A REVIEW ARTICLE ON IMPACT OF URBANIZATION ON HYDROLOGICAL PARAMETERS

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ABSTRACT

As long as human being continues to exists, urbanization continues. Urbanization has a direct effect on environment which in turn effects the variations in hydrology. It may results from changes in the land use pattern to built-up areas resulting in runoff which ultimately leads to flood. Most of the studies revealed that land use pattern has drastically changed in which the built up area increases year after year. The land use land cover changes can be identified using GIS. Many researchers have found that urbanization has an impact on hydrological parameters such as runoff volume, discharge in drains, infiltration, interception, evapotranspiration etc. An attempt has been made to consolidate the review of literature related to impact of urbanization on hydrological parameters.

Key words: Urbanization, runoff, built up areas, infiltration capacity, flood

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1. INTRODUCTION

Urbanization is an important aspect of human activity which influences the environment. During the process of urbanization the land use changes and large areas of natural and agricultural lands are converted into built up areas. These changes affect the atmosphere and hydrological environment. Hydrological impacts then include the effects of these changes on natural drainage, runoff, groundwater, sediment, water quality, water demand etc. Among the hydrological problems associated with urbanization are the continually increasing demands for water for various uses, changes in the physical environment that alter the natural water balance, and the disposal of wastes that may contaminate streams and groundwater. The growth of urban areas results in significant changes in the physical properties of the land
surface. Increased surface runoff would eventually result in alteration of the prevailing hydrologic system. The effect of urbanization not only affects the humans but at the same time it affects ecosystem, water bodies etc. Land use land change is the main phenomena which occur due to urbanization. The main variable considered are the imperviousness and population density. For a city like Ernakulam, the impact of urbanization is so crucial. Studies reported that the land use pattern has changed a lot. The effect of these changes has extended not only in the city area but also towards the watershed area. This ultimately leads to the problem of flooding. The present study is an attempt to consolidate the literature related to urbanization which leads to various hydrological parameters.

2. STUDY AREA
The area selected for study purpose is Muvattupuzha River Basin in Ernakulam. As Ernakulam is the commercial capital of Kerala the city prone for urbanization. The district is divided into highland, midland and lowland. The altitude of highland is 300 m. The important rivers of the district are the Periyar and the Muvattupuzha of which the former flows through Kothamangalam, Aluva, Kunnathunad and Paravur taluks. The Chalakudy River which flows through the north of Aluva merges with the Periyar at Elamthikara. The river Thodupuzha, the Kaliyar and the Kothamangalam merge together to form the Muvattupuzha River. Muvattupuzha is a common place of three rivers – namely Thodupuzhayar (Thodupuzha River), Kaliyar (Kali River) and Kothayar (Kothamangalm River) called Thriveni Sangamom. Studies show that this basin experiences good rainfall and humid atmosphere throughout the year. The normal daily mean temperature of this basin varies from 25.9°c to 28.7°c as observed at I. M. D Observatory. The Muvattupuzha basin is getting rainfall both South-West and North-East monsoons. The South-West monsoon begins in June and ends in September and North-East monsoon begins in October and ends in November.

3. REVIEW OF LITERATURE
Archana et al. (2015), defined urbanization as the process of land use alteration. The growth of urban areas results in significant changes in the physical properties of the land surface. The consequence is increase in the area of impervious surface resulting in enhanced surface runoff. Increased surface runoff would eventually result in alteration of the prevailing hydrologic system. They made an attempt to quantify the impact of land use changes due to urbanization on surface runoff and thereby to study the emerging challenges it impart on the water management and sustainable development. The study area was Cochin, one of the fast developing second tier metros in India. The land use pattern in the area has changed considerably since 1965. The built-up area has increased from 36.51 km$^2$ in 1965 to 46.09 km$^2$ in 2005. This increase in built-up area has resulted in an increase in runoff volume of 23.5Mm$^3$ in the last 45 years. The built-up area has increased by 2% in the last 5 years resulting in an increased runoff volume of 1.8 Mm$^3$.

