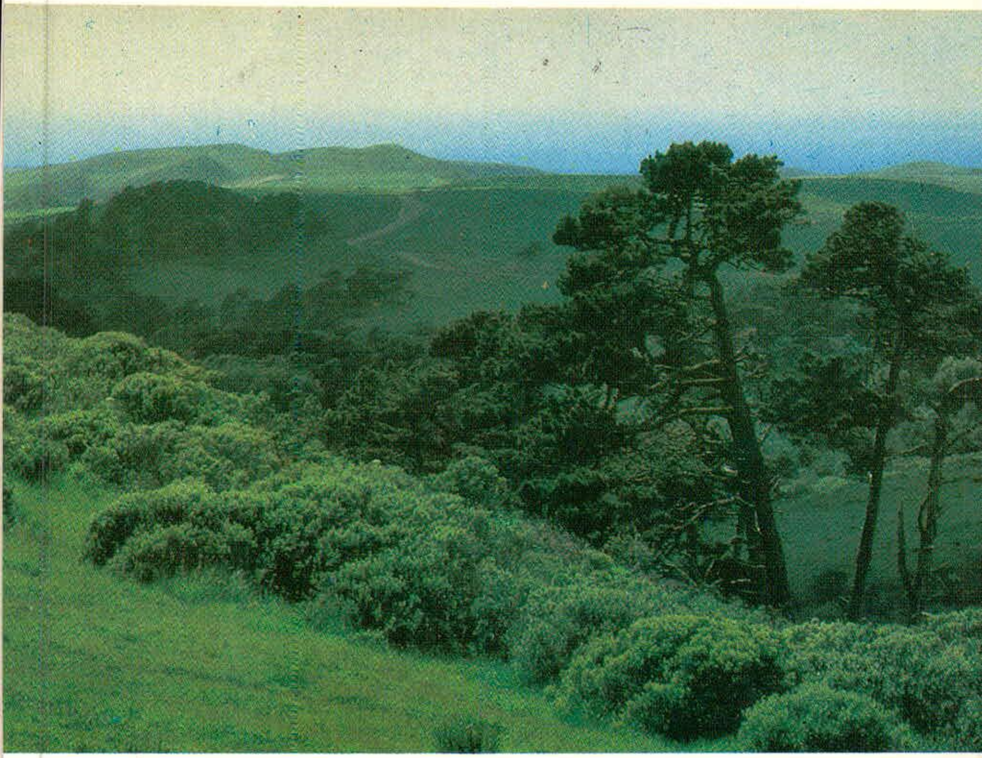
# HYDROLOGICAL INFLUENCES OF LAND USE CHANGES



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## Introduction

Land and water resources are two vital gifts of nature to mankind. Their rational utilisation largely helps meeting the primary needs of human beings on a sustained basis. Being closely related, unscientific and over utilisation of one resource has strong influence on the other.

Various parameters viz. population growth, ever increasing demand of food grains and water have a major bearing on land use of the culturable area of the country. The rapid increase in population over the years is a matter of concern to policy planners in the country. Reliable statistics suggest that the population of the country has increased from 36,10,88,090 in 1951 to 54,81,59,652 in 1971. The 1981 census reported the population figure as 68,51,84,692. It is estimated that by 2000 A.D. the population of the country will cross one billion mark. With the increase in population the demand for food grains has also been increasing rapidly. More and more area has been brought under agriculture to meet the ever increasing demand of food grains. According to a survey report, the net sown area in the country has increased from 119 million hectares in 1950-51 to 142 million hectares in 1981-82. As a result, the annual production of food grains has increased from 5.49 million tons to 151 5 million tons in the same period. The present level of productivity is reported as 170 million tons. Reliable calculations show that by 2000 A.D. the food grain production may have to increase atleast upto 240 million tons per annum. To achieve this production level better facilities of irrigation are being developed. It is in this context irrigation potential has been steadily increasing over the years. The irrigated area which was only about 21 million hectares in 1950-51 is anticipated to be about 77 million hectares upto

