the upper reaches while sub-dendratic to sub parallel drainage found in the region of Siwalik formation.

The climate of study area is sub-tropical to temperate on higher elevation (more than 1,800 m.) It varies greatly from tropical to severe cold depending upon the altitude of area. The average annual temperature of 21^{o}C in summers to 5^{o}C in winters. Most of the annual rainfall in study area received during the months from June to September, July and August being rainiest. The mean annual rainfall in the watershed is around 1,917 mm. Relative humidity is recorded as 91% in January. There are three distinct seasons of Monsoon, winter and summer. The extreme of temperature recorded in the area as 0^o to 42^o during winter and summer season respectively.

3. Methodology Adopted

The effect of the urbanization on the hydrological regime of Asan River watershed has been studied through hydrological modeling approach. Initially, the change in LULC has been detected between the two period i.e. 2000 - 2010. For the purpose, the cloud free Landsat TM satellite images which cover entire Asan River watershed area of date 25 November 2000 and 15 December 2010 (Path 146, Row 39) have been downloaded (http://glovis.usgs.gov) as shown in Figure 2 and 3, respectively.

These Landsat images have been used to derive land use/ land cover map of each year 2000 and 2010. The supervised classification derived LULC maps of year 2000 and 2010 are shown in Figure 4 and 5, respectively. The LULC has been classified into eight classes namely cropland, Sal forest, Pine forest, grassland, plantation, built up, water and dry river bed. The Selaqui, Sahaspur and Sidhonwala were good agriculture and forested area before year 2000. However, now Selaqui, which has become huge industrial area after the declaration of Uttarakhand state in year 2000, can easily be interpreted visually. The Sidhonwala region, which was dense Sal forest, is now hub for new educational institutions and universities. Similarly, Sahaspur and Premnagar town grown much faster to cater the needs of these industrial and institutional areas. The year wise fraction of area of each class and subsequent change has been given in Table 1. It was noticed that mostly agricultural area has been converted into urban in the watershed.

Table 1 depicts that there is change in LULC, mainly from cropland to built up due to industrialization/urbanization. Therefore, surely there will be some impact of these changes on hydrology of the watershed too. To analyze these impact, hydrological modeling approach has been adopted. In order to simulate watershed hydrology, VIC macroscale hydrological model has been adopted, which works on grid basis.

3.1 VIC Hydrological Modeling

VIC is a semi-distributed macroscale hydrological model, developed to study surface energy, hydrological fluxes and states at scales from large river basins to the entire globe. It is grid based semi distributed hydrological model which quantifies the dominant hydro-meteorological process taking place at the land surface atmospheric interface. VIC computes the vertical energy and moisture flux in grid cell based on specification at each grid cell considering soil properties and vegetation coverage. Also it includes the representation of sub grid variability in soil infiltration capacity and all mosaic of vegetation classes in any grid cell. The further details about the model can be found at VIC website http://www.hydro.washington.edu/Lettenmaier/Models/VIC. The successful application of the model for hydrological simulation can be seen in Liang (1994), Liang et al. (1994), Liang et al. (1996), Abdulla et al. (1996), Nijssen et al. (1997), Wood et al. (1997), Lohmann et al. (1998a, b), Cherkauer and Lettenmaier (1999), Lettenmaier (2001), Maurer et al. (2001a,b), Yuan et. al. (2004), Liang et al. (2004) and Gao et al. (2009). The model has also been used to study the impact of LULC change on hydrology by various researchers across world (Matheussen et. al. 2000; VanShaar et al. 2002; Dadhwal et al. 2010).

As mentioned above, the model works on grid basis, a square grid of area 1 x 1 km was generated over the study area (Asan watershed) as shown in Figure 6. The grid map was intersected with the watershed boundary and it was identified that 676 number of grids out of 1,120 lie within watershed boundary which are to be run for analysis. The extracted grid network for the watershed was used to overlay with the other thematic layers and hence to define the distribution of various parameters and properties in watershed. VIC model requires the definition of input parameters for each grid distributed uniformly over area. In order to implement VIC model, five main input files are required namely forcing, soil parameter, vegetation parameter, vegetation library and global parameter file in ASCII format.

The main aim of the study was to study the impact of LULC change on hydrological regime of Asan River watershed, therefore, the meteorological forcing has been kept constant. For the preparation of meteorological forcing, the Indian Meteorological Department (IMD) gridded data of daily rainfall (0.5°); maximum and minimum temperature (1.0°) correspond to year 2005 was used. However, the soil parameter file was derived based on the texture retrieve from National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) as shown in Figure 7. It was observed that mainly loam, sandy clay loam and silt loam are present in study area. The soil parameters such as bulk density, field capacity, wilting point, saturated hydraulic conductivity (k_{sat}), slope of retention curve (b) correspond to each texture were taken from the standard table and remaining were calculated as available/directed on VIC model website under VIC model input section. The ASTER digital elevation model (DEM) with 30 m resolution, shown as base map in the Figure 1, has been used for elevation and slope parameters. For average rainfall, 30 years (1976 - 2005) IMD gridded rainfall data has been averaged for each grid under consideration.

