ICIMOD

CLIMATIC AND HYDROLOGICAL ATLAS OF NEPAL

International Centre for Integrated Mountain Development
Kathmandu, Nepal
1996

Printed at:
Nepal Lithographing Co. Pvt. Ltd.
Goldhunga (Balaju), Kathmandu, Nepal.
Tel: 227975 Fax: 413641

Climatic and Hydrological Atlas of Nepal

Mountain Natural Resources' Division
International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu, Nepal

1996

ISBN 92-9115-600-0

Published by
International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu,
Nepal

Typesetting at ICIMOD Publications' Unit

Climatic and Hydrological Atlas of Nepal

A Project Undertaken by ICIMOD under Its Programme on Landslide Hazard Management and Control with the Assistance of the Government of Japan

Suresh R. Chalise
Mountain Natural Resources' Division, ICIMOD

Madan L. Shrestha
HMG, Department of Hydrology and Meteorology

Khadga B. Thapa
Central Department of Meterology
Tribhuvan University, Kathmandu

Basanta R. Shrestha
MENRIS, ICIMOD

Birendra Bajracharya
MENRIS, ICIMOD

Abbreviations

DHM	Department of Hydrology and Meteorology
HMG/N	His Majesty's Government of Nepal
ICIMOD	International Centre for Integrated Mountain Development
MENRIS	Mountain Environment and Natural Resources' Information Service
UTC	Universal Time Coordinated (Equivalent to GMT)
WMO	World Meteorological Organisation

Foreword

Climate plays a very important part in the life of the people, particularly in the harsh and high mountain environments and hilly slopes of the Hindu Kush-Himalayas (HKH). Apart from its influence on agricultural and sociocultural practices, it also acts as a cyclical triggering factor for various natural disasters in the mountains. Whether as a causative factor in Glacial Lake Outburst Floods in the higher altitude snowy regions, or in landslides and debris flows in the middle hills or floods in the lower basins, climatic factors play a very important role. These disasters cause regularly widespread damage to life and property all over the HKH and also destroy vital infrastructure such as roads, bridges, and power plants built at substantial cost. For both agriculture and tourism, which are so important for the people and economy of the region, climate is of critical importance too. The wide climatic variety in this region, both from south to north and from east to west, contributes also to its great biological and ecological diversity.

Recently, the frequency of occurrence of extreme weather events has been found to be on the increase in these mountains. Again, one of the principal climatic parameters - viz., precipitation and its seasonal character, greatly influences the hydrological regimes of the glaciers, rivers, and streams and determines the degree of availability of water in different seasons.

Both climatic and hydrological information are equally important and indispensible for planning for and development of agriculture, modern infrastructure, and tourism. Thus, for all of us engaged in the search for ecological and economically sustainable development of the HKH mountains as well as sustainable options for better livelihoods for the people inhabiting these mountains, the importance of climatic and hydrological information cannot be overemphasised.

Since its inception, ICIMOD has been promoting the development of a better understanding of natural hazards. Various activities have been completed so far, and these include several training programmes dealing with mountain risk engineering, focussing on improving road construction along unstable mountain slopes, and reviews of landslide hazard management activities in China, India, Nepal, and Pakistan.

One of the goals set by ICIMOD in its Regional Collaborative Programme for the Sustainable Development of the Hindu Kush-Himalayas under its Mountain Natural Resources' Programme is to improve the conditions of mountain resources and environments through various programme activities including:

- a better understanding of mountain hazards and identification of mitigation measures; and
- a better understanding of mountain climatic changes.

ICIMOD's programme on "Landslide Hazard Management and Control" focusses on these concerns and the relationships between mountain climate, mountain hydrology, and natural hazards in the Hindu Kush-Himalayas. This programme, which was developed on the basis of the previous activities of ICIMOD in the field, has received support from the Government of Japan since the end of 1993.

The unprecedented intense rainfall that took place during July 1993 caused a terrible disaster in south-central Nepal. ICIMOD undertook a field study of this disastrous event. The results of this study were presented at a special workshop in November 1993 in which the National Planning Commission and key institutions from Nepal concerned with natural hazards participated. One of the major recommendations of this national workshop was the need for ICIMOD to prepare a Climatic Atlas for Nepal, and this provided the main incentive for producing this Atlas.

The Atlas is the result of fruitful and close collaboration between ICIMOD and the Department of Hydrology and Meteorology (DHM) of the Ministry of Water Resources of His Majesty's Government of Nepal and the Central Department of Meteorology of Tribhuvan University, Nepal. All the relevant data for its preparation were made available by DHM and both the institutions also made available the services of their experts for this project.

This work is also an example of inter-divisional collaboration between different divisions and services of ICIMOD. It was undertaken by the Mountain Natural Resources' Division of ICIMOD within its programme on Mountain Risks and Hazards and Mountain Hydrology and Climate Change under the project on Landslide Hazard Management and Control. The Mountain Environment and Natural Resources' Information Service (MENRIS) provided all the technical inputs for preparation and printing of the maps. The financial support of the Government of Japan is gratefully acknowledged. The Mountain Environment and Natural Resources' Information Service (MENRIS) of ICIMOD provided all the technical assistance for the analysis of data (furnished by the DHM and other line agencies in Nepal). MENRIS also carried out the spatial analysis that has been presented in the form of maps which can be visualised as an excellent representation of the existing information in a comprehensive manner. It is hoped that such visualisation can be widely used for planning the use of natural resources for sustainable development.

Considering the multifarious needs of climatic and hydrologic information for various sectors and development activities, it is hoped that this Atlas will be a useful addition to the knowledge and information on the climate and hydrology of Nepal. Hopefully, it will serve as a useful guide and reference material not only for planners and technical experts but also for general readers who are interested in the climate and hydrology of Nepal. It is also hoped that it may help to reduce the impact of extreme weather events on life and property.

Thanks are due to all those who worked in various capacities to complete this Atlas. Any comments and suggestions for its improvement are most welcome and will help us to improve this and similar work undertaken for other countries of the Hindu Kush-Himalayas.

Egbert Pelinck
Director General

Preface

This Atlas has two sections. The first section contains the climatic maps and diagrammes. A brief introduction to these two sections follows. Explanatory notes on each thematic map and chart for each section are provided at the end. For easy reference, a transparency with district boundaries and major towns and cities is provided with this Atlas. This is placed in a folder inside the back cover.

All the meteorological and hydrological data were made available by the Department of Hydrology and Meteorology of the Ministry of Water Resources of His Majesty's Government of Nepal.

Climate, in general terms, is the summary of the day-to-day weather in any place or region which affects the daily life of the inhabitants. In a country like Nepal, dominated by mountains, the study of climate requires access to records of meteorological parameters and networking among many stations over a long period of time. According to the World Meteorological Organisation (WMO), a standard average of 30 years of continuous records is considered normal. Unfortunately, only a few stations in Nepal have records for such a long period of time, mainly due to the topographical and also, of course, owing to the economic constraints. Natural phenomena such as droughts, floods, heat waves, and cold spells can only be studied with reference to climatic norms. Such studies are important in planning for the socioeconomic development of the country.

In this atlas, available data based on meteorological parameters, such as temperature, precipitation, relative humidity, duration of sunshine, and frequency of fog, are used to prepare the climatic maps and diagrammes. The database used here includes climatic data for some stations commencing in 1947 and ending in 1990. The period for which records are available for different meteorological parameters is not the same for all stations. For example, for the precipitation maps the number of stations used is 264 with records for more than five years. It is to be noted that, among these, there are 13 stations with records going back less than 10 years. According to the WMO standard, precipitation records for 30 years or more are needed to prepare a normal climatological map for precipitation. In Nepal, there are only 89 stations with precipitation records going back 30 years and more. Therefore, to produce a spatially normal climatological map, many other stations with records going back less than 30 years have been included. This scarcity of data is evident in all other meteorological parameters. As mentioned in the explanatory notes, in preparing maps some compromises have been made between the number of stations and the number of years of record, without, of course, losing the main characteristics of the parameters.

In the case of temperature, which is in general controlled by variables such as elevation, latitude and longitude, a model has been developed so that temperature can be generated from information about the elevation, latitude, and longitude. This aspect has been covered in the explanatory notes.

In preparing the climatic maps, actual averages are used, except in the case of temperature for which the data generated, as mentioned above, are being used.. During the computer analysis and mapping procedures, software packages such as Win-surfer and GIS-arc/info were used. The Programme Win-Surfer was used for the preparation of a digital surface that could generate regions for various climatic and hydrological parameters, e.g., temperature, precipitation, humidity, sunshine duration, and fog frequency. The GIS analysis was carried out using the work-station version of ARC/Info on an IBM RISC 6000 platform which involved integration of such digital surfaces with relevant attribute data. Finally, the automated maps thus prepared were printed using the latest Tektronix Colour Printer.

In the hydrologic section, the availability of data is still more limited. Prior to 1960, very little work on hydrology was carried out in Nepal. The Swiss Mission had collected data for the Rosi Khola at Panauti. The Government of India had collected data for the Trisuli River at the proposed power site, for the Koshi River at Barahkshetra, and for the Sarada River at Banbasa. However, the data were only available for those agencies that collected the data.

Detailed hydrologic surveys and investigations began on November 17, 1960, following an agreement between His Majesty's Government (HMG) and the United Nations Development Programme. A systematic hydrological data collection network was established in 1962, following an agreement between HMG and the United States Agency for International Development (USAID). This marked the beginning of the establishment of the present Department of Hydrology and Meteorology.

Thus, Nepal has a relatively short history in the field of hydrology. A systematic hydrologic data collection network was introduced only in 1962, the main obstacles being remoteness of gauging sites and economic constraints. Because of data constraints, the hydrologic section of the climatic atlas, therefore, consists of maps and figures that give general information only for some drainage basins and rivers.

The river network map shows the main catchment boundaries and regularly operating stations, including stations that have been operating for at least ten years. River characteristics such as: i) hydrographic schemes for three major river systems, ii) drainage density, iii) monthly distribution of flow for different types of rivers, iv) water availability for rivers on an annual as well as on a seasonal basis, and the v) average monthly flow and average annual flow for major rivers are included. The water balance is presented for some typical stations only.

High and low flows are also important hydrologic information for planning water resources' projects. The flow duration curves for typical Himalayan rivers like the Karnali have been presented. Estimated and recorded high flows in Nepal have been plotted on envelope curves together with those from other regions of the world for comparison. Flood frequency curves have also been presented for some rivers. Rivers at higher altitudes and those originating in the Siwalik ranges have not been included due to inconsistency in data.

In both sections, individual maps do not provide information on the location of towns, districts, or prominent peaks. A transparency containing this information has been provided, and it can be overlaid on all the maps; it is placed in an envelope inside the back cover.

This work took longer to complete than anticipated. This was due to the fact that colour schemes were revised following comments and suggestions received on the first draft. It is hoped that colour schemes will be further improved in the next edition.

In addition to the principal members, the project team also consisted of other experts and individuals without whose contributions and inputs this Atlas could not have been completed. Mr. Kiran Shankar Yogacharya, presently Director General, Department of Hydrology and Meteoroogy, Nepal, provided substantial inputs in the preparation of the hydrological section of the Atlas. Similarly, Dr. Bidur P. Upadhyaya, Professor and Head, Central Department of Meteorology, Tribhuvan University, Kathmandu, has also contributed significantly to the hydrological section of the Atlas. Mr. Lochan M. Acharya, presently Deputy Director General, Department of Hydrology and Meteorology, Nepal, has contributed to the Climatic Section. Messers Ratna P. Nayaju, Mani R. Chitrakar, Sarju Baidya, Ramesh K. Regmi, Gautam Rajkarnikar, and Ms.Samita Shrestha of the Department of Hydrology and Meteorology also provided inputs to the preparation of this Atlas. Mr. Govind Joshi of MENRIS, ICIMOD, provided excellent support in computer processing throughout the work period.

For most of the project team members, it was a learning process in working together, as the team consisted of members drawn from various institutions, most of whom were not on a full-time basis, and the demands of parent institutions could not be ignored. However, the lessons have been valuable and all the members of the project team have contributed their best to complete this work. It is hoped that this Atlas will be of some use not only to planners and development practitioners engaged in the development of Nepal, but also to researchers and students interested in the climate and hydrology of Nepal. Comments and suggestions for improvement are expected from readers and will be incorporated in the next edition.

Suresh R. Chalise
Project Team Leader

Acknowledgements

This project was undertaken with financial assistance from the Government of Japan. The excellent support and cooperation from His Majesty's Government of Nepal, Ministry of Water Resources, Department of Hydrology and Meteorology, and Tribhuvan University, Department of Meteorology, throughout the project period in providing the necessary data and the services of their experts and staff were critical to the successful completion of this project. Thanks are due to the members of the Advisory Committee who provided valuable inputs and guidance at all stages of the Project. Thanks are also due to Dr. Harka Gurung, Director, Asia and Pacific Development Centre (APDC); Prof. M. S. Manandhar, Head, Central Department of Geography, Tribhuvan University; and Dr. M. Spreafico, Swiss National Hydrological and Geological Survey for reviewing the Atlas and providing their valuable comments and suggestions for its improvement. Thanks are also due to Dr. Rolf Weingartner, Department of Geography, University of Berne, for his valuable comments and inputs during the course of the preparation of this Atlas.

The project could not have been completed without the encouragement and valuable inputs and advice from Mr. Egbert Pelinck, Director General, and Dr. Mahesh Banskota, Deputy Director General of ICIMOD. Suggestions and comments from all the professional staff of ICIMOD were available during the preparation of this Atlas and specific comments from Mr. Hubert Trapp (MENRIS) and Mr. P. B. Shah (MNR) were helpful in finalising it. Thanks are also due to Mr. Narendra Khanal, Lecturer, Central Department of Geography, for his comments and suggestions at various stages during the preparation of this document.

Mrs. Reeta Rana and Mrs. Sarita Joshi of MNR Division, ICIMOD, provided secretarial support with patience and speed during the preparation of this document. The Publications' staff of ICIMOD's Documentation, Information, and Training Service looked after the editing and preparation for printing.

The project has also benefitted from the comments and suggestions from several experts from Nepal and abroad whose names are not mentioned but to whom grateful thanks and acknowledgement are due.

