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Review Article

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Water Sensitive Urban Planning

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Abstract

Extreme weather events responding to imbalances in natural and physical environment systems have been observed recently with floods, droughts, tsunamis etc, mostly in the urban areas of the world. Several studies carried out have modelled surface water runoff from land use and land cover with differential precipitation and found that surface runoff increases with the proportion of built up areas. Despite these facts, some urban catchments still reveal a better natural water cycle though built up is more in them as compared to others having less built up but facing disturbed natural hydrological cycle. Considering this, hypothesis can be made that only built up is not responsible for the runoff generation but some other factor like open spaces, planning, geology plays an important role in the behavior of runoff. The paper attempts to correlate land use, land cover, built up and resulting runoff for urban watersheds. It also finds out correlation between local bye laws and behavior of water cycle over it.

Considering runoff modification as prime effect of urbanization to the hydrological cycle in terms of behavior of surface water, the intention of the study is to contribute to a better understanding of the relation of the local hydrological parameters in urban areas to the physical transformation of land covers as impervious built ups and develop an understanding of the resulting effects of components of one system on other. This will help to predict and project the changes in hydrological cycles due to land use /land cover transformation and thus help urban planners in physical planning of new urban areas as well as development of an existing urban area to achieve a maximum sustainability in the city. Hence, water sensitive urban planning with combination of built up, open spaces and geology will help planners to cope with the unwanted increase in runoff leading to flash floods. For this purpose, 19 urban water catchments were studied for their development scenario byelaws, built up, runoff and water tables for past 30 years and above. Observations were used to correlate urban parameters like land cover, runoff, infiltration, and evaporation with hydrological ones and bring a model solution for balanced water cycle achievement during urbanization.

Introduction

Urbanization mostly leads to imperviousness of the natural land. Impervious surfaces associated with buildings, roads, manmade drainages, under ground and over ground infrastructure; impervious areas etc. lead to developed land rather than virgin land. As built up. CIESIN's (Center for International Earth Science Information Network) Global Rural Urban Mapping program have revealed that urbanization increasing by 1 to 2 % decadal and almost 15 % in these recent years. Worlds has uplifted its urban population by 20 to 3 billion in 20th century and it is predicted that coming future will experience growth of more than 50% urban people on earth. This figure can cross 80% marks growth in some under developed areas by 2030 [1-3].

Across all regions and for all three decades, the expansion rates are higher than or equal to urban population growth rates with increase in population altogether, suggesting that Urbanization is now the future world for all the habitants [4].

Panelists from IPCC, (International Panel on Climate Change) UNEP, USGS, (Unites States Geological Survey) Rio Summit, and SDG(S) sustainable Development Goals etc. Have identifies Increasing Urbanization, reducing recharge, extreme weather events, varying precipitation and climate change as alarming indicators for present conditions [5, 6]. (World Water day panelists identified unplanned development and over misuse of resources as main challenges facing water management in cities. Thus, urbanization and unplanned development has been the basis of these unnatural behavioral changes in main cycles of earth system. Water cycle is affected greatly along with wind and air cycle leading to floods, droughts, pollution, ozone layer depletion, Coe increase etc [7, 8].

The knowledge of water cycle is of utmost importance to take a step forward in way of sustaining the remaining misbalance on earth. Relation of urban area with water cycle and rural area with the same has to be studied because urban areas are more disaster prone to flash floods and droughts. Every aspect of this cycle need to be emphasized with the role of each action on other. The research in this paper is correlating built up, open spaces, precipitation, runoff and recharge among themselves and also worth the physical planning bye laws to see the effects of planning, development on natural cycle.

Literature review

In changing urban and climate scenarios, urban functions and the natural cycle of environment working is greatly affect due to higher degree of incompatibility. Urban planners have the pressure to safeguard the hydrological cycle as almost all urban areas have hampered the cycle and resulting floods are common everywhere even in ordinary rail fall. Existing natural environment offers good opportunities to be integrated with the urban areas to be developed and though natural environment suffer, they can be restored by applying new measures and regulations. New environment suitable for natural water cycle can be developed or added as and where needed to the existing situation. Since urban areas are developed as per the guidelines of planning documents, the conservation and development of natural and urban compartments becomes a necessity of planners. Physical planning is a key tool with urban planners to develop an area with minimum disturbance to natural working by mimicking natural systems. Physical planning leads to changes in Land Use, land cover changes and runoff converting to flash floods disturbing any harming life and property are growing issues today.

