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Estimation Of Temperature Over •Nepal

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Temperature is a significant factor limiting plant growth. Knowledge of the characteristics of the seasonal distribution of temperature and the extreme occurence of high and low temperatures are important factors for agricultural planning.

REVIEW OF EXTRAPOLATION METHODS

Nepal has only a few temperature recording stations[1] with a long period of data. The variation of temperature over a region, given a few point observations, is often achieved by multiple regression methods. Hopkins studied least square regression of mean monthly air temperatures in central and southern Alberta and Saskatchewan with latitude, longitude and elevation from 44 stations as independent variables.[2] Later Hopkins used 206 climatological stations to further investigate the spatial variation of temperature[3] He remarked that the linear equation could be used to interpolate acceptable estimates of climatological averages for points between stations. Based on 22 years climatic data, Hopkins Jr. estimated mean monthly

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1, Department of Hydrology and Meteorology, Climatological records of Nepal, 1968, 1971, 1972, 1973, 1977, Vol I, Vol II, HMG, Nepal.

2, J. W. Hopkins, Agricultural Meteorology: Correlation of air temperatures in central and southern Alberta and Saskatchewan with latitude, longitude and altitude. **Can. J. Res.** Vol 16 (1938), pp. 16 - 26.

3. J. W. Hopkins, Correlation of air temperature normals for the Canadian Great Plains with latitude, longitude and altitude. **Can. J. Earth Science.** Vol. 5 (1968) pp. 199 - 210

maximum and minimum and mean temperatures in New England and New York with elevation and latitude as independent parameters.[4] In Newfoundland and Labrador, Solomon **et al** estimated mean monthly temperatures using latitude, elevation and distance from the coast as the independent variables.[5] Lee estimated mean monthly and mean annual temperatures from elevation and latitude within a uniformly humid, temperate climate in northeastern USA, based on 30 years monthly and annual means.[6] Thompson revealed that maximum and minimum temperature distribution over the tableland stations around 1000 m elevation in northeastern New South Wales, Australia, was primarily controlled by the relief variation and slope orientation.[7] Thompson used mesoscale classification of airflow to study the mesoscale variation of temperature and rainfall in the same area.[8] Johnson, Kalma and Caprio estimated mean air temperatures from elevation, latitude and distance from the coast from the 22 station network for south eastern New South Wales.[9]

DERIVATION OF EXTRAPOLATION MODELS

Thirty five meteorological stations recording temperature throughout Nepal have been used to develop an equation to predict maximum and minimum temperatures at different places. The period 1970-75 was chosen

4. C. D. Hopkins, A method of estimating basin temperatures in New England and New York. J. **Geophys. Res.** Vol. 65 (1960), pp. 367-37.

5. S. I. Solomon, and et al, The use of a square grid system for computer estimation of precipitation, temperature and runoff. **Water Resources Res.** Vol. 4 (1968), pp. 919 - 929.

6. R. Lee, Latitude, elevation and mean temperature in the North East. Prof. Geogr. 21, (1969), pp. 227 - 231

7. R. D. Thompson, The influence of relief on local temperatures: Data from New South Wales, Australia. **Weather**, Vol, 28(1973), pp. 377 - 382,

8. R, D, Thompson, Some aspects of the synoptic mesoclimatology of the Armidale district, New South Wales, Australia, J. **App. Meteorology** Vol. 12 (1973), pp. 578 - 588,

9. M. Johnson. J. D. Kalma and J. Caprio, The spatial distribution of mean air temperature in southeastern New South Wales, **Aust. Met. Mag.** 24, (1976), pp.73 - 84,

