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AGRICULTURAL DROUGHTS AND WATER TRANSFER IN SOUTHERN GANGA BASIN

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ABSTRACT

The southern region of Ganga basin comprises of three major tributary sub-basins and six minor tributary sub-basins having 15 drought prone districts classified on the basis of selected 10 indices. An improved agroclimatic classification is applied and appropriate indices for identification of droughts are recommended Revised Herbst model provides detailed information about drought condition as illustrated with application study of a district in Southern Ganga Basin(SGB).

Results of Linear Programming model study of irrigation development in the tributary sub-basins suggest that entire region can be made drought free. Conjunctive use management of surface water, soil moisture recharge and ground water potential should receive priority over development of new irrigation schemes in the region.

System study shows that under ultimate stage of development, some tributary sub-basins would have surplus water during monsoon season. Transfer of surplus monsoon runoff to deficit areas in adjacent tributary sub basins is possible through creation of storage schemes. The study does not consider domestic and industrial requirements as well as downstream release requirements for environmental and other purposes.

Introduction

Drought in India subcontinent are caused by (i) annual precipitation being less than normal, (ii) late on-set of monsoon, (iii) early withdrawal of monsoon or (iv) long inter-dry spells in the monsoon period. Criteria adopted by CWC for drought identification are i) When the annual rainfall is less than 75% of the normal in 20% of the years examined and ii) Less than 30% of the cultivated area is irrigated.

The irrigation Commission, 1972 had identified 67 drought prone districts comprising of 326 talukas located in 8 states having an area of 49.73 M. ha. The National Commission on Agriculture, 1976 identified some more drought prone areas with slightly different criteria. The erstwhile Drought Area Study and Investigation Organization of CWC set up in 1978 has identified 99 districts after considering the list of districts identified in the Irrigation Commission report(1972) and also by the National Commission on Agriculture(1976). The Central Water Commission adopted a small unit viz., Talukas for drought identification and identified a total of 315 out of 725 Talukas in 99 districts (Table 1). Accordingly out of 108M ha area of 99 districts, only 51.12 M ha spread over 74 districts have been considered as drought prone. Thus in comparison to total geographical area of the country (329 M ha) about 1/6th is drought prone. About 29% of the population of the country is affected by drought. It affects about 39% of the culturable area of the country.

Table 1 List of identified Drought prone states and Numbers of Talukas Affected

S.No	States	No. of Talukas	As per CWC's Study	
			No. of Talukas affected by draught	Area affected by drought (km^2)
1	Andhra Pradesh	79	19	32839.51
2	Bihar	15	-	-
3	Gujarat	124	103	106818.40
4	Haryana	15	8	8338.50
5	Jammu & Kashmir	8	2	2407.60
6	Karanataka	139	42	57645.54
7	Madhya Pradesh	47	26	37307.93
8	Maharashtra	100	45	57664.70
9	Orissa	6	1	2002.07
10	Rajasthan	76	57	194203.27
11	Tamil Nadu	77	8	7451.66
12	Uttar Pradesh	31	4	4609.40
13	West Bengal	8	-	-
Total		**725**	**315**	**511288.64 (in 74 districts)**

Sources: 1. Central Water Commission (N.W.P. Directorate); 2. Compendium of Environment statistics, 2000, Central Statistical Organization, Ministry of Statistics and Progrmme Implementation, Govt. India, as given by in Agricultural Research, Data Book,2003 p.9-11

Ganga basin and southern tributary subbasins

The Ganga basin with a drainage area of 104.62 million hectare is a part of the Ganga Brahmaputra-Meghna rivers system spread over Bangladesh, Bhutan, India, Nepal and China (Figure 1). Within India, the basin is spread over several administratively independent regions as defined for water development purposes.