The overall physical planning challenge is concerned with providing policy guidelines towards the envisioned growth of a country in a manner that is efficient, equitable, and sustainable. In particular, the policy guidelines need to address the specific challenges like increasing urban population, density , demand for urban services; unplanned expansion of settlement areas, declining agricultural productivity in urban context, land degradation, limited access to land, outdated land use plans; the increasing role of local government units in planning; and lack of institutional linkages. Thus, land use and land cover is mainly affected by policy guidelines for physical planning. The challenges and desired development directions suggest several strategies including, among others, the promotion of national dispersion through regional concentration, strengthening of urban-rural linkages, resource area-based development, and installation of mechanisms for effective regional development. Despite the perceived parallels between land use controls and water quality controls, the two areas have usually developed independently of each other, presenting significant differences in fields such as management, regulations or administration. Many efforts already though being done in this field are insufficient, management practices and other effects of urbanization on natural resources like water are yet to be tackled carefully by planners [9].

From school of architecture UCD, have explained in spatial planning and hydrology at different scales that in order to make informed decisions about future hydrology policies for expanding cities, it is crucial to determine where change to the landscape is likely to occur [10]. The majority of surfaces within a city are sealed preventing the infiltration to groundwater and aquifers, and increasing the possibility of flood that may endangering the quality of the water supply Furthermore there are additional behavioral changes arising from lifestyle choices and fashions. In addition, climate change is going to increase the intensity and frequency of floods in many areas. It is therefore imperative to examine the local landscape and examine the pre-existing drainage systems that currently are operating and look at means of improving this to cope with changing climates and surfaces. U.S Land Cover change and EPA, Research Project, 1999 developed a methodology and determined the variables of land cover change by using temporal and spatial frameworks and categorizing land cover types into Urban and Built-Up ,Agriculture (Cropland and Pasture) , Forests and Woodlands , Rangeland/ Grassland , Wetland , Water bodies , Snow and Ice , Natural Barren ,Disturbed or Transitional Land Cover Change ,General Land Cover Type, Landscape, biophysical properties, Landscape properties and concluded that and land cover changes occur at all scales, and changes at local scales can have dramatic, cumulative impacts at broader scales. Consequently, land use and land cover changes are not just of concern at local and regional levels (i.e., because of impacts on land management practices, economic health and sustainability, and social processes), but globally as well [11].

Land use and Land Covers changes are driven by Natural processes-Climate and atmospheric changes, wild fire and Pest Infestation, Direct effects of human activity, such as deforestation and road building ,Indirect efforts of human activity , as water diversion leading to lowering of water table. Unfortunately, there is a paucity of information on land use and land cover change except at local levels. The successful implementation and planning of SUDS (EU 2013) (Sustainable urban drainage systems) have introduced an Ecosystem Approach to sustainable use of natural resources – flood control, water storage, and reuse. Conservation of natural resources – pollution attenuation at source, supporting and maintaining wildlife habitats. Rainfall and the soil conditions are the direct causes of urban runoff. Rainfall can take one of several routes once it reaches the earth’s surface. Rainwater can be absorbed by the soil on the land surface, intercepted by vegetation, directly impounded in many different surface features from small depressions to large lakes and oceans, or infiltrated through the surface and subsurface soils into the groundwater. Another route taken by falling precipitation is runoff. Soil characteristics in a watershed have a direct effect on the rainfall-runoff process and these include soil layer thickness, permeability, infiltration rate, and the degree of moisture in the soil before the rain event. The greater the permeability of the soil, or the ability to infiltrate rainfall to its lower strata, the less remaining to become runoff Causes and effects of runoff on urban land surfaces vs. rural Land Surfaces- Population effects on runoff, vegetative cover, and water flow velocity, changes to natural hydrologic cycle [12]. Remedies suggested were porous pavements, green belts, adsorbents in sewer inlets and surface cleaning using wet scrubbing.