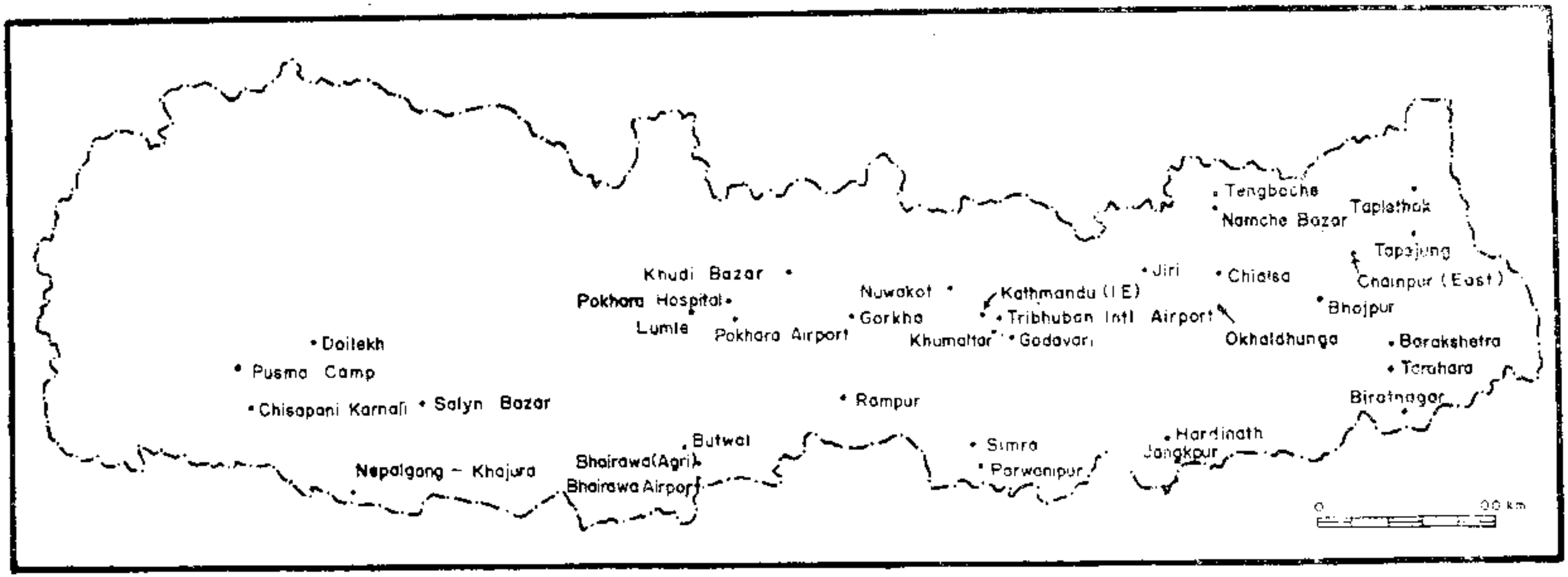
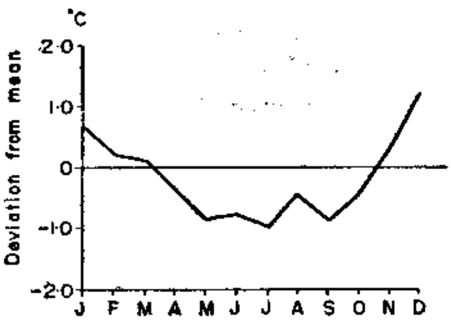
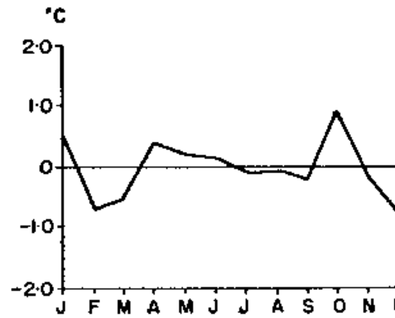


