DIMINISHING DISCHARGES OF MOUNTAIN SPRINGS IN A PART OF KUMAUN HIMALAYA

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ABSTRACT

Deforestation of vulnerable hill slopes leading to 13.1% reduction of the protective forest cover in 22 years up to 1985 and accelerated erosion at the rate of 170.3 cm/1000 years have greatly affected the hydrologic regime in the catchment of the Gaula River—a tributary of the Ramganga in the Kumaun Himalaya. This is manifest in the drying up of springs and the diminished discharges in more than 40% villages of the Gaula catchment. The extent of decrease in discharge ranges from 25 to 75% during the past 5 to 50 years. Consequently, the flow in the Gaula River has also diminished—29.2% between 1951–60 and 1961–70 and 38.5% between 1971 and 1981. Deficiency in rainfall amounting to 9.5 to 76% between 1958 and 1986 has been noticed in many parts of the catchment area.

INTRODUCTION

General conditions in Kumaun

With the population of Kumaun growing at an exponential rate\(^1\) of 2.28% and the people living on extremely restricted cultivable stretches, it is but natural that the density of population in these areas is four times higher than in the plains of UP, while the productivity of the land is very much less\(^2\). The pressure of grazing is 2.5 to 4.7 times higher than the supporting capacity of the forests\(^3\), with the result, the forest cover has been reduced to less than 30% of the surface area\(^4\). The regional rate of erosion estimated at 1 mm per year\(^5,6\) implies an alarming state of the environment. The increasingly greater use of water and land resources in the face of impairment of natural environment has a telling effect on the quality of life of the people of the region. Springs are drying up or becoming seasonal\(^7\), and the difference in the volume of water flowing down the rivers during dry and rainy seasons is commonly more than 1000 times, resulting in the too-little-and-too-much-water syndrome—a common feature of the desert country\(^5\). The evaporation of moisture in the soil on the tree-less slopes is very high, and xerophytes are beginning to find footholds on naked slopes. These features can be described as harbingers of the onset of desertification\(^5,6\).

The hydrologic responses of any watershed in the form of great fluctuation in water yield of springs, recurrence of floods in valleys and variation in the water quality depend upon the geology of area, the

Figure 1. Location of the Gaula basin in the Lesser Himalayan drainage network.
activities. The present work provides the appraisal of fast-changing land use pattern and its impact on water resources.

Gaula catchment

The Gaula is a wholly Lesser Himalayan river, draining the south-central part of Kumaun (figure 1). The 600 km² catchment area of the Gaula (29°17'36"–29°27'48"; 79°49'20"–79°26') ranges in elevation from 500 to 2610 m above MSL.

The average annual precipitation during 1958–1986 over the whole catchment area was about 209 cm of which 70 to 90% took place mainly in three months (mid-June to mid-September). The mean annual temperature is 15.7°C, the mean monthly evaporation ranges from 0.6 cm (in August at Paharpuri) to 49 cm (in June at Bhimtal), and the mean monthly relative humidity varies from 12% (in January at Bhimtal) to 92.5% (in August at Paharpuri).

The catchment area falls in two physiographically well-defined lithotectonic belts (figure 2). The Siwalik, constituted of sandstones and mudstones of the Middle Miocene age, is sharply separated from

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**Figure 2.** Location of springs and seepages in relation to lithology, faults and lineaments in the catchment of the Gaula River.
the Lesser Himalaya by a deep tectonic plane known as the Main Boundary Thrust (MBT). The ruggedly mature but deeply dissected topography of the Lesser Himalayan subprovince of Precambrian sedimentary rocks overlain successively by huge sheets of metamorphic and granitic rocks (as old as 1900 ± 100 and 550 ± 50 m.y.) is cut by a multiplicity of faults and fractures trending NW–SE, N–S and NE–SW. The faults, fractures and joints are developed prominently in all rock-formations and play very important role in promoting the groundwater recharge, location of springs and the incidence of mass-movements.

