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 land use pattern and the degree and nature of disturbances resulting from deforestation and human

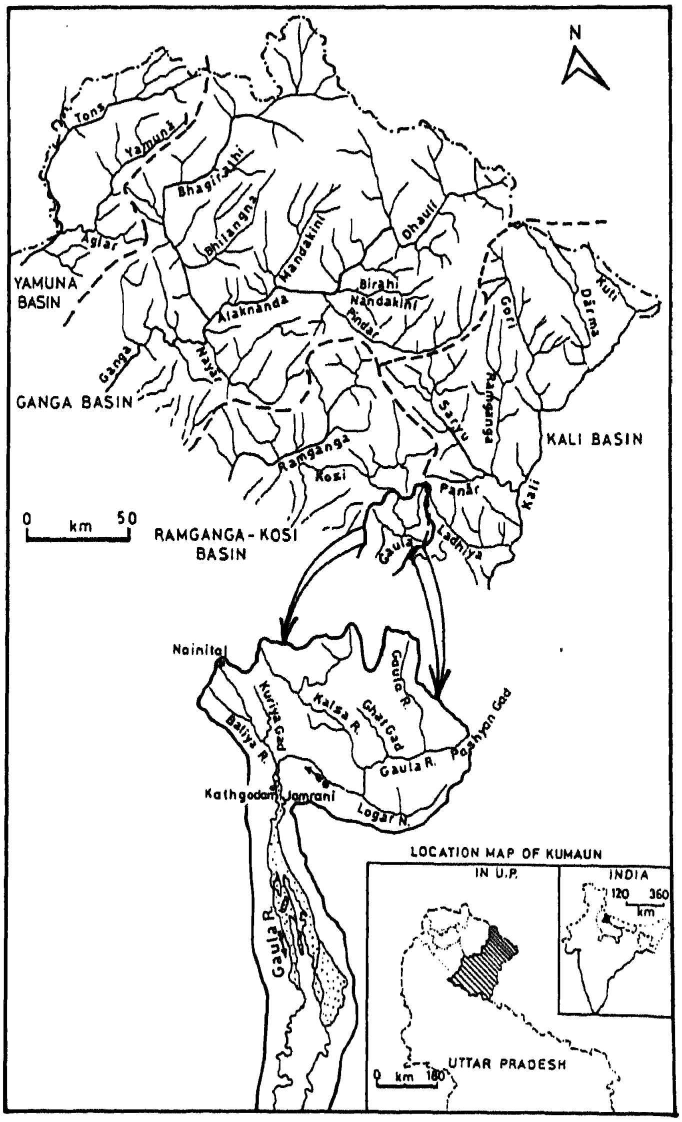


Figure 1. Location of the Gaula basin in the Lesser Himalayan drainage network.

activities. The present work provides the appraisal of fast-changing land use pattern and its impact on water resources.