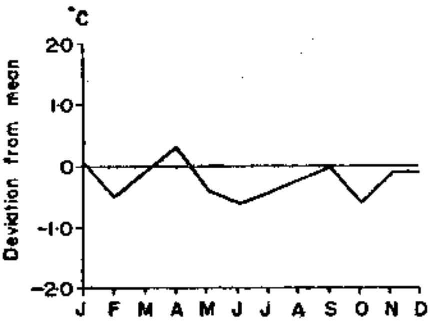
Fig. 1. Selected temperature stations



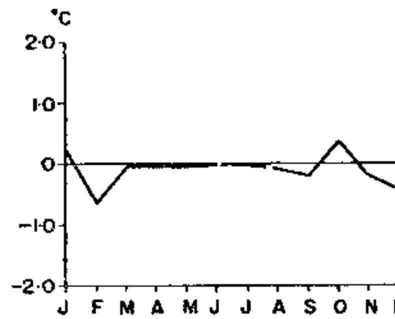
Difference of mean monthly maximum temperature at Kathmandu (I.E.) 1921-75/1970-75



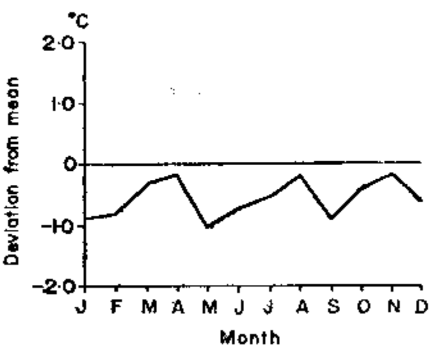
Difference of mean monthly minimum temperature at Kathmandu (I.E.) 1921-75/1970-75



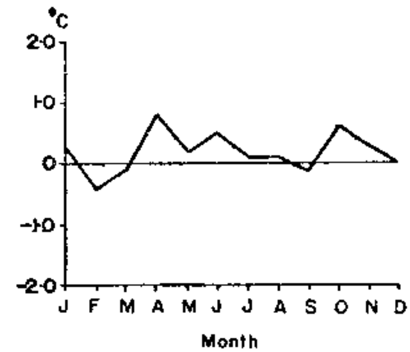
Difference of mean monthly maximum temperature at Pokhara 1957-75/1970-75



Difference of mean monthly minimum temperature at Pokhara 1957-75/1970-75



Difference of mean monthly maximum temperature at Butwal 1961-75/1970-75



Difference of mean monthly minimum temperature at Butwal 1961-75/1970-75

Fig. 2 Deviation of temperatures

to maximise the number of available temperature stations as shown in Fig. 1 but still a gap is occured in the north west of Nepal, due to the non existence of temperature stations on that area. Maximum and minimum temperatures from this six year period together with and 55 year mean (1921-75) from Kathmandu (Indian Embassy), 15 year mean from Butwal and 19 year mean from Pokhara were compared (Fig. 2). On average, the annual march of temperature of the recent six year period and the long term 15, 19 and 55 year means have a difference of less than 1°c for the maximum and minimum temperature. Hence the network of recent six year mean temperatures of Nepal is acceptable as the base for the estimation of the average mean monthly maximum and minimum temperatures for the 168 station network.

Three models have been developed, all of which give satisfactory results with regression coefficients usually greater than 0.9.

(a) one model takes an account of latitude, longitude, elevation and rain as the independent variables; the latter is considered to be a measure of the mean cloudiness.
(b) a second model considers latitude, longitude and elevation, and
(c) in the last model, elevation is the sole dependent variable.

The coefficient of correlation explained by the regression is not significantly different between these three models as shown in Table 1 except that correlation shows a lower value in the winter months, particularly in model III and with mean minimum temperature as the dependent variable.

These three models have been run to select the most suitable variables for the different months for predicting the best mean monthly maximum and minimum temperatures for the 168 stations. Model predicted temperatures were verified with the observed temperatures in order that suitable variables might be chosen. Finally, the first model was chosen for January to November to predict mean monthly maximum temperatures. When the first model was used for December to predict the mean monthly maximum temperatures, the predicted value was much higher in a few places. Therefore, the second model being closer to reality was chosen to predict mean monthly maximum temperatures for December.

