



## Prediction of rainfall, runoff and sediment yield of Dolgad watershed of Himalayan agroecosystem

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A watershed is a hydrological unit that drains its water through the landscape, into tributaries and into the main river channel through the process of precipitation. It is also commonly known as 'catchments', 'drainage basins' or 'river basins'. The landscape of a watershed is composed of different ecosystem like forests, grasslands, cultivated areas, riparian areas and wetlands. These ecosystems provide many number of soil services/ watershed services like soil formation, carbon sequestration, ground water recharge, water holding service, clean drinking water etc. The quantitative and qualitative nature of water in a watershed depends on amount and intensity of rainfall and the types of soil water conservation practices adopted in a watershed. Objective of any watershed management programme is to provide sufficient water for drinking and irrigation and to reduce peak runoff and thereby soil and water erosion for increasing ground water recharge. Rainfall-runoff-sediment yield is the most complicated hydrological phenomenon because of spatial variability of watershed characteristics and rainfall patterns which makes physical modeling relatively complex and tedious (Morin *et al.* 2006). The amount of runoff and sediment yield generated from a given rainfall is governed mostly by rainfall intensity, duration, and distribution in addition to other factors like initial soil moisture, land use, slope, etc (Wei *et al.* 2007). The runoff generated is crucial for many watershed activities like design of flood protection structures, protection of cultivated lands, scheduling of water storage and release, etc. Soil is a fundamental resource of any ecosystem that provides many number of services (Pathak *et al.* 2017).

Accelerated erosion due to heavy runoff threatens these services. Sediments produced in a watershed decreases the storage capacity of a watershed and can carry pollutants like radioactive materials, pesticides etc.

Integrated landscape approach of conservation aims to improve rural livelihoods and maintain agricultural productivity as well as provide ecosystem services, and assist in forest conservation (McNeely and Scherr 2003). Several linear and non-linear hydrological models have been developed since 1930's for relating the processes of rainfall-runoff, runoff-sediment yield, and rainfall-runoff-sediment yield in a watershed. The main objective of the study is to predict the rainfall, runoff and relationship after treating the watershed with suitable soil water conservation measures. In this paper, a study has been carried out in Dolgad Watershed of Nainital district of Uttarakhand. The total area of the watershed is 7094 ha and lies between latitude 29°20'33" to 29°27'42" and longitude 79°40'24" to 79°46'18". Relevant information and necessary data of the selected Dolgad Watershed, Uttarakhand were collected. The topography of the study area is mostly hilly and elevation varies between 1191 m to 2383 m. Average annual precipitation of the watershed is about 2500 mm out of which 85% of precipitation occurs during monsoon season (June-October). Average highest and lowest temperature of the region is recorded as 24°C and 8°C occurs in the month of July and January, respectively. Plenty of natural springs of variable discharge capacity are available in the watershed. ASTER DEM data (<https://asterweb.jpl.nasa.gov/gdem.asp>) with spatial resolution of 30 m has been employed in ArcMap 10.1 software for delineation of watershed boundary and preparation of drainage map (Fig 1). Slope map of the watershed has been created using the Digital Elevation Model (DEM) data. It shows that almost the land of the watershed is highly sloppy in nature and about 59.30 % of the watershed area comes under 50-100% slope class. It is well known that higher the slope of a land more will be the overland flow velocity which is the prime factor for excess runoff as well as sediment yield. Fig 2 shows the land use/land covers (LULC) map of Dolgad watershed obtained