Advisory Committee

Dr. Mahesh Banskota
Deputy Director General
ICIMOD

Dr. Hari Man Shrestha
Senior Adviser
HMG, Ministry of Water Resources
Water and Energy Commission Secretariat

Dr. Sharad P. Adhikary
Executive Director
HMG, Ministry of Water Resources
Water and Energy Commission Secretariat

Mr. Hidetomi Oi
Chief Technical Adviser (JICA)
HMG, Ministry of Water Resources
Water Induced Disaster Prevention Technical Centre (DPTC),

Dr. Pitamber Sharma
Mountain Enterprises and Infrastructure Division
ICIMOD

Mr. Pramod S. Pradhan
Head
Mountain Environmental and Natural Resources' Information System (MENRIS)
ICIMOD

Prof. Suresh R. Chalise
Mountain Natural Resources' Division
ICIMOD

Contents

SECTION 2 - **Hydrologic Maps/Figures** 223

Section 1
Climatic Maps

List of Meteorological Station

Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
0101	Kakerpakha	842	29°39'	80°30'
0102	Baitadi	1635	29°33'	80°25'
0103	Patan (West)	1266	29°28'	80°32'
0104	Dadeldhura	1865	29°18'	80°35'
0105	Mahendra Nagar	176	29°02'	80°13'
0106	Belauri Shantipur	159	28°41'	80°21'
0107	Darchula	1097	29°51'	80°34'
0108	Satbanjh	2370	29°32'	80°28'
0201	Pipalkot	1456	29°37'	80°52'
0202	Chainpur (West)	1304	29°33'	81°13'
0203	Silgadhi Doti	1360	29°16'	80°59'
0204	Bajura	1400	29°23'	81°19'
0205	Katai	1388	29°00'	81°08'
0206	Asara Ghat	650	28°57'	81°27'
0207	Tikapur	140	28°30'	80°57'
0208	Sandepani	195	28°45'	80°55'
0209	Dhangadhi	170	28°41'	80°36'
0210	Bangga Camp	340	28°58'	81°07'
0212	Sitapur	152	28°34'	80°49'
0214	Kola Gaun	1304	29°07'	80°41'
0215	Godavari (West)	288	28°52'	80°38'
0217	Mangalsen	1345	29°09'	81°17'
0218	Dipayal (Doti)	617	29°15'	80°57'
0301	Mugu	3803	29°45'	82°33'
0302	Thirpu	1006	29°19'	81°46'
0303	Jumla	2300	29°17'	82°10'
0304	Guthi Chaur	3080	29°17'	82°19'
0305	Sheri Ghat	1210	29°08'	81°36'

Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
0306	Gam Shree Nagra	2133	29°33'	82°09'
0307	Rara	3048	29°33'	82°07'
0308	Nagma	1905	29°12'	81°54'
0309	Bijayapur (Raskot)	1814	29°14'	81°38'
0310	Dipal Gaun	2310	29°16'	82°13'
0311	Simikot	2800	29°58'	81°50'
0312	Dunai	2058	28°56'	82°55'
0313	Darma	1950	29°44'	82°06'
0401	Pusma Camp	950	28°53'	81°15'
0402	Dailekh	1402	28°51'	81°43'
0403	Jamu (Tikuwa Kuna)	260	28°47'	81°20'
0404	Jajarkot	1231	28°42'	82°12'
0405	Chisapani (Karnali)	225	28°39'	81°16'
0406	Surkhet (Birendra Nagar)	720	28°36'	81°37'
0407	Kusum	235	28°01'	82°07'
0408	Gulariya	215	28°10'	81°21'
0409	Khajura (Nepalganj)	190	28°06'	81°34'
0410	Bale Budha	610	28°47'	81°35'
0411	Rajapur	129	28°26'	81°06'
0412	Naubasta	135	28°16'	81°43'
0413	Shyano Shree	302	28°27'	81°35'
0414	Baijapur	226	28°03'	81°54'
0415	Bargadaha	200	28°26'	81°21'
0416	Nepalgunj (Reg. Off.)	144	28°04'	81°37'
0417	Rani Jaruwa Nursery	200	28°23'	81°21'
0418	Maina Gaun (D. Bas)	2000	28°59'	82°17'
0419	Sikta	195	28°02'	81°47'
0501	Rukumkot	1560	28°36'	82°38'

Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
0502	Shera Gaun	2150	28°35'	82°49'
0504	Libang Gaun	1270	28°18'	82°38'
0505	Bijuwar Tar	823	28°06'	82°52'
0507	Nayabasti (Dang)	698	28°13'	82°07'
0508	Tulsipur	725	28°08'	82°18'
0509	Ghorahi (Masina)	725	28°03'	82°30'
0510	Koilabas	320	27°42'	82°32'
0511	Salyan Bazar	1457	28°23'	82°10'
0512	Luwamjula Bazar	885	28°18'	82°17'
0513	Chaur Jahari Tar	910	28°38'	82°12'
0514	Musikot (Rukumkot)	2100	28°38'	82°29'
0601	Jomsom	2744	28°47'	83°43'
0604	Thakmarpha	2566	28°45'	83°42'
0605	Baglung	984	28°16'	83°36'
0606	Tatopani	1243	28°29'	83°39'
0607	Lete	2384	28°38'	83°36'
0608	Ranipauwa (M. Nath)	3609	28°49'	83°53'
0609	Beni Bazar	835	28°21'	83°34'
0610	Ghami (Mustang)	3465	29°03'	83°53'
0612	Mustang (Lomanthang)	3705	29°11'	83°58'
0613	Karki Neta	1720	28°11'	83°45'
0614	Kushma	891	28°13'	83°42'
0615	Bobang	2273	28°24'	83°06'
0616	Gurja Khani	2530	28°36'	83°13'
0619	Ghorapani	2742	28°24'	83°44'
0701	Ridi Bazar	442	27°57'	83°26'
0702	Tansen	1067	27°52'	83°32'
0703	Butwal	205	27°42'	83°28'

Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
0704	Beluwa (Girwari)	150	27°41'	84°03'
0705	Bhairahawa Airport	109	27°31'	83°26'
0706	Dumkauli	154	27°41'	84°13'
0707	Bhairahawa (Agric)	120	27°32'	83°28'
0708	Parasi	125	27°32'	83°40'
0710	Dumkibas	164	27°35'	83°52'
0715	Khanchikot	1760	27°56'	83°09'
0716	Taulihawa	94	27°33'	83°04'
0721	Pattharkot (West)	200	27°46'	83°03'
0722	Musikot	1280	28°10'	83°16'
0723	Bhagwanpur	80	27°41'	82°48'
0725	Tamghas	1530	28°04'	83°15'
0726	Garakot	500	27°52'	83°48'
0727	Lumbini	95	27°28'	83°17'
0728	Simari	154	27°32'	83°45'
0801	Jagat (Setibas)	1334	28°20'	84°54'
0802	Khudi Bazar	823	28°17'	84°22'
0803	Pokhara (Hospital)	866	28°14'	84°00'
0804	Pokhara Airport	827	28°13'	84°00'
0805	Syangja	868	28°06'	83°53'
0806	Larke Samdo	3650	28°40'	84°37'
0807	Kunchha	855	28°08'	84°21'
0808	Bandipur	965	27°56'	84°25'
0809	Gorkha	1097	28°00'	84°37'
0810	Chapkot	460	27°53'	83°49'
0811	Malepatan (Pokhara)	856	28°13'	83°57'
0813	Bhadaure Deurali	1600	28°16'	83°49'
0814	Lumle	1740	28°18'	83°48'

Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
0815	Khairini Tar	500	28°02'	84°06'
0816	Chame	2680	28°33'	84°14'
0817	Damauli	358	27°58'	84°17'
0818	Lamachaur	1070	28°16'	83°58'
0820	Manang Bhot	3420	28°40'	84°01'
0821	Ghandruk	1960	28°23'	83°48'
0823	Gharedhunga	1120	28°12'	84°37'
0824	Siklesh	1820	28°22'	84°06'
0902	Rampur	256	27°37'	84°25'
0903	Jhawani	270	27°35'	84°32'
0904	Chisapani Gadhi	1706	27°33'	85°08'
0905	Daman	2314	27°36'	85°05'
0906	Hetaunda N.F.I.	474	27°25'	85°03'
0907	Amlekhganj	396	27°17'	85°00'
0909	Simara Airport	130	27°10'	84°59'
0910	Nijgadh	244	27°17'	85°10'
0911	Parwanipur	115	27°04'	84°58'
0912	Ramoli Bairiya	152	27°01'	85°23'
0917	Hetaunda (Ind.Dis)	466	27°26'	85°02'
0918	Birganj	91	27°00'	84°52'
0919	Makwanpur Gadhi	1030	27°25'	85°10'
0920	Beluwa	274	27°30'	84°45'
0921	Kalaiya	140	27°02'	85°00'
0922	Gaur	90	26°46'	85°18'
1001	Timure	1900	28°17'	85°26'
1002	Aru Ghat D. Bazar	518	28°03'	84°49'
1003	Trishuli	595	27°55'	85°09'
1004	Nuwakot	1003	27°55'	85°10'

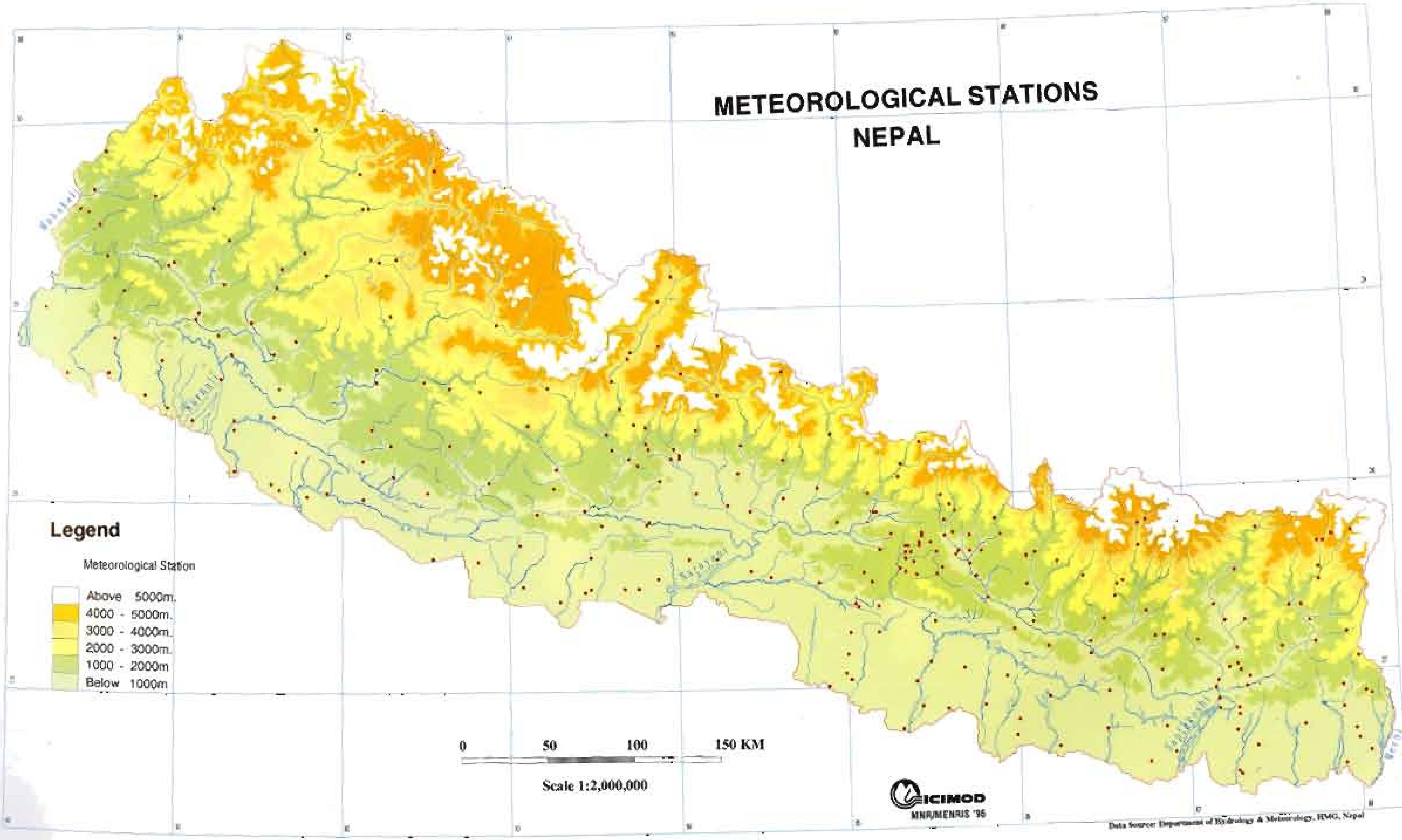
Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
1005	Dhading	1420	27°52'	84°56'
1006	Gumthang	2000	27°52'	85°52'
1007	Kakani	2064	27°48'	85°15'
1008	Nawalpur	1592	27°48'	85°37'
1009	Chautara	1660	27°47'	85°43'
1011	Kathmandu (USAID)	1335	27°42'	85°20'
1012	Sundarijal (Pwr. House)	1364	27°45'	85°25'
1013	Sundarijal (Water Res.)	1576	27°47'	85°26'
1014	Kathmandu (I.E.)	1324	27°44'	85°20'
1016	Sarmathang	2625	27°57'	85°36'
1017	Dubachaur	1550	27°52'	85°34'
1018	Bahunepati	845	27°47'	85°34'
1020	Mandan	1365	27°42'	85°39'
1022	Godavari	1400	27°35'	85°24'
1023	Dolal Ghat	710	27°38'	85°43'
1024	Dhulikhel	1552	27°37'	85°33'
1025	Dhap	1240	27°55'	85°38'
1027	Bahrabise	1220	27°47'	85°54'
1028	Pachuwar Ghat	633	27°34'	85°45'
1029	Khumaltar	1350	27°40'	85°20'
1030	Kathmandu Airport	1336	27°42'	85°22'
1035	Sankhu	1449	27°45'	85°29'
1036	Panchkhal	865	27°41'	85°38'
1038	Dhunibesi	1085	27°43'	85°11'
1039	Panipokhari (Kathmandu)	1335	27°44'	85°21'
1043	Nagarkot	2163	27°42'	85°31'
1047	Pharping	1500	27°37'	85°18'
1049	Khopasi (Panauti)	1517	27°35'	85°31'

Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
1052	Bhaktapur	1330	27°44'	85°25'
1054	Thamachit	1847	28°10'	85°19'
1055	Dhunche	1982	28°06'	85°18'
1056	Tokha	1790	27°48'	85°26'
1057	Pansayakhola	1240	28°01'	85°07'
1058	Tarke Ghyang	2480	28°00'	85°33'
1059	Changu Narayan	1543	27°45'	85°25'
1060	Chapa Gaun	1448	27°36'	85°20'
1061	Lubhu	1341	27°39'	85°23'
1062	Sangachok	1327	27°42'	85°43'
1063	Thokarpa	1750	27°42'	85°47'
1101	Nagdaha	850	27°41'	86°06'
1102	Charikot	1940	27°40'	86°03'
1103	Jiri	2003	27°38'	86°14'
1104	Melung	1536	27°31'	86°03'
1106	Ramechhap	1395	27°19'	86°05'
1107	Sindhuli Gadhi	1463	27°17'	85°58'
1108	Bahun Tilpung	1417	27°11'	86°10'
1109	Pattharkot (East)	275	27°05'	85°40'
1110	Tulsi	457	27°02'	85°55'
1111	Janakpur Airport	90	26°43'	85°58'
1112	Chisapani Bazar	165	26°55'	86°10'
1114	Hardinath	93	26°48'	85°59'
1115	Nepalthok	1098	27°27'	85°49'
1116	Hariharpur Gadhi	880	27°20'	85°30'
1117	Hariharpur Gadhi Valley	250	27°20'	35°30'
1118	Manusmara	100	26°53'	85°25'
1119	Gausala	200	26°53'	85°47'

