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To,

Dear **M.Bal, M.Purnima, Dr. B.Naik, and Dr. S.N.Sahoo**

Subject: (a) Acceptance of Research Paper for ORAL Presentation
(b) Submission of Registration Fee for its publication in Proceedings

Ref.: Paper No. 443 (Effect of land use and runoff characteristics in Rourkela city using SWMM5.1)

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Looking forward to see you in HYDRO 2018 International at NIT Patna.

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(PROF. (DR.) RAMAKAR JHA)

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Effect of land use and runoff characteristics in Rourkela city using SWMM5.1

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Abstract

This study examined the effects of land use and land cover changes due to urbanization on the annual direct runoff of Rourkela city. Urbanization is the index of the transformation of the rural areas to the developed new industries. The land cover (Built-up Area) change caused due to different activities in Rourkela City and its surroundings. For this purpose, 6 digital images are used for the years 2002, 2003, 2009, 2010, 2011, and 2015. These images are analyzed using the data processing techniques in ArcGIS software – Arc Map 10.1. Remote sensing can provide a better picture of monitoring land use and land cover changes. These maps revealed that the watershed experienced conversion of approximately 16% non-urban area to urban area between 2002 and 2015. The Storm Water Management Model (SWMM) was used to calculate direct runoff generation. The model was repeatedly run with different urbanization scenarios to investigate the hydrological response to land use changes. The simulation results of SWMM model for the various urbanization scenarios indicate that when the impervious surface area changed from 21.05% of 2002 scenario to 32.56% of 2009 scenario, the average annual direct runoff depth would increase from 988.26 mm to 1881.71 mm. The results also indicate that the annual direct runoff depth is highly correlated with the percentage of impervious surface area. When impervious surface area is less than 25%, the annual direct runoff depth will increase linearly with impervious surface area *(R^2 =0.86);* however, when impervious surface area is greater than 25%, the annual direct runoff depth will also increase linearly with impervious surface area (R^2 = 0.81) but at much lower rate.

Keywords: *SWMM, Arc GIS, Runoff, LULC, Remote sensing, Percentage of impervious*

1. Introduction

From the last few decades, the established and developed countries both have observed rapid urbanization. Due to this a range of complex problems are arising which is linked to the management of surface runoff and storm-water in the cities. Along with the enlarged impervious tiles of the urban region the water percolation to soil, infiltration, transpiration, depression storage and underground water table are absent and this results plane runoff and flooding in the cities roads and it's adjacent. The discharge through point and non-point sources which badly affects the water quality parameters of storm-water and runoff. If this drainage water is not managed appropriately, it may lead to economic sufferers, spread of diseases, drop of water quality in rivers and receiving waters due to the frequent flooding of municipal areas. Sustainable Urban System (SUDs) is a methodical approach to create the surface drain and storm water in a manner that will decrease the possible impact of new development and improvement with respect to the discharges**.** Land use and land cover (LULC) alteration has a major impact on water resources. At a watershed scale, LULC change due to urbanization can increase runoff, flooding, and nonpoint source pollution and can degrade downstream water bodies. Thus it is essential to assess the probable hydrologic impacts of LULC change former to watershed improvement. To evaluate the hydrologic impacts of LULC change at a revolution point scale, many hydrological models have been developed such as the Storm Water Management Model (SWMM), and Soil and Water Assessment Tool (SWAT) Cell Based Long Term Hydrological Model and Hydrologic Engineering Centre's Hydrologic Modelling System (HEC-HMS), Technical Release 55. To assess the long-standing impacts of LULC changes on the hydrology of a sub catchment, some of these models mention above require many types of data inputs and parameter evaluation that are usually not readily accessible for land-use planners. Therefore, it is necessary to develop a much easier-to-use model to evaluate hydrological. The raise in population density and construction density affect the most visible manipulate on hydrological processes in a municipal area. Adaption of the land surface during urbanization alters the storm-water runoff explanation. The major alteration which alters the runoff process is the impervious surfaces of the catchment such as roofs, sidewalks, roadways and parking lots, which were early pervious. Another aspect is the natural channels, which were in being before urbanization, are often straighten, deepened and lined to make them hydraulically smoother. Gutters, drains and storm drainage pipes are laid in the urban area to convey runoff rapidly to rivulet channel. These increase flow velocities, which directly influence the timing of the runoff hydrographs. The combined effect of all these changes is to ease the lag time of runoff. Since a overweight volume of runoff (due to urbanization) is discharged within a shorter period interval, the peak discharge inevitable increased. Due to urbanization, administration of urban water is very difficult. Customary drainage has many disadvantages like disorder of water balance, include to of runoff and flooding downstream, loss of groundwater recharge and base flow, increases heat land mass sound effects due to loss of evapo-transpiration and pollute acceptance water bodies by oils, pure substances and heavy metals etc. The following paper focused on the integrated approach to sustainable urban drainage system (SUDS) by Using Storm Water Management Model (SWMM 5.1). SUDs are deliberate to planning and management strategies to control quality and quantity of storm water or plane runoff intend to overcome the problems of long-established drainage system. Sustainable drainage network is used to be modelled and analysis by Storm Water Management Model SWMM 5.1. It is a complete simulation model used for lively rainfall runoff calculations for shorter and longer time span to calculate the runoff quality and quantity of metropolitan region.

