Mausam, (1984), 35, 1, 55-60

551.57 : 633 (548)

Water balance and crops in Karnataka

A. R. SUBRAMANIAM and A. V. R. KESAVA RAO

Dept. of Meteorology & Oceanography, Andhra University, Waltair

(*Received 17 June 1982*)

सार — कर्नाटक में नम जलवायु की विविधता होने से वहां विभिन्न प्रकार की फसलें उगाई जा सकती हैं। थोर्नवाइट का अनुसरण करके जलवायु जलसंतुलन के तत्वों एवं सूचकांकों की राज्य के सभी उपलब्ध मौसम स्टेशनों के लिए गणना की गई है। फिर उनका मानचित्रों के आधार पर विश्लेषण किया गया है। धान, ज्वार, बाजरा, रागी, गन्ना, मूंगफली, कपास और कॉफी जैसी कुछ प्रमुख फसलों के लिए नमी की सीमा की जानकारी हेतु फसलों के सामान्य बंटन और नमी की पर्याप्तता के विश्लेषणों के परिणामों की तुलना की गई है। खरीफ ऋतु में ज्वार की उपज उन क्षेत्रों में ज्यादा हुई है, जहां नमी 70 प्रतिशत है।

ABSTRACT. Karnataka with a spectrum of moist climates offers scope for a wide variety of crops to be grown. Following Thornthwaite, climatic water balance elements and indices have been calculated for all the available meteorological stations in the State and they are cartographically analysed. The general distribution of crops and the results of the analysis of moisture adequacy are compared to identify the limits of moisture adequacy for certain important crops like rice, jowar, bajra, ragi, sugarcane, groundnut, cotton and coffee. In kharif season, jowar yields are generally found to be recording high production in areas of 70% moisture adequacy.

1. Introduction

Study of water balance in relation to climate is one of the important disciplines of applied climatology. For the growth and development of vegetation, heat and moisture are the two most important requirements. In a tropical country like India, the limiting factor for successful agriculture is moisture, as there is no dearth of thermal energy. Though rainfall is the main source of water that is available to crops, the actual availability to crops does not depend on rainfall alone, as it should be balanced against the amounts due to evapotranspiration. In the present paper an attempt is made to study the water balance and crops in Karnataka, a State in peninsular India with a full range of moist climates from per-humid to arid offering scope for a wide variety of crops to be grown under different moisture stresses. Climatic types and water balance over India have been studied earlier by Subrahmanyam (1956a, 1956b, 1958) and Rao *et al.* (1976).

Karnataka is the sixth largest State in India in terms of area and may be divided into three natural regions: (1) The coastal plains, (2) The Malnad, and (3) The Maidan. Base map of the State is shown in Fig. 1. Malnad is essentially a hilly country with heavy rainfall and low temperatures, and is known for its luxurious vegetation. Mixed soils are found in coastal plains and laterites in Malnad. Deep black and medium black soils predominate in the northern part of the Maidan and medium red soils are found mostly in southern Maidan.

2. Data and methodology

Data regarding climatic normals is obtained from information published by India Meteorological Department (1966) for all the stations available in Karnataka. Climatic water balances are calculated for each station adopting the modified scheme of Thornthwaite (1955). Potential Evapotranspiration (PE) is calculated adopting Thornthwaite's method. The equation is as follows:

$$e = \left(\frac{10\ t}{I}\right)^a$$

Where, t = mean monthly temperature °C

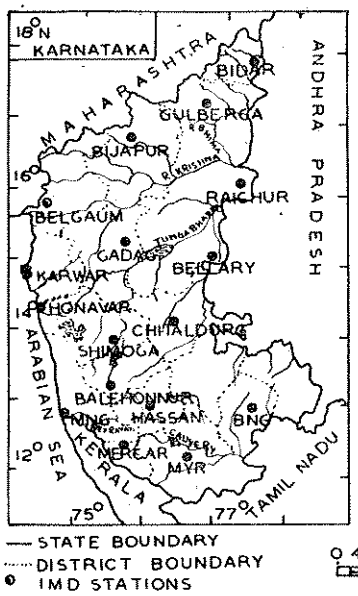

Fig. 1. Location map

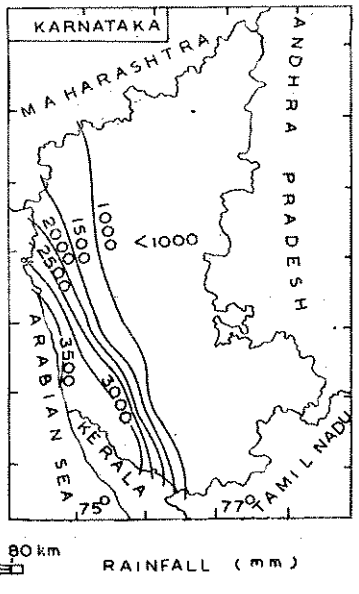

Fig. 2. Climatic annual rainfall (mm)