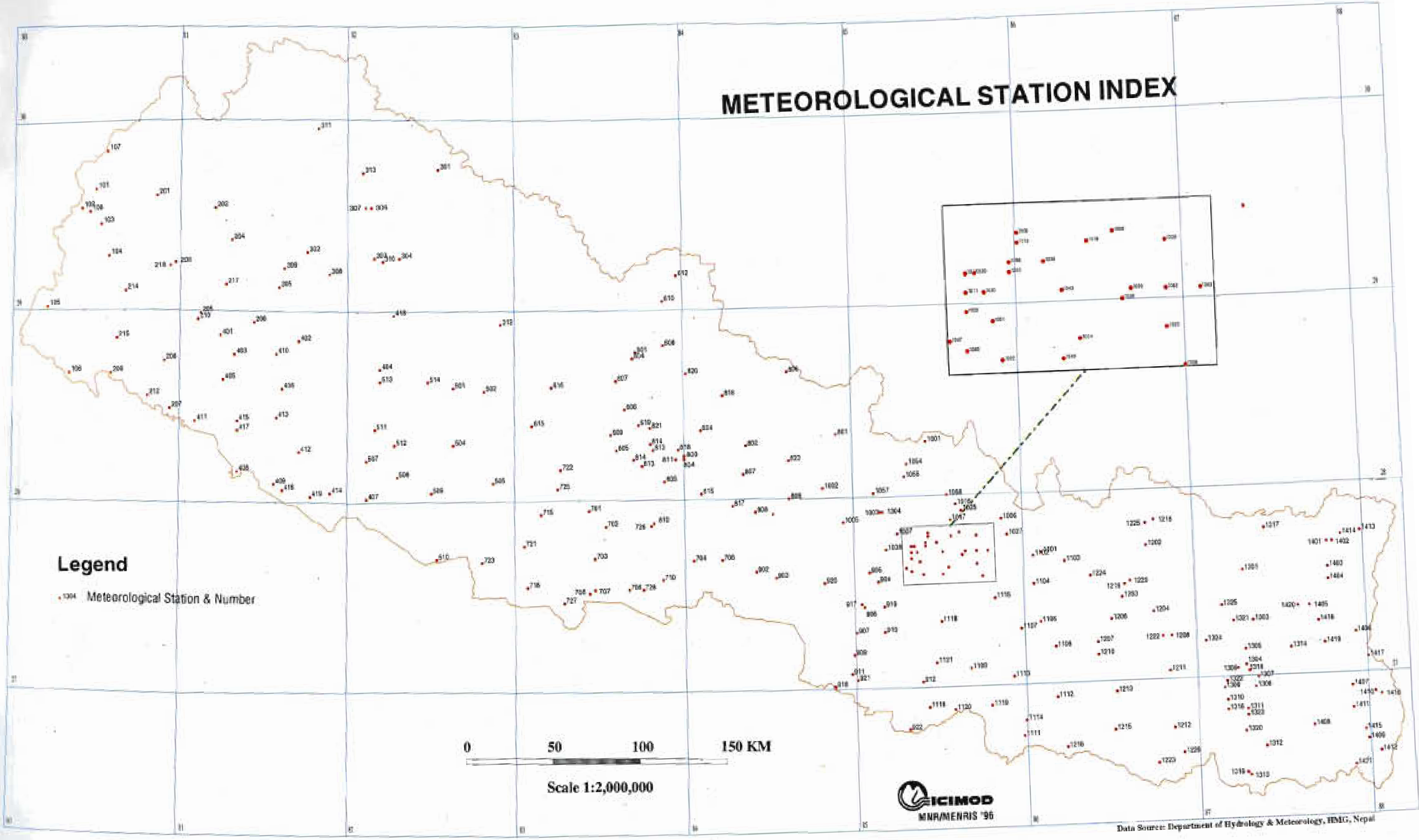
Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
1120	Malangwa	150	26°52'	85°34'
1121	Karmaiya	131	27°07'	85°28'
1201	Namche Bazar	3450	27°49'	86°43'
1202	Chaurikhark	2619	27°42'	86°43'
1203	Pakarnas	1982	27°26'	86°34'
1204	Aiselukhark	2143	27°21'	86°45'
1206	Okhaldhunga	1720	27°19'	86°30'
1207	Mane Bhanjyang	1576	27°12'	86°25'
1208	Dwarpa	1829	27°13'	86°51'
1210	Kurule Ghat	497	27°08'	86°25'
1211	Khotang Bazar	1295	27°02'	86°50'
1212	Phattepur	100	26°44'	86°51'
1213	Udayapur Gadhi	1175	26°56'	86°31'
1215	Lahan	138	26°44'	86°30'
1216	Siraha	102	26°39'	86°13'
1217	Khumjung	3750	27°49'	86°43'
1218	Tengboche	3857	27°50'	86°46'
1219	Salleri	2378	27°30'	86°35'
1220	Chyalsa	2770	27°31'	86°37'
1222	Diktel	1623	27°13'	86°48'
1223	Rajbiraj	91	26°33'	86°45'
1224	Sirwa	1662	27°33'	86°23'
1225	Syangboche	3700	27°49'	86°43'
1226	Barmajhiya	85	26°36'	86°54'
1301	Num	1497	27°33'	87°17'
1303	Chainpur (East)	1329	27°17'	87°20'
1304	Pakhribas	1680	27°03'	87°17'
1305	Leguwa Ghat	410	27°08'	87°17'

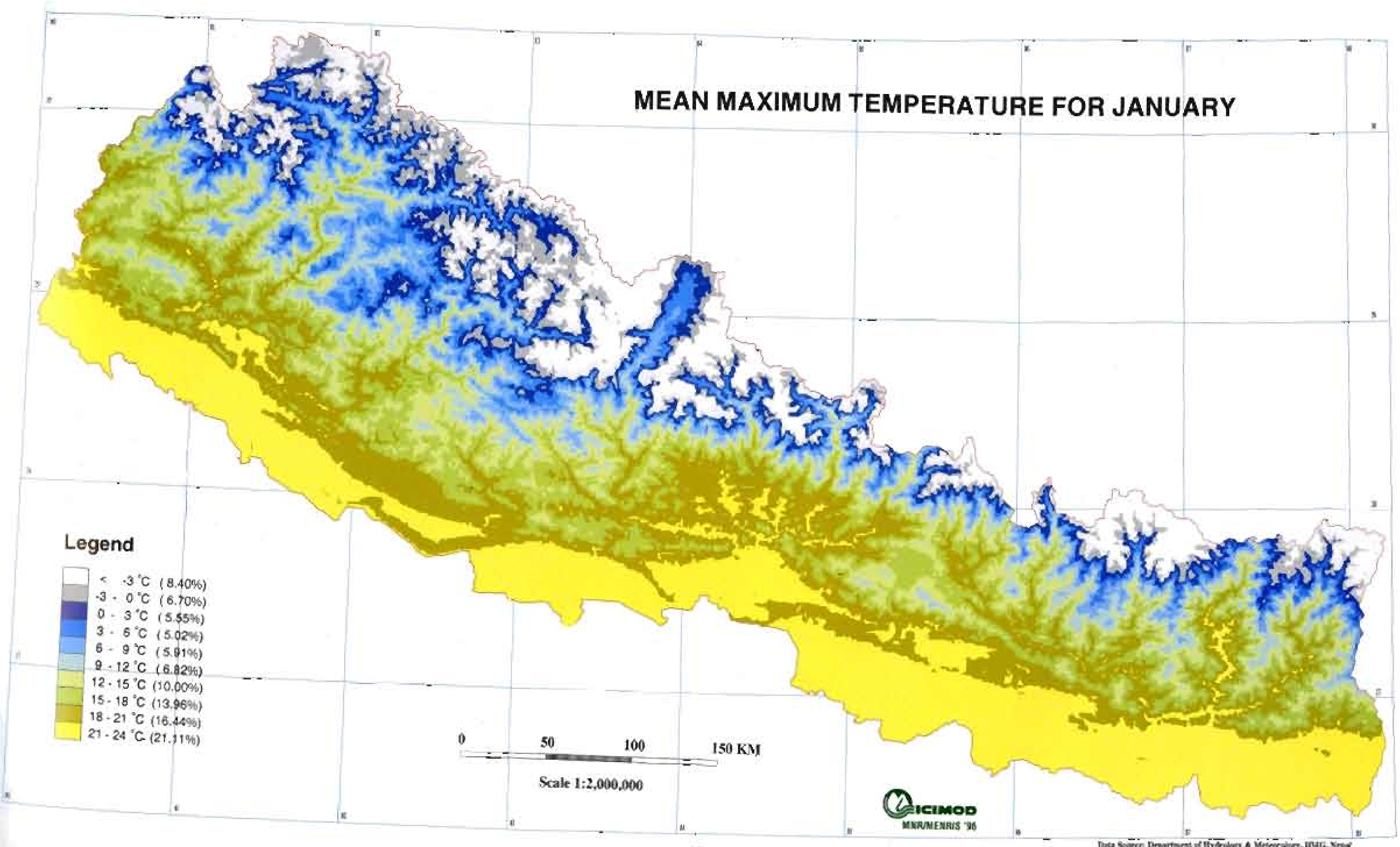
Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
1306	Munga	1317	27°02'	87°14'
1307	Dhankuta	1445	26°59'	87°21'
1308	Mul Ghat	365	26°56'	87°20'
1309	Tribeni	143	26°56'	87°09'
1310	Barahkshetra	146	26°52'	87°10'
1311	Dharan Bazar	444	26°49'	87°17'
1312	Haraincha	152	26°37'	87°23'
1313	Biratnagar (City)	67	26°28'	87°17'
1314	Terhathum	1633	27°49'	87°33'
1316	Chatara	183	26°49'	87°10'
1317	Chepuwa	2590	27°46'	87°25'
1318	Paripatle (Horti)	1364	27°01'	87°18'
1319	Biratnagar Airport	72	26°29'	87°16'
1320	Tarahara	200	26°42'	87°16'
1321	Tumlingtar	303	27°17'	87°13'
1322	Machuwaghat	158	26°58'	87°10'
1323	Dharan British Camp	400	26°47'	87°17'
1324	Bhojpur	1595	27°11'	87°03'
1325	Dingla	1190	27°22'	87°09'
1401	Olangchung Gola	3119	27°41'	87°47'
1402	Pangthung Doma	2818	27°41'	87°49'
1403	Lungthung	1780	27°33'	87°47'
1404	Taplethok	1383	27°29'	87°47'
1405	Taplejung	1732	27°21'	87°40'
1406	Memeng Jagat	1830	27°12'	87°56'
1407	Ilam Tea Estate	1300	26°55'	87°54'
1408	Damak	163	26°43'	87°40'
1409	Anarmani Birta	122	26°38'	87°59'

Index No.	Station	Elevation (m)	Latitude (N)	Longitude (E)
1410	Himali Gaun	1654	26°53'	88°02'
1411	Soktim Tea Estate	530	26°48'	87°54'
1412	Chandra Gadhi	120	26°34'	88°03'
1413	Khamachin	4242	27°44'	87°59'
1414	Nup	4000	27°43'	87°52'
1415	Sanischare	168	26°41'	87°58'
1416	Kanyam Tea Estate	1678	26°52'	88°04'
1417	Jaubari	3050	27°04'	88°00'
1418	Angbung	1219	27°16'	87°43'
1419	Phidim (Panchthar)	1205	27°09'	87°45'
1420	Dovan	763	27°21'	87°36'
1421	Gaida (Kankai)	143	26°30'	87°54'

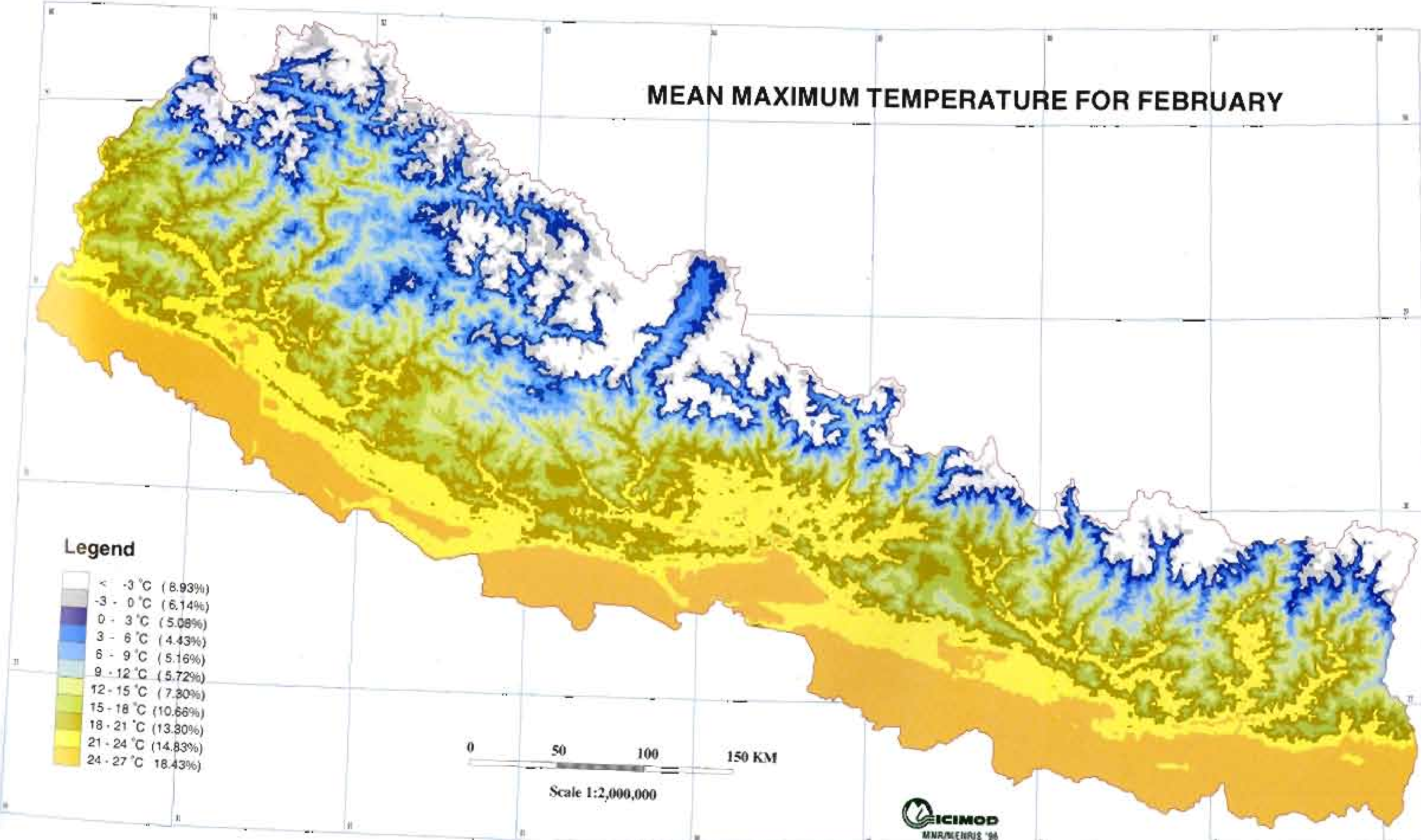


METEOROLOGICAL STATIONS
NEPAL
Legend
Meteorological Station
Above 5000m.
4000 - 5000m.
3000 - 4000m.
2000 - 3000m.
1000 - 2000m
Below 1000m
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