Similarly, the first model was chosen for March to October to predict mean monthly minimum temperatures. The second model was considered a most appropriate for November to February to predict mean monthly minimum temperatures. The co-efficients used to predict temperatures are shown in Tables 2 and 3.

Finally, after having established a set of estimated mean monthly maximum and minimum temperatures for the station network, the estimated temperature was replaced by the observed temperature records of the 35 stations. The combined observed and estimated mean monthly maximum temperatures are shown in author's thesis.[10] This broad picture of variation of mean monthly maximum and minimum temperatures and extremes are shown in a few selected places (Fig. 3).

Table I:- Cofficient Correlation of Temperature Model

Model		Jan.	Feb	Mar.	Apr.	May	Jun.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
I	T Max: Lat. Long. Elev. & Rain	0.96	0.97	0.98	0.97	0.97	0.98	0.97	0.97	0.98	0.97	0.95	0.95
	T Min: Lat. Long. Elev. & Rain	0.89	0.84	0.83	0.90	0.96	0.98	0.97	0.97	0.97	0.96	0.85	0.79
II	T Max: Lat. Long. and Elev.	0.96	0.97	0.98	0.97	0.96	0.96	0.97	0.97	0.97	0.96	0.95	0.95
	T Min: Lat. Long. and Elev	0.85	0 84	0.83	0.90	0.96	0.98	0.97	0.97	0 97	0 96	0 84	0.75
III	T Max: Elev.	0.95	0.96	0.98	0.95	0.92	0.94	0 97	0.97	0.97	0 96	0 94	0.94
	T Min: Elev.	0.80	0.81	0.79	0.89	0.96	0.98	0.97	0 97	0.97	0.96	0.82	0.75

10. J. L. Nayava, **The climates of Nepal and their implications for agricultural development** Ph. D. thesis submitted to Australian National University, 1980, Canberra.