The vegetation parameter and vegetation library files were prepared correspond to LULC classes present in LULC maps derived earlier. The fraction of each LULC class under each grid has been extracted and saved as vegetation parameter file. However, the parameters namely leaf area index, albedo, roughness length, displacement height, overstory, architectural resistance, minimum stomatal resistance correspond to each LULC class for the generation of vegetation library file have been taken from Land Data Assimilation System data (http://ldas.gsfc.nasa.gov/nldas/NLDASmapveg.php). Finally, the global parameter file, which is main control file, comprises of all instruction and location of all input files has been prepared. Then, the VIC model has been run on Linux platform and the results obtained are discussed in following section.

4. Results and Conclusions

To study the impact of LULC change on hydrological regime of Asan River watershed, VIC hydrological modeling approach has been adopted. The VIC model is grid based model as mentioned above. Initially, the grid has been identified where the maximum change especially urbanization has taken place. In this section, results based on runoff potential has been discussed for the grids those have been transformed to urban/industry from some other LULC class. It was noticed that mainly such grids are located in Selaqui and Premnagar region of the basin. For example, the grid wise results of grid number 870 and 910which belong to Premnagar; and grid number 577, 537 and 617 those belong to Selaqui industrial area are discussed here with bar chart showing change in their runoff potential in Figure 8.

A summary of result of impact LULC change of hydrology (runoff potential) of each grid under consideration is provided in Table 2. According to Table 2, the grids 577, 537 and 617, belongs to Selaqui industrial area, those are mostly comprised of the built up area especially industries, those have come after year 2000 when Uttarakhand State has been divided from Uttar Pradesh State. As the capital and plane region of hilly state Uttarakhand, the Dehradun city is favorable spot for industrialization. Even, Government of Uttarakhand has taken steps to develop industry in Dehradun city for economic growth of the state. Since then, huge industries are established and number of industries are being constructed in this area. However, the grids 870 and 910, those belong to Premnagar, Dehradun city, exposed to maximum increase in built up area, become urban to cater the needs of Selaqui industrial and Sidhonwala institutional areas.

The impact of this industrialization/urbanization has been studied in the present study, it was noted that wherever, built-up area increases runoff potential increases. Such change in hydrology may lead to urban flooding in years to come in the region. Moreover, the industrialization in the region has been taken place along tributaries of river Asan, which may lead to pollution and deteriorate the quality of water. It was also realized that due to its distinguishing characteristics such as subgrid variability in land surface vegetation classes; soil moisture storage capacity; base flow as a nonlinear recession; inclusion of topography (that allows for orographic precipitation and temperature lapse rates), the VIC model, results in more realistic hydrology in mountainous regions.

References

Abdulla, F.A., Lettenmaier, D.P., Wood, E.F. & Smith, J.A. (1996), "Application of a macroscale hydrologic model to estimate the water balance of the Arkansas-Red river basin", *Journal of Geophysical Research* **101**(D3), 7449 - 7459.

Ahn, G-C., Merry, C.J. & Gordon, S.I. (2008), "The effect of urbanization on the hydrologic regime of the Big Darby Creek Watershed, Ohio", *Proceedings of ASPRS 2008*, Annual Conference Portland, Oregon, 28th April - 02 May.

Carlson, T.N. & Arthur, S.T. (2000), "The impact of land use - land cover changes due to urbanization on surface microclimate and hydrology: a satellite perspective", *Global and Planetary Change* **25**, 49 - 65.

Cheng, S-J. & Wang, R-Y. (2002), "An approach for evaluating the hydrological effects of urbanization and its application", *Hydrological Processes* **16**, 1403 - 1418.

Cherkauer, K.A. & Lettenmaier, D.P. (1999), "Hydrologic effects of frozen soils in the upper Mississippi River basin", *Journal of Geophysical Research* **104**(D16), 19,599 - 19,610.

Cowden, J.R., Watkins, D. & Croley II, T.E. (2006), "Investigating urban land use effects on runoff by using the distributed large basin runoff model", *Proceedings of The World Environmental and Water Resources Congress*, Examining the Confluence of Environmental and Water Concerns, Environmental and Water Resources Institute, ASCE, Omaha, Nebraska, May 21 - 25.

Dadhwal, V.K., Aggarwal, S.P. & Misra, N. (2010), "Hydrological Simulation of Mahanadi River Basin and Impact of Landuse/Landcover Change on Surface Runoff Using A Macro Scale Hydrological Model", *In* W. Wagner and B. Szekely, eds. *Proceedings of ISPRS TC VII Symposium - 100 years ISPRS*, Vienna, Austria, July 5 - 7, ISPRS, XXXVIII(7B), 165 - 170.

DeFries, R. & Eshleman, K.N. (2004), "Land-use change and hydrologic processes: a major focus for the future", *Hydrological Processes* **18**, 2183-2186.

Gao, H., Tang, Q., Shi, X., Zhu, C., Bohn, T.J., Su, F., Sheffield, J., Pan, M., Lettenmaier, D.P. & Wood, E.F. (2009), "Water Budget Record from Variable Infiltration Capacity (VIC) Model", Algorithm Theoretical Basis Document for Terrestrial Water Cycle Data Records, Project Report "Developing Consistent Earth System Data Records for the Global Terrestrial Water Cycle".

Kjeldsen, T.R. (2009), "Modelling the impact of urbanization on flood runoff volume", *Proceeding of the Institution of Civil Engineers - Water Management*, Paper No. 800052, **162**(WMS), 329-336. doi: 10.1680/wama.2009.162.5.329.

Leopold, L.B. (1968), "Hydrology for urban land planning - a guidebook on the hydrologic effects of urban land use", *Geological Survey Circular* **554**, U.S. Geological Survey, Washington D.C.