2. Material and Methods

2.1. Study Area

Rourkela, one of India's most important industrial cities, is located in Sundergarh district of western Odisha. The city lies between Latitude 22°25'N and Longitude 84°00'E in the heart of the mineral belt of the state. The area is rich in iron ore and due to this reason has many industrial plants located here. The city is well thought-out Odisha's commercial capital because of the presence of the steel industry. The Steel authority of India (SAIL) has one of its biggest plants -The Rourkela Steel plant is located here. population in the surrounding areas is mostly tribal Rourkela has a hilly and undulating topography .The city was once surrounded by forests and today there are two reserved forests around the area of the city. The steel city is divided mainly into two sections: Old Rourkela (sections of the city near the railway station that were settled prior to RSP coming up) and the much larger Steel Township. The Steel Township till 1999, was divided into 18 Sectors, Sector 6 being the largest of them. The Steel Township and Fertilizer Township are under the Steel Plant Administration while the other sections of the city are under the Rourkela Municipal Corporation. Some rural areas of South Rourkela are managed by the Jalda Panchayat. Central Water Commission has its sub-divisional headquarters near Panposh.Rourkela has a tropical climate and receives high rainfall during Southwest monsoon (June – September) and retreating Northeast monsoon (December – January). Average annual rainfall ranges between 160 and 200 cm. The minimum and maximum temperatures are in the range of 5 C to 49.7 C with a mean minimum and maximum temperature range of 12.0 C to 31.5 C during coldest and hottest months. Thirty six percent of the geographical area of the district has semi-evergreen or tropical dry deciduous forest. The fig.1 and fig.2 represent that Rourkela city and Global location of Rourkela respectively.

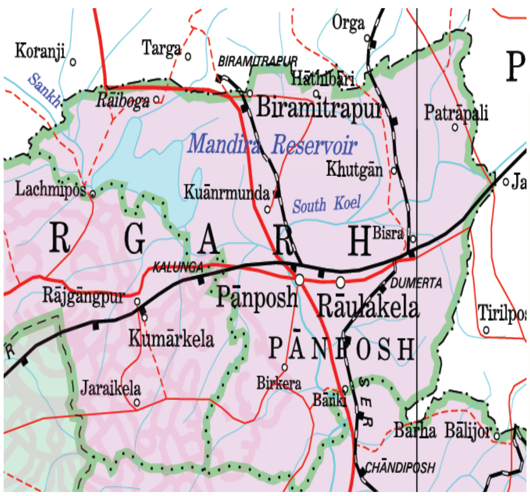

FIG.1:- Rourkela City

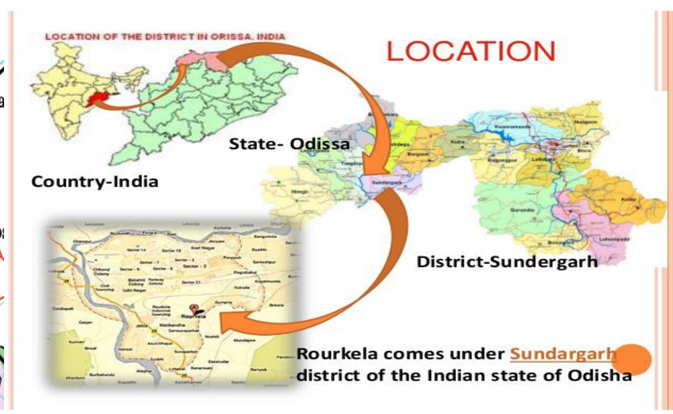

FIG.2:-Global location of Rourkela

2.2. Data Acquisition

In this study, totally, seven LULC classes were established as Forest, Agricultural Land Built up Area (Commercial, Industrial, Public Utility, Residential, and Transport), Barren land, Water Bodies.