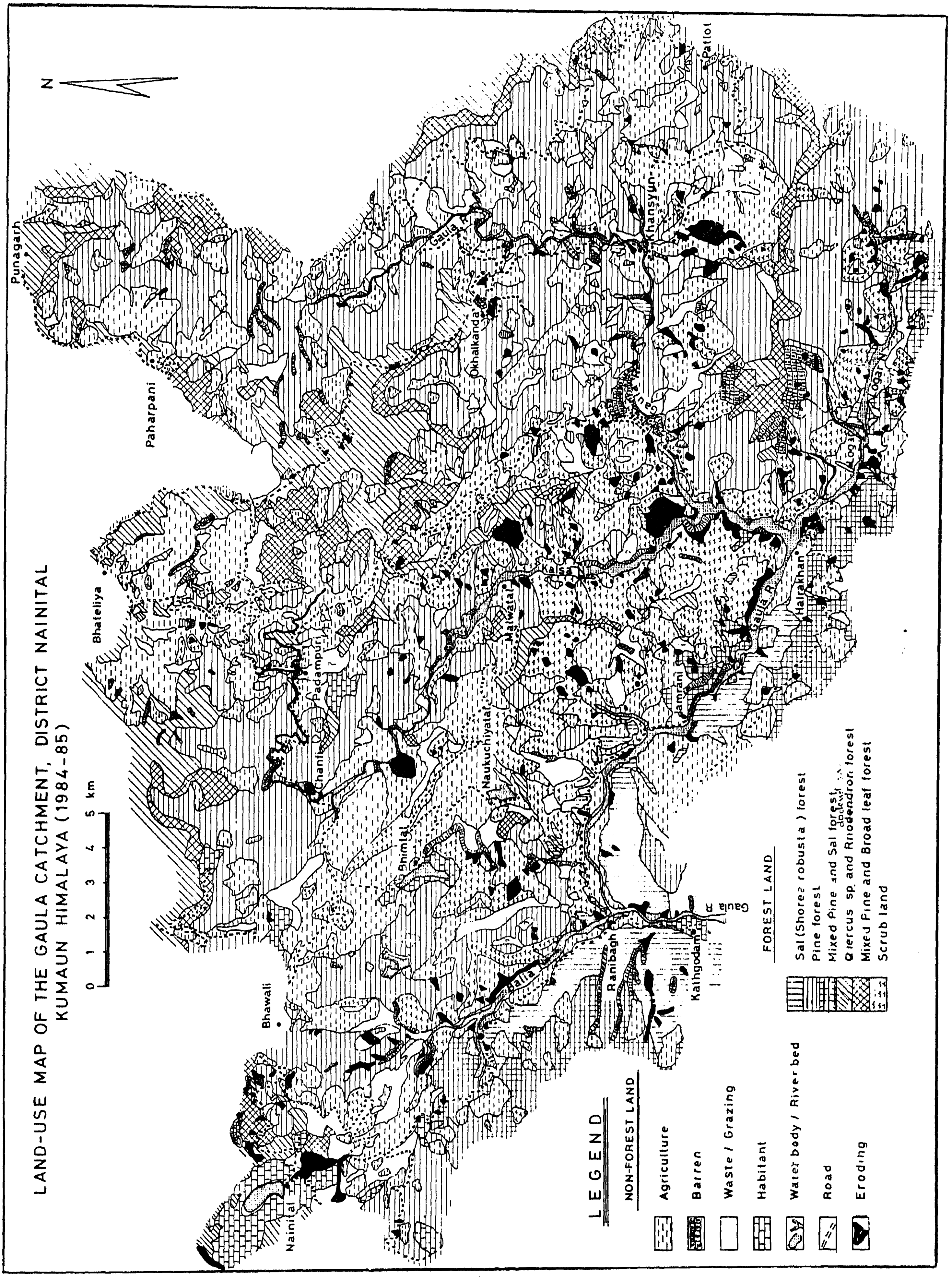
Gaula catchment

The Gaula is a wholly Lesser Himalayan river, draining the south-central part of Kumaun (figure 1). The 600 km^2 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 Paharpani) 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 Paharpani).

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

Figure 2. Location of springs and seepages in relation to lithology, faults and lineaments in the catchment of the Gaula River.


LAND-USE MAP OF THE GAULA CATCHMENT, DISTRICT NAINITAL
KUMAUN HIMALAYA (1984-85)
N
0 1 2 3 4 5 km
Punagarh
Pallot
Khansyun
Gaula R
Okhalkanda
Paharpani
Bhateliya
Padampuri
Dhari
Logar
Kalsa
Malwatal
Haitakhan
Gaula R
Naukuchiyatal
Amrani
Bhimtal
Gaula R
Ranibagh
Kathgodam
Bhawali
Gaula
Nainital
LEGEND
NON-FOREST LAND
Agriculture
Barren
Waste / Grazing
Habitant
Water body / River bed
Road
Eroding
FOREST LAND
Sal (Shorea robusta) forest
Pine forest
Mixed Pine and Sal forest
Quercus sp. and Rhododendron forest
Mixed Pine and Broad leaf forest
Scrub land

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 ground-water recharge, location of springs and the incidence of mass-movements.