HYDROGEOLOGY OF SPRINGS

The Gaula River and its tributaries are dependent on the groundwater for their round-the-year, steady flows. The groundwater is discharged in the form of springs and seepages (figure 2) through faults, fractures, joints and permeable layers. In valleys the groundwater occurs largely as disconnected local bodies such as landslide-debris fans and cones, river terraces in favourably perched aquifers under both confined and unconfined conditions, and in zones of jointing, fracturing and faulting. Relatively flat areas and gently sloping grounds characterized by deep weathering such as hill-tops, ridges, saddles, spurs and bulges of old landslide-debris, river terraces, fluvial fans and lacustrine terraces form the recharge areas, while steeper hill-slopes, first- or second-order streams at slopebreaks, and scarps of alluvial terraces and colluvial fans are sites of discharges. The saucer-shaped upper portions of the catchment areas (as in Jaunsali, Dhur and east of Bhimtal) have given rise to large underground bodies of perched water. Overlapping of lineament map on the spring map shows a good correlation between these linears and the concentration of springs of the hard-rock terrains. The springs having higher discharge lie directly on or within a few tens of metres of these lineaments. It is thus obvious that the lineaments

Figure 4a, b. a. Expansion of agricultural and grazing land at the cost of forests in the Kasiyalekh, Chauchhutia, and Majina areas, NW of Padampuri. The discharge of the springs has gone down by 50%, and b. Slope devoid of vegetation near Maharagaon (near Bhimtal) has become prone to shallow soil-slumps.

Figure 5. Percentage of reduction in forest cover in the Gaula catchment since 1963. Deduced on the basis of comparison of the 1963 Survey of India map with the 1973 LANDSAT photographs and field survey.
produced by joints, fractures and faults play a very significant role in the making of the hydrological regime of the study area.

LAND USE PATTERN AND HYDROLOGICAL PROBLEMS

A land use map (figure 3) has been prepared on the basis of field survey carried out in 1984-85 during geological and hydrogeological investigations. Comparison of the 1985 land use map with the Survey of India toposheets of 1963 (as interpreted by the authors) and with the Landsat photo of 1973 (as interpreted by Tewari et al) has brought out very significant facts.

In 1985 out of 597 km$^2$ of the Gaula catchment approximately 258 km$^2$ area (43.2%) was non-forested—162.37 km$^2$ (27.2%) being used for agriculture, horticulture and related purposes and 30.06 km$^2$ (5%) converted into grazing land (figures 3, 5). The agricultural fields are confined largely to river terraces and fan-shaped old landslide deposits where water is available. Grasslands and barren lands account for 6.95% and major roads (approximately 350 km in aggregate length) cover another 2.2% of the study area.

In 1985 a little less than 339 km$^2$ (56.8%) area was under the forest cover of sorts. In 22 years between 1963 and 1985, the forest cover shrank by 13.1% (figure 5). The extent of land under agriculture has increased by 7.1%, of the grazing land by 2.3%, and of other uses, by 2.6%. Needless to state, this increase occurred at the cost of forests. Among the varied causes of the deterioration and reduction in the size of forests at the rate of 0.6% per annum are forest clearance for agriculture and horticulture, overgrazing, forest-fires, road construction, large-scale lopping and felling of trees, etc.

Table 1  Annual rainfall (mm) recorded by raingauge stations in the catchment of the Gaula River

<table>
<thead>
<tr>
<th>Year</th>
<th>Paharpani</th>
<th>Okhalkanda</th>
<th>Chanphi</th>
<th>Nainital</th>
<th>Bhimgal</th>
<th>Kathgodam</th>
<th>Jamrani</th>
<th>Logar</th>
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<td>Total</td>
<td>27483.7</td>
<td>22775.41</td>
<td>2987.17</td>
<td>14890.74</td>
<td>45749.33</td>
<td>53247.6</td>
<td>17683.81</td>
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<td>Average (1958–1986)</td>
<td>3053.7</td>
<td>3795.90</td>
<td>995.72</td>
<td>2445.0</td>
<td>1838.00</td>
<td>2129.90</td>
<td>2526.26</td>
<td>1838.19</td>
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</table>
IMPACT ON VEGETATION AND CLIMATE

Large portions of tree-less land are now cluttered with cactus indicating severe depletion of soil moisture. Broad-leaf oaks and rhododendrons, which grow in humus-rich soils, are being replaced at an alarmingly fast rate by pines. The lower reaches of the catchment have been invaded by the pest *Lantana camara*, eliminating vegetation of all kinds.