2.2.1. LULC study of Rourkela city

LULC maps of 2002, 2003, 2009, 2010, 2011 and 2015. In order to analyze hydrological effects of urbanization, the urbanization scenarios were built by overlaying each impervious surface of 2002, 2003, 2009, 2010, 2011, and 2015 to the land use map. That way, the hydrologic effect of urbanization could be assessed, avoiding the effects cause by all other land use change. The changes in direct runoff with different urbanization scenarios were analyzed, and the relationship between annual direct runoff and the impervious surface area was investigated. Five land cover module namely Forest land, Built up area, Water Bodies, Agricultural Land, Barren land are identified in the study area. The table 1 represents that land use types of Rourkela city from year 2002 to 2015.

Table 1:- Land use types of Rourkela city from year 2002 to 2015

Year	Forest	Agricultural land	Built-up area	Barren land	Water bodies
2002	22.56	53.17	20.01	1.8	2.16
2003	22.32	52.74	21.02	1.65	2.25
2009	20.56	51.73	24.05	1.44	2.58
2010	20.13	50.61	26.03	1.26	1.97
2011	19.86	49.83	26.93	1.03	2.35
2015	18.04	47	32.56	0.86	1.54

2.3. Model Configuration

It is feasible to classify the variables and parameter in to two categories as sub catchment characteristics and hydraulic characteristics.

2.3.1. Sub catchment characteristics

In sub catchment characteristic Sub catchment area, average of sub catchment width, average width of overland flow path, average slope, , impervious and pervious area, infiltration and depth of depression storage on impervious and pervious area, Manning roughness coefficient were resolute based on the properties of the studied area, related formulas, complementary tables and recommendations presented by SWMM model. Depth of depression storage on impervious and pervious area parameters has been extracted from the values recommended by ASCE, (1992). Manning roughness coefficient was obtained from ASCE (1982) manual. Land use map was collected from e- thesis, NIT Rourkela. Based on land use map, five classes of land use include i.e.

1. Forest
2. Agricultural land
3. Built-up Area
4. Baren Land
5. Water Bodies

Soil texture was achieved by ARC GIS 9.3 Software using clipping tool box from spatial analysis tool box. Here shape file of Rourkela and world soil shape file which was collected from food and agriculture organization of united nation. Digital elevation model (DEM) was generated from topographic map and data uploaded from Arc view, by using Arc GIS 9.3 software the average surface slope has been calculated.

Average width of sub catchment was calculated via equation

$$L=\frac{C\sqrt{A}}{1.128}\left[1-\sqrt{1-\left(\frac{1.128}{C}\right)^{2}}\right] \qquad (1)$$

C= compactness coefficient

A= Area of sub catchment

Compactness coefficient was calculated by equation (2) for sub catchment with compactness coefficient greater than 1.128 otherwise based on user manual of SWMM hydrology unit was divided by the average maximum overland flow length.

$$C=0.282\frac{P}{\sqrt{A}} \qquad (2)$$

Where P is the perimeter of the sub catchment in (km)

2.3.2 Hydraulic characteristics

Hydraulic parameter such as stream are determined with the help of GIS, values of parameter such as manning's coefficient, depth of depression storage and conduit roughness for natural channel are obtained from literature. SWMM uses the Manning equation to express the relationship between flow rate (Q), cross sectional area (A), hydraulic radius (R), and slope (S) in all conduits. For standard U.S units.