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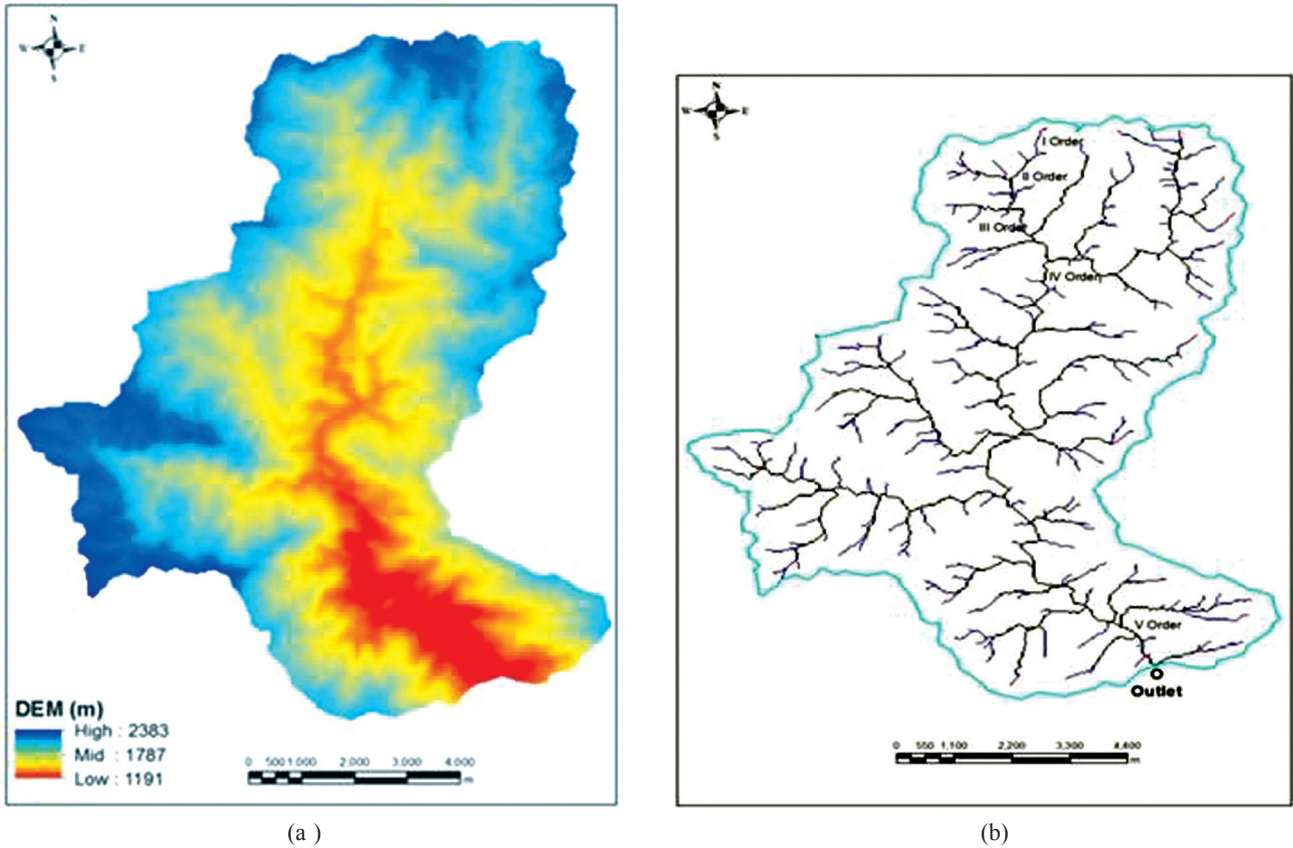


Fig 1 (a) DEM and (b) drainage map of Dolgad watershed.