HYDROGEOLOGY OF SPRINGS

The Gaula River and its tributaries are dependent

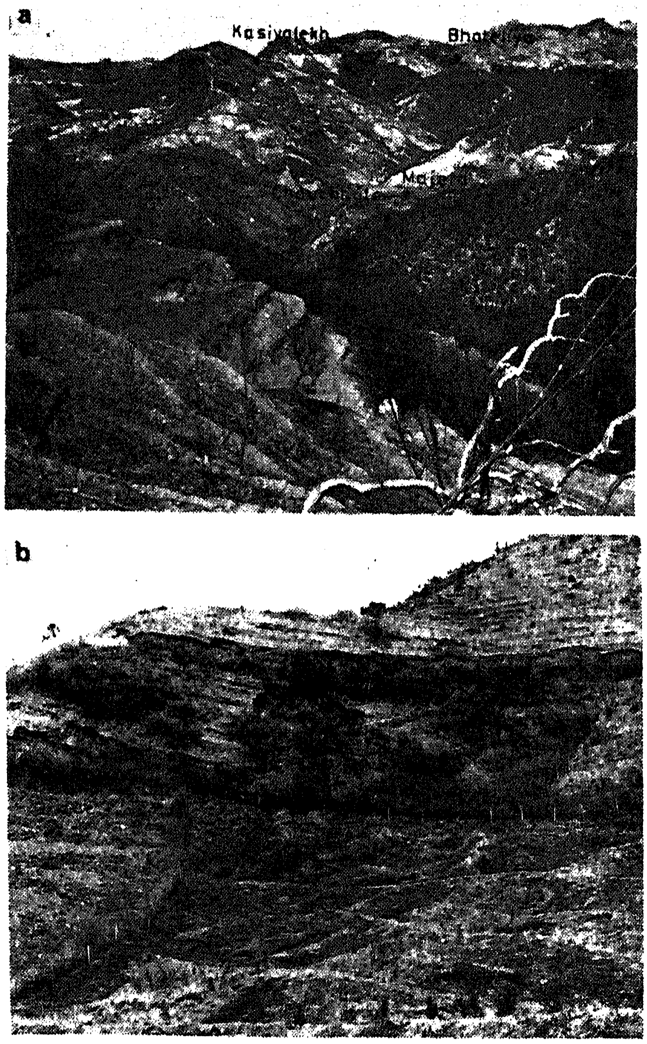


Figure 4a, b. **a.** Expansion of agricultural and grazing land at the cost of forests in the Kasiyalekh, Chauchhutia, and Majina areas, NW of Padampuri. The discharge of the springs has gone down by 50%, and **b.** Slope devoid of vegetation near Maharagaon (near Bhimtal) has become prone to shallow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