1989-90. As a result of increased irrigation potential, more area is coming under agricultural practices. The rapid growth of population and large scale migration of rural mass to urban areas are leading to extension of urban areas. These all factors are ultimately leading to changed land use of the geographical area of the country. The land use classification figures as reported by Min. of Agriculture are presented in the following table :

**Land use Classification**

Unit : Million ha.

| Classification | | Area |
|---|---|---|
| Area under forest | | 67.16 |
| Area not available for cultivation | | 40 48 |
| i) Land put to non-agricultural uses | 20.41 | |
| ii) Barren and uncultivable land | 20.07 | |
| Other cultivated land excluding fallow land | | 31.06 |
| i) Permanent pastures and other grazing land | 11 93 | |
| ii) Land under misc. tree crops and groves not included in the net sown area | 3.39 | |
| iii) Culturable waste | 15.74 | |
| Fallow land | | 24 91 |
| i) Fallow land other than current fallow | 9.55 | |
| ii) Current fallows | 15.36 | |
| Net area sown | | 140.72 |
| Total reporting area | | 304.32 |
| Total cropped area | | 175.96 |
| Area for which no return exists | | 24.41 |
| Total geographical area | | 328 73 |
| | Say | 329.00 |

Source : Directorate of Economics and Statistics,
Department of Agriculture and Cooperation,
Ministry of Agriculture. (As on 1/1/1988)

## Land Use and Hydrologic Cycle

The land use changes have a direct bearing on the hydrologic cycle. The land use which may be forests, orchards, agriculture, grasslands or a mixture of these, their extent and management practices directly influence the hydrologic cycle.

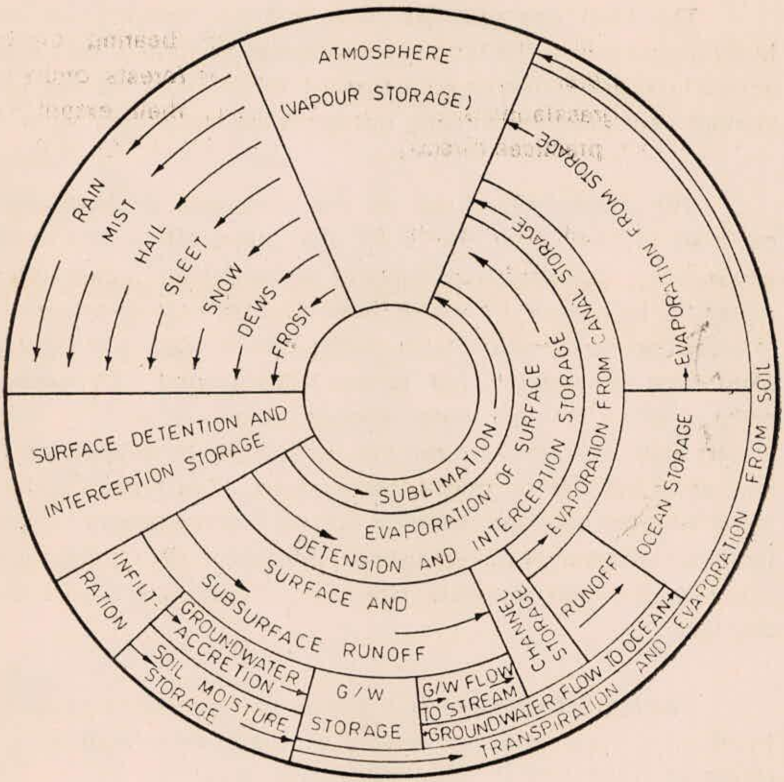
The effects of land use on the processes of hydrologic cycle are realised from the point the precipitation strikes the vegetation. The density and extent of vegetation cover determines the behaviour of water flow process such as storage in interception, evaporation from vegetation surface and flow as stem flow or through fall to reach the ground. The second point of attack is when water reaches the ground surface. Here water may be retained on the surface to be evaporated or may enter the soil or runoff the surface. The type of surface cover whether bare soil, litter on surface, forest lands or grasslands will determine the amount of infiltration taking place into the soil, the soil moisture retention, the surface runoff and soil loss.