Lettenmaier, D.P. (2001), "Present and future of modeling global environmental change: toward integrated modeling", *In* T. Matsuno and H. Kida, eds. *Macroscale Hydrology: Challenges and Opportunities*, 111 - 136.

Li, N., Xu, Y-P. & Guo, H-C. (2007), "Analysis of long-term impact of urbanization on surface runoff in Xitiaoxi River Basin", *Environmental Informatics Archives*, **EIA07-038** (6), 346 - 353.

Liang, X. (1994), "A two-layer variable infiltration capacity land surface representation for general circulation models", *Water Resources Series* **TR140**, Univ. of Washington, Seattle.

Liang, X., Guo, J. &Ruby Leung, L. (2004), "Assessment of the effects of spatial resolutions on daily water flux simulations", *Journal of Hydrology* **298**(1-4), 287-310.

Liang, X., Lattenmaier, D.P., Wood, E.F. & Burgess, S.J. (1994), "A simple hydrologically based model of land surface, water, and energy flux for general circulation models", *Journal of Geophysical Research* **99**(D7), 14,415-14,428.

Liang, X., Lettenmaier, D.P. & Wood, E.F. (1996), "One-dimensional statistical dynamic representation of subgrid spatial variability of precipitation in the two-layer variable infiltration capacity model" *Journal of Geophysical Research* **101**(D16), 21,403-21,422.

Lohmann, D., Raschke, E., Nijssen, B. & Lettenmaier, D.P. (1998a), "Regional scale hydrology: I. Formulation of the VIC-2L model coupled to a routing model", *Hydrological Sciences Journal* **43**(1), 131-141.

Lohmann, D., Raschke, E., Nijssen, B. & Lettenmaier, D.P. (1998b), "Regional scale hydrology: II. Application of the VIC-2L model to the Weser river, Germany", *Hydrological Sciences Journal* **43**(1), 143-158.

Matheussen, B., Kirschbaum, R.L., Goodman, I.A., O'Donnell, G.M. & Lettenmaier, D.P. (2000), "Effects of land cover change on streamflow in interior Columbia River Basin (USA and Canada)", *Hydrological Processes* **14**, 867-885.

Maurer, E.P., O'Donnell, G.M., Lettenmaier, D.P. & Roads, J.O. (2001a), "Evaluation of the Land Surface Water Budget in NCEP/NCAR and NCEP/DOE Reanalyses using an Off-line Hydrologic Model", *Journal of Geophysical Research* **106**(D16), 17,841-17,862.

Maurer, E.P., O'Donnell, G.M., Lettenmaier, D.P. & Roads, J.O. (2001b), "Evaluation of NCEP/NCAR reanalysis water and energy budgets using macroscale hydrologic model simulations", In V. Lakshmi, J. Albertson, and J. Schaake, eds. *Land Surface Hydrology, Meteorology, and Climate: Observations and Modeling*, Water Science and Application, AGU, Washington, D.C. **3**, 137–158, doi:10.1029/WS003p0137.

Nijssen, B.N., Lettenmaier, D.P., Liang, X., Wetzel, S.W. & Wood, E.F. (1997), "Streamflow simulation for continental-scale river basins", *Water Resources Research* **33**(4), 711-724.

O'Driscoll, M., Clinton, S., Jefferson, A., Manda, A. & McMillan, S. (2010), "Urbanization effects on watershed hydrology and in-stream processes in the Southern United States", *Water* **2**, 605-648. doi:10.3390/w2030605.

Olivera, F. & DeFee, B.B. (2007), "Urbanization and its effect on runoff in the Whiteoak Bayou Watershed, Texas", *Journal of the American Water Resources Association* (Paper No. J05171) **43**(1), 170 - 182.

Rose, S. & Peters, N.E. (2001), "Effects of urbanization on streamflow in the Atlanta area (Georgia, USA): a comparative hydrological approach", *Hydrological Processes* **15**, 1441 - 1457.

Roy, A.H., Dybas, A.L., Fritz, K.M. & Lubbers, H.R. (2009), "Urbanization affects the extent and hydrologic permanence of headwater streams in a Midwestern US metropolitan area", *Journal of the North American Benthological Society* **28**(4), 911-928.

Sung, C.Y. & Li, M-H. (2010), "The effect of urbanization on stream hydrology in hillslope watersheds in central Texas", *Hydrological Processes* **24**, 3706-3717.

Suriya, S. & Mudgal, B.V. (2012), "Impact of urbanization on flooding: the Thirusoolam sub watershed - a case study", *Journal of Hydrology* **412-413**, 210-219.

Tang, Z., Engel, B.A,, Lim, K.J., Pijanowski, B.C. & Harbor, J. (2005), "Minimizing the impact of urbanization on long term runoff", *Journal of the American Water Resources Association* (Paper No. 04103) **41**(6), 1347 - 1359.

VanShaar, J.R., Haddeland, I. & Lettenmaier, D.P. (2002), "Effects of land-cover changes on the hydrological response of interior Columbia River basin forested catchments", *Hydrological Processes* **16**(13), 2499-2520.

Wood, E.F. (1991), "Global scale hydrology: advances in land surface modeling", *Reviews of Geophysics Supplement* **29**, 193 -201.

Wood, E.F., Lettenmaier, D.P., Liang, X., Nijssen, B. & Wetzel, S.W. (1997), "Hydrological modeling of continental-scale basins", *Annual Review of Earth and Planetary Sciences* **25**, 279-300.