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}} \qquad (3)$$

Where n is the Manning roughness coefficient. The slope S is interpreted as either the conduit slope or the friction slope (i.e. head loss per unit length), depending on the flow routing method used. For pipe with circular force main crossection either the Hazen-Williams or Darcy-Weisbach formula is used in place of manning's equations for fully pressurized flow. For U.S units the Hazen-Williams formula is

$$Q=1.318CA R^{0.63} S^{0.54} \qquad (4)$$

Where C is the Hazen-Williams C-factor which varies inversely with surface roughness and is supplied as one of the cross section's parameter.

2.3.3. Time series

Time series object are used to describe how certain object properties many very with time. Time series can be used to describe how certain object properties may vary with time. Time series can be used to describe rainfall data. Each time series must be given a unique name and data can be assigning to number of time value data pairs. Time series data can either entered to the program or assessed from a user supplied time series file. For rainfall time series file it is necessary to enter periods with non-zero rainfall amounts. The time series graph obtain during this modeling are given below. The fig.3, fig.4, fig.5, fig.6, fig.7and fig.8 represent that computed graph of precipitation (mm) vs time (hour) in SWMM of year 2002, 2003,2009,2010,2011 and 2015 respectively.

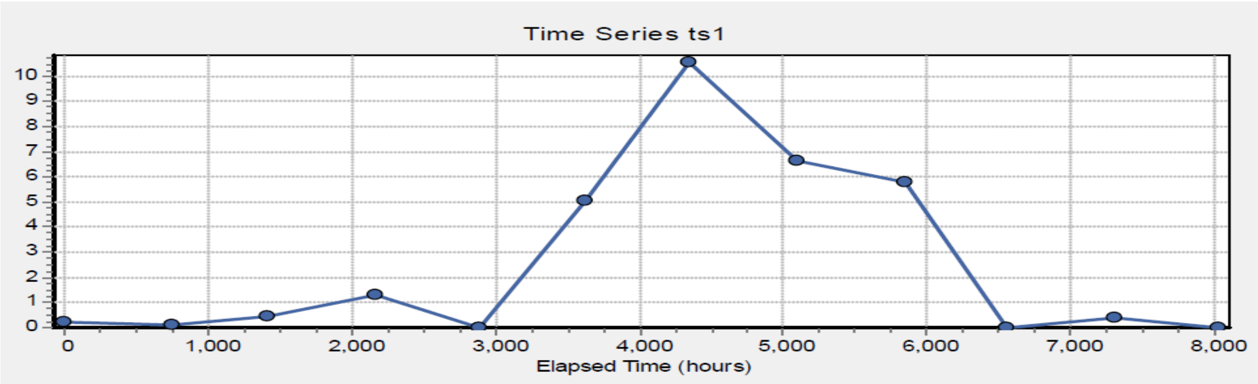

Fig.3:- Computed graph of precipitation (mm) Vs time (hour) in SWMM of year (2002)

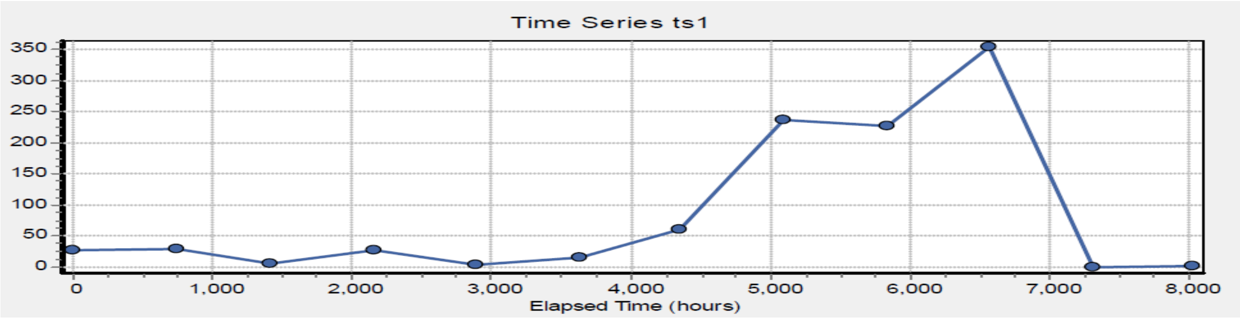

Fig.4:- Computed graph of precipitation (mm) Vs time (hour) in SWMM of year (2003)

