Assessment of Effect of Land Use Change on Hydrological Response and Sediment Yield for Catchment Area of Simly Lake, Pakistan

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Abstract

The aim of this research is to identify the effects of land use changes on the rainfall-runoff and runoff-sediment relations in Simly watershed, Islamabad. In this study Double Mass Curve was used to identify the change in rainfall-runoff and runoff-sedimentation relationship of Simly catchment. The rainfall -runoff data of Simly catchment for the period 1983-2012 were drawn, for two periods that is from 1983 till 1994 and 1995 to 2012 and were selected for analysis by using Double Mass Curve. Double Mass Curve s were plotted for annual and monsoon month's rainfall-runoff and runoff-sediment. From the slope trend lines it was observed that more runoff and sedimentation occurred during 1995-2012. Satellite images of 1992, 2000 and 2010 were classified to get land use information of the Simly catchment and it was observed that more land use changes occurred during 1995-2012. The significant result showed that water bodies reduced by 46 %, forest reduced by 26%, vegetation and agriculture reduced by 16%, Rangeland increased by 15%, built up area increased by 271%, bare land increased by 129 %. In order to reduce Soil erosion Deforestation and loss of water bodies, developmental activities should be reduced in catchment area of Simly dam.

Keywords.

Catchment, runoff, rainfall.

1. INTRODUCTION

Development activities have impact on Water resources and land use change is significant of them. Land use change can affect the Hydrology of a watershed by changing the water cycle. The changes of agriculture land and forest into urbanization directly affect runoff volume and ground water recharge. Due to residential activities Ground water recharge decreases and runoff increases. Due to deforestation in catchment area sediment rate increases which decreases the life of water reservoir. Due to human alteration and development activities in a catchment area, changes occur in process of runoff generation because infiltration rate is reducing. Land use changes can alter the timing and size of flood peak (Tali 2011). Different climate model studies concluded that by altering the precipitation and temperature pattern land use change alters the global water cycle. Since 1900 river discharges has increased prominently in all over the world and study suggests that land use change may be responsible for this increase (Berga 2011). Land use change have significant effect on hydrology of a small basin (Jones et al 1996).The hydrological effect of land use changes also depends on spatial distribution of land use types (Schumann et al 2000).

2. Methodology

2.1. Study Area

The Simly Dam is located at 330 43' 8" north latitude and 730 20' 25" east longitude in 30 Kilometers East of Islamabad and its watershed extends from 35km North-East of Islamabad up to Murree Hills. It is the largest reservoir of drinking water to people living in Islamabad capital of Pakistan up to 47 MGD water is supplied to Capital Development Authority from Simly Dam. It is constructed on Soan River and khad Nullah. Simly Dam was developed in 1982 and its storage capacity was 23000 acre-feet which was increased up to 33000 acre-feet in 2005. In Simly Dam catchment heavy precipitation occur in snow and rainfall form during December to January and July to September respectively, the annual precipitation in Simly Dam catchment is 1788 mm (Pakistan Metrological Department 2012). Its watershed size is 59 sq. miles rhomboidal in shape "about 11.80 miles long and about 5 miles wide" on average. Its watershed is located in Margalla Hills which is in north of Islamabad Capital of Pakistan. The elevation of Simly catchment ranges from 643-2274 meter Above Mean Sea Level. The watershed map of Simly Dam is given in Figure 1, the Current storage capacity of Simly Dam is 32219 acre-feet comparing it with actual storage it can be observed that 2.36 % storage capacity of Simly Dam is lost due to land use changes (IUCN PAK 2005). Therefore it is strongly needed to evaluate land use change impacts for sustainable management of water resources.

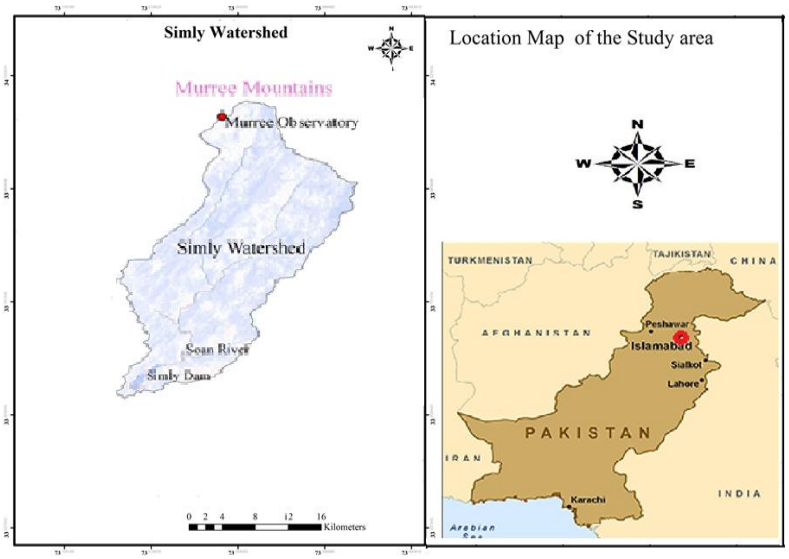

Fig. 1 Location map of the study area

2.2. Materials

The topographic maps of scale 1:50000 were obtained from Survey of Pakistan. Using Planimeter the catchment area of Simly Dam was computed as 153.5 km2. The rainfall data of Simly catchment is observed by Murree observatory which is the only observatory station in Simly catchment. The location of Murree observatory is shown in Figure 1. The rainfall data of Simly catchment for the period 1983-2012 was collected from Pakistan Metrological Department. Similarly the runoff data and sediment data of Simly catchment for the period 1983-2012 and 1983-2005 were collected from Water and power development authority. Land use classification was done using Landsat TM and ETM+ data and satellite images for the period 1992, 2000 and 2010 were used. Digital Elevation Model (DEM) of the study area was taken from ASTER G DEM 30 and DEM for Simly catchment is given in Figure 2.