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

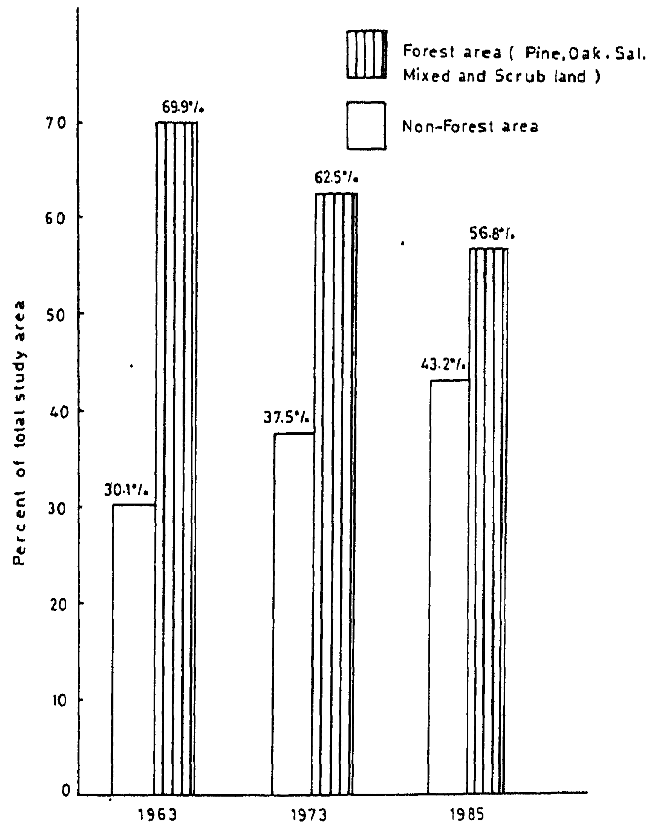


Figure 5. Percentage of reduction in forest cover in the Gaula catchment since 1963. Deduced on the basis of comparison of the 1963 Survey of India map with the 1973 landsat photographs and field survey.

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[7]) and with the landsat photo of 1973 (as interpreted by Tewari *et al*[8]) 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 sort. 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*

Year	Paharpani	Okhalkanda	Chanphi	Nainital	Bhimtal	Kathgodam	Jamrani	Logar
1958	—	—	—	—	2556.00	2465.00	—	—
1959	—	—	—	—	2773.00	2010.00	—	—
1960	—	—	—	—	2211.00	—	—	—
1961	—	—	—	—	3252.20	2373.50	—	—
1962	—	—	—	—	2503.40	—	—	—
1963	—	—	—	—	3214.00	2286.00	—	—
1964	—	—	—	—	2962.50	1725.00	—	—
1965	—	—	—	2088.50	1462.10	1377.60	—	—
1966	—	—	—	2189.70	1681.80	1981.00	—	—
1967	—	—	—	2971.20	2329.40	2271.00	—	—
1968	—	—	—	2162.60	1102.00	1531.00	—	—
1969	—	—	—	3037.80	1089.50	1820.00	—	—
1970	—	—	—	2357.70	1372.30	1639.00	—	—
1971	—	—	—	3003.90	1753.80	2433.00	—	—
1972	—	—	—	2601.80	876.00	1309.00	—	—
1973	—	—	—	2837.10	—	3171.00	—	—
1974	—	—	—	1589.14	—	—	—	—
1975	—	—	—	2492.52	2007.23	2828.00	2613.00	—
1976	6874.00	1155.66	—	1900.00	1074.10	1531.00	4317.00	1714.53
1977	10485.95	11829.00	—	1719.20	1974.00	1533.00	1927.95	—
1978	3684.44	6089.88	—	4886.26	2020.00	2603.00	2765.62	1879.91
1979	915.62	1141.42	945.55	1563.35	1505.60	1395.00	1996.58	1804.69
1980	1209.70	1482.41	1401.19	1985.76	1664.76	1700.00	1983.70	2024.80
1981	935.21	1077.04	640.43	2016.00	1645.50	2203.00	2074.88	1767.02
1982	—	—	—	—	—	—	—	—
1983	—	—	—	—	—	2307.00	—	—
1984	509.5	—	—	1108.3	660.7	2716,00	—	—
1985	1368.3	—	—	3517.1	990.3	3226.00	—	—
1986	1497.1	—	—	2278.8	1188.1	2814.00	—	—
Total	27483.7	22775.41	2987.17	148907.4	45749.33	53247.6	17683.81	9190.95
Average (1958–1986)	3053.7	3795.90	995.72	2445.0	1838.0	2129.9	2526.26	1838.19

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 25.3%. Upstream up 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