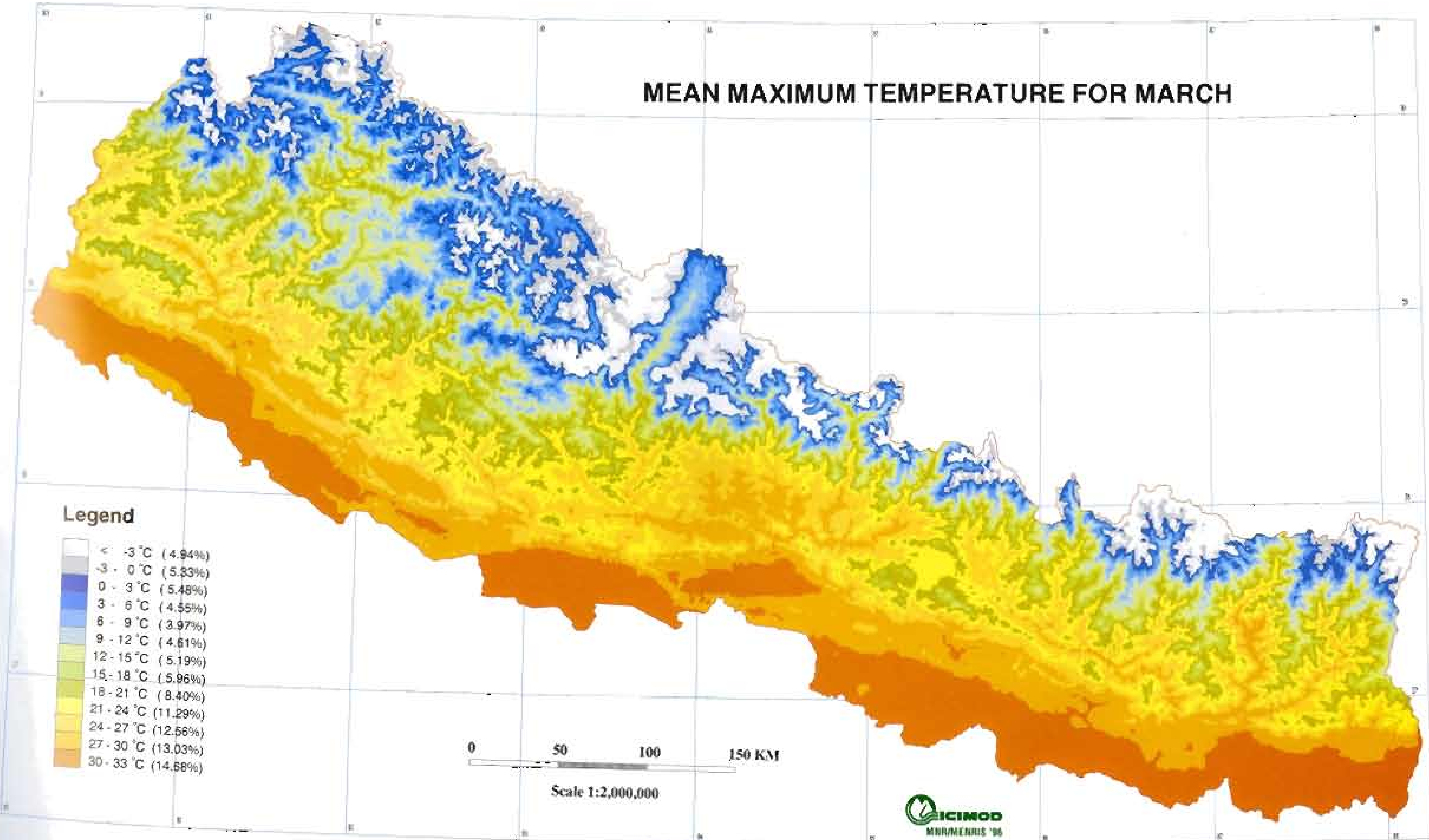

METEOROLOGICAL STATION INDEX
Legend
Meteorological Station & Number
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN MAXIMUM TEMPERATURE FOR JANUARY
Legend
< -3 °C (8.40%)
-3 - 0 °C (6.70%)
0 - 3 °C (5.55%)
3 - 6 °C (5.02%)
6 - 9 °C (5.91%)
9 - 12 °C (6.82%)
12 - 15 °C (10.00%)
15 - 18 °C (13.96%)
18 - 21 °C (16.44%)
21 - 24 °C (21.11%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