Yuan, F., Xie, Z., Liu, Q., Yang, H., Su, F., Liang, X. & Ren, L. (2004), "An application of the VIC-3L land surface model and remote sensing data in simulating streamflow for the Hanjiang River basin", *Canadian Journal of Remote Sensing* **30**(5), 680-690.

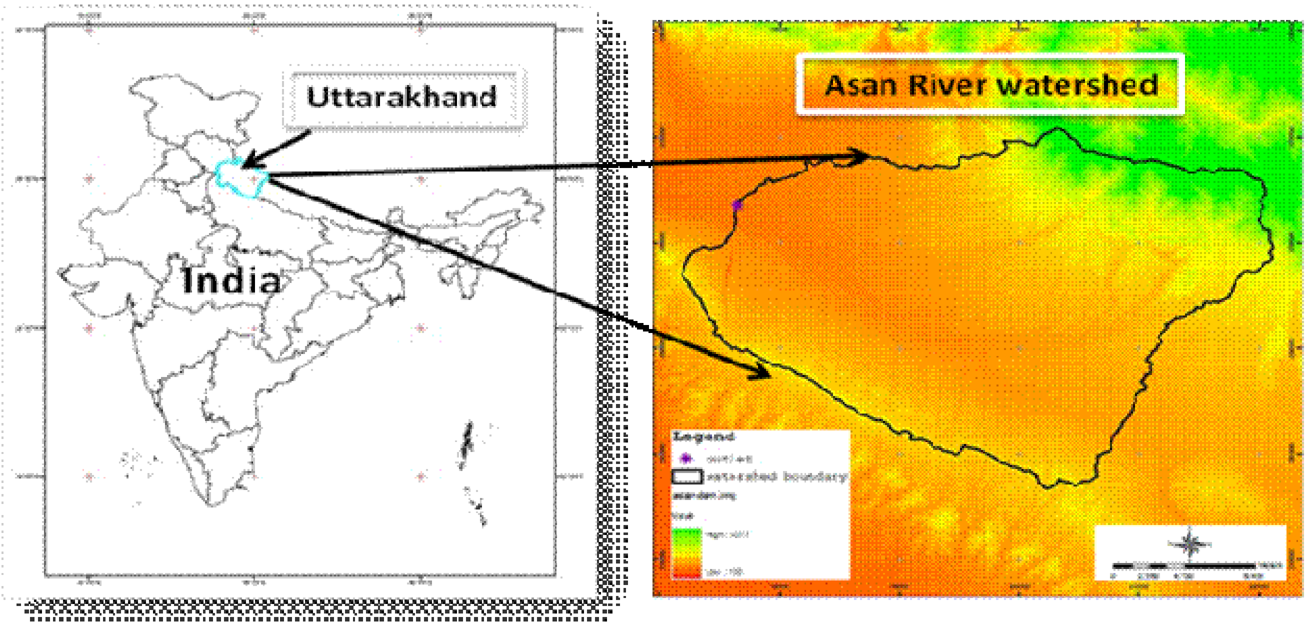


Figure 1. Location of study area on ASTER GDEM

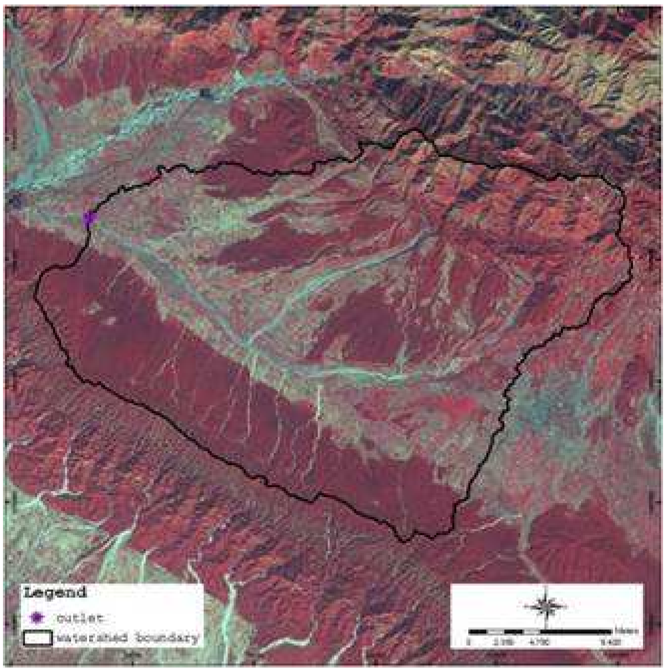


Figure 2. Landsat TM satellite image of the study area (date: 25.11.2000)

