LONG TERM SPATIAL ANALYSIS OF HYDROLOGY OF A RIVER BASIN

By

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CERTIFICATE

This is to certify that the thesis entitled " Long Term Spatial Analysis of Hydrology of a River Basin" being submitted by Mr. Rakesh Khosa to the Indian Institute of Technology, Delhi, India, for the award of the degree of DOCTOR OF PHILOSOPHY, is a record of bonafide research work carried out by him under my supervision and guidance. The thesis work, in my opinion, has reached the standard, fulfilling the requirements for the DOCTOR OF PHILOSOPHY degree. The research report and results presented in this thesis have not been submitted, in part or in full, to any other university or institute, for the award of any degree or diploma.

Prof. Subhash Chander,
Emeritus Professor,
Deptt. of Civil Engg,
I.I.T., New Delhi.

ACKNOWLEDGEMENT

It is customary, in studies such as the one being reported, to acknowledge and highlight the significance of the role of the thesis supervisor. I too, in any case, would have followed the same age old tradition of beginning the venerations with a paragraph, in words, of gratitude expressed towards my thesis supervisor. In deference to etiquette, this is what is expected of a student and this is what I do.

Having been done with this usual practice, I would now like to place on record, my own personal sense of gratitude and indebtedness towards my teacher, and my guide in this effort, Professor Subhash Chander, for the way he led me, literally by the hand, through this effort. There has got to be a way to express these feelings of mine through words, and strangely, I confess, I seem to have lost mine. I have spent a considerable amount of time trying to construct a paragraph, of an expression of gratitude, which matched the intensity of my feelings but everything that I wrote seemed so pale in comparison. Simply put, there is nothing in the study reported, that does not reflect the immense contribution, in terms of ideas, discussions and labour, of my guide. I, truly, consider it a privilege to have been his student and perhaps his last in his capacity as Professor of Civil Engineering, IIT, Delhi.

During the course of the study, Mrs. Subhash Chander was taken ill and was on life support systems in the hospital for just under six months. During the days of her personal agony, she would keep enquiring about the progress of my thesis. Those were touching moments indeed. I am forever beholden to her for such maternal concern.

Such is the nature of the study being reported, that there is an extensive data requirement. The data had to be collected from various sources and agencies, assessed for accuracy and consistency, and integrated into an organised data base. The whole exercise, which took over two years of cumulative intensive effort, was possible only due to the help rendered by various officers of WRDO, Bangalore. These officers sat with me through endless hours and numerous revisions in this exercise. Amongst these officers of WRDO, I express a special word of thanks to Er. Hrishikesh, Er. Vijay Kumar, Er. Ram Priya and Er. Ram Kumar.

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RAKESH KHOSA

ABSTRACT

Modelling of hydrology of a river basin, in terms of rainfall to runoff transformation has been attempted by modelling the twin components of the hydrologic cycle and the branch cycle. This approach is seen to facilitate separation of impacts due to climatic and anthropogenic factors. In basins where irrigated agriculture is the principal end use of water, the heterogeneous character of the study basin is recognised and irrigated and non-irrigated parts of this basin are modelled separately. The study explores a class of simple parametric conceptual rainfall-runoff models for the purpose of runoff simulation. These models range in complexity from one to five parameters.

In recognition of the purely anthropogenic nature of agricultural and other related water resources developmental activities in a given basin, and the consequent differences in the the runoff generation processes from irrigated and non-irrigated areas of a heterogeneous basin, runoff modelling accords a priority to runoff generation in non-irrigated areas and to evapotranspiration abstraction in irrigated areas.

The study proposes a procedure to reconstruct the time series of virgin flows. For this purpose, it is assumed that the irrigated area, prior to development, would behave hydrologically as a non-irrigated area. Therefore, the model for non-irrigated area is used for the entire study basin to obtain the time series of unimpaired or virgin flows. This reconstruction is shown to enable an objective

differentiation, between the impacts due to climatic and anthropogenic factors, on the hydrologic cycle of a basin.