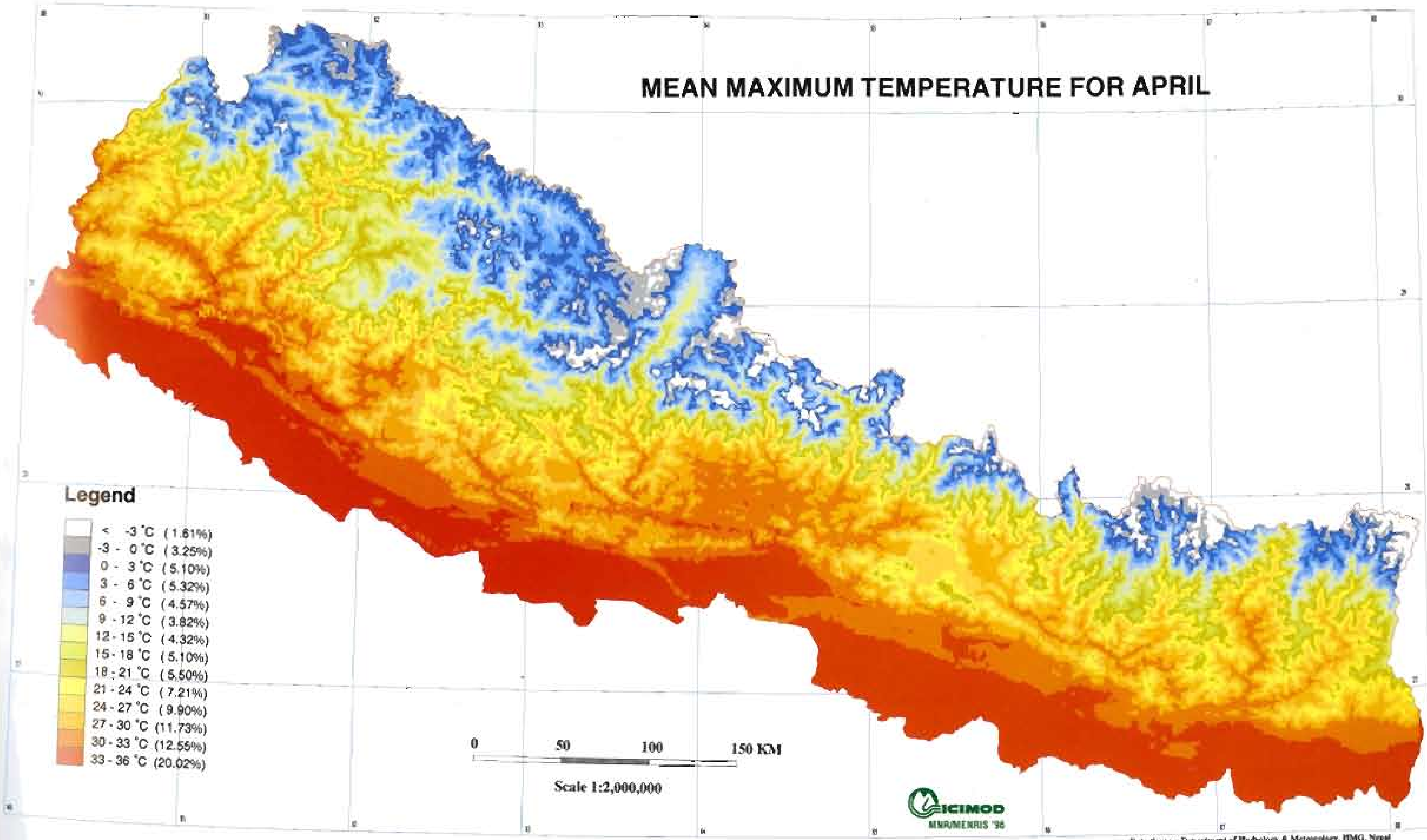
MEAN MAXIMUM TEMPERATURE FOR FEBRUARY

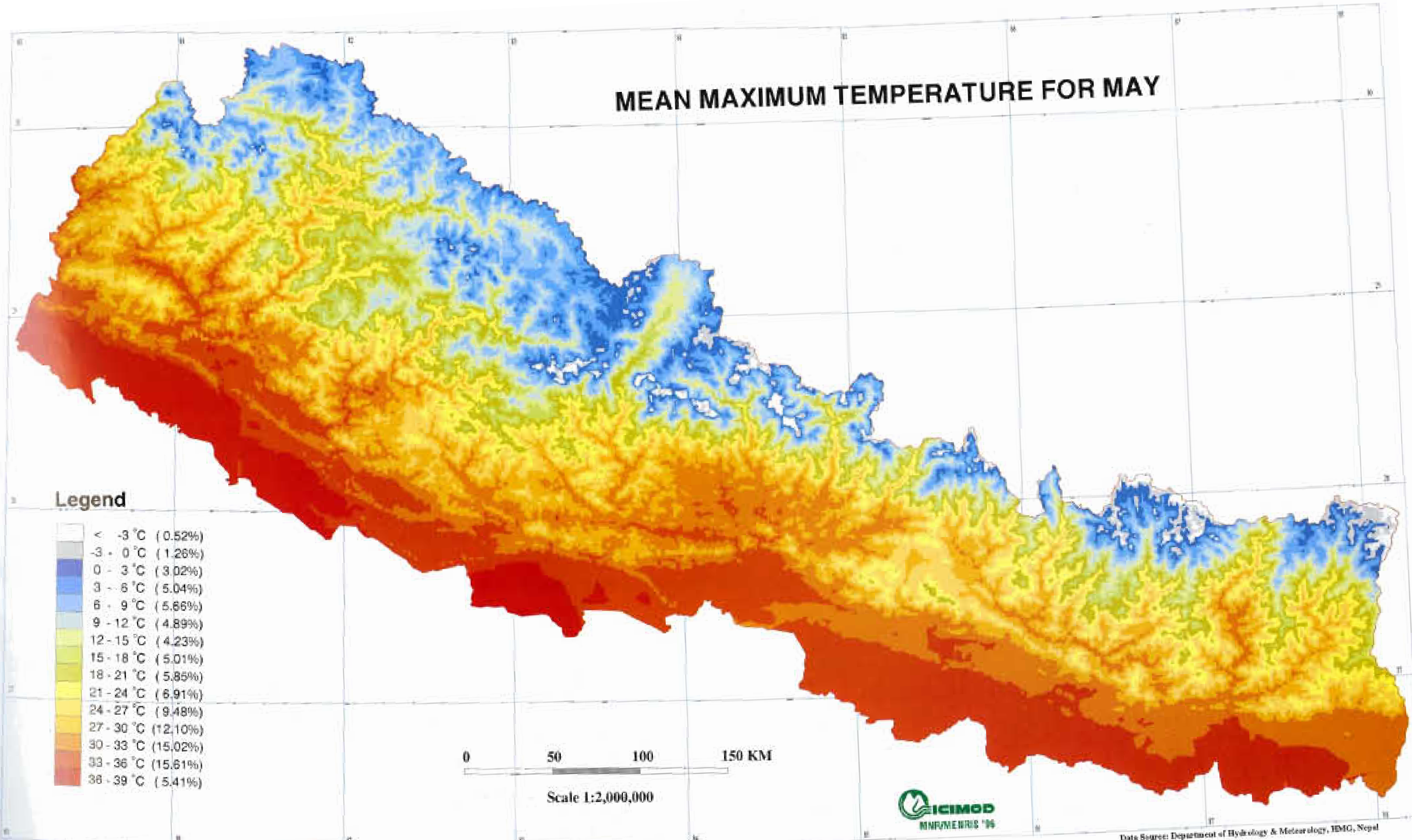


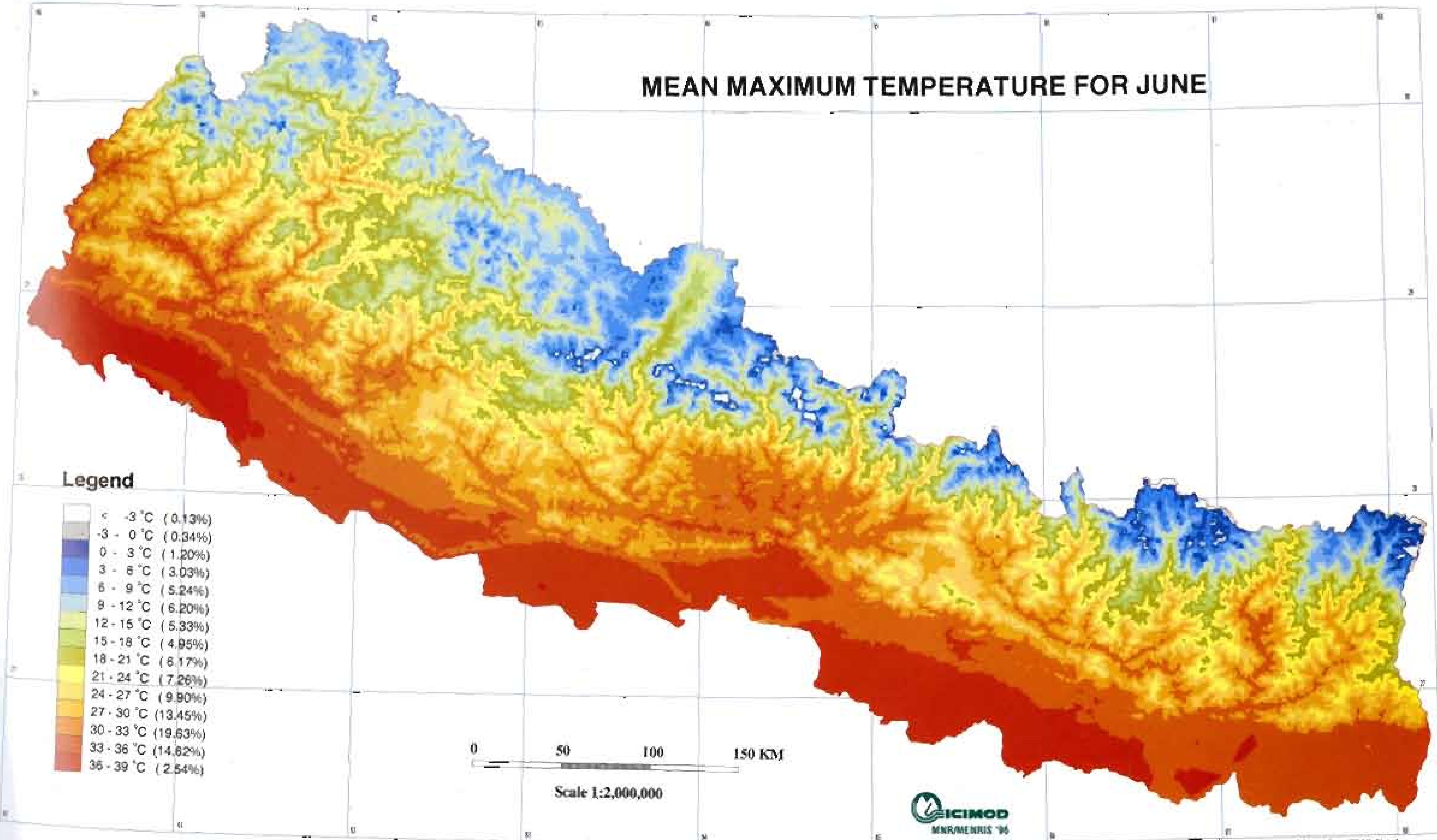
Data Source: Department of Hydrology & Meteorology, HMG, Nepal



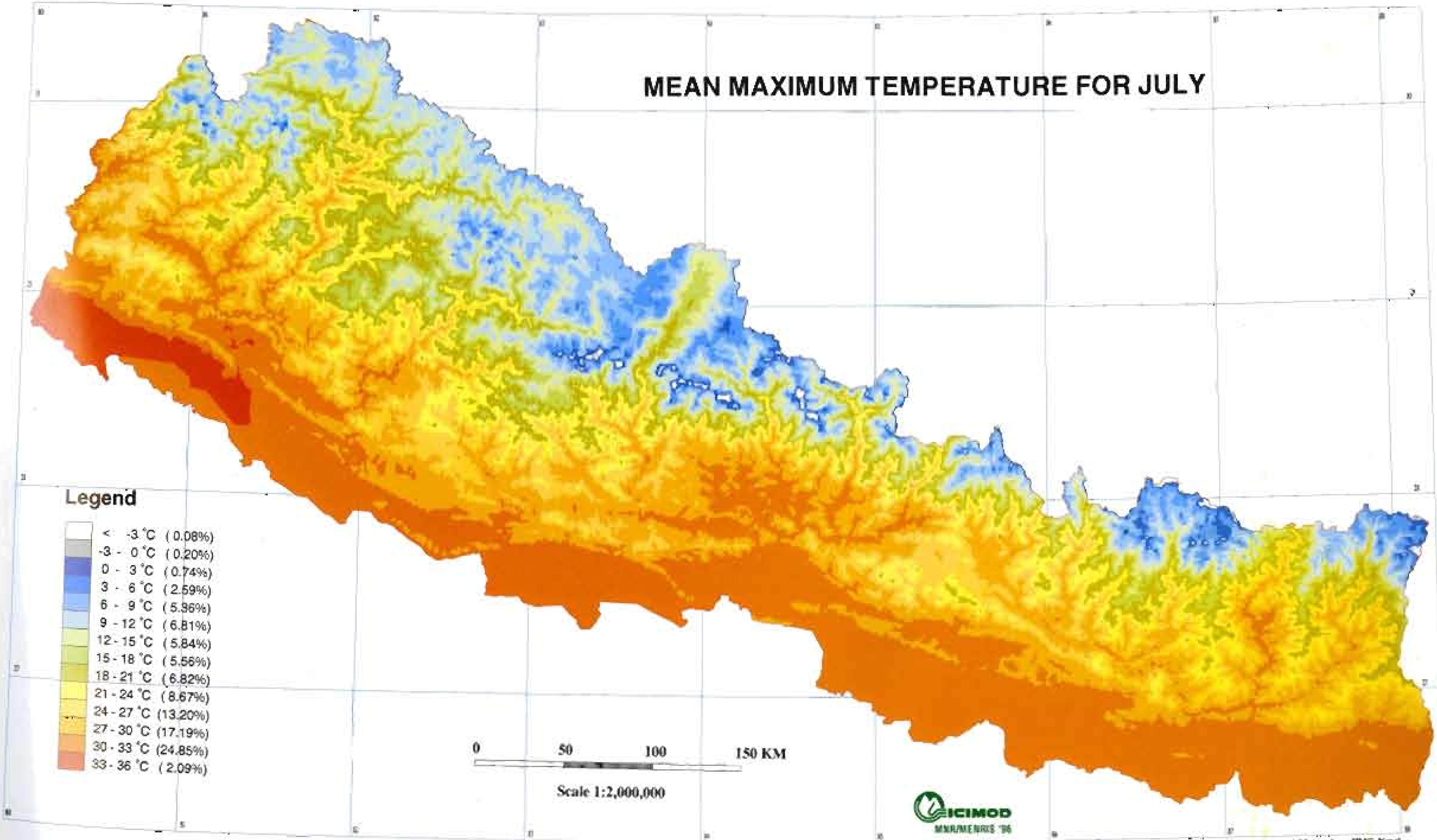
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

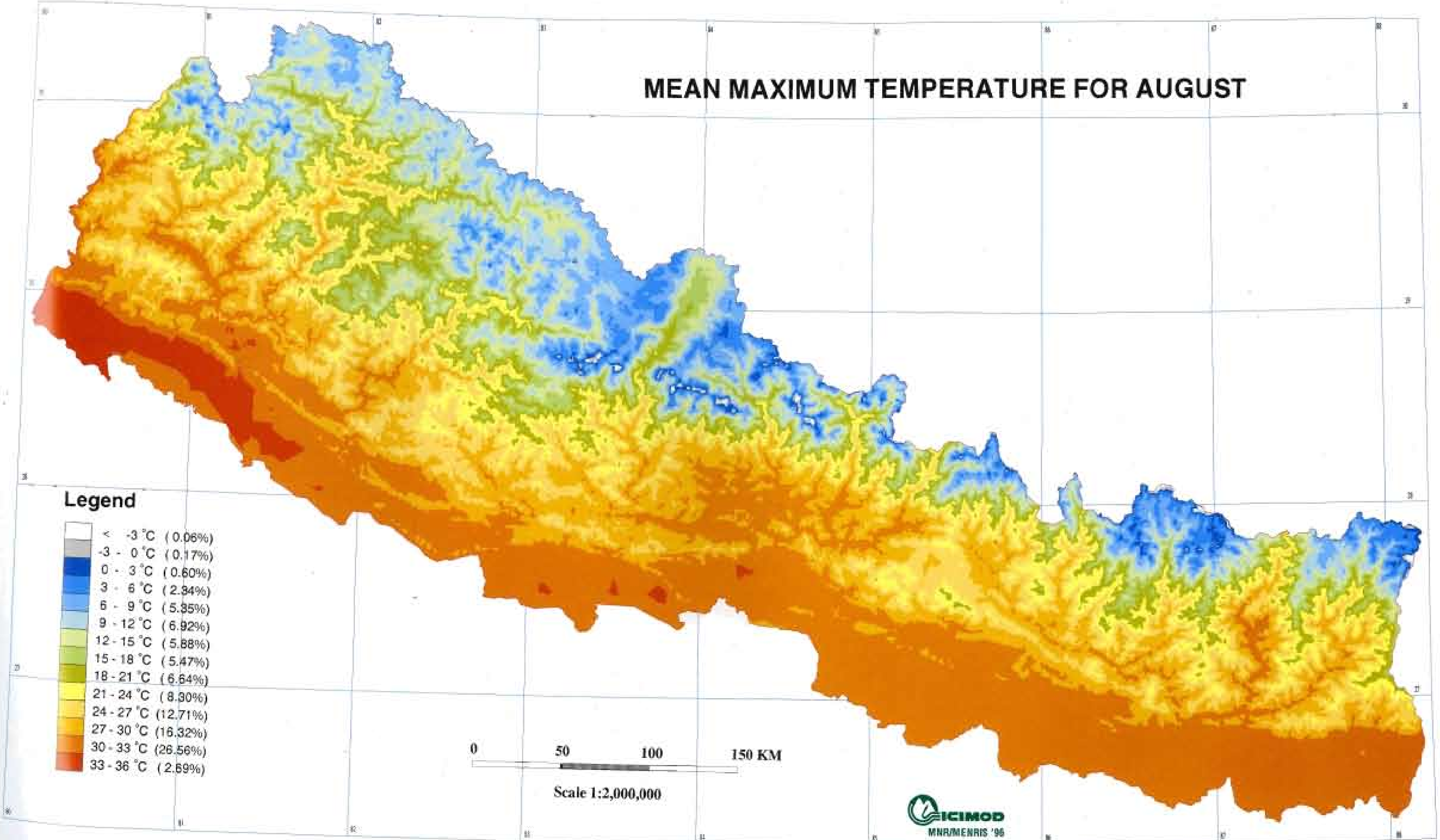

MEAN MAXIMUM TEMPERATURE FOR APRIL
Legend
< -3 °C (1.61%)
-3 - 0 °C (3.25%)
0 - 3 °C (5.10%)
3 - 6 °C (5.32%)
6 - 9 °C (4.57%)
9 - 12 °C (3.82%)
12 - 15 °C (4.32%)
15 - 18 °C (5.10%)
18 - 21 °C (5.50%)
21 - 24 °C (7.21%)
24 - 27 °C (9.90%)
27 - 30 °C (11.73%)
30 - 33 °C (12.55%)
33 - 36 °C (20.02%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN MAXIMUM TEMPERATURE FOR MAY
Legend
< -3 °C (0.52%)
-3 - 0 °C (1.26%)
0 - 3 °C (3.02%)
3 - 6 °C (5.04%)
6 - 9 °C (5.66%)
9 - 12 °C (4.89%)
12 - 15 °C (4.23%)
15 - 18 °C (5.01%)
18 - 21 °C (5.85%)
21 - 24 °C (6.91%)
24 - 27 °C (9.48%)
27 - 30 °C (12.10%)
30 - 33 °C (15.02%)
33 - 36 °C (15.61%)
36 - 39 °C (5.41%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