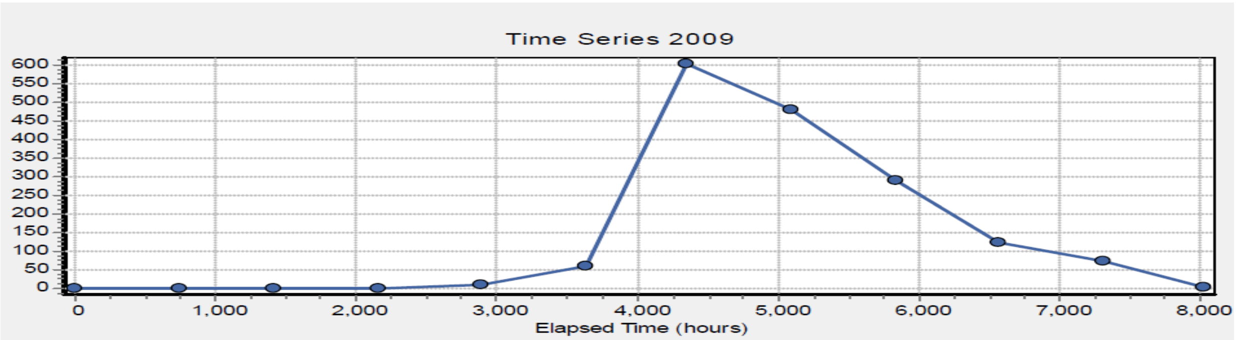

Fig.5:- Computed graph of precipitation (mm) Vs time (hour) in SWMM of year (2009)

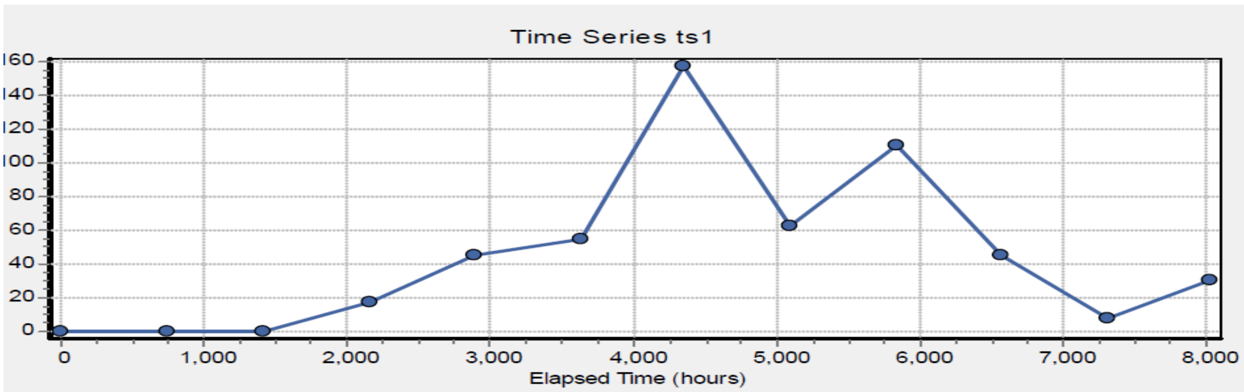

Fig.6:- Computed graph of precipitation (mm) Vs time (hour) in SWMM of year (2010)

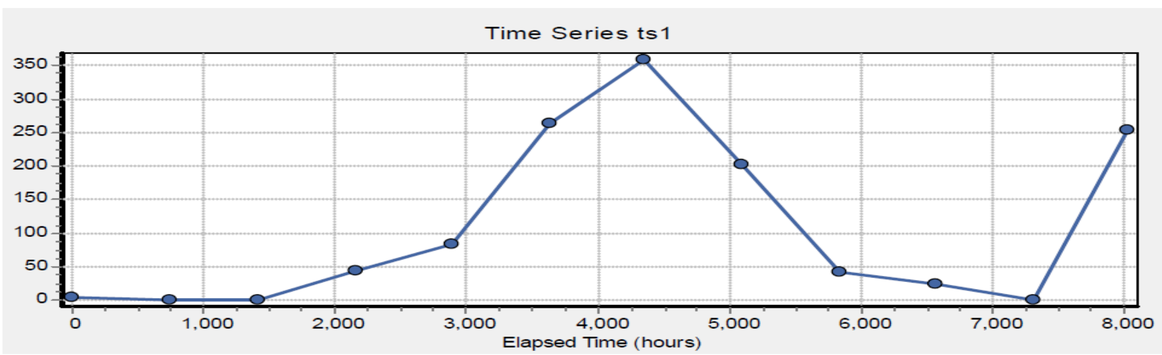

Fig.7:- Computed graph of precipitation (mm) Vs time (hour) in SWMM of year (2011)