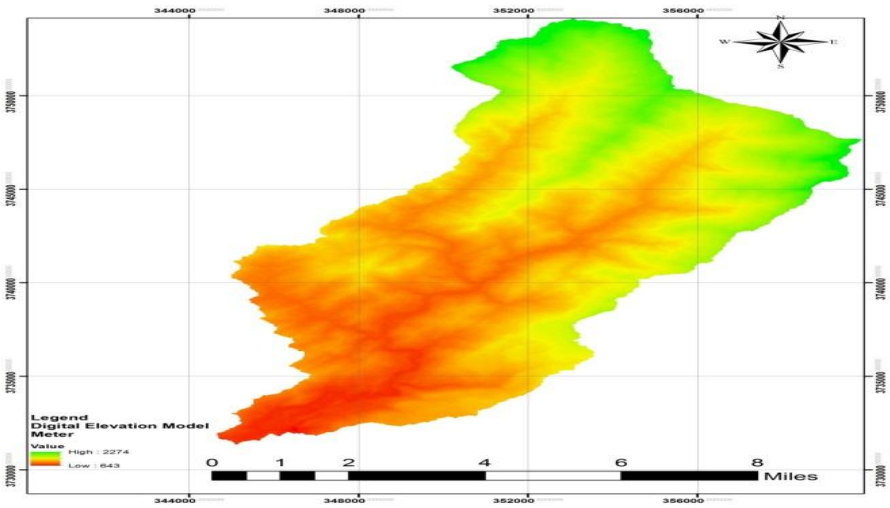

Fig. 2 Digital elevation model of Simly catchment

2.3. Methods

The effect of land use changes on catchment runoff can be found from statistical methods, experimental catchment studies and hydrological models. In this study Double Mass Curve was used to find the effect of land use change on rainfall-runoff and runoff sedimentation relationship. Double Mass Curve is plotting of cumulative value of one variable against the cumulative value of other quantity keeping time period the same for both variables. Double Mass Curve can give us the significant information about the time period in which changes occurred in those variables for which Double Mass Curve is plotted. Generally it is a rule if the break in slope occurs for less than 5 years then it is ignored but if break in slope occurs for more than 5 years then it can be considered as trend and it can be investigated (Searcy. K. J 1960, Albert. M. J 2004). Recently the employment of Double Mass Curve analysis by researchers for analyzing the effect of soil and water conservation, detection of land use change effect on runoff and sedimentation bore reasonable results (Li .R et al 2011). Based on the rainfall- runoff relationship of Simly catchment shown in Figure 3 Double Mass Curve was drawn for periods 1983-1994 and 1995-2012. Land sat TM and ETM+ data of 1992, 2000 and 2010 were selected for land use mapping. The Unsupervised classification of satellite images was done. Six land use classes i.e. Water bodies, Forest, Vegetation & Agriculture, Range land, Built-up area, and bare land were generated.