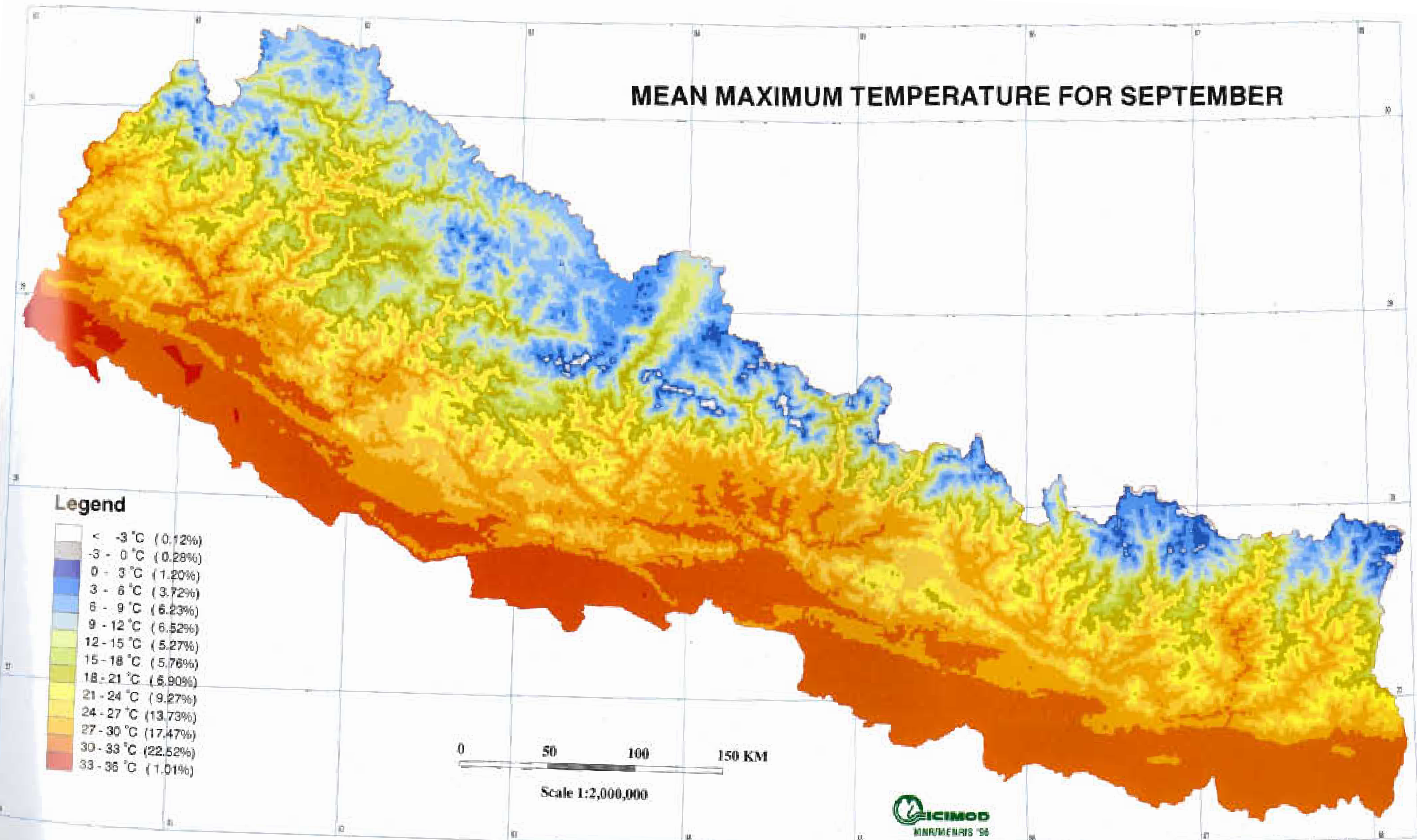


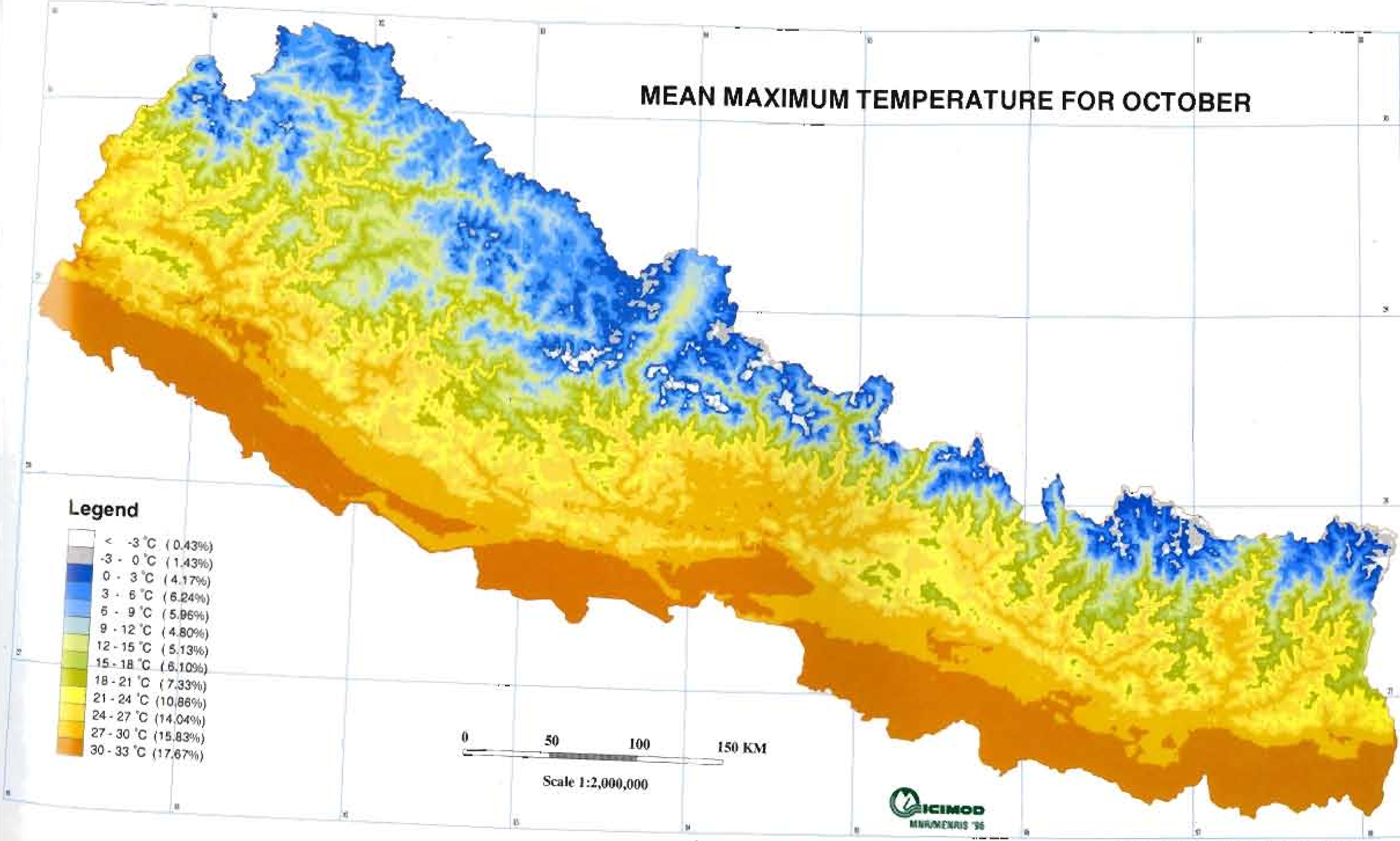
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN MAXIMUM TEMPERATURE FOR JULY
Legend
< -3 °C (0.08%)
-3 - 0 °C (0.20%)
0 - 3 °C (0.74%)
3 - 6 °C (2.59%)
6 - 9 °C (5.36%)
9 - 12 °C (6.81%)
12 - 15 °C (5.84%)
15 - 18 °C (5.56%)
18 - 21 °C (6.82%)
21 - 24 °C (8.67%)
24 - 27 °C (13.20%)
27 - 30 °C (17.19%)
30 - 33 °C (24.85%)
33 - 36 °C (2.09%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

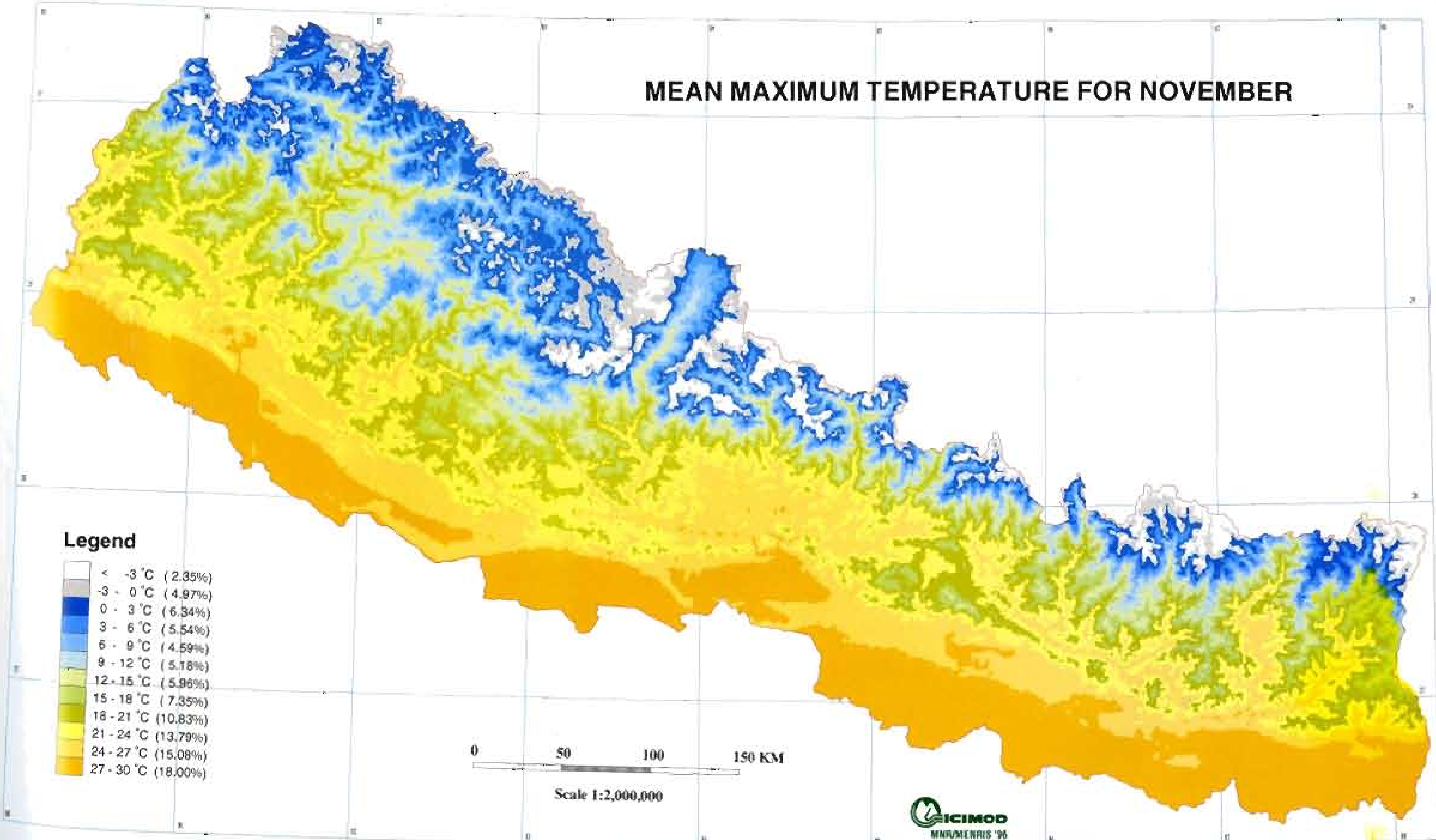


Data Source: Department of Hydrology & Meteorology, HMG, Nepal

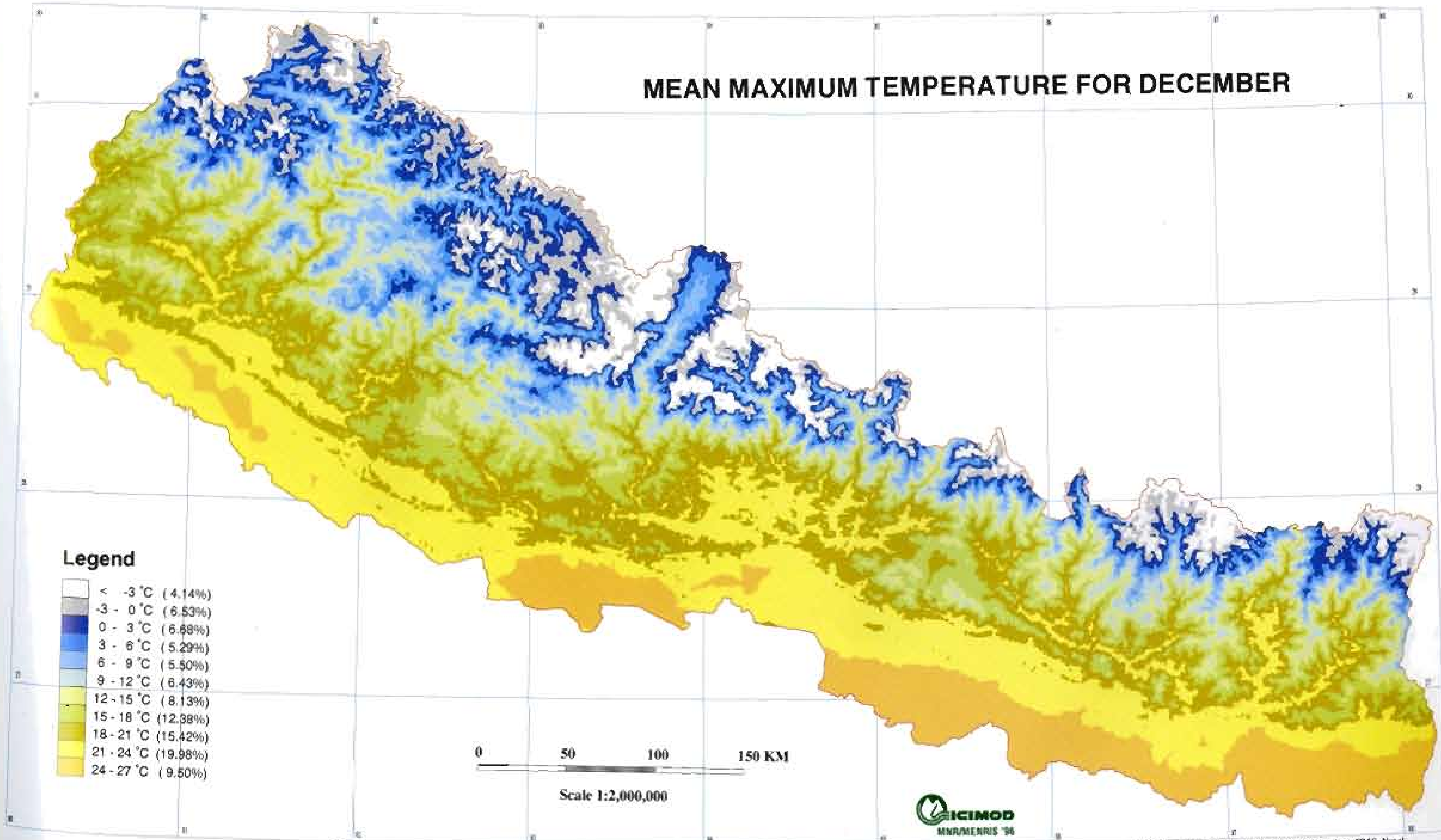

MEAN MAXIMUM TEMPERATURE FOR SEPTEMBER
Legend
< -3 °C (0.12%)
-3 - 0 °C (0.28%)
0 - 3 °C (1.20%)
3 - 6 °C (3.72%)
6 - 9 °C (6.23%)
9 - 12 °C (6.52%)
12 - 15 °C (5.27%)
15 - 18 °C (5.76%)
18 - 21 °C (6.90%)
21 - 24 °C (9.27%)
24 - 27 °C (13.73%)
27 - 30 °C (17.47%)
30 - 33 °C (22.52%)
33 - 36 °C (1.01%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