Baiyinbaoligao et al. (2011) adopted the distributed Kinematic Wave hydrological model to calculate the two rainfall-runoff events in 2005 and 2006. They used Esri’s ArcView 8.3 and its Spatial Analyst extension module to determine the flow direction, flow accumulation, and stream network as features. They used a 50 m DEM spatial data issued by Japan Geographical Survey Institute in 1996 to produce the digital basin of the Kuronagi River. They also utilized the Arc Hydro Tools to divide the catchment into 27 sub-catchments and then to calculate the slope, area, average slope, river’s length, and slope for each sub-catchment.

Benson Nyayieka (2016) highlighted the key issues related to urbanization. It was reported that urbanization altered the land use. They also reported that a change in land use will lead to
changes in soil, ecosystem, environment, water resources and bio diversity. A change in the land use pattern of the Kapsabet town was mainly mentioned in this article. From the study it is clear that urbanization changed the habitat through housing, road construction, and soil pattern change. He concluded that the development should be guided through a sound knowledge about the soil information of the urban areas

Borys et al. (2014), expresses their concerns over the growth of urban population on basic outflow area. It is said that developments along the basin area not only influence the catchment but also the water balance. They reported that the hydrological modeling of rainfall runoff was the best method for assessing the growth of urbanization. The selected study area has undergone a rapid development. For assessing the land use data pertaining to years 2000 & 2011 were considered. HEC-HMS package was used for the runoff rainfall analysis of the basin. SCS-CN method was applied for analyzing the effective rainfall calculations. Synthetic and historical hyetograph was considered for evaluating the impact of urbanization on basin runoff under storm conditions. The result showed that due to urban development of the basin area, peak discharge and runoff volume increased and peak time is decreased. Also a significant reduction in peak values was noticed for a decrease in normal storage level in reservoir or green commercial center was present.

Chithra et al. (2013) reported that the as the population increases, the impervious areas of the city increases. LULC is the driving force behind the increase in impervious surface which results from urbanization. Satellite remote sensing images integrated with GIS were used for identifying and estimating the impervious surface. For preparing the LULC of study area, LISS IV imagery for the year 2012 was adopted. Additionally they determined the total pervious and impervious areas under the city. It was concluded that supervised classification proves to be a good method in mapping impervious surfaces if ground knowledge is available.

Chithra et al. (2015) reported that urbanization increases impervious area which indirectly affects the environment. Impervious areas also reduce water quality and quantity. Urban heat island, another factor which causes imperviousness which also relates to reducing the aquatic life. A measure to quantify the impervious area was emphasized. Impervious surfaces significantly reduce the water quantity and quality in a watershed. It is reported that the impervious surface degrades the watershed quality by greatly reducing the stream flow and increasing the stream temperature. They carry huge pollutant loads downstream, causing due harm to aquatic life. Landsat TM and ETM were used in the study purpose.

Deepak et al. (2017), reported that rainfall and land use land cover influence the hydrological characteristics of a river basin. Since the runoff potential is altered naturally it increases the runoff volume. Soil conservation Service model was applied to identify the runoff characteristics in the study area. The study reported that there is a wide decrease in the vegetation cover due to urban expansion. The obtained runoff value was compared with the calculated value. The study concluded that estimated surface runoff increased by 3 percent in 10 years from 1990 -2000 considering the same rainfall. The future runoff of the river can estimated by observing the land use land cover of the catchment area.

