An Integrated Water Resource Management Plan for Indo-Gangetic Basin Area

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ABSTRACT *Water and soil both are very sensitive to climate change. These changes occur very fast in arid and semi arid regions of the world. Ganga basin area has been severely affected with changing climatic conditions. Changes in temperature has already depleted majority of the water resources and decreases the agricultural production in Ganga basin area. Some of the prominent affects are, growing deserts, increase in the magnitude of the floods and droughts and the most important are the sharp decrease in the agricultural production. To fulfill the continuous escalating water and food demand for increasing population watershed development and management plans are important for Ganga basin area to make productive the available surface water and groundwater resources. In this study a comprehensive recharge plan has been developed for entire Ganga basin area and all the morphometric parameters of the study areas have been analyzed.*

1. Introduction

The Ganga basin lies between east longitudes 73° 30' to 89° 0' and north latitudes 22° 30' to 31° 30'. This basin has an area of about 1,086,000 Sq km. The Ganga basin is one of the highly cultivated lands and its cultivatable land covers approximately 509,994 km2, consisting almost 62.5 percent of the total area of basin. It contributes to about 37 percent of the total population of the country, of which about 84 percent in rural areas and 16 percent live in towns and cities. Due to continuous escalating population and water demand most of surface and groundwater resources are depleting very fast. In near future it is going to be difficult to fulfill the increasing food demand because climate warming is causing serious problems like soil salinity, soil erosion, desertification and depletion of water resources in Ganga Plain as well as other parts of the country. It's now imperative to take effective actions related with integrated water resource management in Ganga plain. Through this paper an attempt has been made to develop a watershed management plan for entire Ganga basin.

2. Objectives of the study

· The main objective of the present study is to derive the different drainage aspects of Ganga river basin and to understand the relationship of the drainage networking.
· To study the quantitative analysis of drainage system.
· To develop a recharge plan for entire Ganga watershed basin and describe different morphometric analysis.

3. Study area

Ganga basin area is bounded on the north by the Himalaya mountain ranges; on the west the Ganga basin borders the Indus basin and then the Aravalli ridge, on the south by the Vindhyas and chhotanagpur plateaus and on the east by the Brahmaputra ridge. Ganga basin area lies in states of Uttar Pradesh, Madhya Pradesh, Bihar, Rajasthan, West Bengal, Haryana, Himachal Pradesh and Delhi. It is one of the highly cultivated lands in the country. Its cultivatable land covers approximately 509,994 km2, consisting almost 62.5 percent of the total area of basin. It contributes to about 37 percent of the total population of the country, of which about 84 percent in rural areas and 16 percent live in towns and cities.

4. Methodology

The morphometric analysis of the Ganga river basin was carried out by generating base maps and topographical maps. Watershed map was generated using GIS software Rolta Geomatica 10.3.2 and stream orders were calculated by following standard drainage network analysis method described by laws of Horton (1945) and Strahler (1964). The quantitative analysis of the basin which include stream orders, stream numbers, stream lengths, bifurcation ratio, basin circularity, drainage density, drainage frequency, drainage texture, etc., have been analyzed through use of a Geomatica software that determines the geomorphic stage of development of the area. Figure 1 shows watershed map of the Ganga basin and suitable location of different recharge structures.
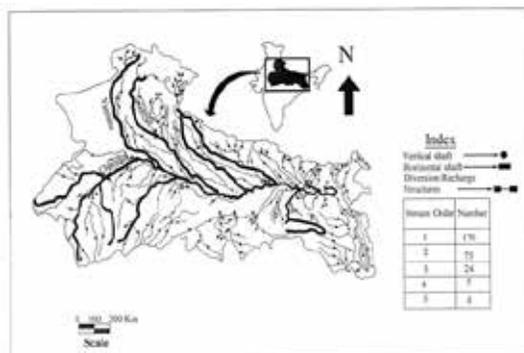

Figure: 1 Watershed map of the Ganga basin showing different stream orders and suitable places for constructing various types of recharge structures.

5. Some important aspects of morphometric analysis
Stream Order:
The streams of the Ganga river basin have been ranked according to the method described by Strahler, when two first order streams join, a stream segment of second order is formed; when two second order streams join, a segment of third order is formed, and so on. The principle drainage line of the basin measured with 5 orders.

Bifurcation ratio:

Bifurcation ratio is the ratio of the number of streams of an order to the number streams of the next higher order (Horton, 1945). Bifurcation ratios are related to the structural control on the drainage (Nautiyal, 1994; Strahler, 1964; Chow, 1964). The bifurcation ratio for 2nd order, 3rd order, 4th order and 5th order streams measured are 2.26, 3.12, 4.8 and 1.25 respectively.

Stream Length (Lu):

It is one of the most significant hydrological features of the basin as it gives surface runoff characteristics of streams. Longer lengths of streams are generally indicative of flatter gradients. Generally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. Total stream lengths of different streams are mentioned in table 1.