The weather of the Bhimtal-Hairakhan-Khansyun belt has become warmer and drier during summers. This is evident from the decline in rainfall (table 1). The annual rainfall over Bhimtal declined by 34% from 2193 mm (average of 13 years from 1958 to 1970) to 1446 mm (average of the subsequent 12 years from 1971 to 1986). During the same period 9.3% of the forest cover was lost due to a variety of causes. At the Jamrani Dam site, the average annual precipitation 3465 mm of the years 1976–78 fell to 2205 mm in the subsequent 4 years ending 1981, thus registering a drop of 35.3%. Upstream to Khansyun the forest cover had decreased by 14.2% between 1963 and 1965. In the Paharpani area, which registered an alarming 76% drop in the rainfall during 1976–1980 to 1981–1986, the extent of forest reduction was 13.3% since 1963. However, at Kathgodam the rainfall does not show any decrease. In the Balia subcatchment, where 17.4% of the forest cover was lost between 1963 and 1985, the average annual rainfall of 2538 mm (average of the years 1974-1985) dropped to 2238 mm (average of 1974–1985) indicating a decline of 9.5% in a decade. It is reasonable to attribute the change in the

Figure 6a, b. a. Hydrograph of the ‘Parda dhara’ (spring) in the karst terrain of Nainital. The broad peaks indicate slower outflow of groundwater and recharge due to winter rains, and b. The hydrographs indicate that the higher discharge in 1985 is a consequence of high rainfall in October, 1985.
conditions of weather as reflected in the decline and rainfall and moisture deficiency in the soil to the deterioration—and decimation in some parts—of the forests. For the forests are known to have great influence on rainfall\textsuperscript{9,10}.

**DECLINE IN SPRING DISCHARGES**

There is a perceptible decrease in the discharges of springs and seepages in more than 40% of the villages studied (figures 6 and 7, table 2). The extent of decrease is 25 to 75% in the past 5 to 50 years. More than 2% of the springs completely dried up in the last 15–20 years. The discharges of the springs downslope of the newly constructed roads at Karail, Ijar, Palara, Thata, Kodal, Kotli, Nai, Takura, Kalwani, Narainagar and others have gone down considerably. The uncontrolled blasting during the excavation for roads has locally upset the pattern of groundwater flow and lowered the piezometric surfaces. This is eloquently manifest at Ramshila, Paniyan, Dharchuli and Dini where the springs have gone completely dry.

**DIMINISHED DISCHARGE IN THE GAULA**

A few streams such as the Dhandwarigad at Khansyun, the Gaula at Shanri (Babyar), the Kalsa upstream of the Gaula–Kalsa confluence, the Logar upstream of Hairakhan and Khalbhajalagad have become gravel-filled dry channels.

The annual flow of the Gaula River at Kath-
### Table 2  Variation and cause of diminishing discharges of the springs (S) and seepages (N) in the Gaula catchment