Indian scenario for variations in water availability

Study of some Indian Major Urban Centre’s for variations in natural hydrological cycle with respect to impervious areas and water availability reveal that built up areas and water withdrawal has resulted in declining of water levels in areas. The Indian Urban centers were compared for the water scenario and their water availability on basis of worldwide ranking as per their urbanization extent and as per their urban land area (footprints) [13]. Water Supply and Demand for these urban cities and the density and source of available water resources were compared to achieve a correlation of water demand and supply as shown in figure 1.

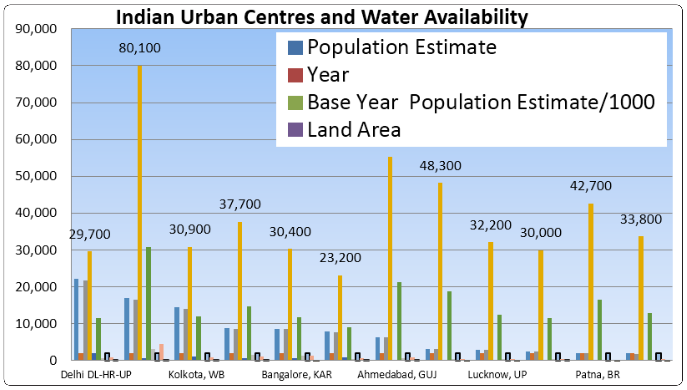


Figure 1: Water availability chart for Major Indian Urban centers [14].

List of parameters-Identified from literature, Computer Model and personal findings:

After referring almost 49 papers, the most related and pointed parameters were sorted out and their occurrence action role of hydrological cycle was counted. The maximum occurred parameter was weighted most and relative a graph was plotted to see the maximum correlated parameters. The parameters in red cloud in Figure no 2 are the most occurring parameters in Hydrological cycle behavior (Refer Figure 2).

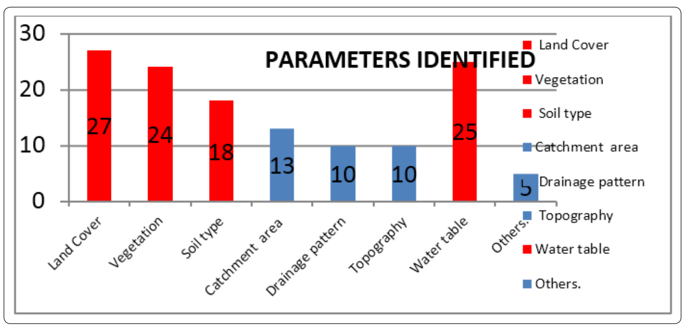


Figure 2: Graph showing maximum value of parameters repeated in Literature review.

Case Study –Bhopal City

Study of Bhopal City comparing decrease in water levels and increase in built up areas of certain localities and villages of Bhopal, India, done by digitizing the wards of Bhopal city and comparing their respective water levels for a span of 40 years along with primary and secondary survey showed interesting inferences having most built up areas with good water level and recharge whereas least built area too faced declining water level as shown in Table 1.

Table 1: Drop in recharge levels in localities of Bhopal city from 1970 to 2010

S.N	WARD	Drop in Recharge % Average
1	25 (Tulsi Nagar)	Decrease 75to 25
2	26, (Panchsheel)	Decrease 95 to 11
3	27 (MANIT)	Decrease 99 to 69
4	28 (Chuna Bhatti)	Decrease 96.55 to 58.85
5	45(Ravishankar Nagar)	Decrease 76.59 to 35.49
6	48 (Arera Colony)	Decrease 65.84 to 6.73
7	52 (Shapura)	Decrease 95.55 to 51.71
8	34 Jawahar Lal Nehru	Decrease 32.17 to 7.18

The Study was carried out in two different watersheds of Bhopal, one being the developed in natural surrounding with physical planning norms gradually and other being rapid development with out or with careless development due to absence of strict Building and land development by w laws. The wards coming within these natural boundaries have been analyses for population density and percentage of built up and open left in their areas. . It consists of Area Colony, Sapura, ChunaBhatti, and MANIT. The study area spreads over 117800 sq.kms. Survey of India Top sheet No. 55 E/8 and bounded by latitudes 230 10' to 23015' N and longitudes 77023'30 to 77027' E. Bhopal- India. Derive the study area of Observations.