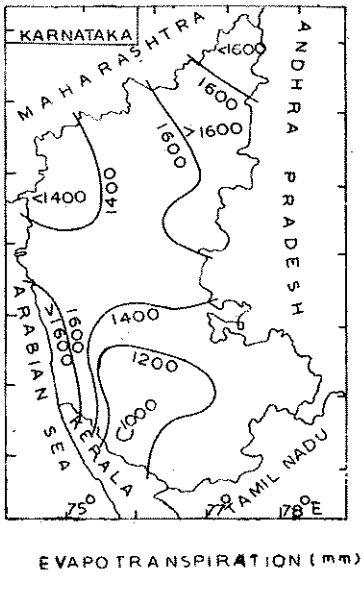

Fig 3. Climatic annual potential evapotranspiration (mm)

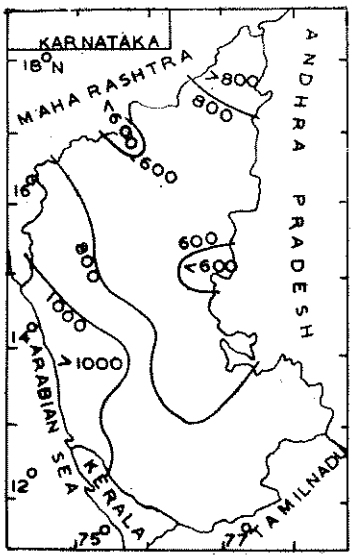

Fig. 4. Climatic annual actual evapotranspiration (mm)

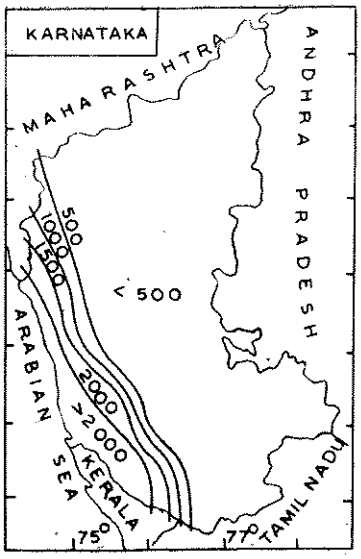

Fig. 5. Climatic annual water surplus (mm)

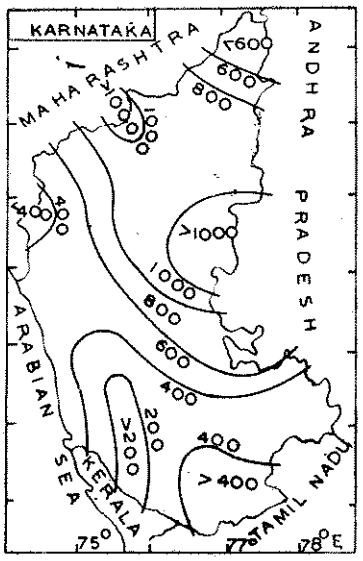

Fig. 6. Climatic annual water deficit (mm)

$$I = \text{annual heat index} = \sum_{i=1}^{12} i$$

i = monthly heat index and is equal to $(t/5)^{1.514}$

and a = non linear function of heat index, approximated by the expression

$$a = 6.75\times10^{-7}\, I^3 - 7.71\times10^{-5}\, I^2 + 0.17921\, I + 0.49239$$

The unadjusted potential evapotranspiration (e) so obtained is for average 12 hours sunshine and 30 day month. The values can be adjusted by multiplying with a latitudinal factor.

Rainfall and the water balance elements such as potential evapotranspiration (PE), actual evapotranspiration (AE), water deficit and surplus, and index of moisture adequacy are cartographically represented and their patterns discussed. The pattern of kharif

(June-November) moisture adequacy is discussed in comparison with kharif yields of jowar crop. Data regarding kharif jowar yields is obtained from the reports of Bureau of Economics and Statistics of the Government of Karnataka (1976-1979).