Ghazi (2013), focused on the effects of urban population on stream flow in an arid region. Various data layers like satellite imagery, DEM, LULC map, soil map were used to delineate the water shed characteristics. Soil Conservation curve Number method was used to determine the curve number and runoff flow distribution. GIS data were used to identify the land use from year 1970 to 2003. The result showed that human activities have a direct correlation with increase in run off flow. The urban area was found to increase from 5.783 km² in 1980 to 13.567 km² in 1990. It was also reported that urbanization has a direct link with hydrological curve number & runoff depth.
Hasan (2017), reported that impervious surfaces prevent water infiltration into the soil resulting in increased runoff generation. The study describes long term hydraulic responses within the rapidly developing catchment area of Erbil city. DEM was used to extract the distribution of the drainage network. LULC data combined with SCS-CN were used to estimate the runoff volume. The data used in the study was multi spectral satellite images to generate LULC. Landsat TM from 1984, 2004 and 2014 were used in the study. It was concluded that the Erbil sub basin was subjected to significant land use changes in the period from 1984 to 2014. More over increased built up area led to obstructions in drainage network leading to environmental problems. Annual runoff volume of built up area increased from 8.6 to 23.5 million m³.

Jie-Ying Xiao et al. (2007), described that urbanization process changed the natural and agricultural area into built up areas which affects the atmosphere land surface energy exchange. They introduced Landsat T M to acquire data to detect the urban expansion and land pattern changes. In order to evaluate the urban heat island, normalized difference temperature index was applied. To identify the urban sprawl on hydrological cycle, a water balance was made before and after urbanization. This paper analyzed the physical aspects of impacts due to urbanization. It is concluded that runoff increased 32% annually and evapotranspiration decreased by 20%.

Karthikeyan et al. (June 2013), reported that urbanization not only affects the built up area, green area, climatic change but it also affects the water demand. Studies revealed that 54% of populations were in urban area by 2050 which increased the domestic water demand to 90 km³. Due to urbanization expansion there is a considerable loss in agricultural lands, vegetation land and water resources. LULC has a direct relationship between environment change and hydrologic cycle. The technology used in this study for assessing LULC was RS & GIS (1990, 2000, and 2009). The study area was Amravati upper watershed including Udumalpet which is the main urban area in which more problems of water scarcity and other hydrological problem facing. In the study Arc GIS 9.3 software was used for developing land use & land cover maps. The main satellite data used was Landsat 5 with TM sensor, Landsat 7 with ETM & Indian RS P6 with LISS III sensor. The different land uses were built up land, water bodies, cultivated land, fallow land & uncultivable land. The preprocessed images are classified by supervised classification method. Result in study showed that surface water body in the study area diminished gradually by 33.2% from 1990 to 2009.

Khaled et al. (2012) presented a positive correlation between urbanization, peak discharge and flood volume. GIS model was used to analyze the flood volume pattern, RS was employed to identify the land use land cover changes. The ArcGIS has been used in the present study to combine all obtainable data in a unique environment. Studies also revealed that urban area increased resulting in an increase of flood volumes from 19.7% to 24.8%.

Li Jiang et al. (2013) this paper reported that the increase in urban expansion changed the agricultural land and its use. Therefore understandability of urban expansion and decrement in agricultural land and its impact was taken into consideration. For analyzing the correlation between urban expansion and agricultural land econometric method was adopted.

Linli and Jun (2012), analyzed the effect of urbanization on land use /covers change and analyzed the correlation of climate based on land temperature, climate, and vegetation index. The data sets used in the study includes land use data in 1980 &2008 from cloud free Landsat multispectral scanner & TM RS images, wind speed data and annual temperature. Remotely sensed images of Landsat TM were interpreted to get the land use land cover data. MODIS LST was retrieved to obtain temperature effects of different land use types. Due to urban growth and rapid urbanization & industrialization and floating population in Shangahai the population density increased from 1734 persons per square kilometres to 3632 persons per
square kilometre during 1970-2010. With this increasing rate of 419 persons per square kilometre per decade. It was also reported that from 1949 to 2010, cultivated land reached the largest area with 388.7 thousand hectares and reached least area with 201 thousand hectares in 2010. It was estimated that mean surface temperature increased by 0.05°C per decade under the impact of urbanization. The construction & maintenance of impervious surface such as buildings and paved surface made the alteration of land surface which resulted in high temperature in urban area. It is inferred that urbanization created serious environmental problems in Shanghai which includes climatic and ecologic changes and environmental pollution.