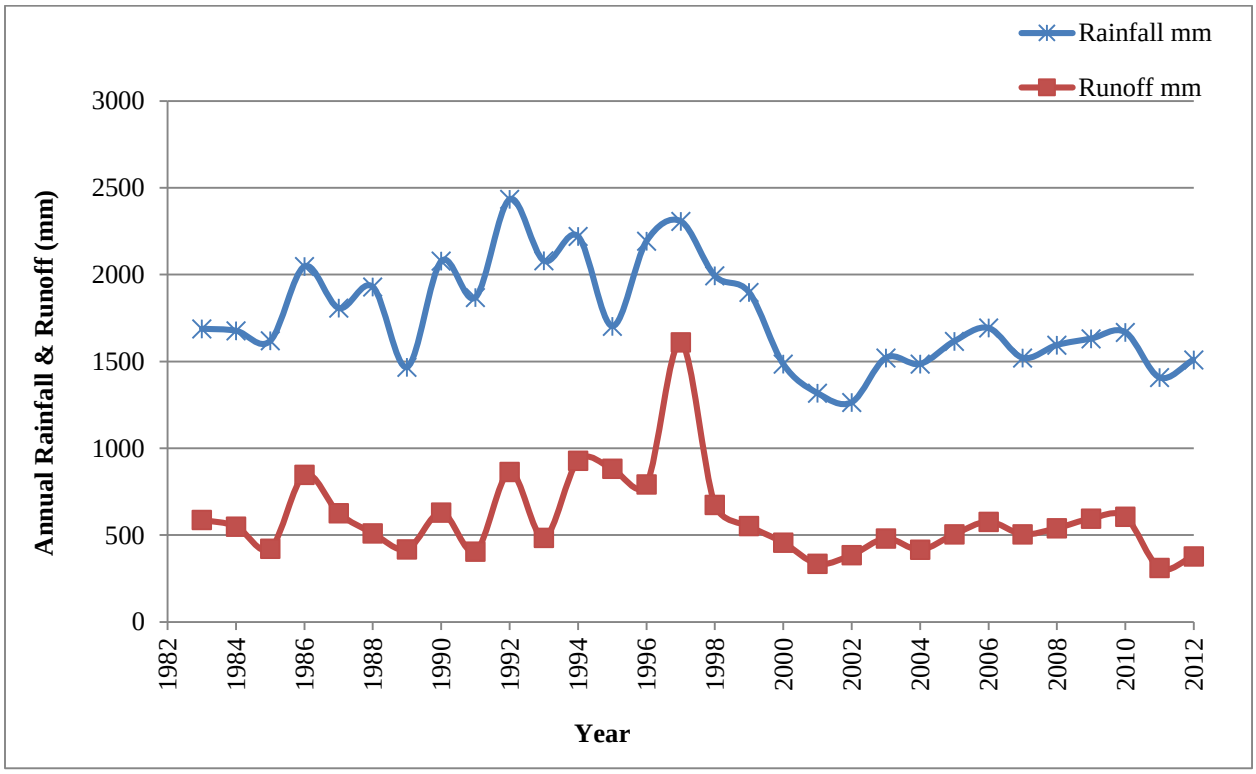

Fig. 3 Rainfall-Runoff Relationship for Simly Catchment

3. Results and discussion

Rainfall is a major factor which controls the hydrology of a region. For this purpose annual, average monthly and monsoon periods rainfall and runoff data of Simly catchment from 1983 to 2012 were plotted to analyze the rainfall-runoff relationship in the study area. The results showed that land use change is the

major factor that affects the rainfall-runoff and runoff-sedimentation relationship and a rapid change in land use was observed from 1995-2012.

3.1 Land use Change Pattern From 1992-2010

Based on rainfall-runoff relationship land use maps were prepared for 1992, 2000 and 2010. The detail of Land use scenario is explained below.

Land Use for Simly Catchment in 1992

Land use map of Simly catchment in 1992 is given in Figure 4 according to this map in 1992 there was 0.8% water, 46.3% forest, 16.9% vegetation & agriculture 29.4% rangeland, 1.6% built-up area and 5.1% bare land in the catchment area of Simly Dam.

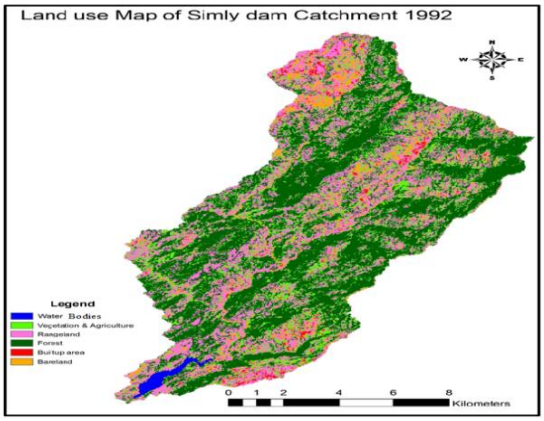

Fig-4 Land use Map for Simly Dam catchment in 1992

Land Use for Simly Catchment in 2000

Land use map of Simly catchment in 2000 is given in Figure 5 according to this map in 2000 there was 0.5% water, 40.3% forest, 15.8% vegetation & agriculture 30.4% rangeland, 4.2% built-up area and 8.7% bare land in the catchment area of Simly Dam.

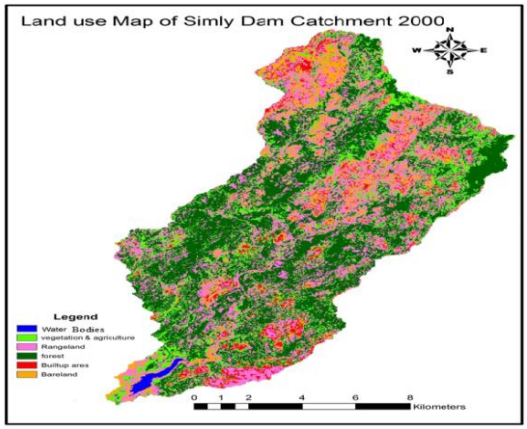

Fig-5 Land use Map for Simly Dam catchment in 2000

Land Use for Simly Catchment in 2010

Land use map of Simly catchment in 2010 is given in Figure 6 according to this map in 2010 there was 0.45 % water, 34.1% forest, 14.2% vegetation & agriculture 33.8% rangeland, 5.8% built-up area and 11.7 % bare land in the catchment area of Simly Dam. In Simly catchment during 1992-2010 the land use changes are given in Table1.