The type of land use thus plays an important role in the hydrologic cycle and the effects of land use alterations are reflected in the various hydrological processes.

Hydrologic cycle

Hydrologic cycle is a continuous process by which water is evaporated from oceans, sea, lakes, soil surface, vegetation etc. and goes to the atmosphere in vapour form. There the vapour gets condensed and returns to the surface as precipitation. After reaching the surface, water moves towards oceans as surface and sub surface flow and the complete process restarts.

## HYDROLOGIC CYCLE




Components of hydrologic cycle :

- Rainfall
- Interception
- Infiltration
- Runoff
- Evaporation
- Transpiration

Rainfall occurs due to the condensation of water vapour present in the atmosphere. Some portion of rainfall after reaching the land surface is retained by vegetative cover known as interception and some of it goes into the soil known as infiltration. Some portion of the precipitation moves as overland flow and reaches oceans via rivers etc. and some part moves as subsurface flow towards the oceans. When solar radiations fall on waterbody, soil surface and vegetation, the water is transformed into vapour state and goes back to atmosphere. This process is called evaporation. Plants also extract some water for their metabolic activities which is known as transpiration.

## Effects of land use on various components of hydrological cycle

**Do you know**

**Rainfall**

* That only limited number of studies have been undertaken to ascertain effects of land use changes on rainfall.
* That the results of limited studies generally conclude that forests do not affect rainfall on a regional scale.
* That persistant cloud forests can capture and condense atmospheric vapour and might increase rainfall.
* That some investigations have however found that in the coastal forests the precipitation is more as compared to an open field. This may be because of interception and then concensation of fog by forest vegetation. Such incidents have been reported in studies in the east coast of Japan and South western coast of Australia where about 6 to 10 times more fog and 12% more precipitation, respectively were recorded as compared with open fields.

**Interception**

* That the interception for forest cover varies as 11.5% to 40.1% of the rainfall while for snowfall it varies from 13.0% to 27.0%

* That Interception for grassland has been estimated as 35% of rainfall.

* That interception for agriculture land varies from 6.9% to 15.5% of precipitation.

* That the interception varies from 15% to 30% of the precipitation depending upon the vegetative characteristic of the area.

## Infiltration

* That the comparative studies on infiltration rates conducted at Dehradun have indicated that infiltration rate for forest cover varies as 2.2 to 17.0 cm/hr.

* That based on the trend of studies conducted in north eastern hill region of the country, it has been estimated that infiltration rate for grassland varies as 0.3 to 5.7 cm/hr. while for grazed grassland the rates were reported as 5.13 to 6.25 cm/hr.

* That in agricultural lands, the infiltration rates varied from 1.0 to 5.0 cm/hr in some typical studies done in Dehradun while for bare ground the rate was recorded as 0.6 cm/hr.

* That the studies done in the black cotton soil in Bellary reported infiltration rates under forests, natural grassland and terraced cultivation as 5.16, 3.00 and 1.40 cm/hr, respectively.

## Soil Moisture

* That the studies conducted in Nilgiris in the laterite soil have indicated that soil moisture mm/m depth is higher under forests than under grasses.

* That the reports of the studies conducted in Nilgiris under laterite soil region have revealed that different types of

forests viz. Bamboo, Teak, Chirpine and Sal, the soil moisture varies as 14 to 102, 20-73, 20-77 and 20-108 mm/m depth, respectively.

### Evapotranspiration

* That studies conducted at north eastern hill region of the country suggest that the evapotranspiration from crops e.g. maize and cocopea is approximately equal to 40% of the rainfall.

* That the evapotranspiration from grasses is estimated to be about 82% of rainfall in a study carried out at Dehradun.