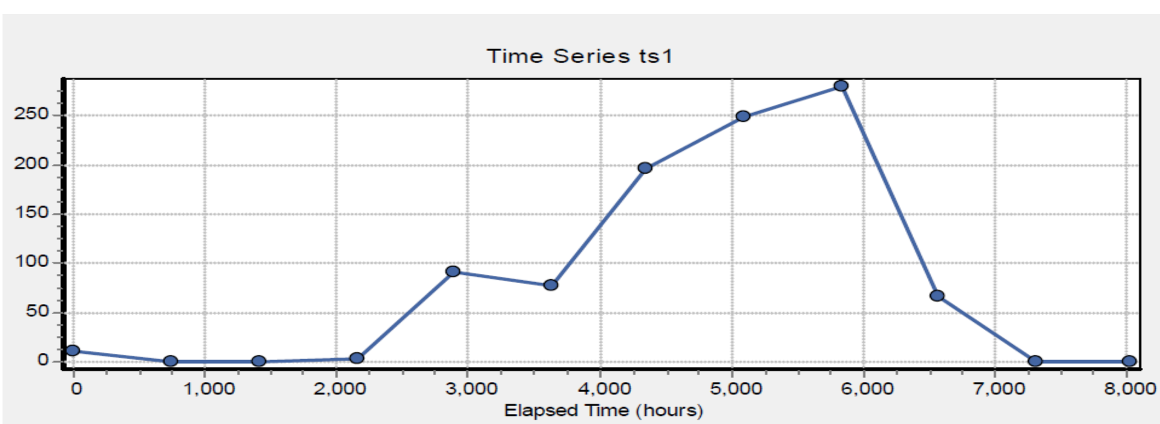

Fig.8:- Computed graph of precipitation (mm) Vs time (hour) in SWMM of year (2015)

3. Results and Discussion

3.1. SCS method for runoff calculation

For model calibration, the land use map of 2002, 2003, 2009, 2010, 2011, 2015 and daily rainfall data for 2002, 2003, 2009, 2010, 2011, 2015were used for simulation. At the alike time runoff calculation was done by using SCS CN curve method. The US Department of Agriculture (USDA) Natural Resources Conservation Service's curve number (CN) method uses data inputs as of daily LULC, rainfall and hydrologic soil group data to calculate direct runoff (Harbor, 1994; Harbor *et al.*, 1998; Wang *et al.*, 2005; Sun *et al.*, 2011). The CN method uses the following equation to compute direct runoff:

$$R = \frac{\left(P - I_a\right)^2}{P - I_a + s} \quad \textbf{(5)}$$

Where, *R* is direct runoff, *P* is the precipitation, I_a is the initial abstraction (initial loss), and *S* is potential maximum retention, or storage capacity a measure of the ability of a division to abstract and retain storm precipitation.

Based on the analysis of the outcome from many small experimental sub catchment, the SCS developed an empirical relationship between I_a and *S* as I_a = 0.2*S*. Therefore, the direct runoff is given as:

$$R = \frac{\left(P - 0.2S\right)^2}{P + 0.8S} \quad \textbf{(6)}$$

The maximum retention (S) is determined using the following equation (SI system):

$$S = \frac{25400 - 254CN}{CN} \quad \textbf{(7)}$$

Where, CN is the curve number, which is an index that represents the muddle of, land use classes, hydrologic soil group and antecedent moisture circumstances. The values of CN can be obtained for different land uses, soil groups, and antecedent hydrologic conditions from the standard table provided by SCS-USA (NRCS, 1986) in manual.to estimate annual direct runoff using daily rainfall data for the period of 2002 - 2015 with different LULC maps of 2002, 2003, 2009, 2010, 2011, and 2015 In order to analyze hydrological effects of urbanization, the urbanization scenarios were built by overlaying each impervious surface to the land use map of these years, producing urbanization scenarios for 2002, 2003, 2009, 2010, 2011 respectively. That way, the hydrologic effect of urbanization could be assessed, avoiding the effects caused by all other land use changes. The changes in direct runoff with different urbanization scenarios were analyzed, and the relationship between annual direct runoff and the impervious surface area was investigated. In SCS CN Curve method, the land use map of 2002 and daily rainfall data for 2002 were used for 2002 simulation; the land use data for 2003 and daily rainfall data for 2003 were used for 2003 simulation; and the land use data for 2009 and daily rainfall data for 2009 were used for 2009 simulation.