Basin area:

The basin area (A) is defined as the total area projected upon a horizontal plane contributing to cumulate of all order of basins. Basin area is extremely important from the hydrological point of view as it directly affects the size of the storm hydrograph and the magnitudes of peak and mean runoff. It is interesting that the maximum flood discharge per unit area is inversely related to size. The total basin area of the Ganga basin was nearly 1086,005 km2.

Drainage Density (D):

Drainage density (D) is an important indicator of the linear scale of land form elements in stream eroded topography (Horton 1932). It is the ratio of total channel segment lengths cumulated for all orders within a basin to the basin area. It indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. The total drainage density (D) for Ganga basin was recorded around 0.017.

Texture Ratio (T):

It is one of the important factors in the drainage morphometric analysis that depends on the underlying lithological conditions, porosity and permeability, infiltration capacity and topography of the terrain. In the present study the texture ratio of the basin is .03. Table 2 shows the outcome of different morphometric parameters recorded for the Ganga basin.

Table 1. Total stream lengths and bifurcation ratio of different streams in Ganga basin.

STREAM ORDER	NO. OF STREAMS	NO. OF STREAMS %	TOTAL LENGTH (Km)	MEAN LENGTH (Km)	BIFURCATION RATIO
1	170	61.15	8954.12	52.67	-
2	75	27	4997.78	66.64	2.26
3	24	8.6	3169.6	132	3.125
4	5	1.79	1448.96	289.8	4.8
5	4	1.43	775.42	193.85	1.25
TOTAL	278		19345.88		

Table: 2 Different morphometric parameters of Ganga basin area.

S. No.	Morphometric Parameters	Symbol / Formula	Values
1.	Area (sq. km)	A	1086,005
2.	Perimeter (km)	P	5666
3.	Drainage density (km/sq. km)	$D = Lu \div A$	0.017
4.	Stream frequency	$Fs = Nu \div A$	0.00026
5.	Texture ratio	$T = N1 \div P$	0.03
6.	Basinlength (km)	Lb	2400
7.	Elongation ratio	$Re = (A/\pi)^{0.5}/Lb$	0.245
8.	Circulatory ratio	$Rc = 4\pi A/(P)^2$	0.425
9.	Form factor ratio	$Rf = A \div (Lb)^2$	0.188

6. Conclusion and recommendation

The study shows that the entire catchment area drainage area of the basin is passing through an early mature stage to old age of the fluvial geomorphic cycle. 1st and 2nd order streams mostly dominate the basin. The development of the stream segments in the basin area is more or less affected by rainfall. The general topographic gradient of the entire area is towards north east.

The findings of the study demonstrated following points:

➢ Entire Ganga basin area is facing frequent droughts and flood situation with greater intensity, due to changing climatic conditions

Depletion of water resources has affected the agriculture production that has gone down and food inflation has escalated manifold.

➢ The areas with semi-arid climatic conditions especially central Indian states with prolonged dry seasons, rain fed crop production may carry a high risk of crop failure.

➢ A comprehensive recharge plan is needed for entire Ganga watershed basin area.

The following recommendations are proposed to tackle the existing problems:

➢ Climate change and its impact on the hydrology and water resources need to be assessed at river basin scales. More emphasis should be given to improve existing capabilities to forecasting short and long-term drought and flood conditions and to make this information more useful and timely for decision making.

➢ Advance studies and developments are required for crop rotation, and adaptation of improved irrigation techniques to cope with drought, and new plant varieties which are resistant to drought or to salt water.

➢ Recycling and reuse of wastewater especially for irrigational purposes has become one of the best solutions for addressing the increasing water demand in agriculture and industrial sector. It should be implemented in Ganga basin area on large scale.

➢ Large scale recharge structures should be constructed. Awareness should also be raised among the people by taking the help of media and NGO's regarding climate and water conservation education and development

➢ There has been drastic change in the land use and land cover of Ganga basin area. To accommodate the increasing population large scale deforestation was carried out, which has increased the problems associated with climate change. Ganga basin area imperatively needs large scales afforestation projects and forest conservation programmes.

REFERENCE

1. Chow Ven T (1964) (ed) handbook of Applied hydrology. McGraw Hill Inc, New York. 2. Horton, R. E (1932), drainage basin characteristics, Trans.Aer.Geophy.Union, 13, pp 350361 http://www.gisdevelopement.net. 3. Horton, R. E., (1945), Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Geol Surv Profess, 282A. 4. Nautiyal, M. D (1994), Morphometric Analysis of a Drainage Basin using Aerial photographs: A case study of Khairakulli Basin, District Dehradun, Uttar Pradesh. Journal of the Indian Society of Remote Sensing, 22(4), pp 251261. 5. Strahler, A. N (1964), quantitative Geomorphology of drainage basins and channel networks. Handbook of Applied Hydrology; edited by V.T Chow (New York, Mc Graw hill) Section, pp 411.