<table>
<thead>
<tr>
<th>Location</th>
<th>Discharge ((\times 10^3 \text{ l/day}))</th>
<th>Extent (%)</th>
<th>Period (year)</th>
<th>Reason</th>
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<tbody>
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<td>Sungarkara</td>
<td>7.8</td>
<td>50</td>
<td>40</td>
<td>Road construction</td>
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<tr>
<td>Katjawa (S)</td>
<td>12.4</td>
<td>75</td>
<td>15-20</td>
<td>Deforestation</td>
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<tr>
<td>Chanoti (N)</td>
<td>10.2</td>
<td>75</td>
<td>15-20</td>
<td>-do-</td>
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<td>Kurthi (S)</td>
<td>29.8</td>
<td>33</td>
<td>15-20</td>
<td>Encroachment of agricultural land into forest</td>
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<td>Shyamkhet (S)</td>
<td>32.4</td>
<td>50</td>
<td>50</td>
<td>Deforestation and replacement of oak by pine</td>
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<td>Sariatal (S)</td>
<td>8.64</td>
<td>25</td>
<td>20-25</td>
<td>Reduction in rainfall and deforestation</td>
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<td>Bhaloti (S)</td>
<td>21.1</td>
<td>~50</td>
<td>20</td>
<td>Land subsidence</td>
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<td>Bhaloti (S)</td>
<td>16.3</td>
<td>~50</td>
<td>25</td>
<td>Diversion of the natural water course</td>
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<td>Bhaloti (N)</td>
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<td>~100</td>
<td>10</td>
<td>Neotectonics movements</td>
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<td>Kasani (S)</td>
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<td>35-40</td>
<td>Earthquake</td>
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<td>Surijayala (S)</td>
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<td>50</td>
<td>Uprooting of trees and partly earthquake</td>
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<td>25-30</td>
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<td>-do-</td>
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<td>25</td>
<td>15</td>
<td>Landslide downslope of the spring and partly deforestation</td>
</tr>
<tr>
<td>Paniyan (S)</td>
<td>28.2</td>
<td>~40</td>
<td>15</td>
<td>Road construction</td>
</tr>
<tr>
<td>Jala (S)</td>
<td>86.4</td>
<td>~30</td>
<td>40-50</td>
<td>Felling of trees</td>
</tr>
<tr>
<td>Matela (N)</td>
<td>7.8</td>
<td>~50</td>
<td>40-45</td>
<td>Deforestation</td>
</tr>
<tr>
<td>Karail (N)</td>
<td>7.8</td>
<td>50</td>
<td>15-20</td>
<td>Road construction upslope</td>
</tr>
<tr>
<td>Ijar (S)</td>
<td>7.8</td>
<td>50-60</td>
<td>10-15</td>
<td>-do-</td>
</tr>
<tr>
<td>Sanjiri (S)</td>
<td>3.6</td>
<td>25-33</td>
<td>30-40</td>
<td>Deforestation upslope</td>
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<tr>
<td>Banjeri (N)</td>
<td>Nil</td>
<td>~100</td>
<td>10-15</td>
<td>Canal construction</td>
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<tr>
<td>Tani (N)</td>
<td>Nil</td>
<td>~100</td>
<td>20</td>
<td>Deforestation</td>
</tr>
<tr>
<td>Talli Gargori (N)</td>
<td>3.5</td>
<td>25-33</td>
<td>30-35</td>
<td>Deforestation upslope</td>
</tr>
<tr>
<td>Lipharakar (S)</td>
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<td>~100</td>
<td>20</td>
<td>Deforestation</td>
</tr>
<tr>
<td>Babyar (S)</td>
<td>5.8</td>
<td>60-70</td>
<td>5-6</td>
<td>Earthquake</td>
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<td>Rikhakot (N)</td>
<td>6.2</td>
<td>60</td>
<td>5-6</td>
<td>-do-</td>
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<td>Dal (N)</td>
<td>1.4</td>
<td>25</td>
<td>40-45</td>
<td>Deforestation</td>
</tr>
<tr>
<td>Syanti (N)</td>
<td>3.54</td>
<td>25-33</td>
<td>20-25</td>
<td>Deforestation and canal construction</td>
</tr>
<tr>
<td>Syanti (N)</td>
<td>Nil</td>
<td>~100</td>
<td>8-10</td>
<td>Canal construction</td>
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<tr>
<td>Tanda (N)</td>
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<td>25</td>
<td>20-25</td>
<td>Deforestation upslope</td>
</tr>
<tr>
<td>Talla Okhalkanda (S)</td>
<td>8.1</td>
<td>25</td>
<td>20-25</td>
<td>Deforestation</td>
</tr>
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<td>Sar Tall (S)</td>
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<td>20-25</td>
<td>-do-</td>
</tr>
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<td>Tussar (S)</td>
<td>34.6</td>
<td>25-30</td>
<td>15-20</td>
<td>-do-</td>
</tr>
</tbody>
</table>

**Reduction in discharge**

**Seasonal**

**Risks**
- Field observations
- Interviews with local inhabitants
- Satellite imagery

---

*Note: The table provides data on the discharges of springs and seepages in the Gaula catchment, along with the extent of reduction, the period over which the reduction occurred, and the cause of the reduction.*
Table 2. (Contd.)