3. Discussion

Climatic annual rainfall over Karnataka is shown in Fig. 2. On the western (windward) side of the Western Ghats, high amount of rainfall is recorded and it decreases on the eastern (leeward) side. Maximum rainfall of 3596 mm is received at Honavar and a minimum of 569 mm at Bellary. From the figure it is evident that relief plays an important role in the distribution of rainfall.

PE over Karnataka is shown in Fig. 3. A maximum PE of 1710 mm is observed at Raichur. It decreases towards the western side to a minimum of 976 mm at Mercara. The coastal plains have again higher values of PE, Mangalore experiencing 1707 mm. High and low values are observed in other parts of the State because of the diverse physical features.

Actual evapotranspiration (AE) represents in a way the absolute amount of water that is actually available in the soil for the use of vegetation. In places where there is adequate moisture, the AE will be high and may equal PE under conditions of saturated soil. On the other hand, in dry areas it will be proportionately smaller inspite of large values of PE. Fig. 4 shows the annual AE over Karnataka. It varies from 1199 mm at Mangalore to 569 mm at Bellary. The coastal plains have values higher than 1000 mm and Malnad around 1000 mm. Southern Maidan region has a value around 800 mm and northern Maidan experiences a value ranging from 600 to 800 mm.

No single element either precipitation or PE is enough to understand the climate or water balance of any region. If precipitation is higher than PE it is called water surplus, and if it is less it is known as water deficiency. Water surplus and water deficit for Karnataka are calculated using the water budgetting technique and shown in Figs. 5 and 6. From Fig. 5 it is evident that the coastal region experiences a surplus of more than 2000 mm and the water surplus decreases towards the eastern side of the State. A maximum of 2498 mm is observed at Honavar. In the northern and southern Maidan there are no water surpluses. From Fig. 6 it is evident that lower values of water deficit are observed at southern Malnad region with a maximum of 104 mm at Mercara. The northern Maidan region has got high values of water deficit with a maximum of 1119 mm at Bellary.

If either AE or PE is considered independently, the suitability of a region for practical agricultural purposes cannot be clearly assessed. The ratio of AE to PE varies with the available soil moisture and is termed as moisture adequacy and expressed as a percentage. This moisture adequacy index provides a good indication of the moisture status of the soil in relation to the water need. Subrahmanyam *et al.* (1963) reported optimal values of this index for efficient growth and development of different crops in India. The general distribution of crops and distribution of annual moisture adequacy over Karnataka is shown in Fig. 7. A highest value of 89% is observed at Mercara and a minimum of 34% at Ballary. Higher values are observed at places where precipitation is high and well distributed. The moisture adequacy value decreases from west to northeast upto Bellary and from there again higher values are observed. Since higher values of this index indicate the availability of large amount of moisture in relation to water need, agricultural operations throughout the year can be expected in those regions. In the regions of low moisture adequacy the growing period is adjusted to rainy season. From the figure it is evident that a close correlation exists between the pattern of moisture adequacy and general distribution of important crops like rice, jowar, bajra, cotton, groundnut, sugarcane and coffee.

Rice is a major crop occupying about 42% in terms of production. Rice requires high temperatures and large amounts of water. Dakshina Kannada district has the largest area and production under rice crop, and this region is found to be having a moisture adequacy of around 70%. It is also grown in the Uttara Kannada, Belgaum, Dharwar, Shimoga, Hassan, Mandya and Mysore districts having a moisture adequacy value over 60%.

Jowar and bajra are major dry crops which require high temperatures and moderate water supply. Excess water is even detrimental to their development. Jowar is grown abundantly in Bijapur, Gulbarga, Dharwar, Raichur, Belgaum and Mysore districts. It is the major crop of the State in terms of area under crop. Bajra is grown abundantly in Bijapur, Gulbarga, Belgaum and Raichur districts. From the figure it can be seen