LIU et al. (2012) revealed that due to urban growth, the land surface and river structures nature are changed which leads to changes in hydrologic cycle. Yi and SHI Perijun(2003) indicated that the major factor of runoff on river basin is due to urban population. The study area selected was Qinghai River which was prone to rapid development. Topographic data was obtained by digitizing the topographic maps. For identifying the land cover, Landsat TM remote sensing data for the years 1991, 2001 & 2006 and the rainfall data were used. Erdas Imagine 9.1 was used for radiometric and geometric correction. Five types of land use categories were identified. The result showed that the main changes happened is in the reduction of paddy field and increase of built up land area. The land area increased in the study area from 8.34% to 16.83%. Previous study showed that land use changed from paddy field and water to forest, later they changed to buildup land and forest. Linear regression analysis was conducted to identify the impact of urbanization. Result showed that due to urban population land use changed, the density of river network declined and the structure was simplified, annual rainfall & flood increased and runoff depth & runoff coefficient have increased.

Manju et al. (2011) reported that Delhi is expanding to its peripheral with the conversion of rural to urban areas. This rapid expansion is in the form of informal settlement, environmental pollution, destruction of ecological scurry and destruction of water bodies. These changes were studied using remote sensing technique. To detect the land use change, satellite imageries for a period of 6 years were used. To obtain the best results maximum likelihood algorithm was used. Result showed that the built up of the city increased mainly due to conversion of the agricultural land, sandy areas etc.

Matey and Jana (2016) estimated and assessed the surface runoff using GIS for the Vycoma Catchment. For assessing the runoff, SCS run off curve number method, modeling in GIS & remote sensing were used. Surface runoff was calculated by considering the potential retention in the catchment using the equation developed by Cronshey et.al.1986. The result concluded that the GIS based method proved to be a suitable tool for assessing the surface run off and recording of rainfall data. For that DEM was created.

Nitin and Ravindra (2014) reported that urban growth resulted in population growth, increased in built up area as well as psychological stage of urban life. They analyzed the changes occurred in land use / land cover using remote sensing and GIS. It was identified that LULC was the driving force behind the temporal and spatial scale. LULC of the study area were detected using Landsat data. The hybrid image classification technique was employed for the image classification using ERDAS software. It was pointed out that uncontrolled growth created many issues which might have positive and negative impacts. The decreasing area under water bodies, vegetation agricultural land directly or indirectly affect degradation of environment. More over built up area increased in the fringe of the city.

Olivier et al. (2016) analyzed the impacts of urbanization and evaluated its effect on hydrological process of Migina Catchment. For analyzing the hydrological fluctuations, GIS technology was adopted. In the study area it was seen that urban sprawl expanded in the
northern zone and the hydrologic cycle was altered. They applied Theissen Polygon method to calculate the average annual rainfall. For measuring the discharge in Migina Catchment, gauging stations were installed and runoff was estimated by rational method. They concluded that the runoff increased by over 3.5 percent which led to more flood prone areas, evapotranspiration and ground water level decreased which led to water scarcity.

Prakash and Sreedevi (2016) studied the problems like urban flooding, water pollution, soil degradation due to runoff pattern and concluded that all were mainly due to urbanization and its development. The study mainly concentrated on the temporal behavior of surface runoff. The outcome of urban expansion and development is the land use /land cover change which results in changes in the runoff pattern. The study revealed that RS and GIS can be used as an effective tool for identifying the urban growth. Different satellite images were used for generating land use/land cover and SCS-CN were used for identifying and estimating the runoff pattern. It was seen that due to urbanization, the land use/land cover changed from 1975 to 2016 and overall increase in runoff was found to be 27.5 percent.