<table>
<thead>
<tr>
<th>Location</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Putpuri (S)</td>
<td>18.6</td>
<td>25</td>
<td>2-3 Road construction upslope</td>
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<tr>
<td>Simalaya (S)</td>
<td>5.24</td>
<td>33</td>
<td>30-35 Deforestation upslope</td>
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<td>Charta (S)</td>
<td>3.1</td>
<td>50</td>
<td>10 Road construction upslope</td>
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<tr>
<td>Bharna (S)</td>
<td>3.1</td>
<td>25-33</td>
<td>15-20 Road construction and deforestation</td>
</tr>
<tr>
<td>Kobura (S)</td>
<td>6.7</td>
<td>50-75</td>
<td>30-40 Oak forest replaced by pine forest</td>
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<tr>
<td>Shala (S)</td>
<td>6.8</td>
<td>50-75</td>
<td><del>do</del></td>
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<tr>
<td>Koidal (S)</td>
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<td>33</td>
<td>15 Road construction upslope</td>
</tr>
<tr>
<td>Koidal (S)</td>
<td>Nil</td>
<td>~100</td>
<td>5-6 Road construction</td>
</tr>
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</table>

Barrage had dropped, from 13,615 cusec/day (the average of the period 1951–1960) to 9,654 cusec/day between 1961 and 1970, registering a decline by 29.2% (figure 8). Similarly, the discharge dropped to 5,935.9 cusec/day during 1971–1981, or a drop of 38.5% (table 3).

Among the causes of decline in discharge could be the larger utilization of upstream water for minor irrigation through canals (numbering 38) constructed during this period in the different subcatchments of the Gaula basin alone to irrigate 1022 hectares of cropland.

Reduction in rainfall in certain basins of the catchment area is probably the major cause of the decline in the monsoon discharge of the Gaula River. However, the decrease in spring discharges accounts for the overall decrease in the river discharges. This fact has great bearing in the general

Table 3 Yearly discharge of the Gaula River at Gaula barrage, Kathgodam (From 1950 to 1981)

<table>
<thead>
<tr>
<th>Year</th>
<th>Discharge cusec/day</th>
<th>Average of the decade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>27,454.5</td>
<td></td>
</tr>
<tr>
<td>1951</td>
<td>10,042.4</td>
<td></td>
</tr>
<tr>
<td>1952</td>
<td>16,181.6</td>
<td></td>
</tr>
<tr>
<td>1953</td>
<td>14,794.8</td>
<td></td>
</tr>
<tr>
<td>1954</td>
<td>14,853.9</td>
<td></td>
</tr>
<tr>
<td>1955</td>
<td>18,173.6</td>
<td></td>
</tr>
<tr>
<td>1956</td>
<td>20,241.1</td>
<td></td>
</tr>
<tr>
<td>1957</td>
<td>8,019.5</td>
<td></td>
</tr>
<tr>
<td>1958</td>
<td>12,255.1</td>
<td></td>
</tr>
<tr>
<td>1959</td>
<td>9,920.3</td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>11,652.6</td>
<td></td>
</tr>
<tr>
<td>1961</td>
<td>13,121.5</td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>9,786.3</td>
<td></td>
</tr>
<tr>
<td>1963</td>
<td>11,269.7</td>
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<tr>
<td>1964</td>
<td>13,976.0</td>
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<tr>
<td>1965</td>
<td>6,251.0</td>
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<td>1966</td>
<td>5,824.4</td>
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<tr>
<td>1967</td>
<td>10,969.3</td>
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<tr>
<td>1968</td>
<td>7,311.1</td>
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<td>1969</td>
<td>10,067.0</td>
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<tr>
<td>1970</td>
<td>7,963.2</td>
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<tr>
<td>1971</td>
<td>7,259.7</td>
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</tr>
<tr>
<td>1972</td>
<td>5,439.0</td>
<td></td>
</tr>
<tr>
<td>1973</td>
<td>5,175.4</td>
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<tr>
<td>1974</td>
<td>3,398.7</td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>8,390.2</td>
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<tr>
<td>1976</td>
<td>6,567.0</td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>5,185.5</td>
<td></td>
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<tr>
<td>1978</td>
<td>8,103.3</td>
<td></td>
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<tr>
<td>1979</td>
<td>4,528.7</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>5,236.9</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>6,210.4</td>
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</tbody>
</table>

Figure 8. Annual discharge of the Gaula River at the Kathgodam barrage, and average rainfall over its catchment for the period 1958 to 1982.
hydrologic scenario of the whole Lesser Himalaya and the Indogangetic plains.

ACKNOWLEDGEMENTS

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NEWS

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The Centre for Science and Technology is a new organization started by a group of students, scientists, and technocrats. It is a registered body under the Karnataka Societies Registration Act 1961.

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