TABLE 1

Percentage of total area under different crops in Karnataka

District	Rice	Jowar	Ragi	Bajra	Cotton	Groundnut	Sugarcane	Coffee
Bidar	1.04	7.37	0.01	3.39	1.18	4.77	6.53	—
Gulbarga	1.14	17.85	0.26	27.03	12.88	14.91	1.71	—
Bijapur	0.14	27.59	—	42.95	16.40	14.60	3.51	—
Belgaum	6.69	13.45	1.62	0.15	8.78	14.49	24.92	—
Raichur	4.98	12.13	0.01	10.91	28.26	15.75	4.80	—
Bellary	2.03	1.94	2.72	7.03	5.59	3.14	7.27	—
Dharwar	7.63	8.99	1.15	0.34	25.10	11.83	2.15	—
Uttara-Kannada	9.16	0.03	0.12	6.59	—	0.36	1.59	—
Shimoga	15.61	0.82	4.31	—	0.49	0.84	5.98	0.40
Chitradurga	3.48	1.44	8.39	0.48	0.43	1.76	1.75	—
Tumkur	1.91	1.87	11.85	0.13	0.06	5.17	2.19	—
Chikmagalore	4.31	0.57	3.47	0.01	0.02	0.27	1.03	41.41
Dakshina-Kannada	16.73	0.01	0.04	—	—	0.03	1.28	—
Hassan	3.79	0.60	8.15	0.02	0.58	0.38	2.26	15.88
Kodagu	4.97	0.02	0.53	—	0.03	0.06	0.01	42.17
Mysore	6.01	5.11	12.24	0.37	0.20	2.70	5.15	0.14
Mandya	4.56	0.07	6.84	—	—	0.57	19.20	—
Bangalore	1.80	0.01	23.81	—	—	1.20	3.78	—
Kolar	4.02	0.13	14.48	0.60	—	7.17	4.89	—

Source : Bureau of Economics & Statistics, Govt. of Karnataka.

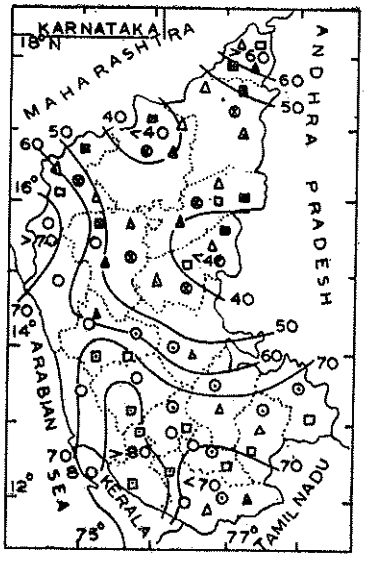

Fig. 7. Distributon of crops and moisture adequacy (%) in Karnataka

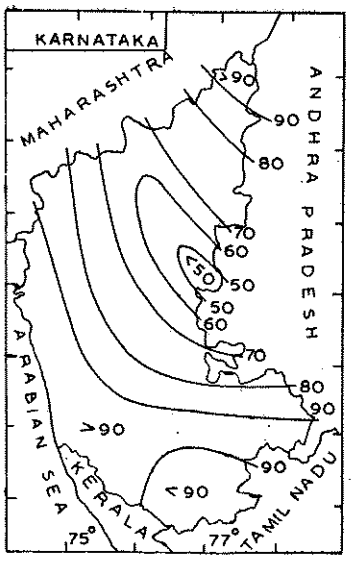

Fig. 8. Moisture adequacy (Ima%) during kharif season (June to Nov)

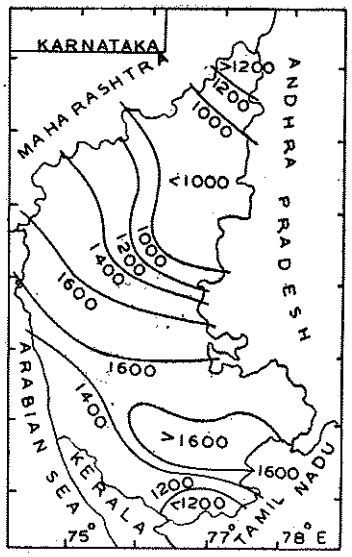

Fig. 9. Kharif jowar yields (Isolines indicate yields in kg/ha)

that areas experiencing less than 60% annual moisture adequacy support jowar and bajra crops.

Ragi is a crop which can survive under drier conditions and poorer soils than rice, and also in the rice growing areas where rainfall is erratic and irrigation facilities are not available or insufficient. It is an important crop in Bangalore, Kolar, Tumkur, Mysore and Hassan districts. Fig. 7 shows that ragi growing areas are bounded by 50% and 70% isolines in the southern Maidan with medium red soils. 50 to 70 per cent moisture adequacy belt in the northern parts of Karnataka is not under ragi cultivation as the soils are mostly medium and deep black.