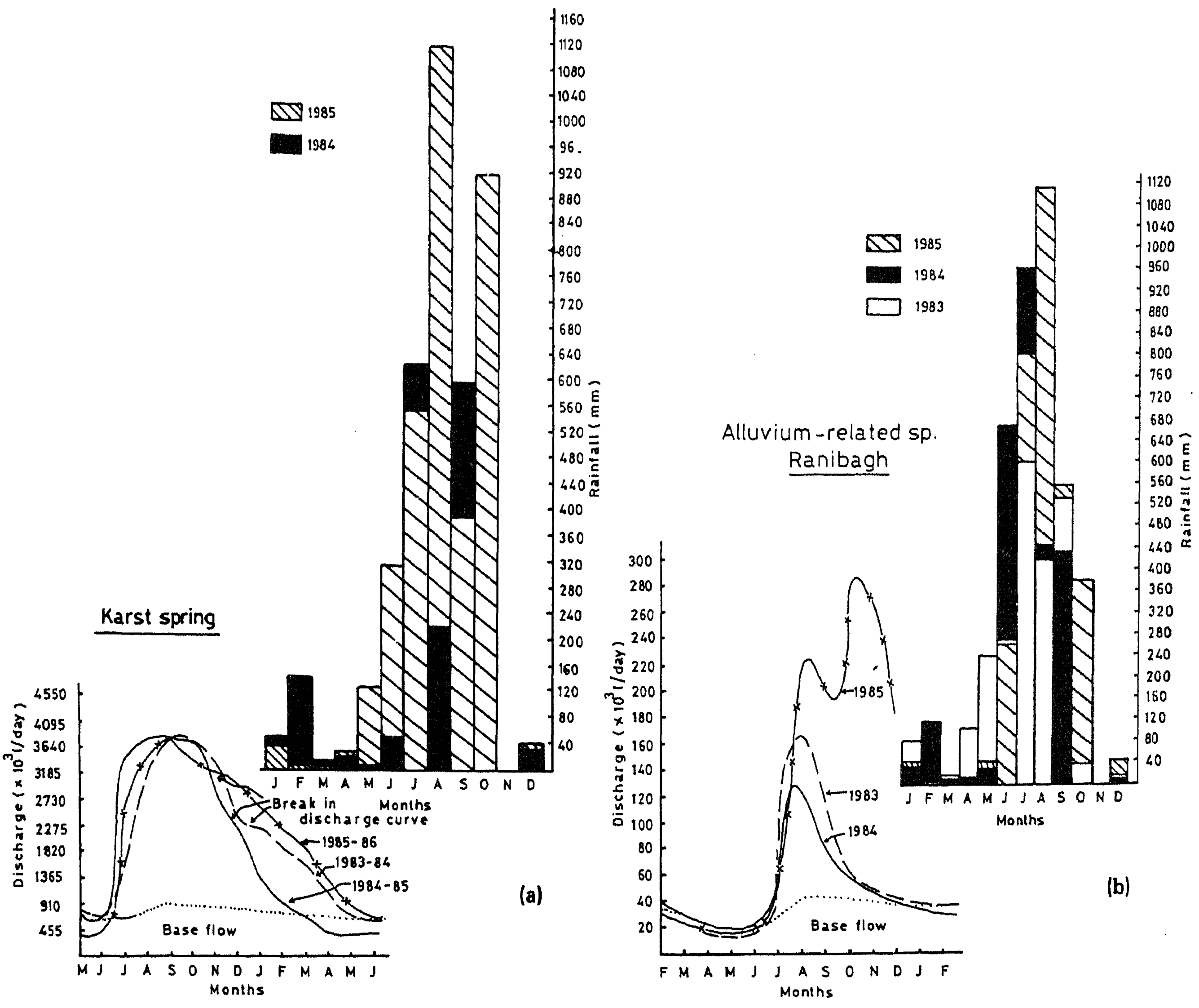


Figure 6a, b. **a.** Hydrograph of the 'Parda dhara' (spring) in the karst terrain of Nainital. The broad peaks indicate slower outflow of groundwater and recharge due to winter rains, and **b.** The hydrographs indicate that the higher discharge in 1985 is a consequence of high rainfall in October, 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[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, Ijjar, Palara, Thata, Koidal, 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 Khalghajalagad have become gravel-filled dry channels.