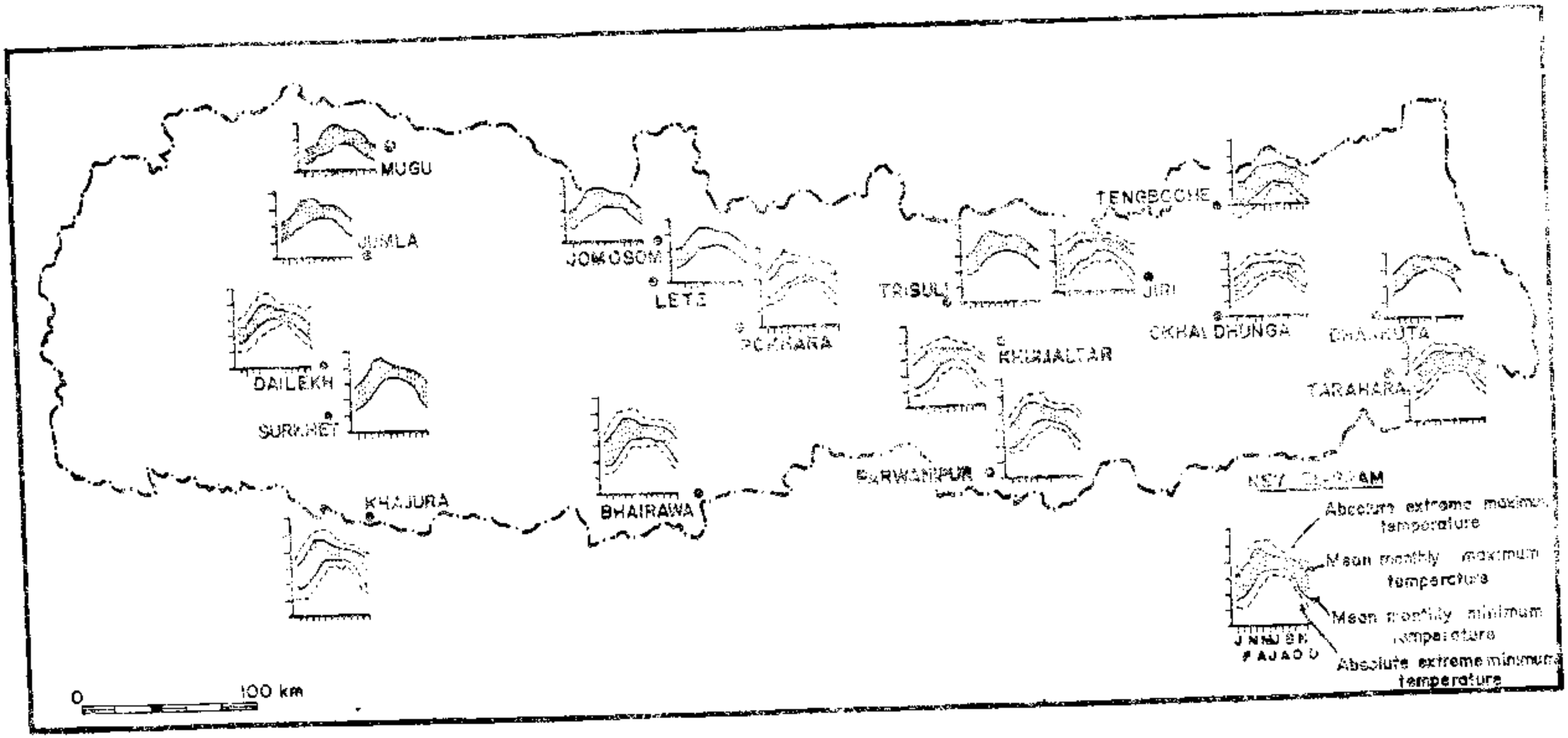


Fig. 3. Variation of temperatures

Table 2:- The Selected Regression Coefficients used to predict Minimum Temperature

	Regress Coefficients for minimum temperature (°C)					
Month	b	c	$-d \times 10^{-2}$	e	a	R^2
January	4.28	1.34	6.02	-	-220.4	0.85
February	3.34	1.11	5.77	-	-174.59	0.84
March	4.35	1.26	5.20	-0.93×10^{-2}	-209.84	0.83
April	0.37	-4.11×10^{-2}	5.98	1.60×10^{-2}	14.00	0.90
May	-0.52	-0.28	5.86	8.15×10^{-4}	62.25	0.96
June	0.37	8.48×10^{-2}	5.64	-1.14×10^{-3}	0.87	0.98
July	0.31	9.16×10^{-2}	5.32	-5.94×10^{-4}	0.99	0.97
August	0.62	0.14	5.44	0.94×10^{-3}	-2.82	0.97
September	0.53	0.17	5.15	-2.02×10^{-4}	-4.71	0.97
October	-5.15×10^{-2}	9.01×10^{-2}	5.76	2.12×10^{-2}	15.59	0.96
November	0.24	0.86	5.83	-	-122.06	0.84
December	3.69	1.21	5.54	-	-193.59	0.75

NB. - Each equation is of the form $T = a + b(X1) + c(X2) + d(X3) + e(X4)$ where T is the mean monthly minimum temperature; $X1$ is the latitude; $X2$ is the longitude, $X3$ is the elevation (m); $X4$ is the rainfall (mm); and b to e are the appropriate regression coefficients for the month and a is the appropriate constants for the month.