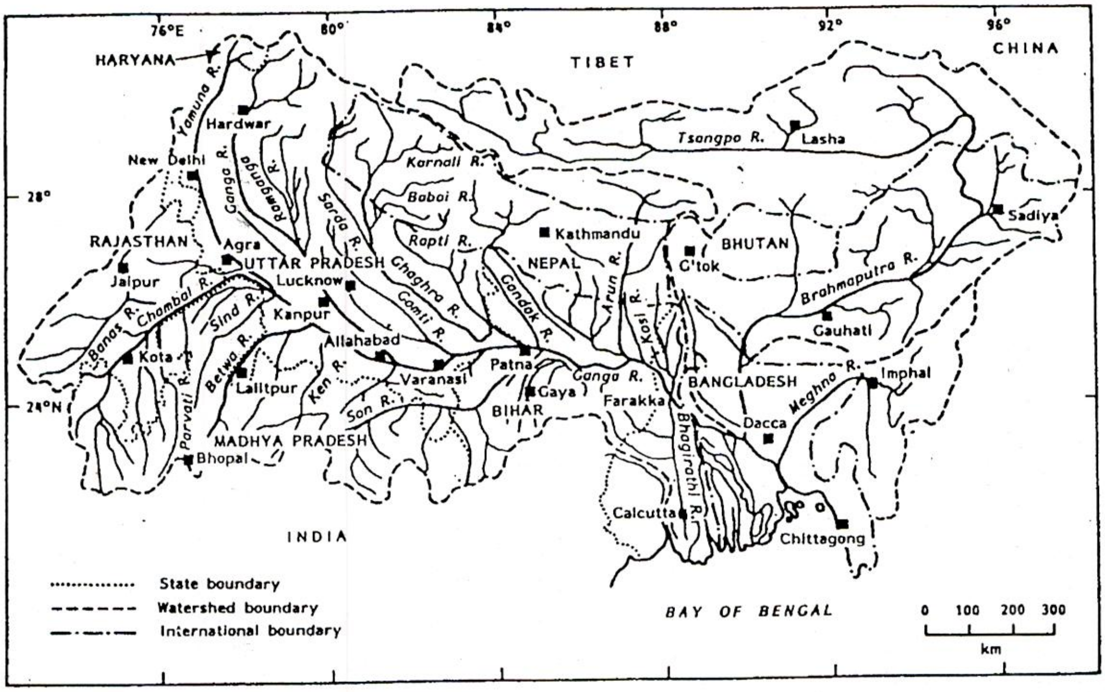

Fig. 1 The Ganga-Brahmaputra-Meghana river system.