* That the report of the FRI, Dehradun suggests that evapotranspiration from cultivated fallow land is nearly 37% of rainfall.

### Soil Loss

The various studies conducted in India at various places for various slopes, different rainfall and soils etc. have reported the soil loss from different land uses. A critical review of these studies have indicated :

* That the soil loss from dense, well managed forest land may vary as 0.5 to 0 9 t/ha/yr and from ill managed forest, it varies as 20.0 to 60.0 t/ha/yr.

* That the soil loss from agricultural lands with soil conservation practice may vary as 1.0 to 19.0 t/ha/yr for hilly areas and 0 0 to 3.0 t/ha/yr for plain areas. Without soil conservation practice the soil loss varies as 20 to 40 t/ha/yr for hilly region and 5 0 to 20 t/ha/yr for plain region.

* That the soil loss from cultivated fallow lands varies as 4.0 to 70.7 t/ha/yr for slope ranges of 1% to 9%.

* That the soil loss from denuded ravine lands may vary as 10.0 to 20.0 t/ha/yr whereas for treated ravine lands it is 0.5 to 5 t/ha/yr.

* That the soil loss from well managed grasslands varies as nil to 1.0 t/ha/yr and from ill managed grassland it is 20.0 to 40.0 t/ha/yr.

**Floods**

The role of land use on floods can be analysed in the light of various reasons of flood cited by the Rashtriya Barh Ayog as below :

* That planned and limited deforestation do not have any untoward consequences with regard to floods.

* That whenever devastating floods occur, the casual factors are sought in the vanishing forest cover.

* That floods can be due to excessive precipitation combined with inadequate channel capacity. The reduction in channel capacity can be attributed to some extent to faulty agricultural practices resulting in high soil loss which in turn gets deposited in the channel.

**Water Yield**

**From Agricultural Land**

* That in N-W Himalayan region of Dehradun the runoff for untreated and treated cover conditions was reported to be of the order of 6% and 9% of the rainfall of that area respectively.

* That in N-E hill region of Shillong the runoff was 6.5% of the rainfall for shifting cultivation and 5.9% of the rainfall for bench terraced treatment.

* That for red soil region with soil conservation measures, the runoff reported was 20% of rainfall whereas for region without soil conservation measures the runoff as percentage of rainfall was reported to be 16%.

**From Forest Land**

* That for N-W Himalayan region of Dehradun the runoff efficiency for coppice sal forest watershed, high sal forest watershed and mixed forest watershed was 14%, 14-23% and 6.5% respectively.

* That for southern hills of Nilgiris the runoff efficiency of 1-1.3%, 1-6% and 30% was reported from runoff plots, forest watershed and Eucalyptus forest respectively.

* That from ravine lands the runoff efficiency of 10% to 20% and 2% to 5% was indicated from denuded and vegetated lands respectively.

**From grassland and others**

* That in N-W Himalayan region of Dehradun the runoff efficiency for grass cover was reported as 21% to 27% for monsoon season and 4% to 11% for winter season respectively.

* That in southern hills of Nilgiris the runoff efficiency for natural grass was found to be 0.01% to 0.4% whereas, for cultivated grass, it was reported to be 2%.

* That for ravine lands of Agra and Mehi including Chambal, the runoff efficiency for grassland cover was reported to be 15% to 32% and 2 5% to 7% respectively.

* Water yield also increases by clearcutting as well as by planned partial cutting of the forests.

**Urbanisation**

The movement of people from rural to urban areas tends to proceed concomitantly for the last few decades. Thus there is more burden of urbanisation in the cities. The rapid growth of industries i.e. industrialisation is one of the factors influencing the growing migration from villages to the city. Among the hydrological problems associated with urbanisation are the continually increasing demand of water. The recent statistics reveal that the total annual water requirement for domestic and industrial purposes in the country in 1985 was 1 6.70 $km^3$ and 10.00 $km^3$ respectively which will be increased to about 28.70 $km^3$ and 30 $km^3$ by 2000 A.D. and to about 40.0 $km^3$ and 120 $km^3$ by 2025 A.D. respectively. Other problems that are surfacing as a result of urbanisation are changes in physical environment, disposal of waste that may contaminate streams and groundwater and the impervious nature of urban areas. The studies carried out to ascertain effects of urbanisation reveal :

* That the impervious nature of urban areas reduces infiltration and increases total volume of runoff.