Table 3:- The Selected Regression Coefficients used to predit Maximum Temperature

	Regression Coefficients for maximum temperature (° C)					
Month	b	c	$-d \times 10^{-3}$	-e	-a	R^2
January	1.14	0 40	5.60	$1,76 \times 10^{-2}$	41,45	0.96
February	2.05	0.57	6.43	$3,77 \times 10^{-2}$	77.69	0.97
March	2.18	0.60	6.92	$5,03 \times 10^{-2}$	77.87	0 98
April	2.47	0.41	7.3	2.91×10^{-2}	64.93	0 97
May	2.54	0.21	6.99	1.34×10^{-2}	49 30	0.97
June	2.20	0.21	6.31	0.60×10^{-1}	41 21	0,98
July	1.39	0 31	5.61	$0,19 \times 10^{-2}$	29.81	0.97
August	1.25	0.31	5.40	$0,11 \times 10^{-1}$	25.81	0,97
September	1 60	0.37	5.75	$0,33 \times 10^{-2}$	41.54	0,98
October	1.48	0.49	6 01	$0,86 \times 10^{-2}$	49.24	0,97
November	-0.22	0.21	0,90	$0,58 \times 10^{-2}$	17.30	0.95
December	0.12	0.28	5.27	—	2.11	0,95

NB - Each equation is the form $T = a + b(\times 1) + c(\times 2) + d(\times 3) + e(\times 4)$
where T is the mean monthly maximum temperature; X_1 is the latitude; X_2 ia the longitude;
X_3 is the elevation (m); X_4 is the rainfall (mm); b to c are the appropriate regression coefficients for the month and a is the appropriate constants for the month.

For comparison, predicted and observed mean monthly maximum and minimum temperatures for January and July for 35 stations have been studied which show that there is no fixed pattern nor trend which can identify positive or negative increments of temperature either in the Tarai, the Hill or the Mountain Regions of Nepal.

Generally, either the four months January, April, July and October or the two months January and July are the months selected to describe the spatial variation of temperature elements, but in this study, mean maximum temperatures of the hottest week and mean minimum temperatures of the coldest week have been chosen. This represents the range of temperature during the year and this is the most useful information for the selection of different species of crops.

INTERPOLATION OF WEEKLY DATA AND DERIVATION OF EXTREME MEAN VALUES

In the coldest month, January, monthly mean minimum and maximum temperatures over Nepal range from – 9.7° C to 10.8° C and from 3.8° C to 23.4° C respectively. The lowest monthly mean minimum temperature was recorded in Tengboche, 3857 m above mean sea level. Generally above that elevation the monthly mean minimum temperature will be much lower than –9.7° C.

In the hottest month mean monthly minimum and maximum temperatures range from 0.9° C to 23.9° C and from 11.9° C to 39.3° C The records show that the hottest month generally lies in the month of May in the Tarai, the Inner Tarai and the river valleys of the Hill Region, slowly the warm air from the low land affects the Hill and Mountain Regions in the following months and ultimately the hottest month lies in June or July in the Hill and Mountain Regions. The extreme maximum temperature was recorded 46.0° C which occured on 9th June 1966 at Karnali, in Far Western Nepal, and the extreme minimum temperature was –17.9° C on 15th January, 1974 at Tengboche.

Mean maximum temperatures for the hottest week and mean minimum temperatures for the coldest week are derived from the six year (1970-1975) monthly mean values using Interp 5[11] Generally estimated weekly values were derived using fourier techniques but the opportunity was taken to use a more recently developed technique which further reduced bias and error.

11. M. Hutchinson, Interp 5 and Interp 3, Division of Land Use Research, C S I R O, 1979, Canberra (private communication).