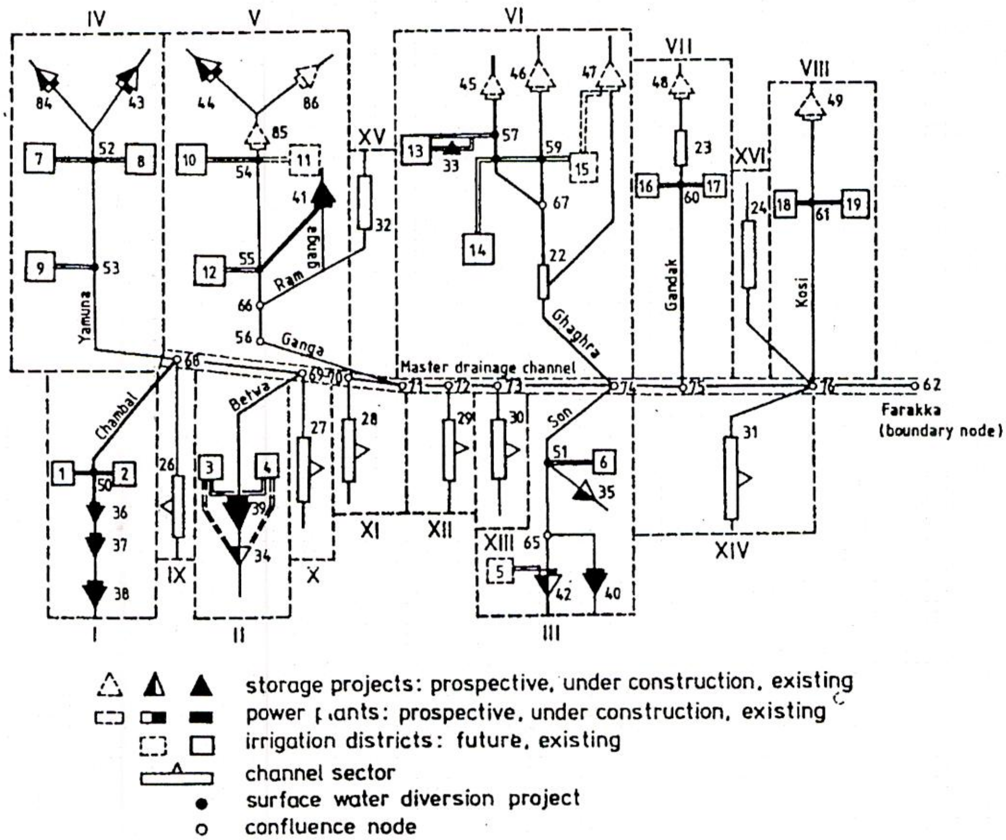

Fig. 2 Tributary sub-systems and project configuration (schematic)

Drainage of the Ganga basin is visualised to consist of several hydrologically independent tributary sub-basins draining water from north (Himalaya) and south (Vindhya) into a master drainage channel flowing from west to east (Figure 2). Southern Ganga basin consists of major Tributary subsystems I,II,III and small tributary subsystems IX, X, XI, XII,XIII and XIV.

Hydrologic Variability and Related Issues

a) 75 to 90 percent of annual rainfall occurs during June/July to September/October and most of it occurs during 25 to 60 rainy days. Annual variability of rainfall (based on 46 years record) is between 20 to 30 percent in the Ganga basin. This variability is significant for agriculture hence first priority continues to be on providing irrigation to largest area possible. Climate is such that crop growth is possible throughout the year.

a) Demand and natural supply of water do not match spatially, temporally and in magnitude; hence the need for conservation and diversion of monsoon runoff.

b) Hydrologically, the Himalayan Rivers are, of greater importance as regards water resources management compared to the vindhyan streams. Amongst the Himalayan streams, the Ghagra with its tributaries contributes maximum run-off (about 94,500 Mm3) and the Gomati contributes minimum run-off (about 7,400 Mm3). Amongst the Vindhyan streams, the Sone contributes maximum run-off (about 32,000 Mm3) and the Kiul contributes the minimum run-off (about 3,500 Mm3).

Drought prone districts in Ganga basin lie in the southern tributary sub basins. The southern region of Ganga basin comprises of the tributary subbasins of Chambal, Banas-Parabati, Betwa, Dhasan, Ken, Tons, Karamnasa, Son and other tributaries east of Son(Figure 1 and Figure 2). The total drainage area of these tributary subbasins is 44.46 percent of Ganga basin in India (861390 square kilometer). The tributaries flow through wide and gently sloping valleys permitting large storages of Kharif season runoff. The region is not rich in ground water resource. Therefore main emphasis has been on the development of surface irrigation schemes. Table 2 shows the drainage area, number of storage and diversion type irrigation schemes (existing and proposed), live storage potential of the schemes and irrigable land in each tributary sub basin. 268500 ha agricultural land is irrigable and live storage potential is 34528 MCM. A large number of major and medium irrigation schemes have already been implemented and yet the region has been experiencing recurring droughts in the following 15 districts spread over the region (Central water Commission, 1982).

Bihar State: Munger, Nawada, Rohtas, Bhojpur, Aurangabad, Gaya
Uttar Pradesh: Allahabad, Banda, Hamirpur, Jalaun, Mirzapur, Varanasi
Madyha Pradesh: Datia, Shahdol, Sidhi

Table 2 Water control structures and irrigable land

Sub basin	Drainage area(sq.km)	Control Structures			Irrigable Land (1000 ha)
		Storage (number)	Diversion (number)	Live storage Potential (MCM)	
Chambal	139470	3	1	9540	570
(major) Banas-Parbati		23	3	817	163
Betwa (major)	46580	2	-	2720	231
Dhasan		8	3	1313	171
Ken,	28570	9	1	1298	130
Tons,		7	1	1260	127
Karamnasa		10	6	1260	121
Son (major)	71260	3	1	15060	779
East of Son	97100	12	15	1260	393
Total	**382980**	**77**	**31**	**34528**	**2685**

Inter- Basin Transfer

National Water Policy states under para 19.1 that drought prone areas should be less vulnerable to drought associated problems through transfer of surface water from surplus areas where feasible and appropriate.