The annual flow of the Gaula River at Kath-

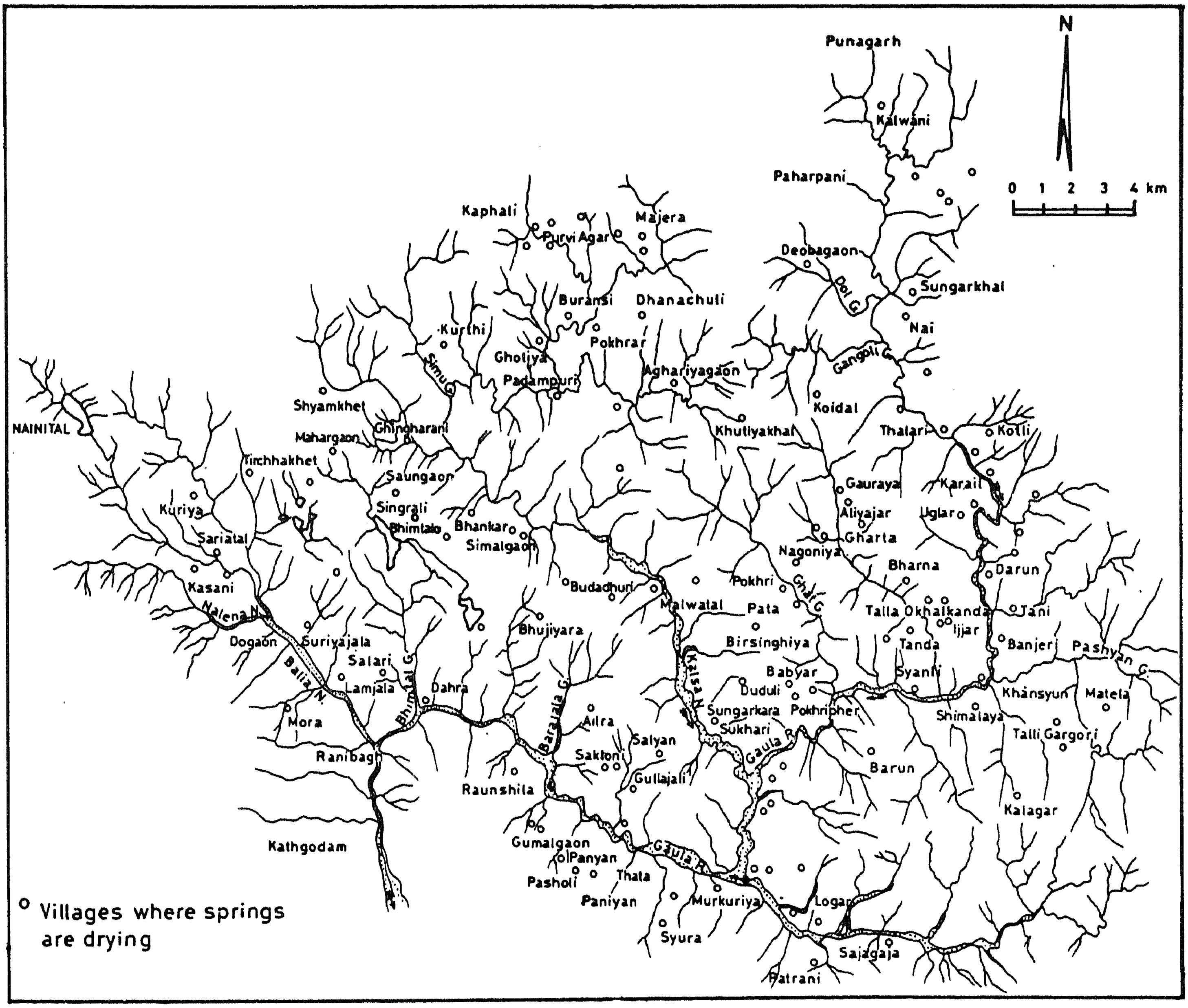


Figure 7. Villages in the Gaula catchment where the springs have either dried up or whose discharges are diminishing.