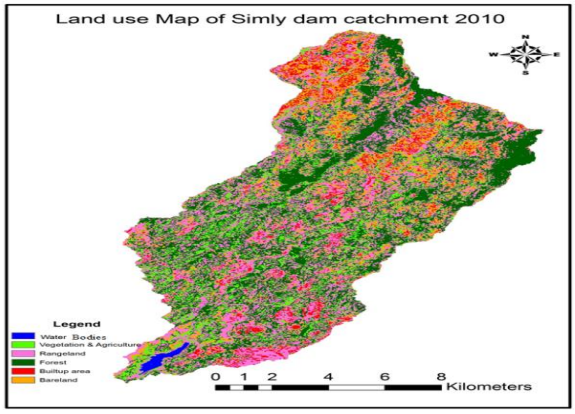

Fig-6 Land use Map for Simly Dam catchment in 2010

Table 1 Land use changes in Simly catchment during 1992-2010

Land use	1992		2000		2010		1992-2010	
	Area (km^2)	% of total area	Area (km^2)	% of total area	Area (km^2)	% of total area	Change (km^2)	Change in %
Water bodies	1.3	0.8	0.8	0.5	0.7	0.46	-0.6	-46
Forest	71	46.3	61.9	40.3	52.3	34.07	-18.7	-26
Vegetation & Agriculture	25.9	16.9	24.2	15.8	21.8	14.20	-4.1	-16
Rangeland	45.1	29.4	46.7	30.4	51.9	33.81	6.8	15
Built-up area	2.4	1.6	6.5	4.2	8.9	5.80	6.5	271
Barren land	7.8	5.1	13.4	8.7	17.9	11.66	10.1	129
Total	153.5	100	153.5	100	153.5	100		

3.2 Effect of Land Use Pattern on Rainfall- Runoff Relationship of Simly Catchment

The average monthly and annual rainfall-runoff relationships for Simly catchment are given in Figures 7 and 8 respectively. It can be observed that with the increase of rainfall runoff is also increasing and from 1998 there is an increase in runoff from almost the same amount of rainfall. This emphasize the fact that runoff amount has increased due to land use change with constant rainfall amount during the same period. As for average monthly rainfall and runoff it is clear in Figure 7 that the highest values of rainfall and runoff occurred during Monsoon months which are July, August and September.

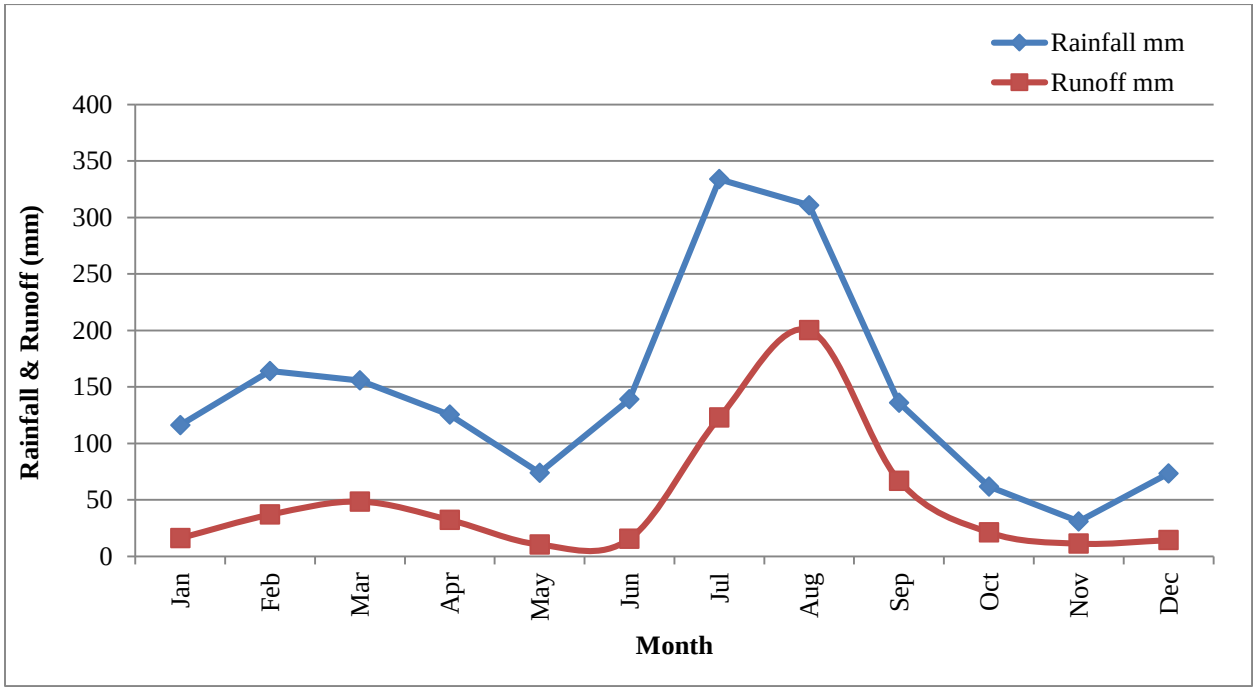

Fig.7 Average Monthly Rainfall & Runoff for Simly Catchment (1983-2012)

In Simly catchment the notable development activities started from 1998, Islamabad Muzafarabad carriage way is one of them which completed in 2008. Islamabad Muzafarabad carriage way is a 4-lane highway being constructed to reduce traffic load from existing Islamabad-Murree road and also to provide an alternate route leading to the Kashmir valley. About 19 km of Islamabad Muzafarabad carriage way passes through the catchment area of Simly Dam. Furthermore over 10 million cubic feet excavated material dumped along Soar river is silting up Simly reservoir. Large scale cutting of trees for the construction of the said highway is also causing environmental impacts and soil loss.