Rong et al. (2014) reported that urban areas arise due to the demand in human life and impervious surfaces increased in the forms of roads, parking lots and shopping mall. The surface imperviousness due to urban expansion altered the hydrological cycle which directly affects the infiltration level of the surface. This paper they mainly analyzed the two urbanization parameters namely impervious and population density which affect the hydrograph parameter of four watersheds which are an index of watershed. A semi distributed model which is a conceptual unit hydrograph based model was used to assess the effect. The mean rainfall was calculated using the Kriging method based on phi index. The result of the study reported that the parameters showed greater sensibility exhibits on changes in imperviousness than to changes in population. They also found that there was a wide change in the hydrograph due to urbanization in the study area.

Saddrodyn et al. (2012) interpreted that hydrological process in watershed and the natural regime of water flow is altered by the changes that occur in land use pattern due to urban expansion. The study area was in a state of urban expansion and development and prone to flooding. For identifying the land use pattern, TM satellite images and ETM were considered for a period of 1988 -2006. Land use was classified according to maximum likelihood algorithm in supervised classification. To understand the runoff variation and flood regime in a watershed, SCS-CN was applied because of its simplicity and reliability. HEC-HMS model was used to model the watershed components. Result showed that there is a wide variation of land use pattern. It was seen that runoff coefficient increased from 56.49 to 64.1 percent. Annual average discharge increased. Urban area had increased from 13.3 square kilometer in 1988 to 26 square kilometer in 2006, agriculture-garden land increased from 9.73 square kilometer to 13.21 square kilometer. They concluded that as the land pattern changes the hydrological components of watershed are also changes.

Sahoo et al. (2016) reported that urbanization results in imperviousness which prevents the free flow of water. The imperviousness was measured in total impervious area(TIA) which is a measure to resist the rainwater flow to infiltrate in the soil .This study also compared the TEI&EIA runoff using remote sensing and GIS.SWMM was used as the hydrologic model. Infiltration was modeled by Green Ampt method. The physical parameters like area, width, and slope were determined from Arc GIS 9.31. It was concluded that peak runoff value increased if TIA used in model than EIA.

Sinha et al. (2015) interpreted that land use land cover (LULC) is an important factor which affects the runoff. In this study Enhanced Thematic Mapper (ETM) images of 2000 were used to analyze the LULC for the basin and classified as wasteland, forest, plantation and urban area. Soil and Water assessment tool (SWAT) was used to assess the impact of potential
LULC and climate change for calibration. The results revealed that forest area, agriculture, land and built up area were predominant. The land use changes increased the runoff but climate change decreased the runoff while the combined effects resulted in the reduction of runoff. Study showed that decrease in discharge was observed from 2000 to 2014. Study revealed that climate change decreased the discharge but land use change increased the runoff.

Shao et al. (2012) highlighted the relationship between model parameters and urban variables for analyzing the urbanization impacts in a watershed. The urbanization variables, imperviousness and population are the changes that can be easily measured in the watershed. Urbanization growth derived from urbanization variables, including imperviousness, population percentage and population density. For identifying the rainfall–runoff simulation Nash Model was adopted. The time variant loss due to rainfall was identified by means of Kriging and non linear programming methods. It was seen that hydrograph parameters were changed with respect to urbanization variables. It was thus concluded that in the selected watershed, the time to peak was reduced and peak flow increased. Thus the watershed area is in a state of occurrence of disaster due to variation in the above variables.

Vaihav Garg et al (2012), highlighted that urbanization results in changes in land use land cover pattern which ultimately affect the hydrologic changes. There are several causes which are related but increase in runoff volume is the main factor due to urbanization. Soil-Vegetation-atmosphere-transfer Scheme (SVATS) was used to identify the radiation effect on land surface with a disadvantage of identifying only vertical column basis. VIC hydrological modeling approach which is a grid based macro scale model developed by Liang et al was adopted for identifying the impact of LULC on hydrological régime. The study concluded that wherever built-up area increases runoff potential increases which may lead to flooding.