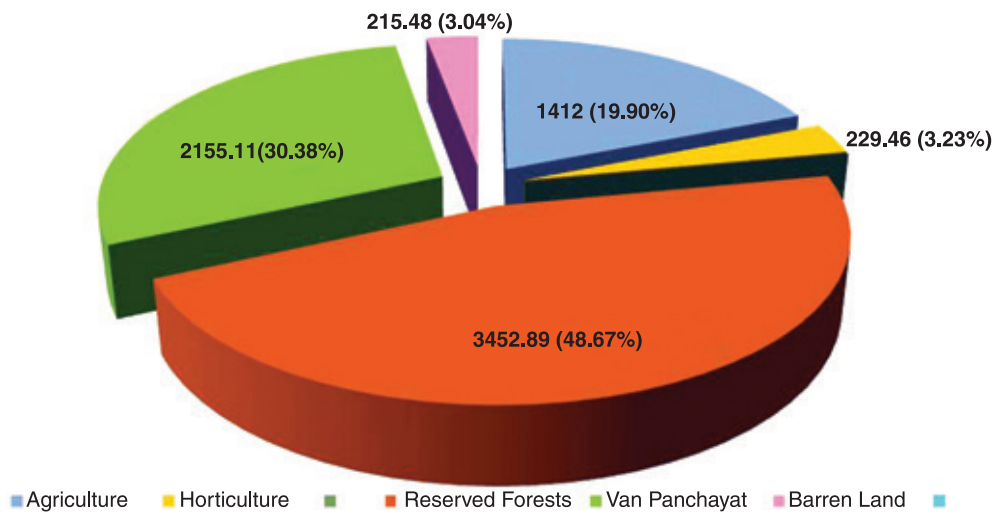


Fig 2 Land use/ Land cover classification of Dolgad watershed.

from Uttarakhand Decentralized Watershed Development Project (UDWDP). It shows that forest area is the major landcover of the watershed occupies 79.05% of total land the watershed followed by agriculture which occupies 19.9% of total geographic area of the watershed. Mostly the cultivation is practised in the watershed in terrace. Maize, soybean, wheat, pea etc. are the major agricultural produce. Though agricultural crops are grown in terraces, they are lacking in excess water disposal. In this watershed, 40% of the existing terraces were repaired and proper drainage

channels were excavated.

As the average annual rainfall of the watershed is high and greater than 100 mm/hr, intensity of rainfall is very frequent in this area which causes overland flow with high velocity. This overland flow under cuts the shallow-depth soil of the watershed and thus decreases the productivity of the land. Small scale landslide is the natural phenomena of this area. After looking into the problem of huge soil loss from the area subsequent reduction in crop productivity, different biological and mechanical soil water conservation measures



Fig 3 Gabion structure constructed



Fig 4 Contour staggered trenches in Dolgad watershed.

were implemented in the watershed. These measures include afforestation, incorporation of gabion structures, contour and staggered trenches, runoff water harvesting ponds, recharge structures etc. Saplings of locally suitable trees were planted in barren sparse vegetated area to hold to soil and restrict further erosion. Gabion structures as shown in Fig 3 made of locally available boulders were constructed across small streamlets within the watershed. These gabions break the slope of the channel. Thus, it reduces as overland flow velocity and consequently the erosive power of the overland flow (Srivastava *et al.* 2010). Apart from that it also accumulates the suspended sediments along with the boulders coming from upstream. Gradually, it stabilizes the channels after allowing vegetation to grow behind the structure. The contour staggered trenches excavated in various places within the watershed break the overland flow velocity and reduces the erosive power of the runoff water as well (Fig 4). It allows accumulating runoff water along with suspended sediments. In this way, it helps in increasing soil moisture and recharging groundwater by allowing infiltration of the ponded water. Similar results were also reported by Patode *et al* (2015) for a small catchment in Maharashtra, India. Similar type of study has been conducted by Kumar and Das (2000) in the watershed system of Ramganga. Ali *et al.* (2017) reported that the effectiveness of different density of staggered contour trenches in conserving the runoff water in establishing horti-pastoral land-use system in a highly degraded ravine watershed. Recharge tanks as well as water harvesting ponds were excavated in downstream area of the watershed to enhance groundwater recharge and increase its potential. Water from the ponds is also used for irrigating vegetable crops. The cropping intensity of the watershed is raised to 1.7 from 1 by creating especially water harvesting structures. It was also observed that soil water conservation measures also rejuvenated the natural springs. After treating the watershed with soil water conservation measures, runoff and sediment yield was measured at watershed outlet and analysed to form an analytical model to predict runoff and sediment yield for the watershed. Average monthly rainfall and runoff depth was fitted and linear relationship shows