It is not easy to formulate norms for identifying a basin as deficit or surplus. Even when such norms are formulated, these may not have ready acceptance due to socio- political reasons. However, it is widely accepted that drought prone areas in the county need priority in the development of water resources.

The irrigation Commission (1972) has suggested that any taluk where 35% or more of the cultivated area is irrigated may be considered to be reasonably protected against drought. National Water Development Agency (NWDA) guidelines suggest that if water resources available in a basin for irrigation are adequate to cover 60% or more of the culturable area then such as a basin/sub-basin will not have any priority for import of water from other basins. NWDA guidelines indicate that extension of irrigation from 30% to 60% of the culturable area in the deficit area by way of transfer of water from other basins should also stand the scrutiny of economic criteria.

In the following paragraphs, agroclimatic classification and drought characteristics of the drought prone districts in southern Ganga basin are analyzed. A system study of irrigation development in the tributary subbasins is presented. Results of the system study are discussed in the context of agricultural droughts and transfer of water among tributary sub basins.

AGROCLIMATIC CLASSIFICATION

Sakar and Biswas (1986) have proposed following modification to Hargreaves classification of agroclimate (1974).

i. Choice of bi-weekly assured rainfall is not desirable for the early growth stage because, in its early stage, crop is very susceptible to moderately prolonged moisture deficiency. Choice of interval of a month for computing moisture availability index (MAI) is too long a period compared to the entire crop life in tropics where the rainfall is showery and highly variable. Therefore consider weekly MAI rather than bi-weekly or monthly MAI.

ii. Range of MAI to be used for classification depends on actual evapotranspiration. It has been found that during its early stage of growth (first 3 to 4 weeks) actual evapotranspiration is about on-quarter of the potential rate due to small and spare foliage. After completion of grain formation, the water demands falls off rapidly becoming small at the ripening stage. In view of the above, classifying the areas based on MAI varying from 0.3 to 10.7 commencing from germination to completion of grain formation stage is quite reasonable.

iii. Different risk factors for different rainfall zones instead of one, so that the planner could choose his own risk level.

Non arid areas (annual rainfall more than 400 mm) are classified into seven crop potential zones on the basis of weekly MAI at 50% probability level of rainfall as shown in Table 3. Applying these criteria (Table 3) for agroclimatic classification of the 15 drought prone districts in southern Ganga basin, it is observed that the districts are in the F, G and H agroclimatic Zones.

The Central Water Commission (1982) has proposed ten indices for study of drought. These indices when applied to the drought prone districts do not show consistent results. Whereas some indices indicate a particular district to be drought affected, other indices show that the district is not affected by drought (Table 4). VRF, ERF, DRO, SMS and AI indices show that these districts are drought prone whereas IRF, IMD, FDRR indices show that these districts are not drought prone.

Table 3 Classification for non arid zone

Classification	Crop Potential	No. of weeks with MAI at 50% probability level of Rainfall	
		0.3	0.7
D	Very low	≤10	≤1
E	Low	≥10	≥1
F	Moderate	≥11	≥4
G	High	≥14	≥7
H	Higher	≥18	≥9
I	Very high	≥20	≥10
J	Highest	≥24	≥12

Table 4 Identification of drought by various indices

State/District	IRF	IMD	VRF	FDRR	ERF	DRO	SMS	AI	IF	CL
BIHAR										
Munger	ND	ND	D	ND	D	D	D	D	ND	ND
Nawada	ND	ND	D	ND	ND	D	D	D	ND	ND
Rohtas	ND	ND	D	ND	D	D	ND	D	ND	D
Bhojpur	ND	ND	D	ND	D	D	D	D	ND	ND
Aurangabad	ND	ND	D	ND	D	D	D	D	ND	ND
Gaya	ND	ND	D	ND	D	D	D	D	ND	D
UTTAR PRADESH										
Allahabad	ND	ND	D	ND	D	D	D	D	ND	D
Banda	ND	ND	D	ND	D	D	D	D	D	D
Hamirpur	ND	ND	D	ND	D	D	D	D	D	D
Jalaun	ND	ND	D	ND	D	D	D	D	D	ND
Mirzapur	ND	ND	D	ND	D	D	D	D	D	D
Varanasi	ND	ND	D	ND	D	D	D	D	ND	ND
MADHYA										
PRADESH	ND	ND	D	ND	D	D	D	D	D	D
Datia	ND	ND	D	ND	D	D	D	D	D	NA
Shahdol	ND	D	D	ND	D	D	D	D	D	NA
Sidhi										