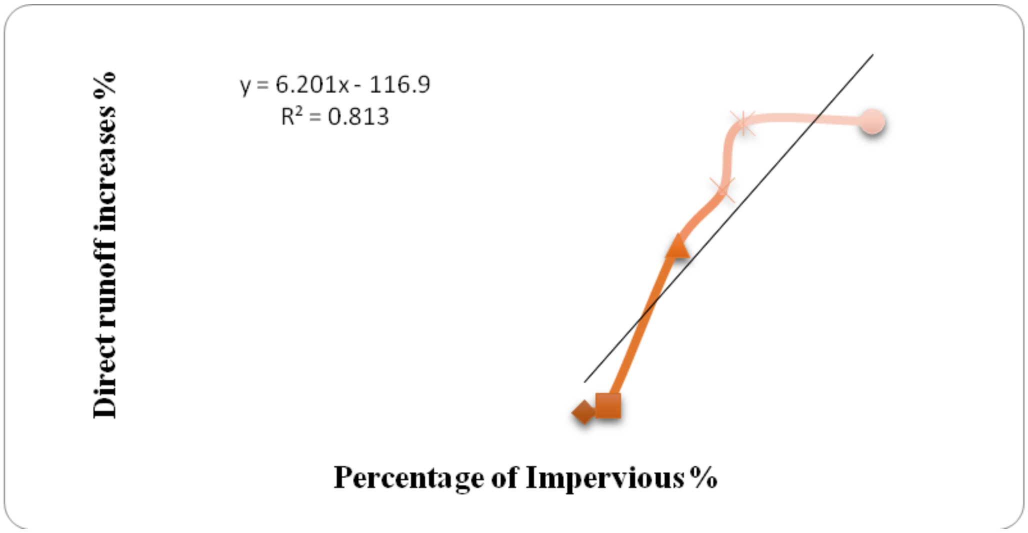

Fig.9:-The linear relationship between average annual direct runoff increases and the impervious surface area (%)

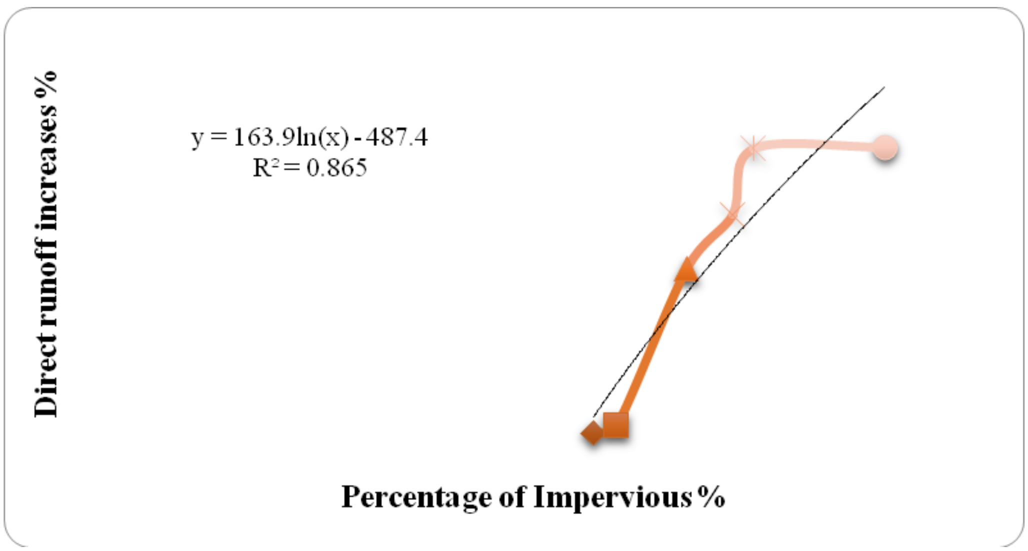

Fig.10:-The logistic relationship between average annual direct runoff increases and the impervious surface area (%)