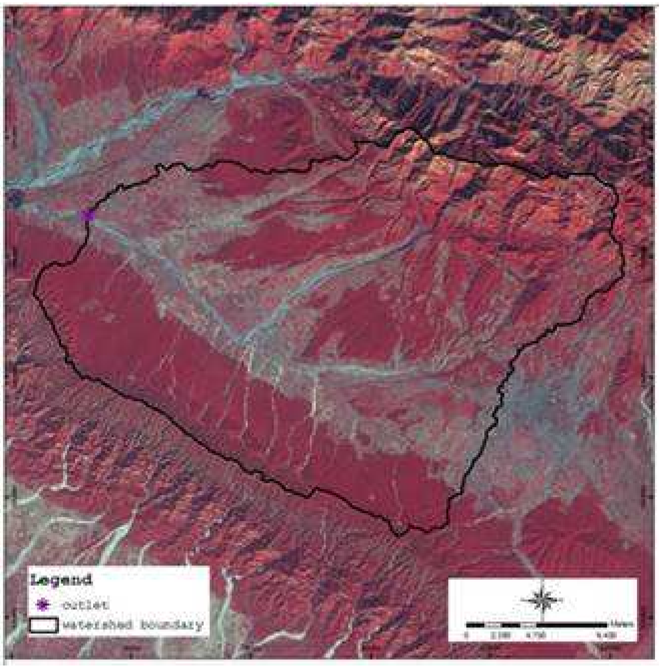


Figure 3. Landsat TM satellite image of the study area (date: 15.12.2000)