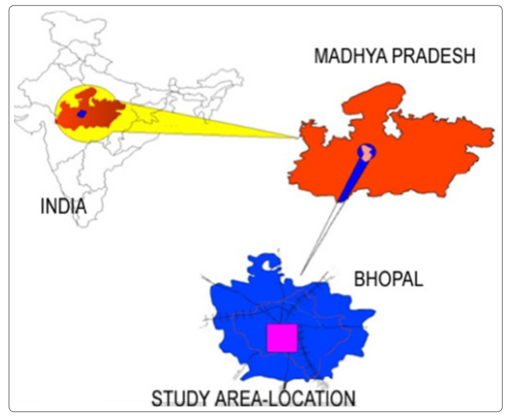
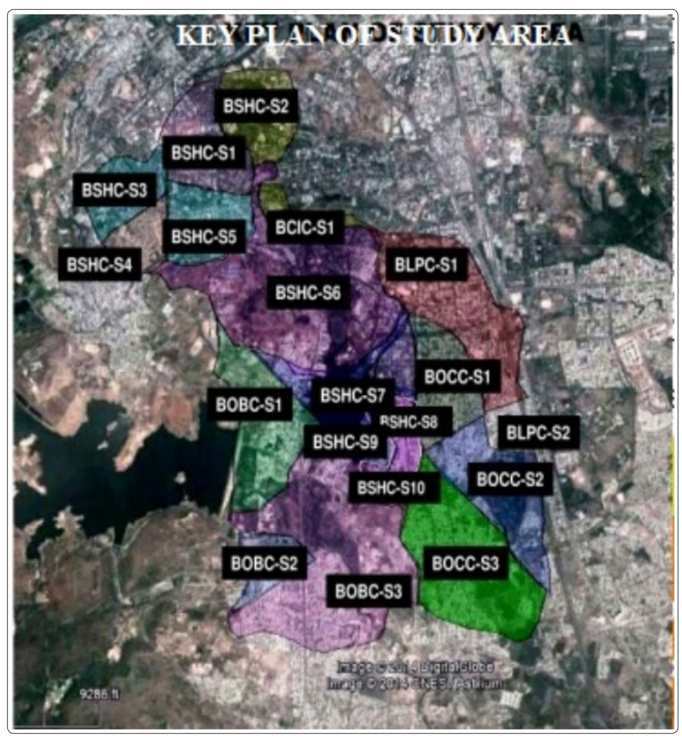