Note: D: Drought, ND= Non Drought; NA: Data not available, IRF: inadequacy of rainfall;IMD: IMD criteria; VRF: Variability of rainfall; FDRR: Frequency of different range of rainfall; ERF: Erratic distribution of rainfall; DRO: Deficiency of runoff; SMS: Soil moisture stress; AI: Aridity Index; IF: Irrigation facilities; CL: Crop loss

Chaube and Viswanath (1993) carried out further study to analyze the ten drought indices with revised approach of agro-climatic classification discussed above. The agroclimatic classification suggested by R.P. Sakar and B.C. Biswas is superimposed on drought district maps and categorization of drought districts that fall in each of the zones is then carried out.

Using the information on drought proneness of 15 districts as per 10 indices and group of districts that are falling in each of the zones, interindices consistency is analyzed zone wise. The degree of consistency between two indices is evaluated by finding the number of districts (as a percentage of total number of districts) in each agroclimatic zone identified either as drought by both the indicators or non drought by both the indicators.

Recommended indices

Suitable drought indices which have a very high degree of interindices consistency in identifying drought are as shown in Table 5.

Out of the ten indices proposed by Central Water Commission (1982) two indices are particularly relevant as these are expected to show high degree of inter-indices consistency. These are irrigation facilities (IF) and Crop losses (CL).

Table 5: Recommended Indices

S.No.	Zones	Districts	Recommended indices
1	Zone – F MAI ≥ 0.3 > 11 weeks ≥ 0.7 > 4 weeks	MP: Datia UP: Part of Banda, Hamirpur, Jalaun	DRO, ERF and AI
2	Zone – G MAI ≥ 0.3 > 14 weeks ≥ 0.7 > 7 weeks	Bihar: Rohtas, Bhojpur, Aurangabad, Gaya UP: Part of Banda, Allahabad, Mirzapur, Varanasi MP: Shahdol, Sidhi	ERF and AI
3	Zone – H MAI ≥ 0.3 > 18 weeks ≥ 0.7 > 9 weeks	Bihar: Munger, Nawada	AI, VRF and DRO

Irrigation Facilities: Irrigation Commission (1972) mentions that if 30 percent of the cropped are is irrigated in drought prone area (taluka/tehsil), it can reasonably sustain a stable agriculture. Based on this, drought proneness may be examined. According to this criteria eight districts are not drought prone (Table 4).

Crop Loss: According to this criteria if there is a fall in the annual production of crops by more than 25 percent from the normal, the area is considered as suffering from drought in that year. When this happens in 20 percent or more of the years considered, the area is classified as drought prone. Crop loss criteria is not consistent with criteria of irrigation facilities in five districts (Rohtas, Gaya, Allahabad, Jalaun and Datia) whereas data on crop loss is not available for two districts. Provision of irrigation facilities in a tributary sub basin is expected to mitigate effect of drought not only in the command area but in surrounding area also due to technological interlinkages.

Herbst model study of droughts

Drought indices/ Criteria have a limited use of identifying drought. Several models have been proposed in literature which provide more detailed information about drought condition. Herbst et.al (1966) proposed a simple mathematical model for identification of agricultural droughts in terms of the duration, intensity, months of their onset and termination and drought severity index.

Chaube (1997) proposed incorporation of rational approach for accounting monthly agricultural water need and monthly effective rainfall so as to improve the reliability of Herbst model in the study of agricultural droughts. Chaube (1997) carried out model study of agricultural drought in Rohtas district utilizing monthly rainfall records for the period 1901 to 1980 and results were compared with original Herbst model and Aridity Index Criteria as shown in table 6.