To check the land use change effects annual Double Mass Curve of rainfall- runoff was plotted which is shown in Figure 8. It can be observed in Figure 8 that with the increase in rainfall runoff is also increasing and this trend can be clearly observed in period of 1998-2008 which was the major development period also it can be observed that in present situation 2009-2012 there is increase in the trend of runoff. For annual and monsoon months Double Mass Curves were plotted which are shown in Figures 9-12. From these Figures it can be observed that with the increase in rainfall, runoff is also increasing and this trend can be clearly observed in period of 1998-2008 which was the major development period also it can be seen that in present situation 2009-2012 there is increase in trend of runoff. From regression coefficients of linear equation it can be clearly observed that for annual and monsoon months Double Mass Curve the value of slope coefficient is more during 1995-2012.

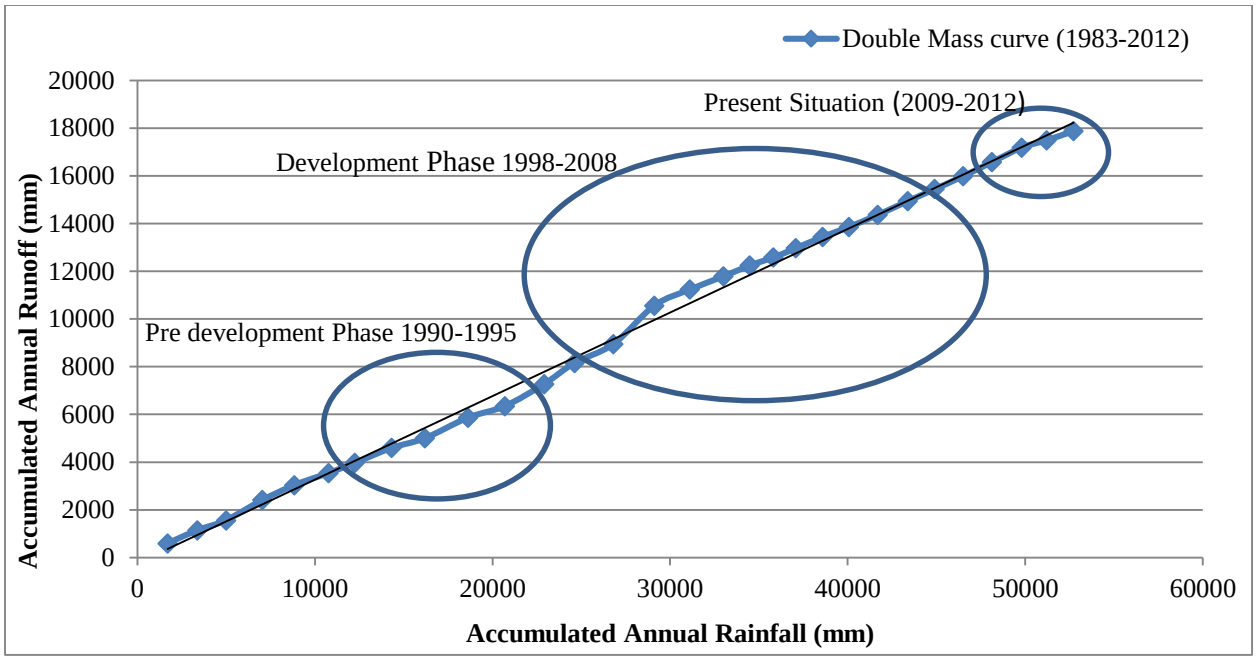

Fig.8 Double Mass Curve of Rainfall & Runoff for Simly Catchment (1983-2012)

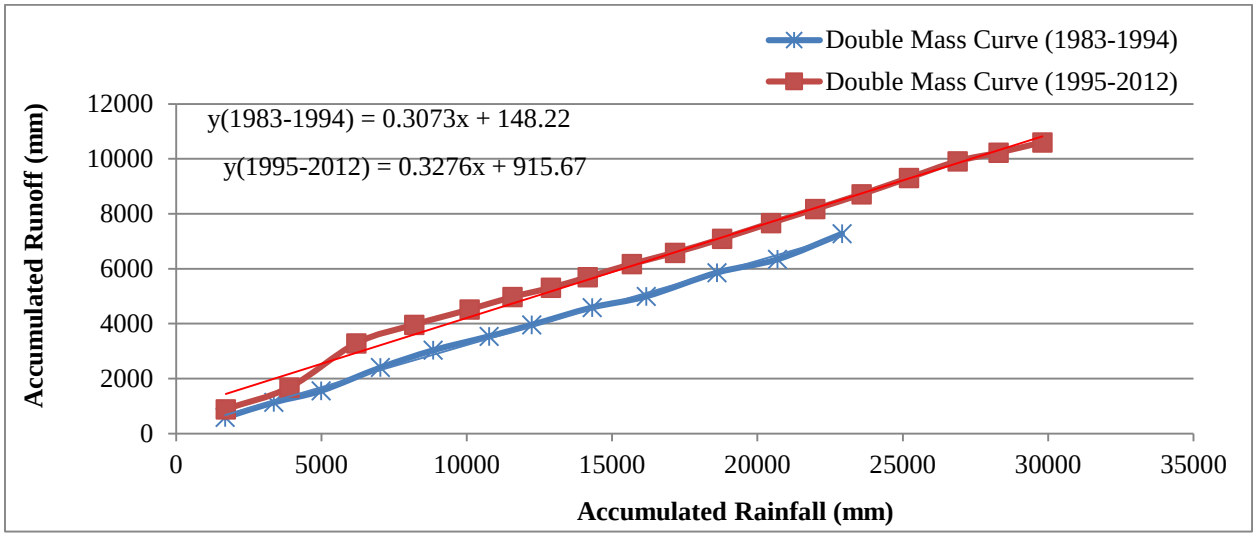

Fig.9 Double Mass Curve of Annual Rainfall & Runoff for Simly Catchment during 1983-1994 & 1995-2012