Figure 3: Bhopal City



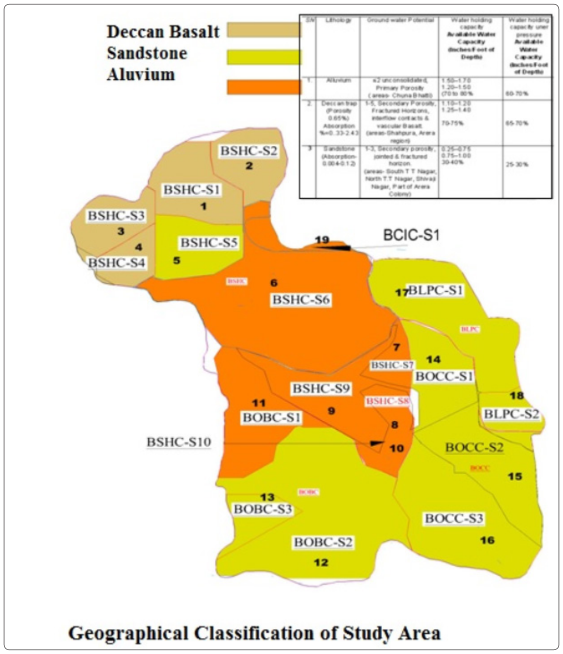


Figure 4 & 5: Sub Catchment and Geological division map of tudy area

The study area consists of three different types of geology as shown in Figure 4. The purpose of selecting sub catchments with different soils was to correlate the built and resulting runoff with respect to the prevailing soil characteristics and the roughness values for different land covers. Hence, for analysis procedure, the sub catchments were divided in three groups and 19 sub catchments with respective soils and forth group is considered for impervious soil, which is present in all catchments in some or other form as shown in Figure 4 & 5. The geology map was made from the GSI map and Geology map of Master plan 2012. The geological characteristics were determined from the hydrogeology report of SGWB.

Methodology

The methodology adopted shown in figure 6 to study and observe this correlation broadly consist of observation for variations in spatial scale for sub watersheds around 500 or more hectares for urban expansion, changes in land use land cover and hydrological components such as water level in aquifers, wells, runoff and drainages from past to present at temporal scale of about 40 years.

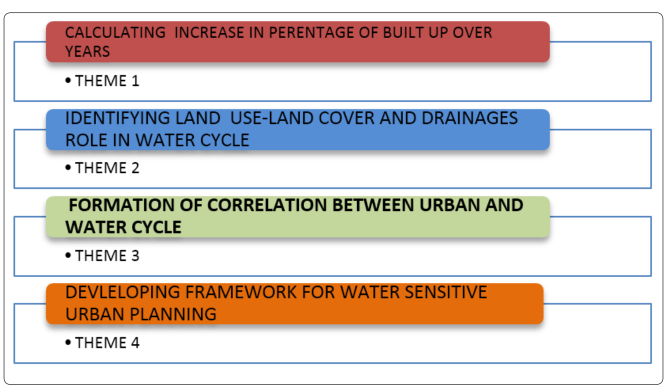


Figure 6: Methodology

The conceptual framework starts with (theme 1) studying processes like induction of impervious layer over natural soil, blocking of natural drainages, withdrawal of ground water etc. within the urban system that contribute to hydrological cycle change by increasing surface runoff, decreasing ground water levels and affecting natural path ways . His second focus (theme 2) is on identifying on the observed pathways through which specific water cycle changes affect the urban system. The third focus (theme 3) is on developing a framework by correlating the pathways and resulting variations on completion of natural and urban processes, to address the resulting interactions and responses within the urban system.

Finally, the framework centers on the formulation and validation of the consequences for the interactions within the urban systems on hydrological processes and vice versa (theme 4). These four thematic foci create a comprehensive perspective of the dynamic, diverse, and complex interactions between urban systems and hydrological change processes. These interactions form the basis of the proposed conceptual model for an effective Land cover planning in relation to physical planning.

Observations

Built up and Runoff variations over years

Figure 7 to 11 show the variation in runoff to built-up in different catchments.

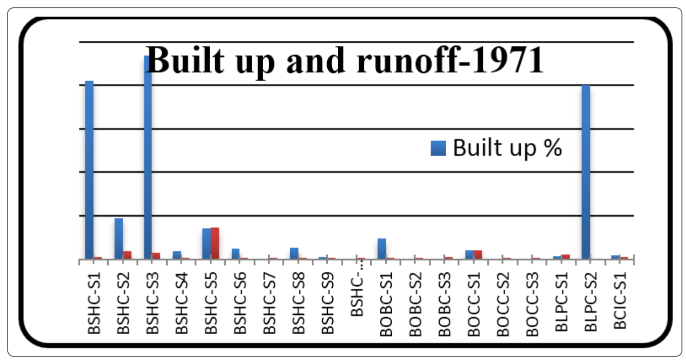


Figure 7: Built up and runoff in catchments for 1971

Here it is seen that catchment BSHC-S1, S2,S3 , S4, BPLC-S1 and S2 have very high built up as compared to other catchments, still the runoff is very low with maximum 7% and minimum 0.03 % which indeed depicts the natural working of hydrological cycle in satisfactory condition as runoff in natural conditions is about 10 to 15 %.