* That in urban areas according to Gleasson the evapotranspiration gets reduced by 30% on residential estates and by 85% on street surfaces.

* That urban areas have specific microclimates which may be able, under marginal conditions, to induce excess precipitation, the most significant contributing factor being the thermal characteristics of urban aerosols.

* That the urban production of heat, moisture, condensation and freezing nuclei is probably responsible for Munich, West Germany, showing 11% more days of light rain and Nurnberg showing 14% more thunderstorms than their rural surrounding.

* That in a storm in the urbanised lower Bull Run Catchment of Occoquan watershed, Virginia, USA, increase in the concentration of suspended solids was reported to be atleast a thousand fold, whilst elevating discharge by four times.

* That as much as 5% of the annual flow of seepage and 20 to 30% of annual volume of solids from urban areas are discharged to water courses, thereby detereorating the quality of water.

**Urban drainage problem : flooding due to intense rain in Delhi**

## Vegetative Management

Vegetative management on upland catchment is one of the ways to increase water supply. The hydrological functioning of a vegetated watershed is influenced by the type of vegetation, its density, composition, extent and management practices. Broadly the vegetation manipulation practices can be classified as forest cutting or removal and secondly changes in forest types and vegetative cover.

The forest cutting or removal can be done by any of the following ways :

* Clearance or complete removal of vegetative cover

* Partial cutting

* Chemical treatment or forest fire.

The results of the selected watershed studies to analyse the influence of clear cutting forest vegetation on water yield have indicated ...

* That 20% increase in water yield is reported in wagon wheel gap experiment at Colorado, USA.

* That the H-J Andrews experiment in Oregon state, USA observed a 34% increase in water yield due to clear cutting of Douglas fir and Western Hemlock vegetation.

* That the results from Beaver Creek 12 watershed indicated 30% increase in water yield due to clear cutting of Ponderosa pine forest.

* That the clear cutting of Aspen conifer in Colorado, USA and Kimakiya, Kenya have reported 20% and 50% increase in water yield respectively.

The experiments conducted on partial cutting of the vegetation have shown :

* That in H.J. Andrews experiment in Oregon, USA, a treatment involving 30% cut in Doughlas fir and Western Hemlock type forest resulted in 10% increase in water yield.

* That the study at Arizona, USA with Ponderosa Pine forest involving 33% strip cutting and 33% clear cut resulted in 16% and 22% increase in water yield respectively.

* That in Coweeta watershed in North California, USA, a treatment involving 22% selection cutting of mixed deciduous forests resulted in 5% increase in water yield.

* That the water yield is reported to increase by 56% when one-third of pine forests were removed at Jankershock in South Africa.

The studies on effects of chemical treatment, foliar sprays and forest fires on water yield at different places have revealed :

* That the areal application of Herbicide mixture of picloram and 2,4-D on Pinyon-Juniper type forest of Beaver Creek, Arizona resulted in 65% increase of water yield.

* That studies on the effect of wildfire in watersheds in Australia have shown to increase streamflow yield by 43-235%.

* That an accidental burn in Japan resulted in annual water yield increase of around 23-26%.

* That the burning followed by maintenance of spraying with Phenoxy herbicides on chaparral with shrubs and grass type forest of three bar watersheds of Arizona resulted in 250% increase in water yield.

Other studies on vegetative management suggest ...

* That water yield increases after implementation of upstream vegetative manipulation.