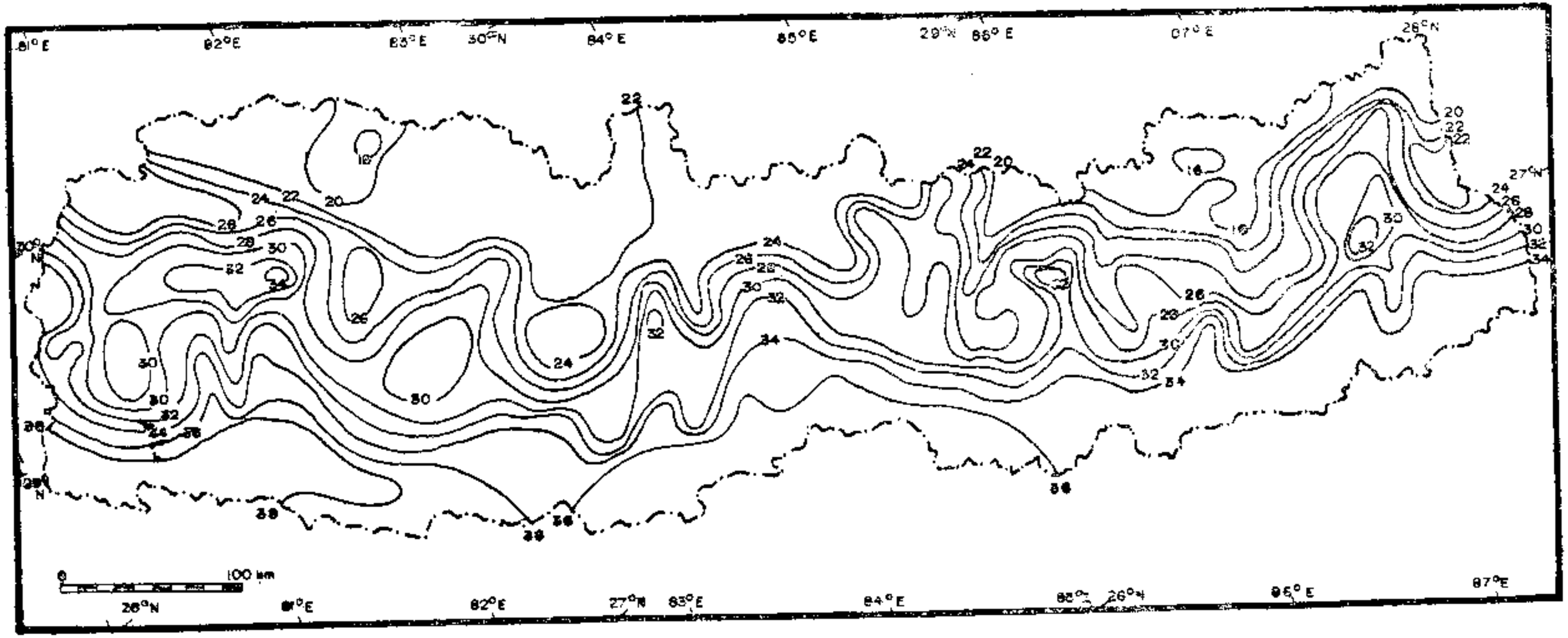


Fig. 4 Mean maximum temperature, hottest week

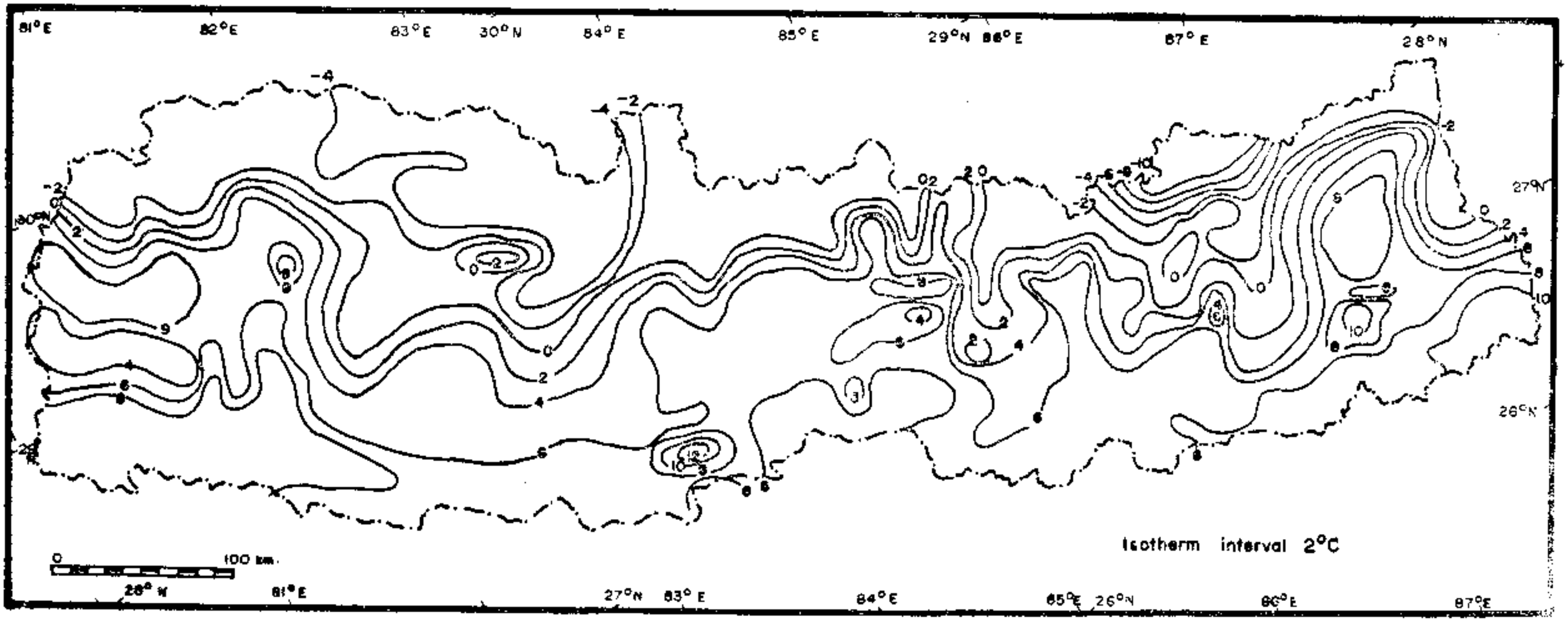


Fig. 5 Mean minimum temperature, coldest week

These derived values of mean maximum temperature of the hottest week and mean minimum temperature of the coldest week are analysed. The spatial variation of isotherms for the highest weekly maximum temperatures and the lowest weekly mean minimum temperatures are shown in Figs 4 and 5. The highest weekly maximum temperature varies from 16°C to 38°C In the Eastern Tarai the temperature is 4°C lower than the Far Western Tarai. The distribution of temperature is complex due to the complexity of landscapes. The coldest weekly minimum temperature varies from -10°C to 10°C respectively (Fig. 5). In contrast to the hottest month, the minimum temperature is highest in the Eastern Tarai exceeding that in the Western Tarai by 2°C.

By analysing highest and lowest temperatures, extreme temperatures which are hazardous for certain crops for maximum production can be determined. In other words, it helps to classify the temperature regimes in Nepal. Fig. 5 demonstrates that even in the coldest week, the mean minimum temperature is generally 8°C in the Tarai Regions. From this observation it seems that the Tarai could be a frost free zone, this is a vitally important consideration for many crops, especially tropical crops, which are frost sensitive.

DISCUSSION

The mean monthly temperature values for 168 locations in Nepal will be further used to investigate the temperature regimes and crop growth studies. In addition, mean monthly maximum and minimum temperatures for 168 locations can be used individually to discuss the temperature pattern at each location. Furthermore, if its geographical co-ordinates are known, mean monthly maximum and minimum temperatures can be predicted in any place in Nepal, but caution should be taken in extrapolating the data, because, for example, the minimum temperature on the valley floor could be higher than the ridges due to valley air drainage. This error is due in part to the ommission of temperature inversions, slope aspects, cloud incidence and vegetation. However the major factors are inversions which are common in the winter months, resulting in nocturnal air drainage and radiational fog.