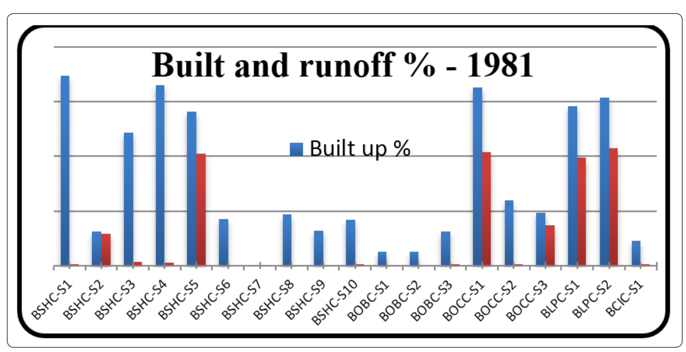


Figure 8: Built up and runoff in catchments for 1981

In 1981, effects can be seen in runoff behavior as built up increased runoff have also increased in some catchments whereas some catchments still show less runoff in spite of increase in built up as in BSHC-S2, BSHC-S8, BSHC-S9, S10, BOBC-S1, and BOBC-S2.

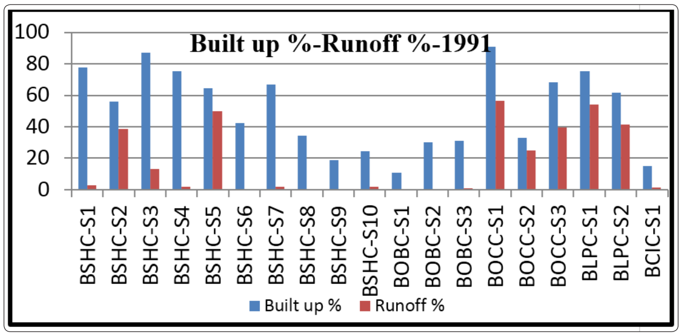


Figure 8: Built up and runoff in catchments for 1991

In 1991 scenario, it is observed that almost same pattern is there for runoff except increase in catchments BHSC-S1 and S2. The maximum runoff % is 56% in BOCC –S1and minimum is 0.05 in BSHC-S9. Maximum built up % is 90.92 in BOCC S1 and minimum is in 10.92 in BOBC S1.

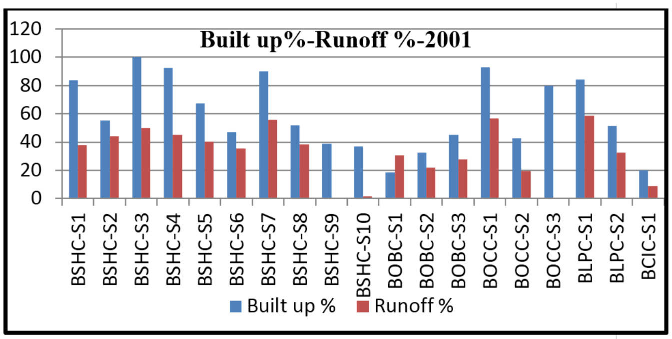


Figure 9: Built up and runoff in catchments for 2001

In 2001, a drastic change in behavior of runoff is observed for maximum catchments with a sudden increase in all except BSHC-S9 and S-10. Catchments experiencing change sin runoff are BSHC-S3, BSHC-S4, BOBC-S2, BOBC-S3 and BOCC-S1. These catchments already had built up of about 30% on it, but they hardly faced more runoff than natural value of 15 to 20 % of runoff until now.