Table 6 Comparison of Aridity Index and Hebst Model

Method	No. of years identified as drought years	No. of years in which drought is common	Identification efficiency (%)
Aridity Index	36	26	72.2
Original Herbst Model	35	26	74.28
Revised Herbst Model	28	26	92.8

The model identified 18 drought spells spanning 28 drought years. The duration of drought spells varies from 10 months to 58 months. The intensity of droughts varies from 0.07 to 2.762.

Such type of studies should be done for other drought prone areas in Southern Ganga Basin to arrive at a scientific basis for assessing water needs in each tributary sub basin.

Irrigation system study

A linear programming model study of optimal irrigation through major and medium projects in the tributary subbasins was carried out by author (Chaube 1982). The results on optimal irrigation and balance flows in each tributary subbasin are summarized in Table 7 along with irrigation potential and surface water availability. Results are given for two conditions of analysis namely optimal irrigation with canal water in existing projects and optimal irrigation under ultimate development of projects with conjunctive use of surface water and groundwater.

Model study shows that ultimate development of projects and with conjunctive use, entire irrigable land in major canal commands can be put under irrigated agriculture. A significant portion of monsoon runoff would still be available for storage and interbasin transfer to water deficit areas to make the region free from recurring droughts.

Optimal annual irrigation from existing projects is 2467000 ha. This could be increased to 4638000 ha. under ultimate stage of development and with conjunctive use.

Actual irrigated area with prevailing field management practices is much less. Data for the same is not available for quantitative analysis. However, it is known that despite creation of so many irrigation facilities, the region continues to suffer from droughts. It is expected that the proper management of available irrigation facilities, droughts can be mitigated to a very large extent.

Table 7 Irrigation and balance releases under various conditions

	Irrigation($x10^3$ha)			Balance Releases(MCM)			
	Rabi	Kharif	Annual	Rabi	Summer	Kharif	Annual
Chambal							
I	570	570	1140	327	109	5012	5448
II	259	95	354	0	779	0	779
III	360	199	559	0	0	0	0
Banas-Parabati							
I	163	163	326	1120	380	17350	18850
II	0	45	45	1008	342	16857	18207
III	163	163	326	0	0	16396	16396
Betwa							
I	231	231	462	360	120	5520	6000
II	195	231	426	0	0	1263	1263
III	231	231	462	303	0	1335	1638
Dhasan							
I	171	171	342	450	150	6830	7430
II	40	40	80	401	322	9860	10583
III	171	171	342	0	0	4273	4273
Ken							
I	130	130	260	678	226	10396	11300
II	62	62	124	286	126	10097	10509
III	130	130	260	0	18	9611	9629
Tons							
I	127	127	254	355	120	5435	5910
II	44	62	106	284	94	4874	5252
III	127	127	254	0	553	3586	4139
Karamnasa							
I	121	121	242	0	775	14695	15470
II	38	89	127	0	618	14110	14728
III	121	121	242	433	605	12874	13912
Son							
I	779	779	1558	2484	891	38916	42291
II	590	430	1020	536	0	30313	30849
III	779	779	1558	845	0	28674	29493
East of Son							
I	393	393	786	895	298	13731	14824
II	27	158	185	636	241	12853	13730
III	242	393	635	0	0	11589	11689
						Total	**127623**

Note I Irrigation potential and surface water availability; II Optimal irrigation with surface water from existing projects; III optimal irrigation under ultimate development of projects and with conjunctive use of surface and ground water

Author had earlier carried out irrigation management studies in Chambal and Betwa subbasins (Chaube 1986, Chaube 1988). These studies have shown that provision of even one irrigation in the rainfed areas could significantly improve the yield. Moisture availability index (MAI) was found to exceed 1.3 in the months of

July and August in Betwa basin whereas MAI exceeds 1.33 is required for 3 consecutive months for rainfed rice cultivation. Kharif rice cultivation could have been possible with conjunctive use of irrigation supplies in June and September. Similar results are expected for other tributary subbasins. Farmers are already practicing use of soil moisture recharge for rainfed cultivation of wheat and gram in rabi season. Soil moisture recharge and ground water potential are not expected to be available in large quantity as is evident from water balance study of Betwa basin (Chaube 1988). However, conjunctive management of surface water, soil moisture recharge and ground water can be effectively utilized to mitigate adverse effects of drought.