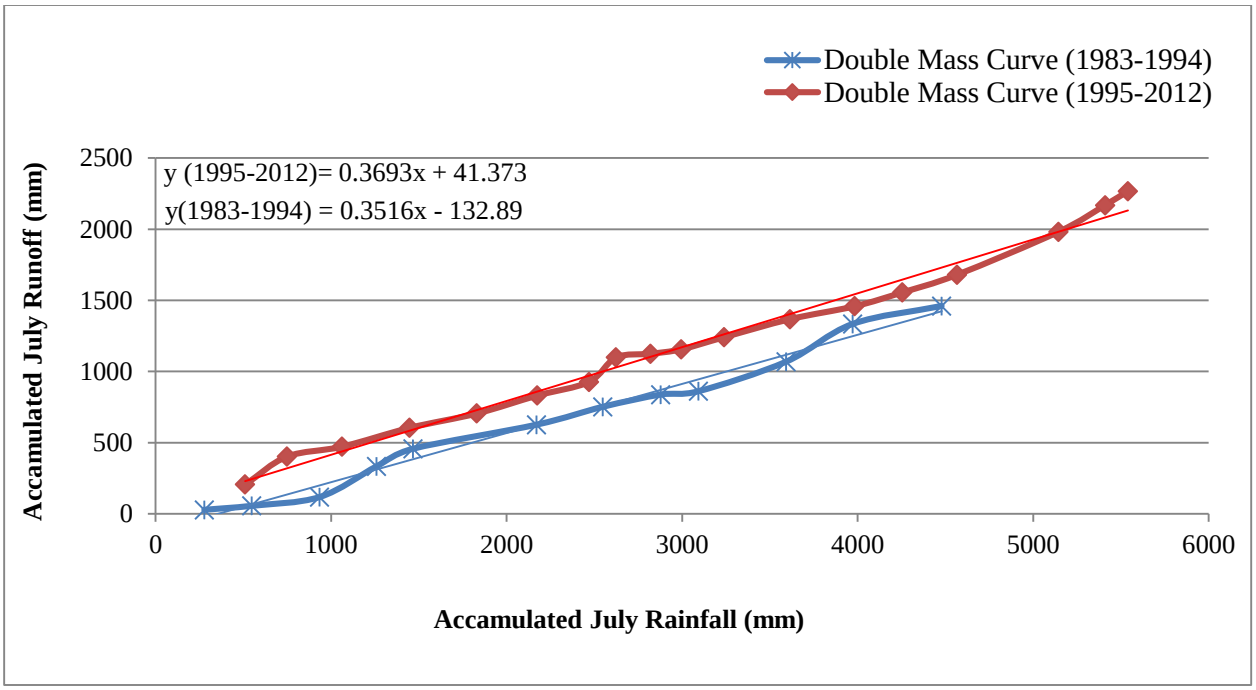

Fig.10 Double Mass Curve of July Rainfall & Runoff for Simly Catchment during 1983-1995 & 1996-2012