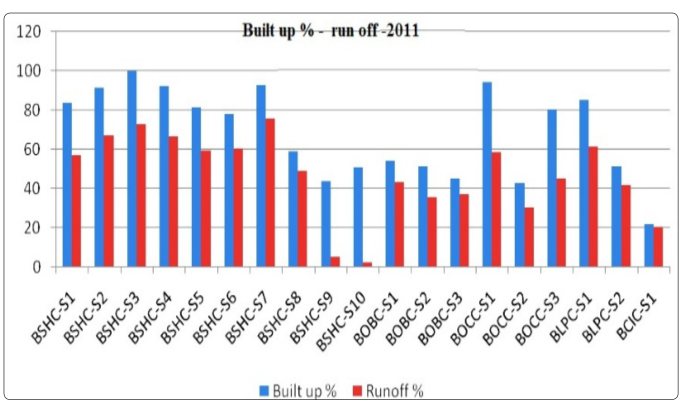


Figure 10: Built up and runoff in catchments for 2011

The fully urbanized study area can now be seen getting affected by the variations in runoff pattern through the study area, almost correlating with the increase in built up % and runoff %. The maximum runoff % is 75.85 in BSHC-S7 and minimum in BSHC-S10 with 2.31 %.

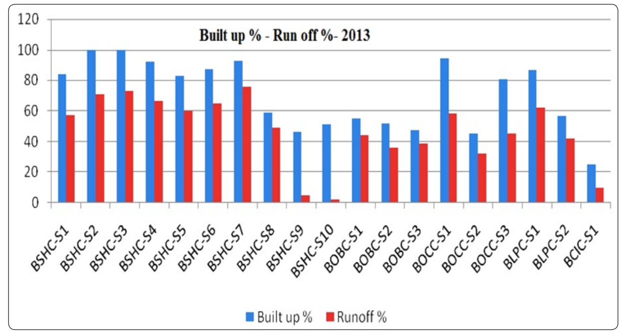


Figure 11: Built up and runoff in catchments for 2013

Almost same pattern of variation observed in 2013 except increased runoff % reaches to 75.86 % stating that only 24.24 % water has been available for infiltration and evaporation, which is just opposite the natural cycle where 10 % is for evaporation, 10 to 15 % is for runoff and rest is to be infiltrated.

Observations from figures 7 to 11 reveal that runoff increases with the increase in Built up having a strong correlation in almost all sub catchments except BSHC-S9, S10, BOBC S-2, BCIC S1 and BOBC-s2. With increasing Built up, runoff has increased simultaneously about 45 to 70 % in some catchments and wards. Catchments like BSHC S9, S10 have natural areas preserved until date. Catchments like BOBC S3 BOCC S2 and BLPC S2 have rapid development in last 10 years ND BOBC S3, BOBC S2 have planned gradual development since last twenty years. Runoff in these areas has increased but not in proportion to rapid urbanization.

Identification of excess Built up/land cover at colony level with respect to by laws:

The observations for colony level survey revealed that most of colonies had residential, commercial, educational and service areas as main land uses with roads. The percentage of these land uses are as per the National Guidelines as proposed by UDPFI (Urban development plans formulation and implementation).

Since there are no such rules for protecting and conserving natural drainages as well as open areas that are good in recharging, new guidelines can be proposed to keep the natural areas preserved for the recharging as well as storing the running water which also leads to implementation of policy catch water where it falls Natural drainages and open spaces in plots as well as roads, parking and other uses should be kept open to sky as well as open to ground with some degree of porosity to let rainwater infiltrate the ground. If proper marginal open spaces and M.O.S along with proper allocation of gardens, parks, playfields, green belts etc are provided, we can achieve around 60% of more recharge area than at present as depicted in colony maps. Also, land uses and land cover with the help of table 55 can be used to attain maximum rechargeable pockets in a colony. These pockets can be obtained by imposing layers of slopes, soil porosity, land covers and drainages to locate the appropriate spaces for recharging pockets. Each colony if planned accordingly with prior EIA and overlapping of layers as above, can manage the runoff created within itself in form of recharge of water levels.

Ideal example of colony with actual development and development as per rules and rechargeable pockets are compared in Figure 12 & Figure 13.