* That 300 fold increase in discharge occurred within 2 hrs. from commencement of heavy rain when forest land was changed to grassland in a study conducted at Fiji.

* That the studies conducted at a forested catchment in south-west USA have indicated that vegetation management replacing a forest area resulted in an increase in streamflow runoff of the order of 30 mm.

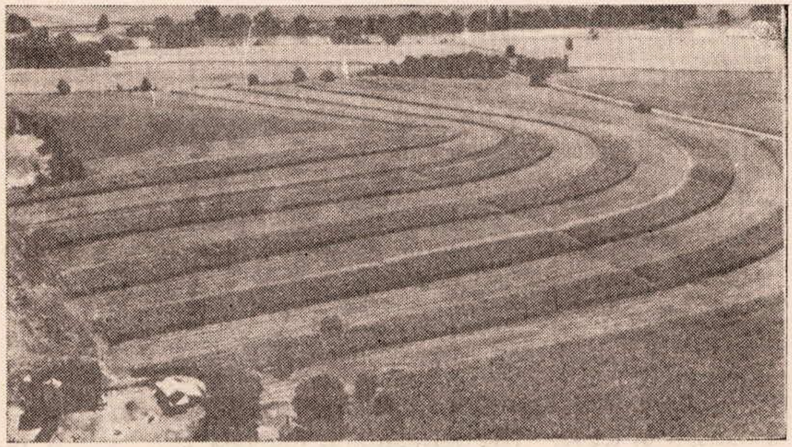
* That the studies done in Kimakia, Kenya indicated that the replacement of high montaine and bamboo forests by pine trees increased water yield by 50%.

## Agriculture practice

Agricultural practices influence the hydrological cycle in a number of ways. The agricultural practice can modify the texture and structure of the soil and the hydrologic properties such as infiltration, interception, soil moisture, sediment yield and runoff pattern can be modified. Besides, agriculture can directly affect nitrogen, phosphorous, potassium and calcium concentration and to a lesser extent sodium, chlorine, magnesium and sulphur concentration in water. The use of fertilizers, pesticides, herbicides have a considerable influence on the quality of water leaving the soil and either entering a water-course or percolating into deeper strata. The per unit consumption of fertilisers in the country is increasing from almost nil in 1950-51 to about 48.44 kg/ha in 1986-87. The various studies conducted on the effects of agriculture practices on hydrologic cycle reveal...

* That the studies on effects of tillage system on pore space and cumulative infiltration indicate that ploughing resulted in 13.7 $cm^3$ of pore space and 17.1 cm of infiltration as compared to 8.1 $cm^3$ of pore space and 0.9 cm of infiltration for untilled soil.

* That in a study at Coshocton, Ohio, USA it has been reported that ploughed, clean tilled sloping rows with 6.6% slope have 14 cm of rainfall, 11.2 cm of runoff and 50.7 t/ha of sediment



**Contour farming—A better agriculture practice**

yield as compared to no tillage contour rows having 20.7% slope have 12.9 cm rainfall, 6.4 cm of runoff and 0.87 t/ha of sediment yield.

* That in a study on the effect of land management on runoff and erosion on a 8% sloping soil at Stateville, North Carolina revealed that from clean tillaged area without cropping, grasscover, forest (burned annually) the runoff was of the order of 29%, less than 1% and 3 5% respectively whereas the soil loss was 143 t/ha, nil and 0.1 t/ha respectively.

* That in a study at Slapton ley lake in South West England, it was disclosed that drainage increased the nitrate concentration in the catchment from 0 2 mg $1^{-}NO_3^{-}$ to 6.6 mg $1^{-}NO_3^{-}N$.

* That in a study at Scotland the surface runoff and drainage from agriculture land (with 70% pasture and 30% arable crop) to the shallow freshwater lakes increased the nitrate concentration in lake from 2mg $1^{-1}$ of solule N to 8 mg $1^{-}N$ mainly as nitrate.

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Note : The above information/statistics have been collected from published literature and all authors are hereby acknowledged.