Water transfer

Table 7 shows that optimal irrigation under ultimate development of projects (including conjunctive use) would result in full utilisation of surface water in Chambal basin. However, Banas-Parbati subbasin would still have excess monsoon flows (16396 MCM). Therefore, feasibility of creating storages in Banas-parbati subbasin and water transfer to deficit areas in Chambal subbasin should be explored. Similarly feasibility of water transfer from Ken to Dhasan and Betwa subbasin for utilization through medium and minor schemes should be explored.

Karamnasa, Son and East of Son subbasins have surplus monsoon runoffs which could be stored/diverted for transfer out of Ganga basin after satisfying multipurpose water demands within these tributary subbasins.

In this study, only major irrigation projects were considered in Chambal, Betwa and Son subbasins. Other tributary subbasins were considered as channel sectors where in medium and minor irrigation projects were considered in lumped form to estimate water utilisation and balance release. Under ultimate stage of development balance releases from channel sectors during rabi and summer seasons are drastically reduced. There is no balance release during rabi in Banas-Parbati, Dhasan, Ken, Tons, East of Son. In summer, there is no balance release from Banas-Parbati, Dhasan, and East of Son. Environmental implications of drastic reduction in lean seasons could be ominous.

The linear programming model studies of the major tributary sub basins (Chambal, Betwa, Son) and water balance studies of channel sectors did not consider domestic and industrial water requirements. Also it did not include water release requirements in downstream for environment and ecological purposes.

Contingency crop plan

To mitigate the effect of drought alternate crops for different region and for different periods matching with the delay in sowing have been recommended in literature (Table 8).

Table 8 Alternate Crops Recommended for different Rainfed Regions of Southern Ganga Basin

Location of research center	Region	June - Mid July	Alternative crops and varieties			
			Mid- August	Mid-September	Mid-October	Mid-November
Alluvial soil (Sub-humid)						
Varanasi	Varanasi, Mirzapur, Jaunpur, Ghazipur and Ballia districts of Uttar Pradesh	Upland Rice, Maize Pearl,millet Black gram, Mung bean, sesame	Short duration rice,pearl millet, black gram, mung bean, fodder crops of sorghum, pearl millet, maize	Toria	Chickpea, barely, wheat, lentil, mustard, Linseed, safflower	Wheat (C360) Mustard
Alluvial soil (Semi Arid)						
Agra	Agra, Aligarh Mathura,Etah Mainpuri Districts of Uttar Pradesh	Pearl millet, Black gram, Mung bean, Pigeon pea, groundnut	Pearl millet, Mung bean, Black gram,	Toria	mustard, barely, Chickpea, safflower	

Source: Sharma and Ramasastri (2005) page 343 to 352

Conclusions

A large number of irrigation scheme have been developed and may more schemes are in the process of implementation (Table 2). The region has live storage potential of 34528 MCM and irrigated land 2685000 ha. And yet the region has been experiencing recurring droughts in 15 drought prone districts. There is a vagueness about the concept of drought as is evident from the inconsistency in identification of drought proneness on the basis of available indices; particularly the criteria of irrigation facilities and crop loss (Table 4). The districts have been classified in to 3 agroclimatic zones and appropriate indices for each zone have been recommended (Table 5). Revised Herbst model provides more meaningful information about drought condition.

Results of optimal irrigation area and balance release (Table 7) show that entire irrigable land can be brought under irrigation and the region could be made free from droughts. Data on existing irrigation in the drought districts is not available to make a comparative study. Studies carried out by author for the Chambal and Betwa basins (Chaube 1986 and Chaube 1988) show that soil moisture recharge and ground water potential, though not in large quantity could be effectively used for live saving irrigation in the drought districts. Conjunctive use management of surface water, soil moisture recharge and ground water should receive priority over development of new irrigation schemes.

The model studies did not consider domestic and industrial requirements. Also water release requirements in downstream and ecological purposes were not considered. Therefore, model results particularly the balance releases are not directly relevant to decision making on inter basin transfer.

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