Table 2 *Variation and cause of diminishing discharges of the springs (S) and seepages (N) in the Gaula catchment*

Location	Discharge ($\times 10^3$ l/day)	Reduction in discharge Extent (%)	Period (year)	Reason
Sungarkara	7.8	50	40	Road construction
Katjawa (S)	12.4	75	15–20	Deforestation
Chanoti (N)	10.2	75	15–20	-do-
Kurthi (S)	29.8	33	15–20	Encroachment of agricultural land into forest
Shyamkhet (S)	32.4	50	50	Deforestation and replacement of oak by pine
Sariatal (S)	8.64	25	20–25	Reduction in rainfall and deforestation
Bhaloti (S)	21.1	~50	20	Land subsidence
Bhaloti (S)	16.3	~50	25	Diversion of the natural water course
Bhaloti (N)	Nil	~100	10	Neotectonics movements
Kasani (S)	8.0	~75	35–40	Earthquake
Suriyajala (S)	38.5	~25	25–30	Deforestation
Dobra (S)	434.9	~33	50	Deforestation
Dolmar (S)	86.4	~50	40	Road construction upslope of springs
Mora (S)	22.3	25	50	Uprooting of trees and partly earthquake
Gullajala (S)	26.2	~33	40	Earthquake
Ailra (S)	12.3	25	5	Landslide debris slid over discharge zone
Raunshila (S)	17.3	33	30–35	Land-subsidence
Gulamgaon (S)		25	18–20	Upslope road construction
Pasholi (S)	18.2	25	18–20	Road construction and uprooting of trees
Bhankar (S)	28.2	50–75	5–6	Earthquake and attendant land-subsidence
Simalgaon (S)	17.3	20	40–50	Uprooting of trees
Bhoriya (S)	8.2	75	20–25	Earthquake
Sejagala (S)	17.3	50	25–30	Reduction in rainfall and partly deforestation
Logar (S)	187.2	25	40	-do-
Logar (S)	28.8	25–30	40	Deforestation
Logar (S)	5.8	33	4–5	Construction of road upslope
Syura (S)	43.2	75	15	-do-
Thata (S)	17.3	75	15	-do-
Patrani (S)	3.0	75	10–15	-do-
Patrani (S)	Nil	100	10–15	-do-
Patrani (S)	12.3	25	15	Landslide downslope of the spring and partly deforestation
Paniyan (S)	28.2	~40	15	Road construction
Jala (S)	86.4	~30	40–50	Felling of trees
Matela (N)	7.8	~50	40–45	Deforestation
Karail (N)	7.8	50	15–20	Road construction upslope
Ijjar (S)	7.8	50–60	10–15	-do-
Sanjri (S)	3.6	25–33	30–40	Deforestation upslope
Banjeri (N)	Nil	~100	10–15	Canal construction
Tani (N)	Nil	~100 Seasonal	20	Deforestation
Talli Gargori (N)	3.5	25–33	30–35	Deforestation upslope
Liphkarak (S)	Nil	~100	20	Deforestation
Babyar (S)	5.8	60–70	5–6	Earthquake
Rikhakot (N)	6.2	60	5–6	-do-
Dal (N)	1.4	25	40–45	Deforestation
Syanli (N)	3.54	25–33	20–25	Deforestation and canal construction
Syanli (N)	Nil	~100	8–10	Canal construction
Tanda (N)	3.5	25	20–25	Deforestation upslope
Talla Okhalkanda (S)	8.1	25	20–25	Deforestation
Sar Talla (S)	1.44	25–33	20–25	-do-
Tussar (S)	34.6	25–30	15–20	-do-