Cotton is a dry crop and it also can be grown under irrigation. Black soils are very suitable for cotton, and as such, northern Maidan is the only region where cotton is grown intensively. Raichur and Dharwar record about 50% in terms of area under cotton in the State. This area is found to have a moisture adequacy of 40 to 60%.

Groundnut is cultivated both as rainfed and as a hot weather irrigated crop. It is intensively grown in Dharwar, Belgaum, Bijapur, Raichur and Gulbarga districts. It requires less water than rice and there should not be any water logging in the field. Areas with less than 70% annual moisture adequacy are seen to support groundnut cultivation. The lower temperatures in the Malnad area restrict the crop to be grown economically there.

Sugarcane requires heavy rainfall or uninterrupted irrigation. It is grown generally all over the State, with the exception of Kodagu district. Belgaum and Mandya districts record about 35% of the State's production of sugarcane. It can be seen from the figure that sugarcane is grown mostly in regions with a moisture adequacy of 60 to 80%.

Coffee requires moderately low temperatures and heavy rainfall. The southern Malnad region is best suited for coffee growth. It can be seen from the figure that coffee is grown generally in areas where moisture adequacy is higher than 80%. Chikmagalore, Kodagu and Hassan districts contribute to more than 99% of State's area and production of coffee.

Districtwise percentage of area under different crops to total area under respective crops in Karnataka is given in the Table 1.

For a better understanding of the relation between moisture adequacy and crop yields, normal kharif seasonal distribution of moisture adequacy and jowar yields over the State are presented in Figs. 8 and 9.

It can be seen from the Fig. 8 that highest values are observed in the coastal belt, Malnad and northern tip of the Maidan region, and lowest values near Bellary area. It increases both in the northeast and southwest directions from Bellary. Mysore district experiences a value of less than 90%.

Average kharif yields (kg/ha) of jowar (1976-1979) are shown in Fig. 9. It can be seen from the figure that high yield rates are observed at Bangalore, Mandya, Hassan, Uttara Kannada, Shimoga and Chitradurga districts. On a comparison of this map with Fig. 8 it can be seen that areas having greater than 70% moisture adequacy record high yields of jowar with the exception of Mysore and Gulbarga districts. It can also be seen that Bellary-Bijapur-Raichur area experiencing a kharif moisture adequacy of less than 70% has low yields of the order of 1000-1200 kg/ha. Hence it can be observed that generally in places where the kharif moisture adequacy is more than 70%, good yields can be expected.

4. Summary

The paper is an attempt to discuss the distribution of water balance elements on an annual basis over Karnataka. These studies are correlated with the distribution of crops grown in different districts of Karnataka. A comparison of the distribution of moisture adequacy and the crops in Karnataka has yielded interesting information on the minimum and maximum values of moisture adequacy required to grow various crops. In the case of kharif jowar it has been observed that generally in places where moisture adequacy is more than 70%, good yields of the order of 1400 kg/ha can be expected.

References

Bureau of Economics and Statistics (1976-1979), Reports on crop estimation surveys in Karnataka.

India Meteorological Department, 1966, '*Climatic normals*'.

Rao, K.N., George, C.J. and Rama Sastry, K.S., 1976, The climatic water balance of India, *Memoirs of the India Meteorological Department*, **XXXII**, Part III.

Subrahmanyam, V.P., 1956 a, Climatic types of India according to the Rational classification of Thornthwaite, *Indian J, Met. Geophys.*,7, 3.

Subrahmanyam, V.P., 1956b, Water balance of India according to Thornthwaite's concept of potential evapotranspiration, *Annals of the Assn. Amer. Geogrs.*, **44** (3).

Subrahmanyam, V.P., 1958, The role of water balance in climatic research, *Bull. Nat. Inst. Sci.* (*Ind.*), 11, pp. 101-104.

Subrahmanyam, V.P., Subba Rao, B. and Subramaniam, A.R., 1963, Moisture adequacy in relation to the distribution of a few crops in India, Proc. Berkeley (California) Symp. of the Internat. Assn. Sci. Hydrol. (IUGG), pp. 462-467.

Thornthwaite, C.W. and Mather, J.R., 1955, 'The water balance, Publ. in Clim. Drexel Inst. Tech. No. 8, p. 104.