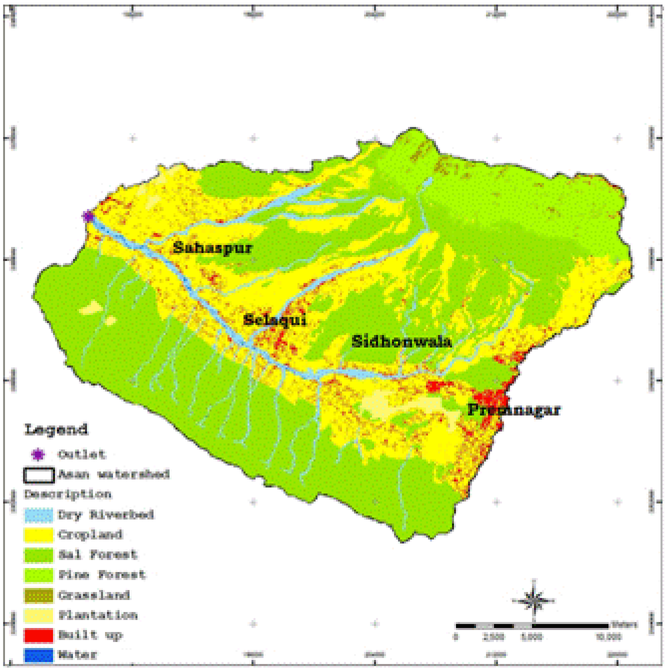


Figure 4. LULC map of year 2000

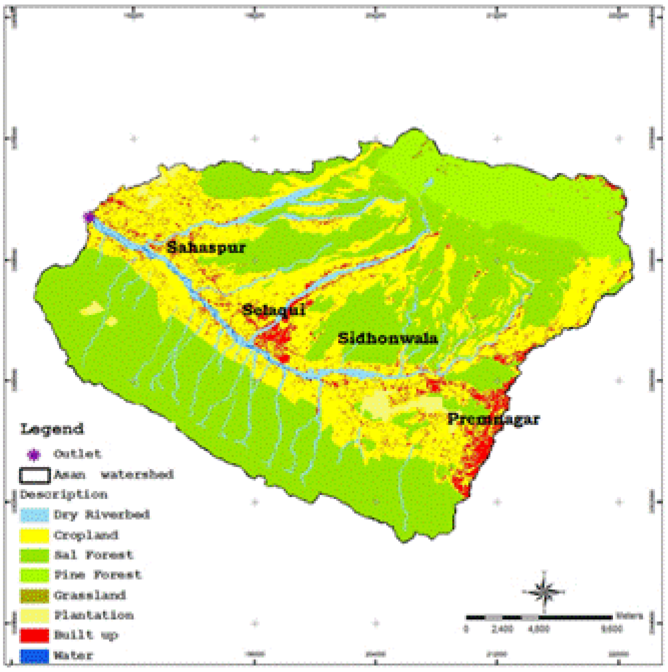


Figure 5. LULC map of year 2010

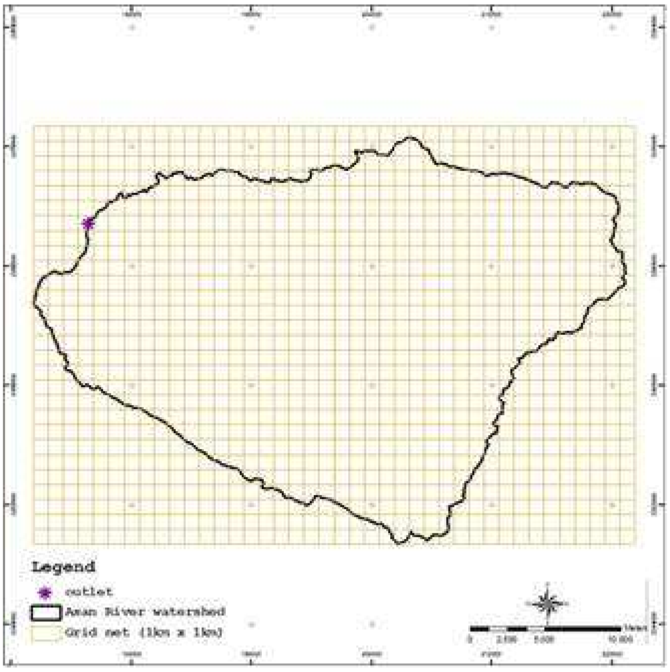


Figure 6. The 1 x 1 km grid map of the Asan watershed

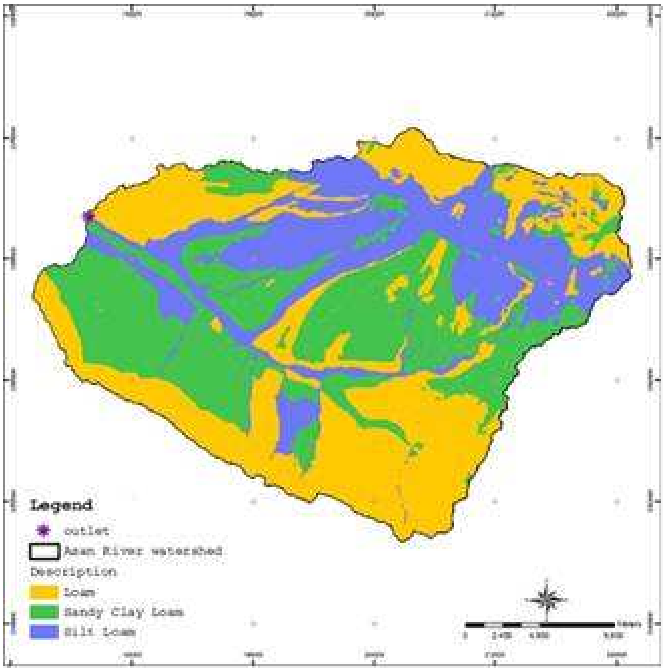
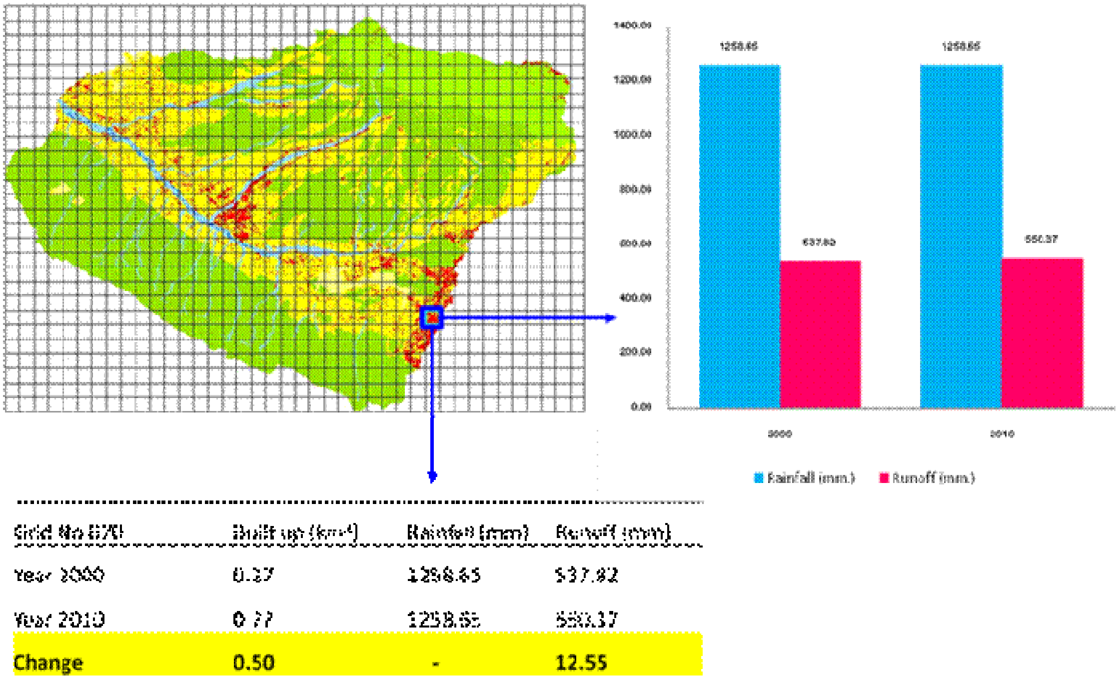
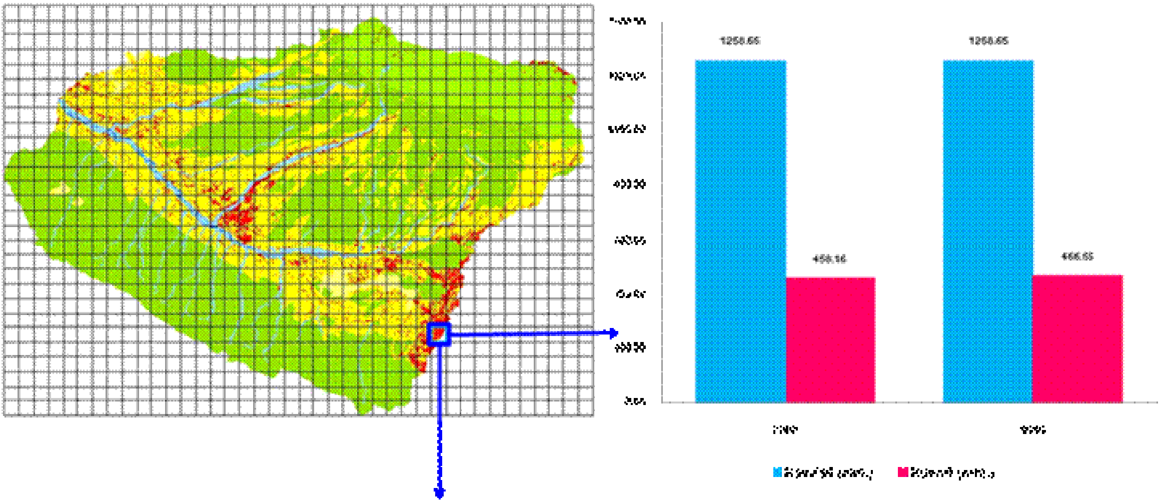