Webster et al. (2014) analyzed the hydrological impacts of urbanization on two medium sized catchment namely Mukuvisi and Marimba. The study showed that due to suburban development there was an accelerated recession phase that increased the peak flow. The changes in land cover due to urban expansion and development were determined through Landsat Thematic Mapper. Assessment of impact was done by hydrological modeling. For analyzing the rainfall interception, SWAP model was adopted. Result showed that urban area increased by more than 500% in the Mukuvisi catchment and by more than 200% in the Marimba catchment between 1986 and 2008.

Xiaoliu et al. (2016) described that land use land cover changes influence the hydrological process which affects the flood characteristics in the city of Beijing. Three approaches followed reproduction of a spatially explicit LUCC ii) application of a 2D hydraulic modeling for flood simulation iii) demonstration of results for Beijing, on a flood prone area. It was concluded that it is an effective tool for mapping land use /change. The GIS and RS provide more details to flood characteristics and change in land use pattern (i.e. transition of less impervious to an impervious one) which can badly affect the flood peak and propagation leading to high flash response.

Xiaowei et al. (2015) reported that by converting the cultivated land into built-up area due to urbanization, various environmental changes occurred. The changes in land use land cover will lead to climatic change, temperature and precipitation. Urbanization and land use changes are closely related. The land use data and meteorological data of the study area were collected from the data centre of Chinese Academy of Sciences. The changes in temperature and precipitation were evaluated by grid of Arc INFO platform spatial and numeric analysis. Thus concluded urbanization changed the land surface, net radiation and latent heat.

Z.Guo et.al (2012), reported that increase in urbanization leads to decrease in green area and increase impervious area which leads to the formation of urban heat island. The main effect of
urbanization is the increase of built-up land cover. As urbanization increases the ratio of built up to land cover increases due to urban heat island. To quantify the degree of urbanization, urbanization index proposed by Wei. et al(2010) were used in the study. For obtaining good quality images, Landsat TM images of Sept. 2, 2009 were selected. All images collected were pre processed for radiometric and geometric corrections. Five major land cover types like water ponds, built up area, bare soil, sparse vegetation and vegetation were identified. Then estimation of the apparent temperature of individual land cover types was carried out from surface temperature. The thermal characteristics and urbanization relationship are examined using TM. Landsat TM and ALOS images were considered for study and concluded that the urbanization degree was 0.91, 0.72,055. Zhongchang et al. (2011) envied that Land use/land cover (LULC) changes have direct impacts on the hydrological cycle and stream quality. They also have indirect impacts on climate change. Therefore, LULC changes have been treated as one of the most important sensitive factors for global environmental change. Urbanization is the major force that is driving LULC changes. They presented the effects of LULC on the surface runoff in the city of Beijing. If the impervious surface is increased, the infiltration in the urbanized area is reduced which increases the peak discharge and leads to flooding. In this study area, different types of LULC were identified. The LULC were derived from Landsat TM/ETM imagery of pixel size of 30 m. The impacts of LULC on urbanized area were assessed by the L-THIA model. For finding the temporal change of LULC on the study area, Support Vector Machine (SVM) along with robust algorithm was applied in the study. Here the LULC was grouped into seven categories: (1) high impervious surface (> 90%), high-density urban, including CBD, roads, squares and so on), (2) medium impervious surface (50% ~ 90%, high-density residential land), (3) low impervious surface (< 50%, low-density residential land), (4) arable land (agricultural land), (5) forest land, (6) bare land, and (7) water body.

4. CONCLUSIONS

Urbanization is a severe problem faced not only in metropolitan cities but also in a developing city like Ernakulam. The following conclusions are made from the study conducted by several authors: LULC change is one important parameter which affects hydrological, parameters. A change in LULC will increase the runoff that will lead to flooding problems. Urbanisation increases built up areas and imperviousness there by reducing the infiltration capacity. Most common methods employed for runoff estimation are SCN-curve method and SWAT models.

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