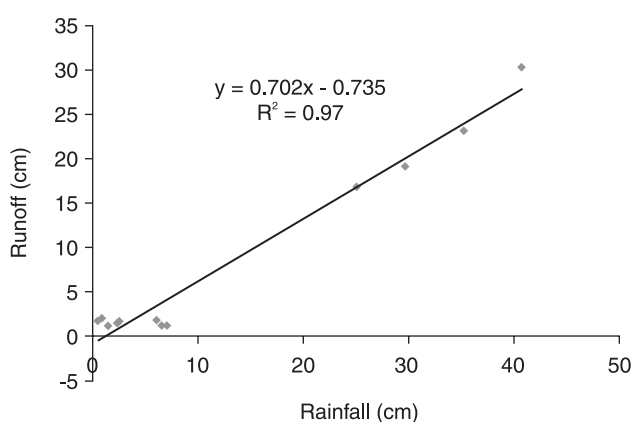


Fig 5 Relationship of rainfall, runoff and R<sup>2</sup> value of Dolgad watershed.

better correlation with a R<sup>2</sup> value of 0.97 (Fig 5). This equation is valid when the rainfall amount is greater than zero. Hence, using the relationship the expected monthly runoff from the watershed can be predicted. It helps in designing the optimum size of the water harvesting structure.

Suspended sediment concentration in runoff water was collected with sediment samplers. The samples were dried in laboratory and sediment concentration in runoff water was calculated. Runoff and soil loss data obtained in this study were plotted to establish relation between runoff and

Table 1 Relationship of runoff, sediment loss and R<sup>2</sup> value (Y= Sediment loss, X= runoff)

Model	Equation	R <sup>2</sup>
Power	$Y = 1.268x^{1.436}$	R <sup>2</sup> = 0.87
Exponential	$Y = 2.302e^{0.143x}$	R <sup>2</sup> = 0.85
Second order polynomial	$Y = 0.288x^2 - 0.841x + 3.373$	R <sup>2</sup> = 0.88
Third order polynomial	$Y = -0.004x^3 + 0.575x^2 - 5.382x + 13.11$	R <sup>2</sup> = 0.88
Fourth order polynomial	$Y = -0.004x^4 + 0.324x^3 - 6.815x^2 + 34.52x - 30.78$	R <sup>2</sup> = 0.96

Table 2 Quality of drinking water of from the Study Area (Dolgad Watershed, Nainital)

Parameter	Permissible limit (BIS)	Dolgad
Odour	Odourless	Odourless
Colour	Colourless	Colourless
pH	6.5 – 8.5	7.5
EC ( $\mu$ S)	200	89
Nitrate (mg/l)	45	31.94
Total hardness (mg/l)	300	59
Chloride (mg/l)	250	17.86
Ammonium (mg/l)		5.05

soil loss from the watershed. It was found that fourth order polynomial gave best fitted result with  $R^2$  value of 0.96 as shown in Table 1. It signifies that as the volume of runoff increases, sediment yield also increases. However, after a threshold depth sediment yield get almost constant.

Samples of water is collected from the water harvesting ponds and quality of water used for drinking purposes by the people of watershed area was assessed (Table 2). The quality parameters are under permissible limit and safe for drinking as per BIS 10500: 1991 standard.

#### SUMMARY

The quantitative and qualitative nature of water in a watershed depends on amount and intensity of rainfall and the types of soil water conservation practices adopted in a watershed. The runoff generated is crucial for many watershed activities like design of flood protection structures, protection of cultivated lands, scheduling of water storage and release, etc. Linear relationship between average monthly rainfall and runoff depth of Dolgad watershed

shows better correlation with a  $R^2$  value of 0.97. Runoff and soil loss data showed fourth order polynomial gave best fitted result with  $R^2$  value of 0.96.

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