Figure 7. NBSS&LUP soil map of the Asan River watershed



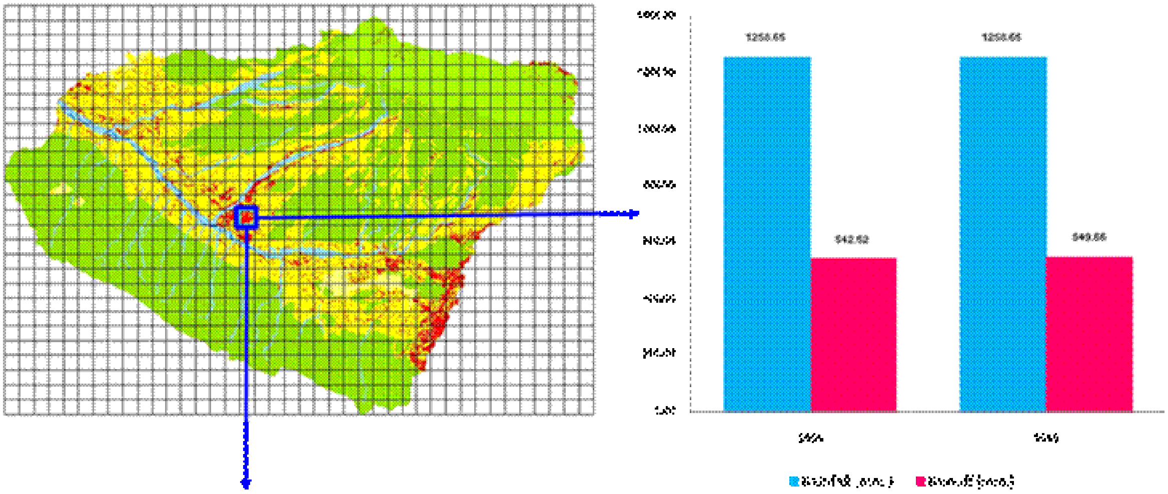
Grid No 870	Built up (km²)	Rainfall (mm)	Runoff (mm)
Year 2000	0.27	1258.65	537.82
Year 2010	0.77	1258.65	550.37
Change	0.50	-	12.55

(a) Grid No. 870



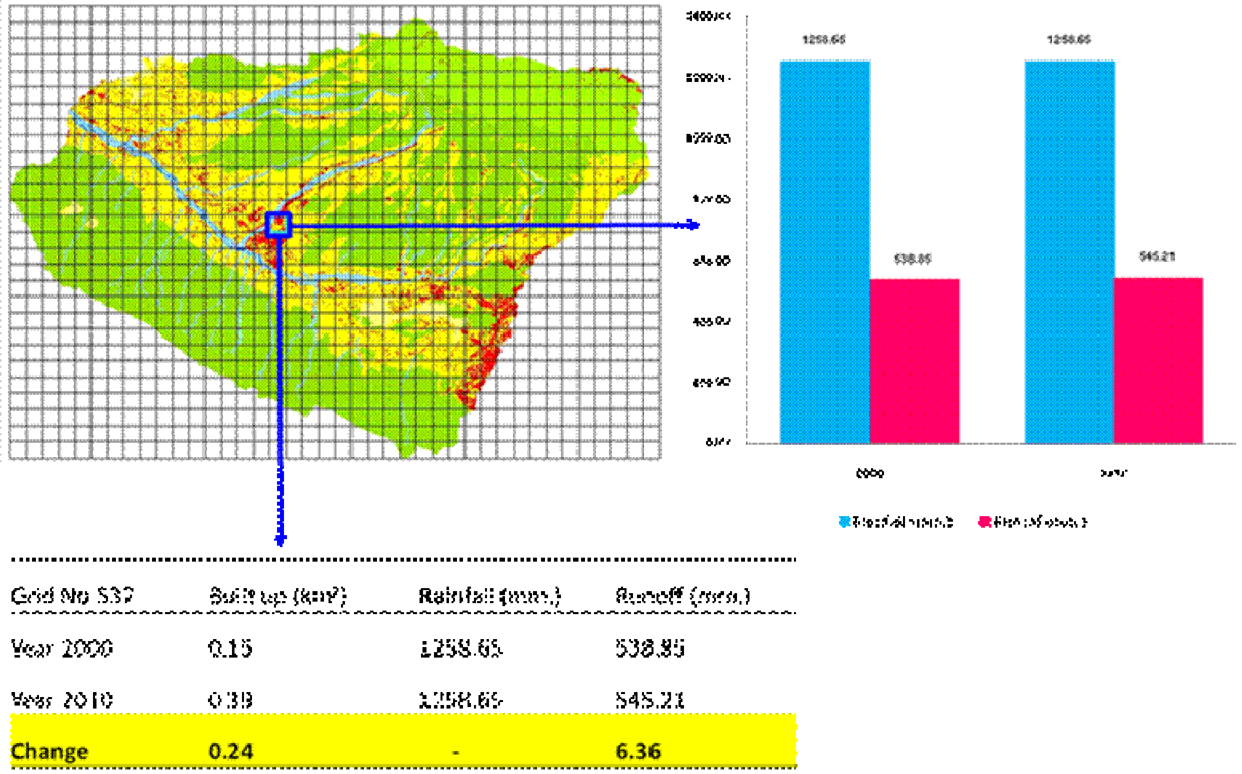
Grid No 910	Built up (km²)	Rainfall (mm.)	Runoff (mm.)
Year 2000	0.28	1258.65	458.16
Year 2010	0.62	1258.65	466.56
Change	**0.34**	-	**8.40**