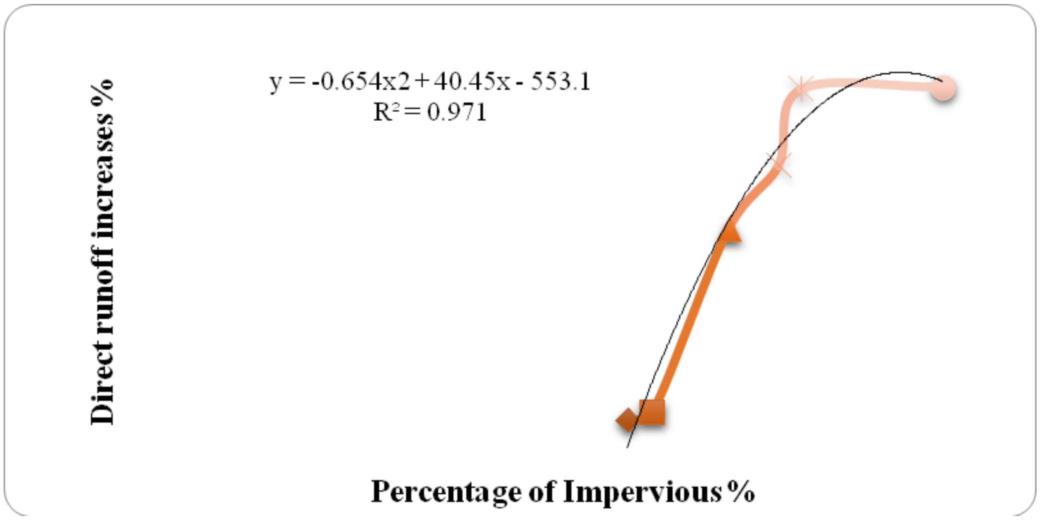

Fig. 11:-The binomial relationship between average annual direct runoff increases and the impervious surface area (%).

Figure-11 shows the relationship between average annual direct runoff percentage increase and the percentage of impervious surface area. Strong and positive binomial relationships (R^2 = 0.971) were observed between runoff percentage increase and impervious surface area, though there was a good logistic relationship between them (R^2 = 0.865)(Figure-10), but linear relationships were more preferred, figure-9 shows that there was two types linear relationships between runoff percentage increase and impervious surface area, when impervious area is less than 9.0%, the direct runoff will increase linearly with the impervious area (R^2 =0.813), however, when impervious area is great than 9.0%, the direct runoff will also increase linearly with the impervious area(R^2 = 1.00), but at much lower rate. The results indicated that the annual direct runoff increase was highly correlated with increasing impervious surface area, which is in agreement with those from Bhaduri *et al*. (2001) and Sun *et al*. (2011), who both applied SWMM model to predict a linear relationship between average annual runoff and increasing imperviousness.

4. Conclusions

The land cover (Built-up Area) change caused due to different activities in Rourkela City and its surroundings. For this purpose, 6 digital images are used for the years 2002, 2003, 2009, 2010, 2011, and 2015. These images are analyzed using the data processing techniques in ArcGIS software – Arc Map 10.1. Remote sensing can provide a better picture of monitoring land use and land cover changes. These maps revealed that the watershed experienced conversion of approximately 16% non-urban area to urban area between 2002 and 2015. The Storm Water Management Model (SWMM) was used to calculate direct runoff generation. The model was repeatedly run with different urbanization scenarios to investigate the hydrological response to land use changes. The simulation results of SWMM model for the various urbanization scenarios indicate that when the impervious surface area changed from 21.05% of 2002 scenario to 32.56% of 2009 scenario, the average annual direct runoff depth would increase from 988.26 mm to 1881.71 mm. The results also indicate that the annual direct runoff depth is highly correlated with the percentage of impervious surface area. When impervious surface area is less than 25%, the annual direct runoff depth will increase linearly with impervious surface area (R^2 =0.86); however, when impervious surface area is greater than 25%, the annual direct runoff depth will also increase linearly with impervious surface area (R^2 = 0.81) but at much lower rate.

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