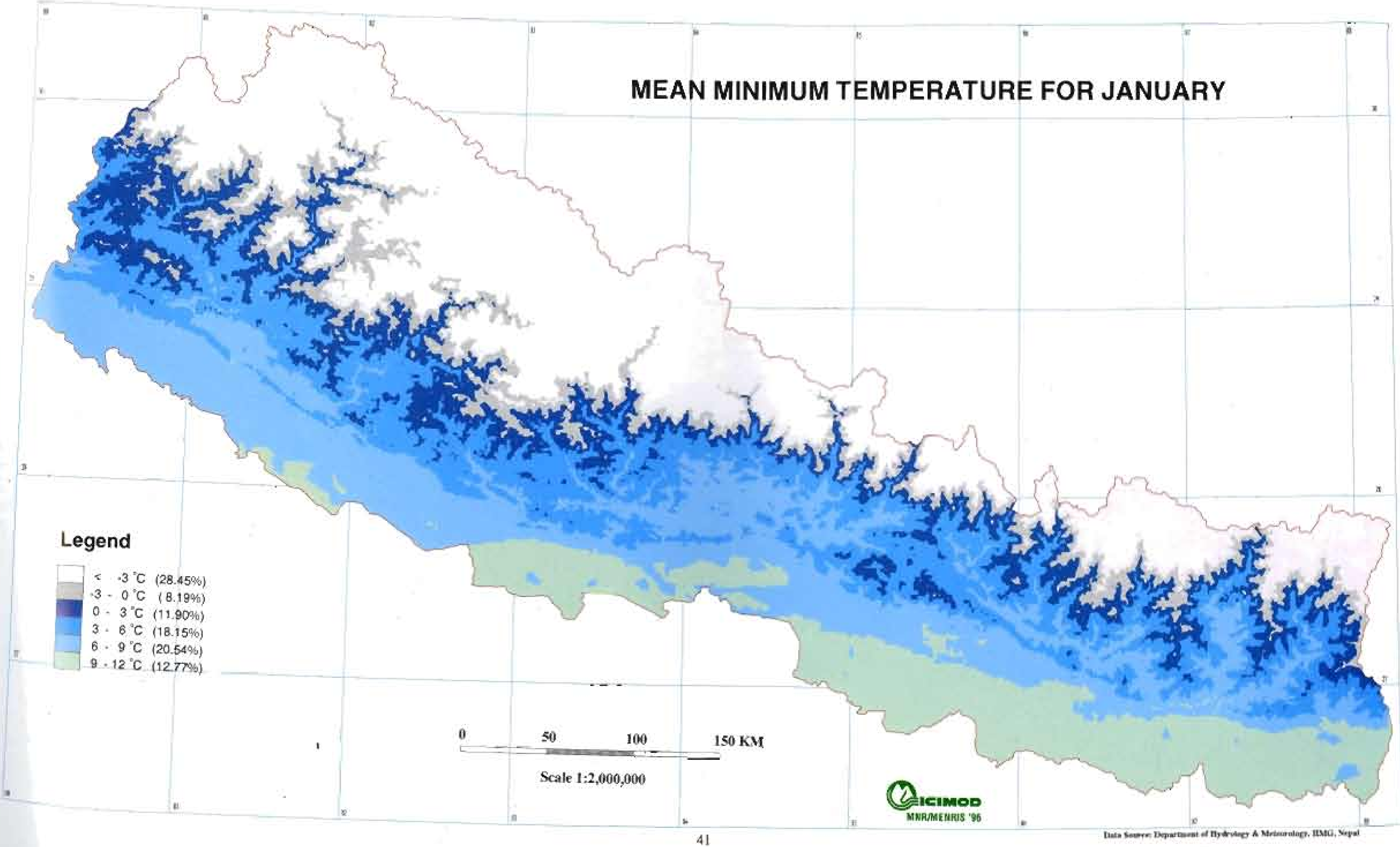


Data Source: Department of Hydrology & Meteorology, HMG, Nepal



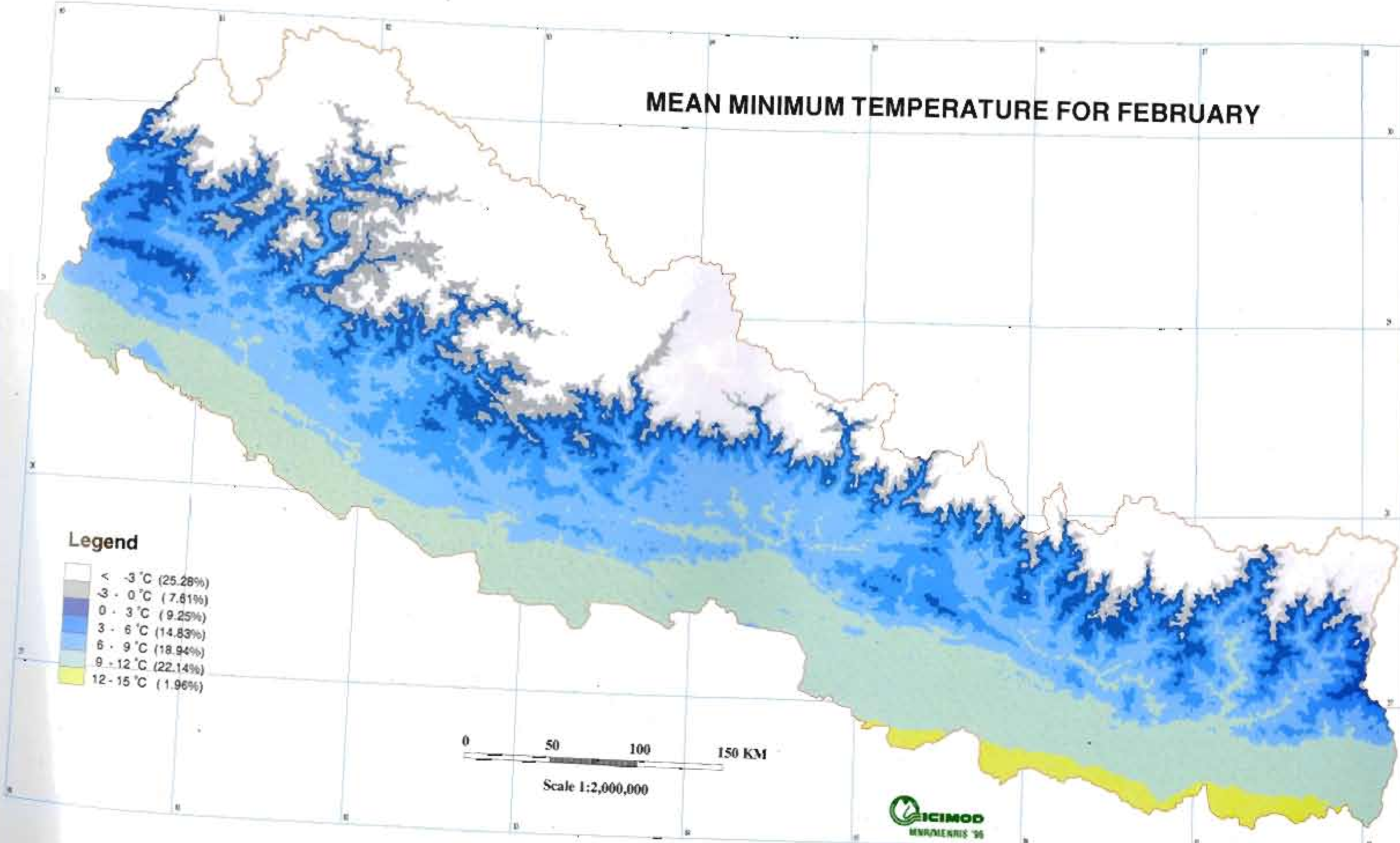
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

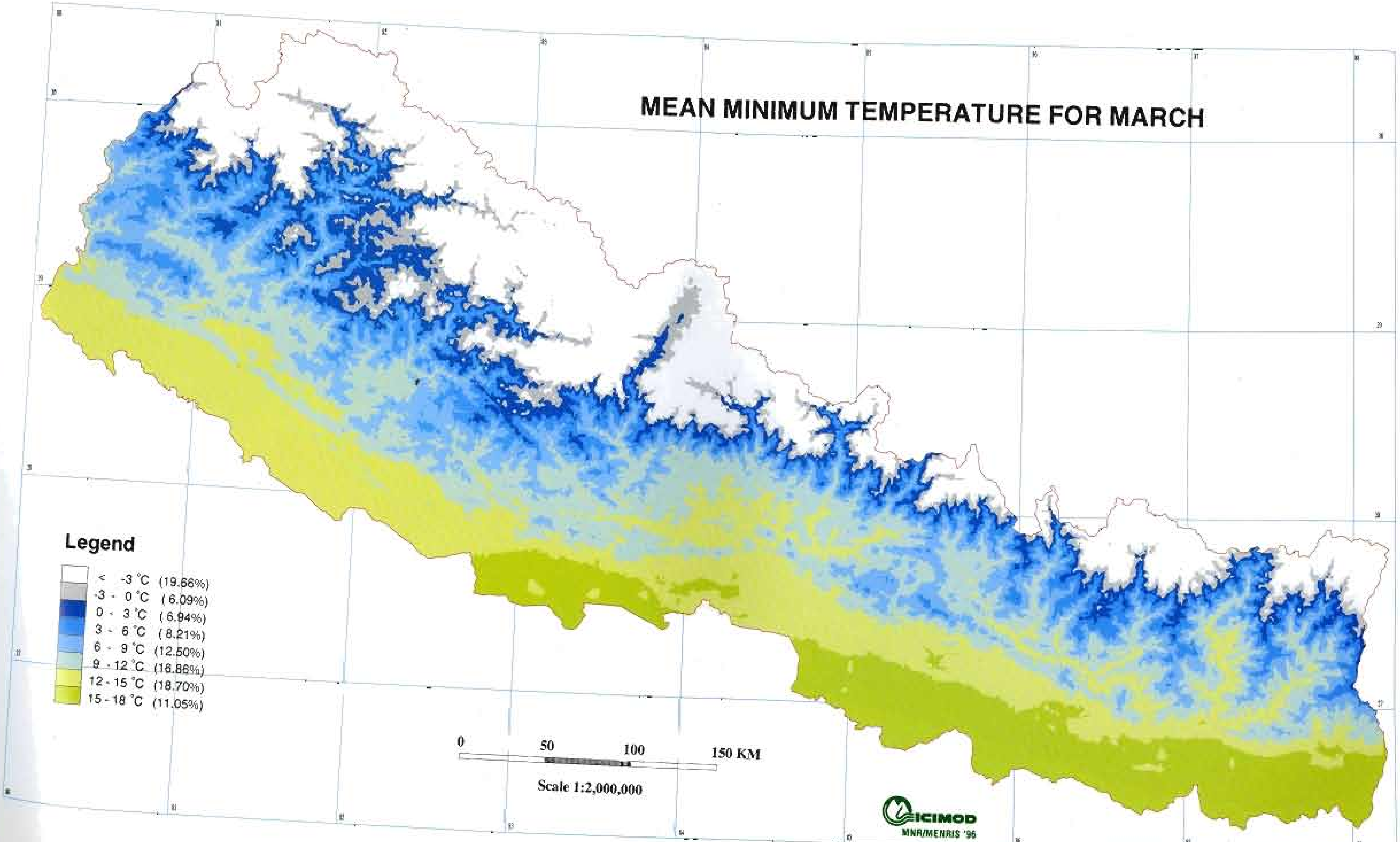

MEAN MAXIMUM TEMPERATURE FOR DECEMBER
Legend
< -3 °C (4.14%)
-3 - 0 °C (6.53%)
0 - 3 °C (6.68%)
3 - 6 °C (5.29%)
6 - 9 °C (5.50%)
9 - 12 °C (6.43%)
12 - 15 °C (8.13%)
15 - 18 °C (12.38%)
18 - 21 °C (15.42%)
21 - 24 °C (19.98%)
24 - 27 °C (9.50%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal



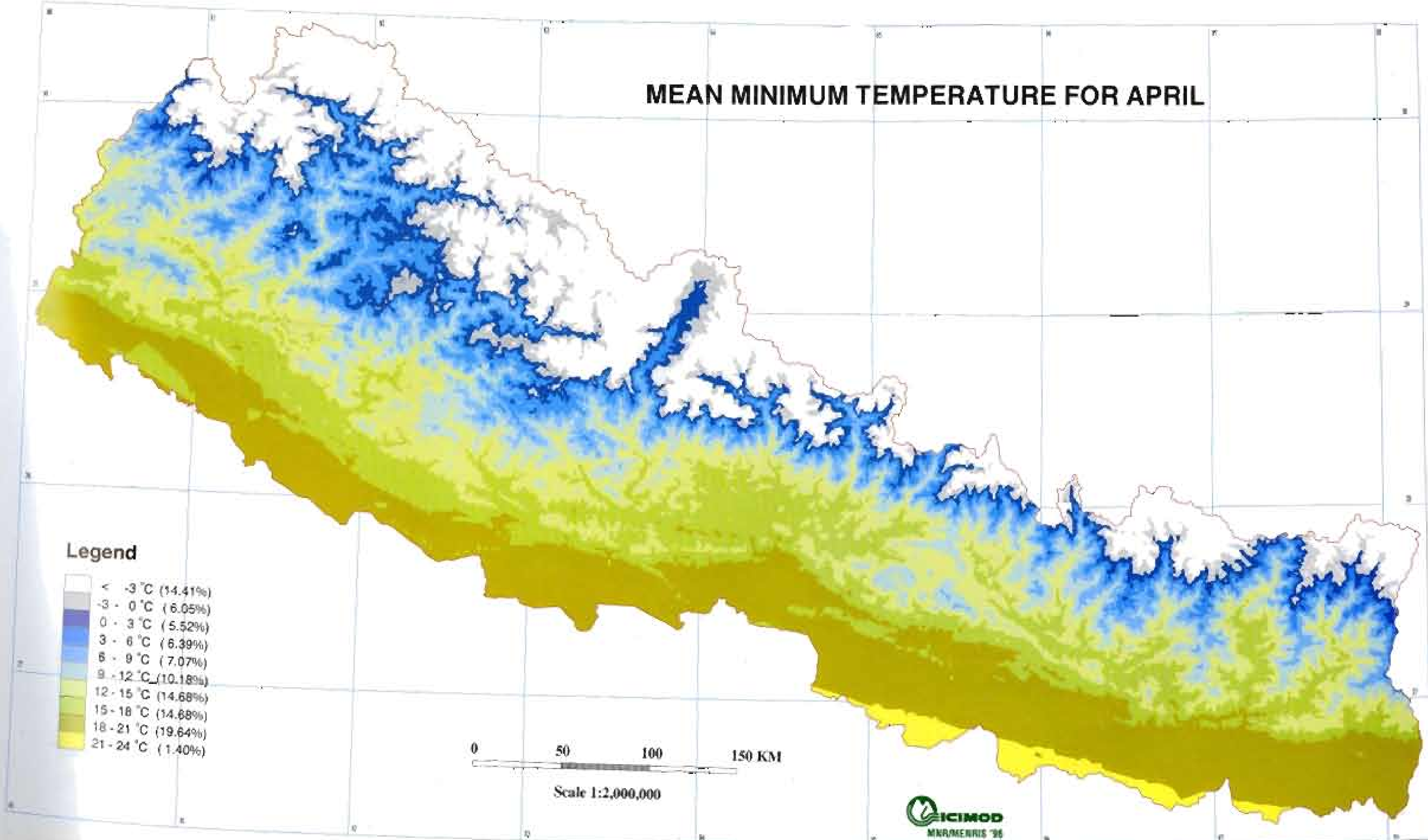
MEAN MINIMUM TEMPERATURE FOR JANUARY
Legend
< -3 °C (28.45%)
-3 - 0 °C (8.19%)
0 - 3 °C (11.90%)
3 - 6 °C (18.15%)
6 - 9 °C (20.54%)
9 - 12 °C (12.77%)
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