(b) Grid No. 910



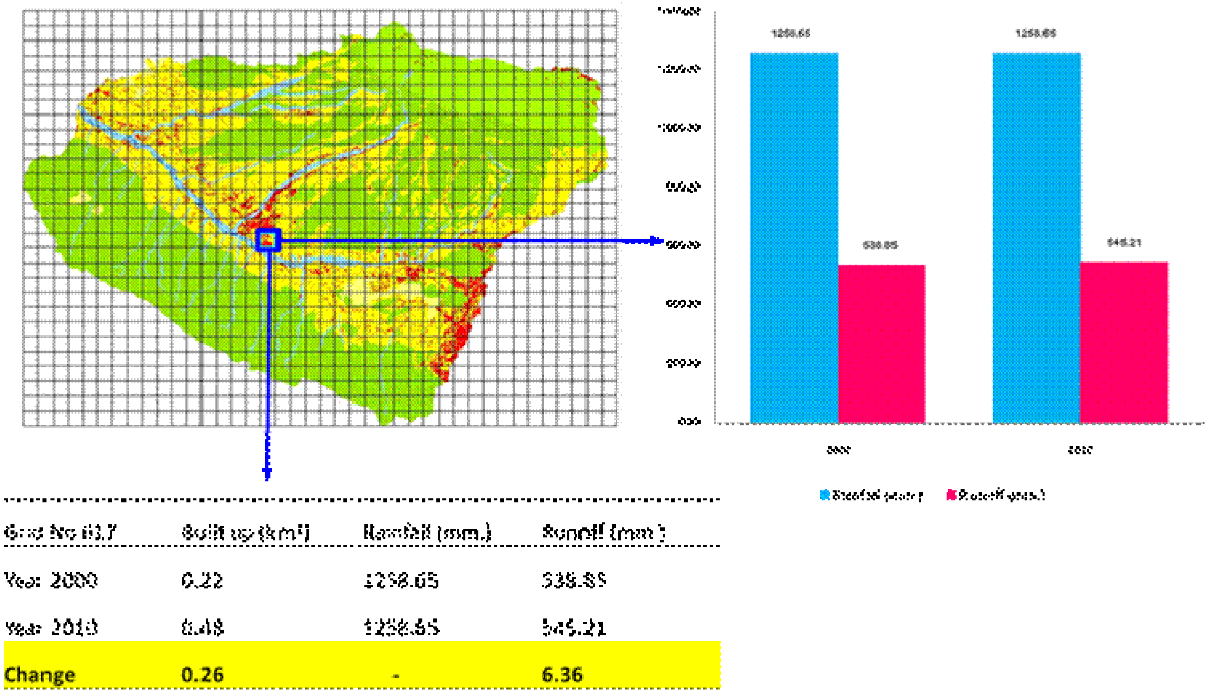
Grid No 577	Built up (km²)	Rainfall (mm.)	Runoff (mm.)
Year 2000	0.37	1258.65	542.52
Year 2010	0.67	1258.65	549.66
Change	**0.30**	-	**7.14**

(c) Grid No. 577



Grid No 537	Built up (km²)	Rainfall (mm.)	Runoff (mm.)
Year 2000	0.15	1258.65	538.85
Year 2010	0.39	1258.65	545.21
Change	**0.24**	**-**	**6.36**

(d) Grid No. 537



Grid No 617	Built up (km²)	Rainfall (mm.)	Runoff (mm.)
Year 2000	0.22	1258.65	538.85
Year 2010	0.48	1258.65	545.21
Change	**0.26**	**-**	**6.36**

(e) Grid No. 617

Figure 8. Grid wise effect of LULC change on hydrology

Table 1. LULC class area and change from 2000 to 2010

LULC Description	Area in year 2000 (km^2)	Area in year 2010 (km^2)	Change (km^2)	% Change	
				Within Class	**Overall**
Pine forest	59.47	61.37	1.90	3.19	0.29
Sal forest	315.75	316.60	0.85	0.27	0.13
Grassland	4.73	0.90	-3.83	-80.97	-0.58
Cropland	206.63	201.92	-4.71	-2.28	-0.72
Plantation	8.84	8.79	-0.05	-0.57	-0.01
Built up	22.31	28.39	6.08	27.25	0.93
Dry Riverbed	37.44	36.70	-0.74	-1.98	-0.11
Water	0.90	1.40	0.50	55.56	0.08

Table 2. Summary of results showing change in built-up fraction and consequently runoff

Grid No.	Fractional Area of Built Up (km^2)			Estimated Runoff Potential (mm)		
	2000	**2010**	**Change**	**2000**	**2010**	**Increase**
617	0.22	0.48	0.26	538.85	545.21	6.36
537	0.15	0.39	0.24	538.85	545.21	6.36
577	0.38	0.67	0.29	542.52	549.66	7.14
910	0.28	0.62	0.34	458.16	466.56	8.40
870	0.27	0.77	0.50	537.82	550.37	12.55

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