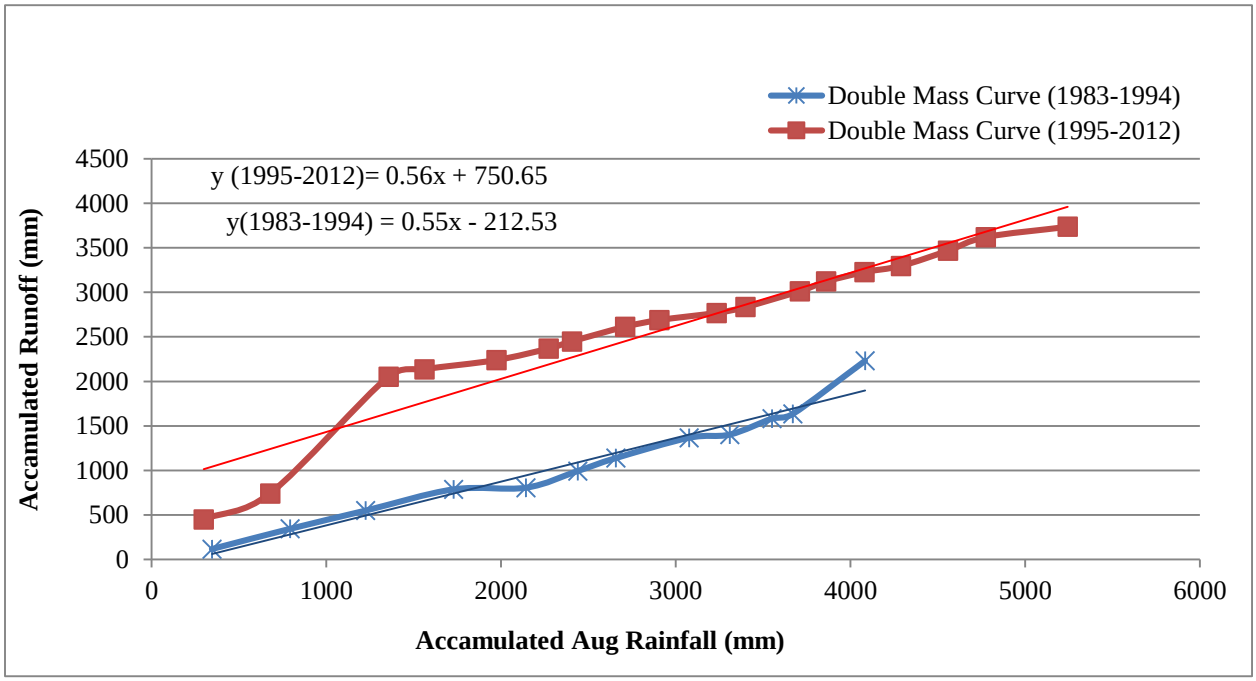

Fig.11 Double Mass Curve of August Rainfall & Runoff for Simly Catchment during 1983-1995 & 1996-2012

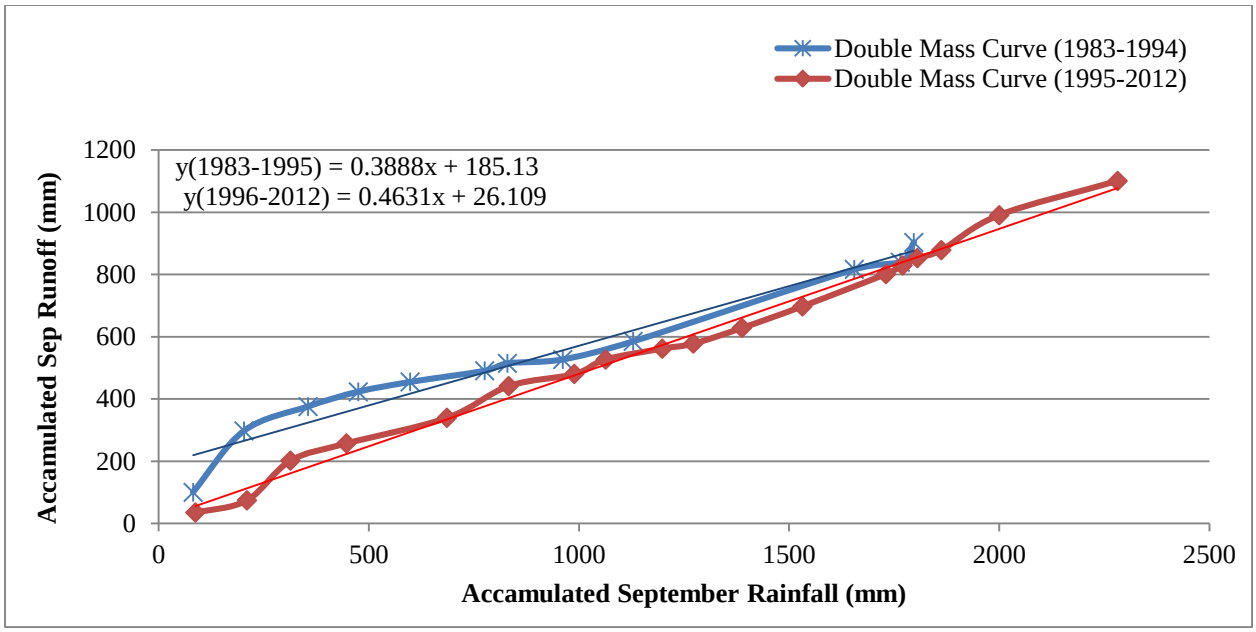

Fig.12 Double Mass Curve of September Rainfall & Runoff for Simly Catchment during 1983-1995 & 1996-2012

3.3 Effect of Land Use Pattern on Runoff-Sedimentation Relationship of Simly Catchment

The accelerated soil erosion in Simly catchment is the considerable issue inducing sedimentation in the Simly Dam. The runoff-sediment relationship for Simly catchment is given in Figure 13 which shows, with the increase in runoff sedimentation is also increasing. The Double Mass Curve for Simly catchment is shown in Figure 14 the regression coefficients of Double Mass Curve shows higher value of slope for period 1995-2005.