Table 2. *(Contd.)*

Putpuri (S)	18.6	25	2–3	Road construction upslope
Simalaya (S)	5.24	33	30–35	Deforestation upslope
Charta (S)	3.1	50	10	Road construction upslope
Bharna (S)	3.1	25–33	15–20	Road construction and deforestation
Kobura (S)	6.7	50–75	30–40	Oak forest replaced by pine forest
Shala (S)	6.8	50–75	30–40	–do–
Koidal (S)	3.54	33	15	Road construction upslope
Koidal (S)	Nil	~100	5–6	Road construction

godam[11] Barrage had dropped, from 13,615 cumec/day (the average of the period 1951–1960) to 9,654 cumec/day between 1961 and 1970, registering a decline by 29.2% (figure 8). Similarly, the discharge dropped to 5,935.9 cumec/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

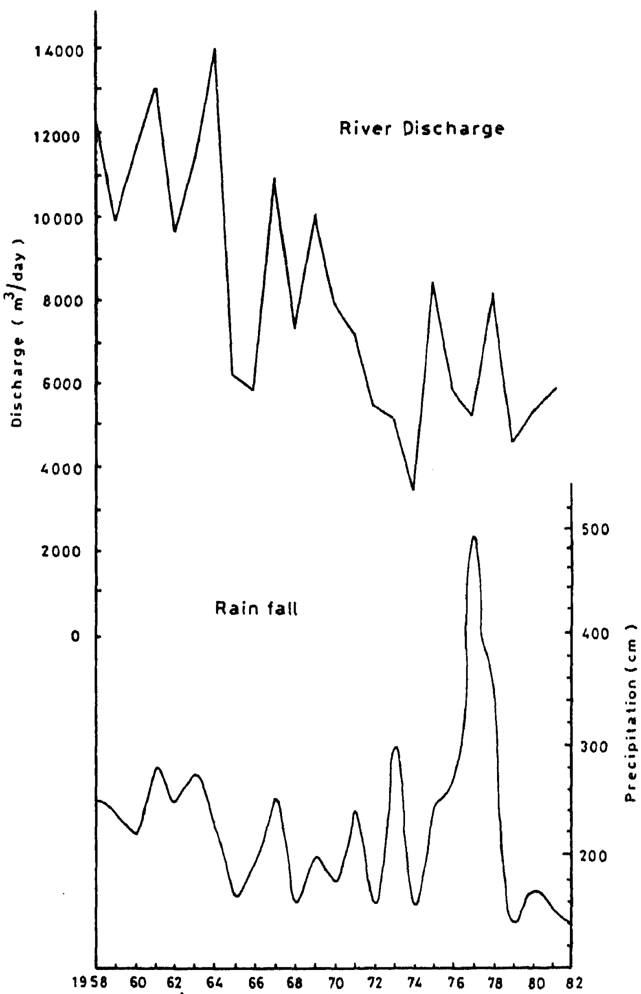


Figure 8. Annual discharge of the Gaula River at the Kathgodam barrage, and average rainfall over its catchment for the period 1958 to 1982.

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

Year	Discharge cumec/day	Average of the decade
1950	27,454.5	
1951	10,042.4	
1952	16,181.6	
1953	14,794.8	
1954	14,853.9	
1955	18,173.6	13,615.0
1956	20,241.1	
1957	8,019.5	
1958	12,255.1	
1959	9,920.3	
1960	11,652.6	
1961	13,121.5	
1962	9,786.3	
1963	11,269.7	
1964	13,976.0	
1965	6,251.0	9,654.0
1966	5,824.4	
1967	10,969.3	
1968	7,311.1	
1969	10,067.0	
1970	7,963.2	
1971	7,259.7	
1972	5,439.0	
1973	5,175.4	
1974	3,398.7	
1975	8,390.2	
1976	6,367.0	5,935.9
1977	5,185.5	
1978	8,103.3	
1979	4,528.7	
1980	5,236.9	
1981	6,210.4	

hydrologic scenario of the whole Lesser Himalaya and the Indogangetic plains.

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NEWS

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