A hydrologic technique to estimate return flows from irrigation application is proposed. This technique is a logical corollary to the reconstruction of virgin or unimpaired runoff. The return flow component of the river runoff represents an index of impact of anthropogenic factors on the hydrology of an agricultural basin.

Spatial and temporal characteristics of rainfall, over the study basin, have been analysed. The possible influence, of some identified global climatic circulation parameters like Southern Oscillation Index, SOI, Northern Hemisphere Surface Temperature, NHST, and the latitudinal position of 500 hPa ridge position along 75°E longitude in April, on rainfall over the study basin, has also been investigated.

Finally, the possible role of atmospheric CO_2 and $\Delta^{14}C$, in influencing the rainfall characteristics over the region of study, has also been investigated.

Some of the important conclusions of the study are briefly given as under.

(1) For the purpose of rainfall-runoff modelling using a conceptual model, the level of complexity desired in the model depends upon the time scale of analysis. In this regard, it is concluded that (1) for rainfall-runoff modelling on an annual basis, a three parameter model is suitable; and (2) for rainfall-runoff modelling on a monthly basis, a five parameter model is suitable. An increase in the level of

complexity in the models by addition of more parameters is not useful on these time scales.

(2) It is difficult to attribute any physical justification to parameters and the modelled state variables. Any attempt to seek a physical basis for the parameters must be done with extreme caution.

(3) It is concluded that model calibrations, in terms of the obtained parameter values, should also be validated by evaluating its implications on the branch cycle of the study basin.

(4) Threshold type models, while being conceptually simple to implement, may be relatively insensitive to rainfall. This was observed in the case of Simsha subbasin upto T.K. Halli.

(5) Under the influence of only climatic factors, the runoff from rainfall, over the entire Cauvery River Basin upto Musiri, is estimated to be 25.89% and 21.73% during the periods from 1916-17 to 1989-90 and 1980-81 to 1989-90 respectively. Anthropogenic factors, in the form of a branch cycle, involving a mean diversion of 128.97 mm/yr and 173.33 mm/yr of water, results in a reduction of runoff, at Musiri, to 18.45% and 11.64% during these two periods respectively.

The reduction of yield at Musiri, reflective of the impact of anthropogenic interference with the hydrologic cycle, is estimated to be 73.94 mm/yr and 92.18mm/yr during the two periods.

(6) Rainfall over the entire headwater regions of Upper Cauvery, Kabini and Bhavani, which include some of Cauvery River Basin's high rainfall areas, show a decreasing trend. However, the entire contiguous region between Kabini Dam, Kattemalalwadi, Chunchunkatte, Akkihebbal, and Biligundlu, having an area of 26980 sq.km. is showing an increasing tendency. Analysis of rainfall data reveals that the region has witnessed a significant change in pattern in 1965.

(7) High frequencies having periods of 2 to 3 years are seen to be important. This suggests the possible influence of QBO's on the rainfall over the study basin. Frequencies with periods ranging from 3.4 to 4 years are also significant in some subbasins.

A cycle having a period of 4.8 years seems to contribute significantly to the variability in rainfall over Cauvery subbasin upto Kudige.

(8) Analysis of SOI, NHST and 500 hPa over 75°E longitude in April show changes in pattern. SOI shows changes in 1970, NHST shows changes in 1967 and the 500 hPa ridge position seems to indicate a southward trend along 75°E longitude beginning between 1962 and 1964.

(9) SOI show important contribution from cycles of period 3.4 years. QBO like influence is also seen to be important. Ridge positions show a high degree of influence from cycles with periods of 3.4 years along with QBO like higher frequencies. Cycles with periods of 2 to 2.4 years are also important in NHST anomalies.

(10) Analysis of measured records of CO_2 and $\Delta^{14}C$ radiocarbon seems to indicate that a change in these parameters has, indeed, occurred in 1965 in the Southern Hemisphere. The rate of increase of CO_2 emission from burning of fossil fuels has increased sharply in 1965 in the Southern Hemisphere. The corresponding change in the Northern Hemisphere is widely believed to have occurred a year earlier.

These results lead to the conclusion that the observed change in rainfall pattern in 1965-66 over the study basin may be attributed to a possible CO_2 induced change in climate regime.

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