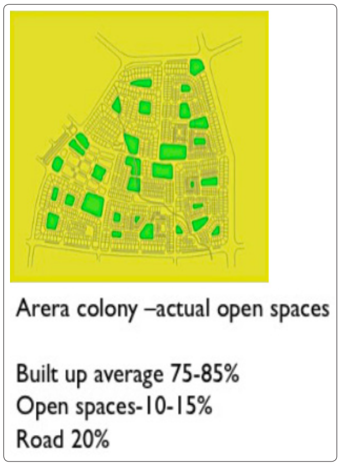


Figure 12: Actual colony layouts with open spaces

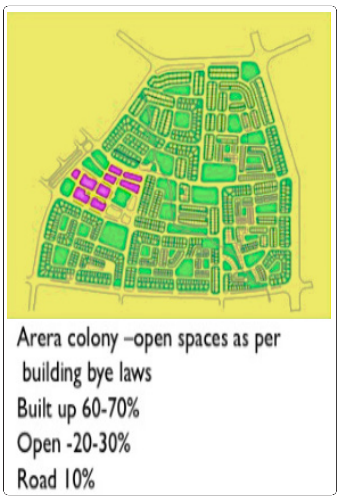


Figure 13: Colony layout as per guidelines and recharge pits as Ideal layout

Identifying correlation between urban and water cycle

Observations of different catchments and land covers show that the catchments having land cover with roughness values ranging from 0.011 to 0.013 had no very less infiltration and most runoff due to absence of vegetation. Similarly, concrete and dense bushes showed slightly better behavior in catchments BSHC S4, BLPC S1 etc. grass and mud surfaces helped more in reducing the runoff intensity and thus helped satisfactory infiltration. Dense bushes and natural soil conditions were best to protect natural cycle of water with least runoff and most infiltration.

The roughness values , land cover and the geology when compared together with runoff pattern it is clear that alluvial soil accompanied by dense bushes and natural soil cover assures best working of natural cycle. Since urbanization does not support this combination all over, it can be planned at some pockets of urban area having alluvial soil as geological base. Similarly, sandstone is good in fast infiltrating the runoff water with the help of grass and medium vegetation land cover.

Basalt shows some scope of infiltration if land cover imposed on it is a dense bush or forest. Hence, city parks and natural drainages with basalt base should be landscaped with dense bushes. Land cover with scanty grass and concrete does not support infiltration greatly and hence development should be proposed on such pockets with impervious base and least grass or natural cover. These observations help to decide the planning perspective based on geology and land cover. This perspective can be further confirmed with long time variations in water levels, which reveal the infiltration pattern of natural cycle in urban areas.

Conclusions and Suggestions

Physical planning can be suitably incorporated with better combinations of land covers, roughness values and vegetation's on specific soils. Pervious connected areas and unconnected impervious area play vital role in intercepting the rainwater and allowing the rainwater to flow in desired direction. Connected impervious areas and disconnected pervious areas play an important role in handling the runoff Physical planning with combined efforts of soil groups, land cover and connected pervious and unconnected impervious areas can reduce the runoff put 40 to 55 percent and increase the recharge up to 60 to 70 percent.

Alluvial soil is best in infiltrating water but needs large amount of time to percolate water deep within and basalt soil does the same in a quicker time, but alluvial if treated merely with grass and raw natural condition also helps in fast infiltration. Basalt does not allow infiltration of rain so easily with normal land covers. Proper land cover in essential for getting optimum use of soil below in catching water. Sandstone infiltrated rainwater easily; peak runoff can be avoided in such areas with land use and land cover planning.

Hence, natural system sustains its working until its carrying capacity is exceeded. When exceeded, it needs man made treatment of few basic planning principles and artificial efforts to maintain its capacity and increase it for sustainable development. Some catchments produce more runoff than others though having same built up percent do. Table 2 suggests some combinations base on Geology, open spaces and proposed land covers to achieve resulting runoff.

Table 2: Suggestions for ideal by- laws at colony level planning

Size	Geology	% open space as per bylaws	Pro-posed land cover	Recharge pit (within or around built up and open space)	Built up as per by laws	Re-sulting runoff
4 acre	Basalt	25%	Semi porous	15%	50%	-35%
8 acre	Sand-stone	35%	Mod-erate porous	25%	55%	-55%
8 acre	Alluvial	30%	Grass/ vegeta-tion	20%	65%	-40%

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