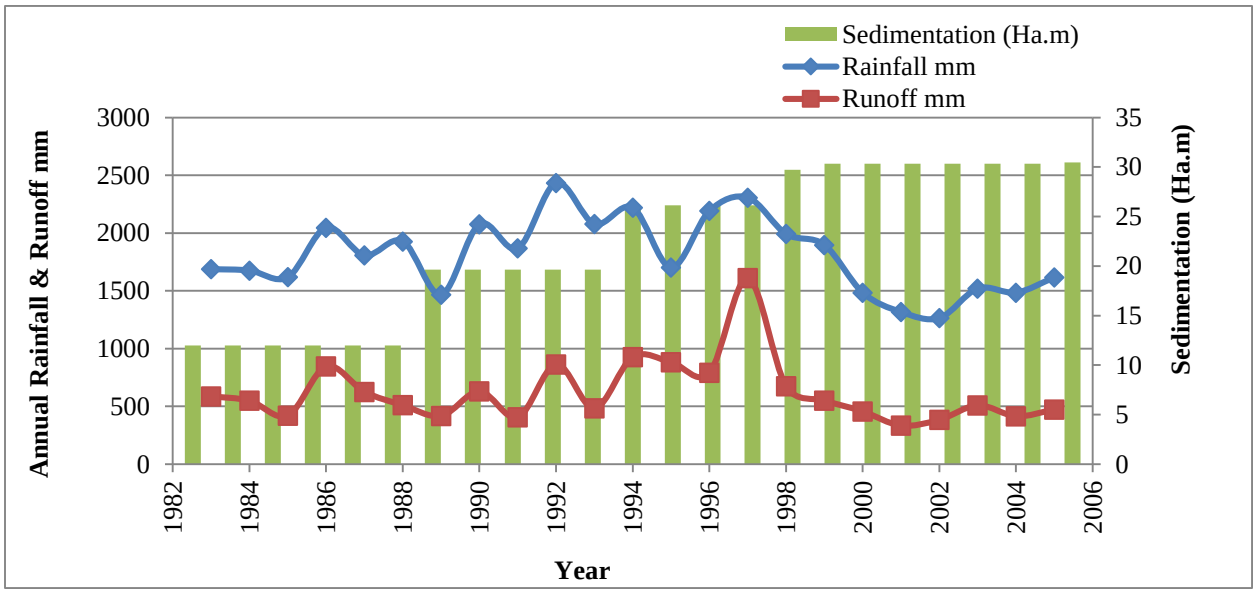

Fig.13 Annual Runoff & Sedimentation in Simly Catchment (1983-2008)

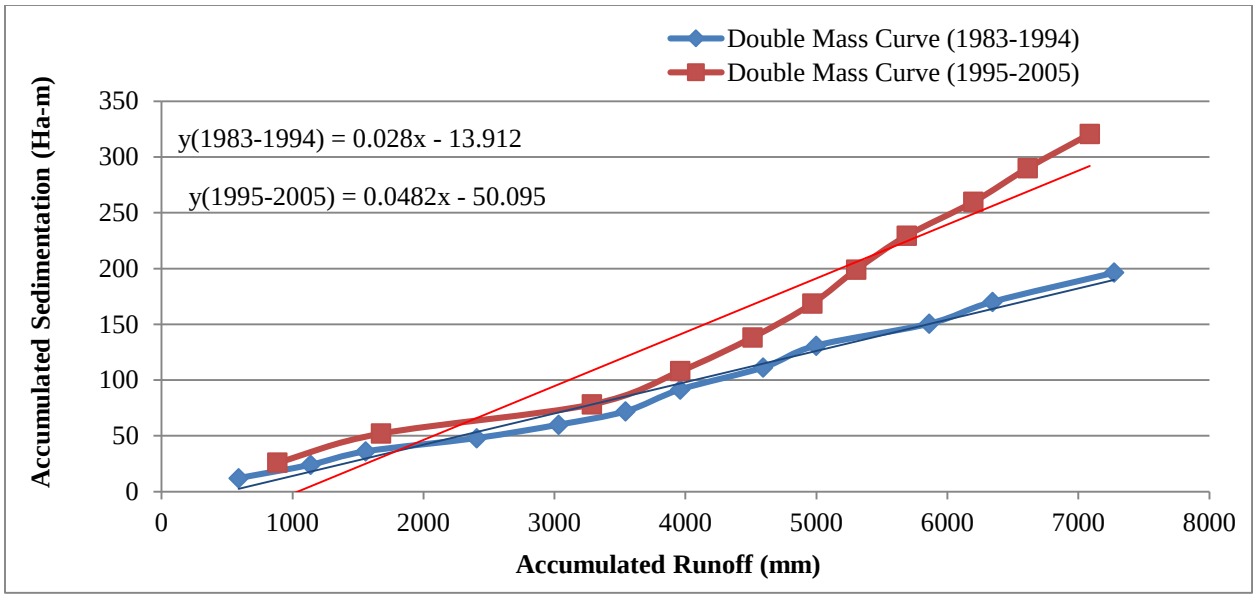

Fig.13 Double Mass Curve of Annual Runoff and Sedimentation

4. CONCLUSIONS

This study developed an approach to evaluate land use change impacts on hydrological response and sediment yield in Simly catchment. The land use analysis for Simly catchment gave land use information of Simly catchment also it showed the extensive land use change in Simly catchment during 1990-2010. The land use analysis showed during 1990-2010 in Simly catchment deforestation increased, bare land, built-up area and range land area increased which lead toward sedimentation and more runoff. From Double Mass Curve analysis it can be concluded that land use change turned the hydrological response and sediment yield in Simly catchment. From Double Mass Curves of annual and monsoon months rainfall-runoff relationship for Simly catchment it can be concluded that during 1995-2012 the value of slope trend curves were higher as compared with the value of slope tend curves during 1983-1994 which means in Simly catchment during 1995-2012 more runoff was observed. Similarly Double Mass Curve of annual runoff and sedimentation reveals that during 1995-2005 the value of slope trend curves were higher as compared with the value of slope tend curves during 1983-1994 which means in Simly catchment more sedimentation was observed during 1995-2005. For better planning and management of Simly catchment it is strongly needed to control deforestation and residential activities in the catchment area.

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