MEAN MINIMUM TEMPERATURE FOR FEBRUARY

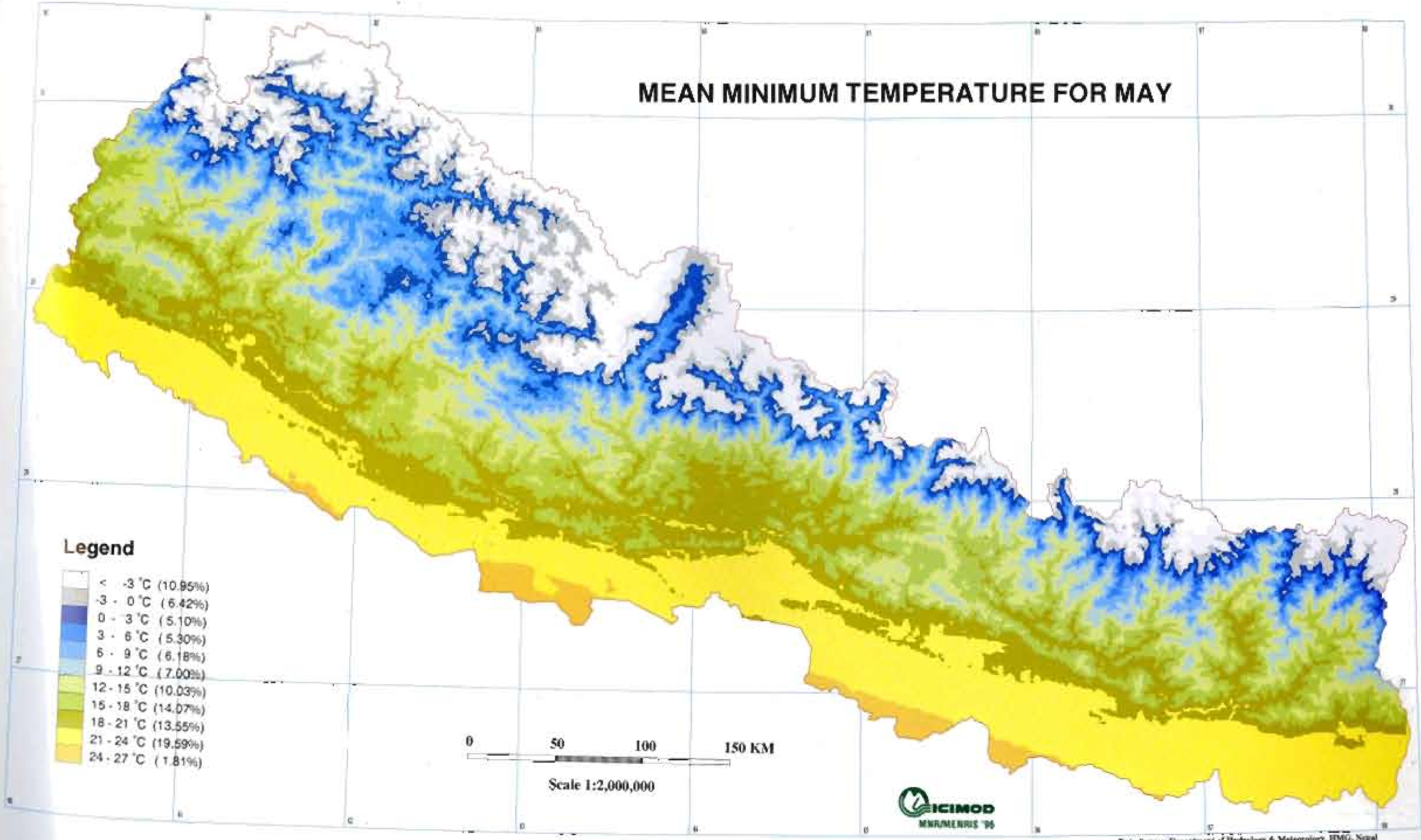


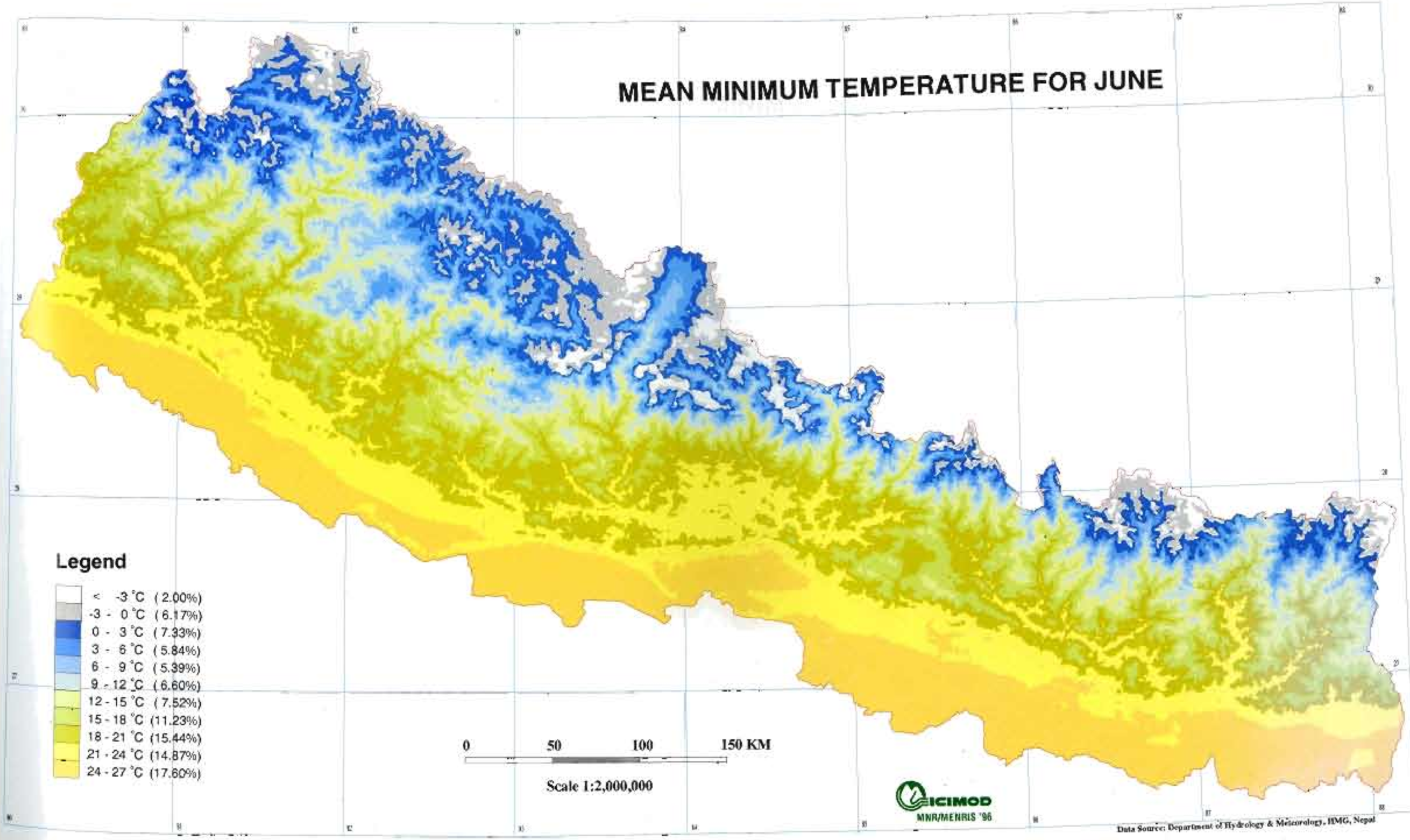


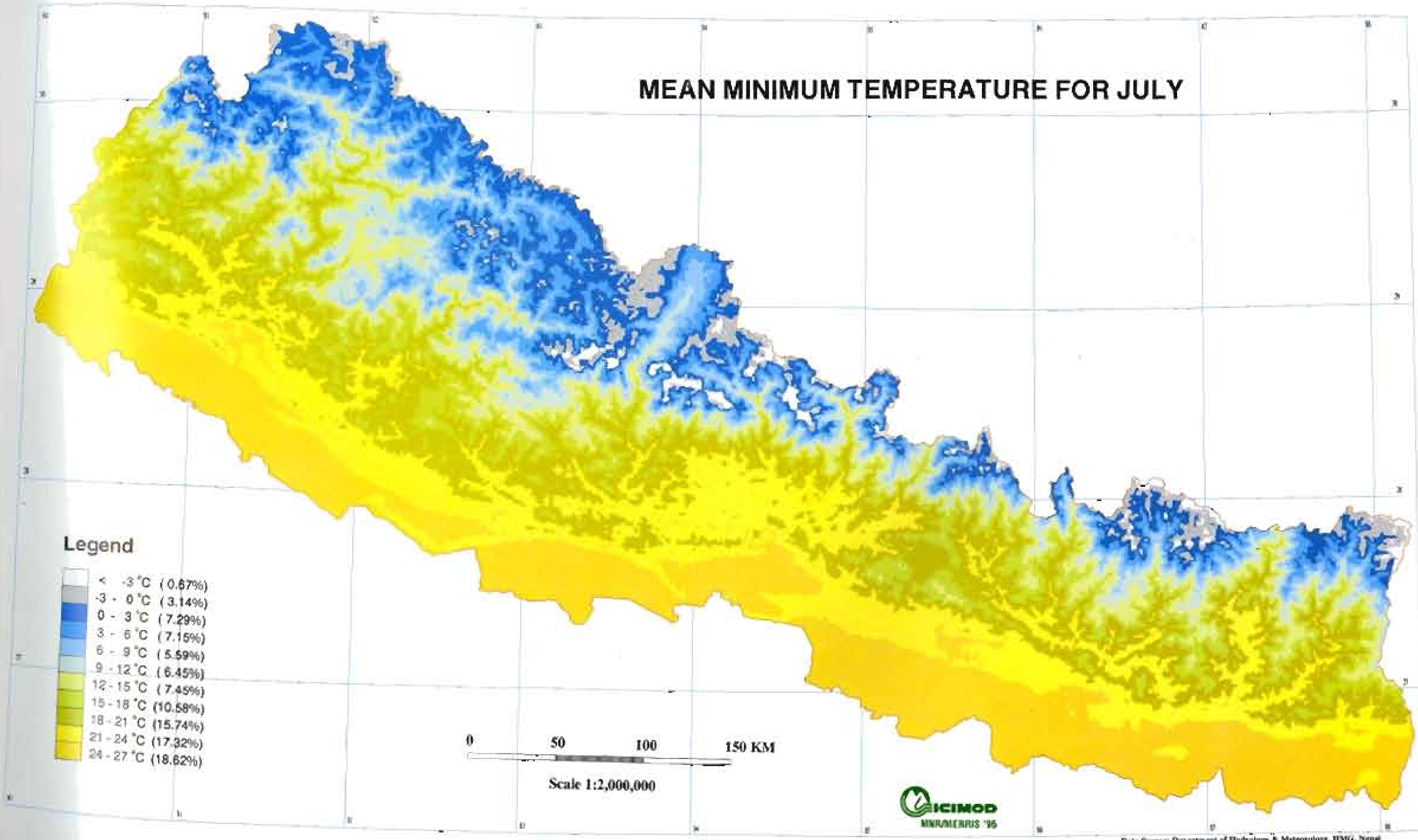
MEAN MINIMUM TEMPERATURE FOR MARCH
Legend
< -3 °C (19.66%)
-3 - 0 °C (6.09%)
0 - 3 °C (6.94%)
3 - 6 °C (8.21%)
6 - 9 °C (12.50%)
9 - 12 °C (16.86%)
12 - 15 °C (18.70%)
15 - 18 °C (11.05%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

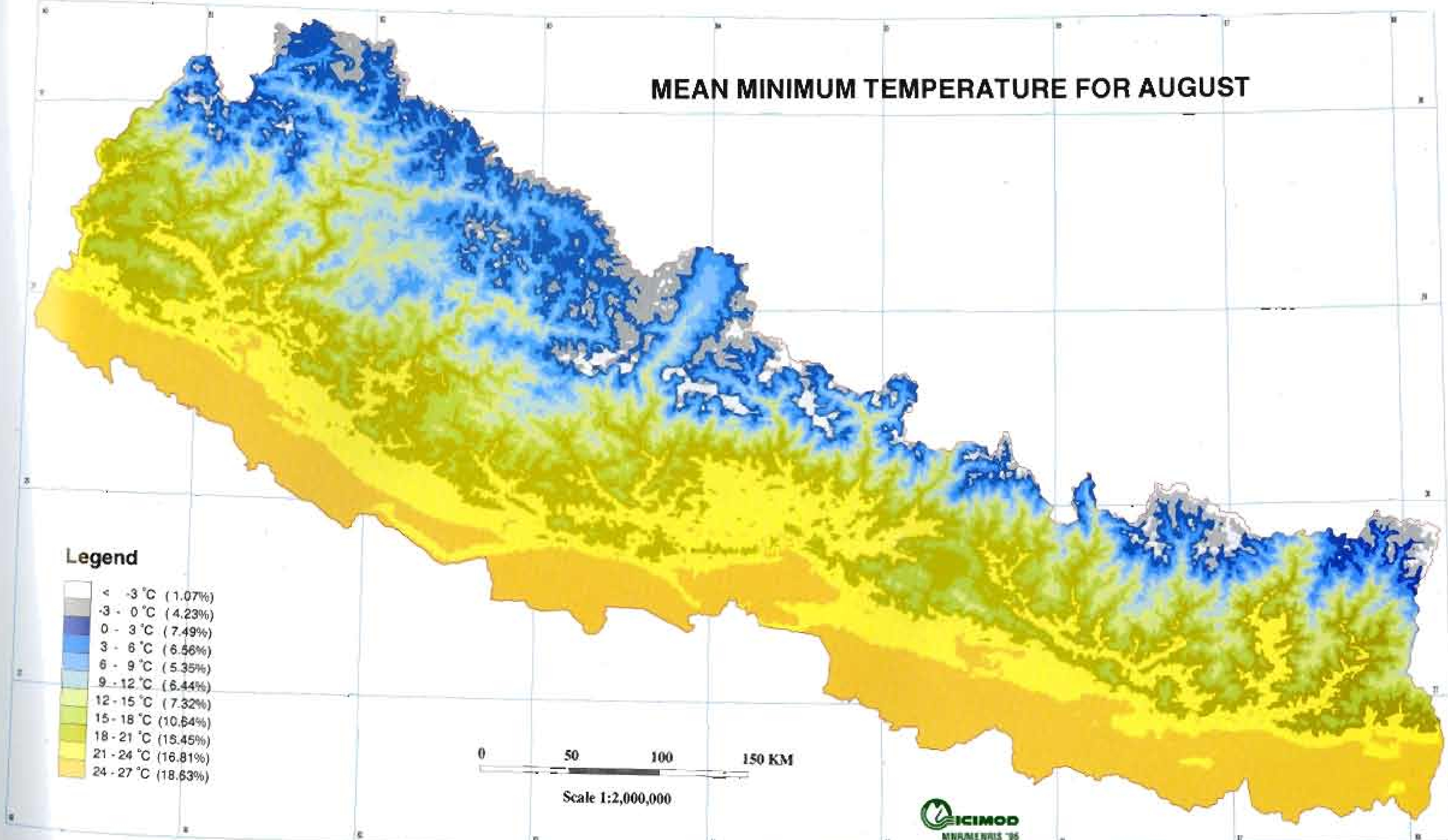


Data Source: Department of Hydrology & Meteorology, HMG, Nepal

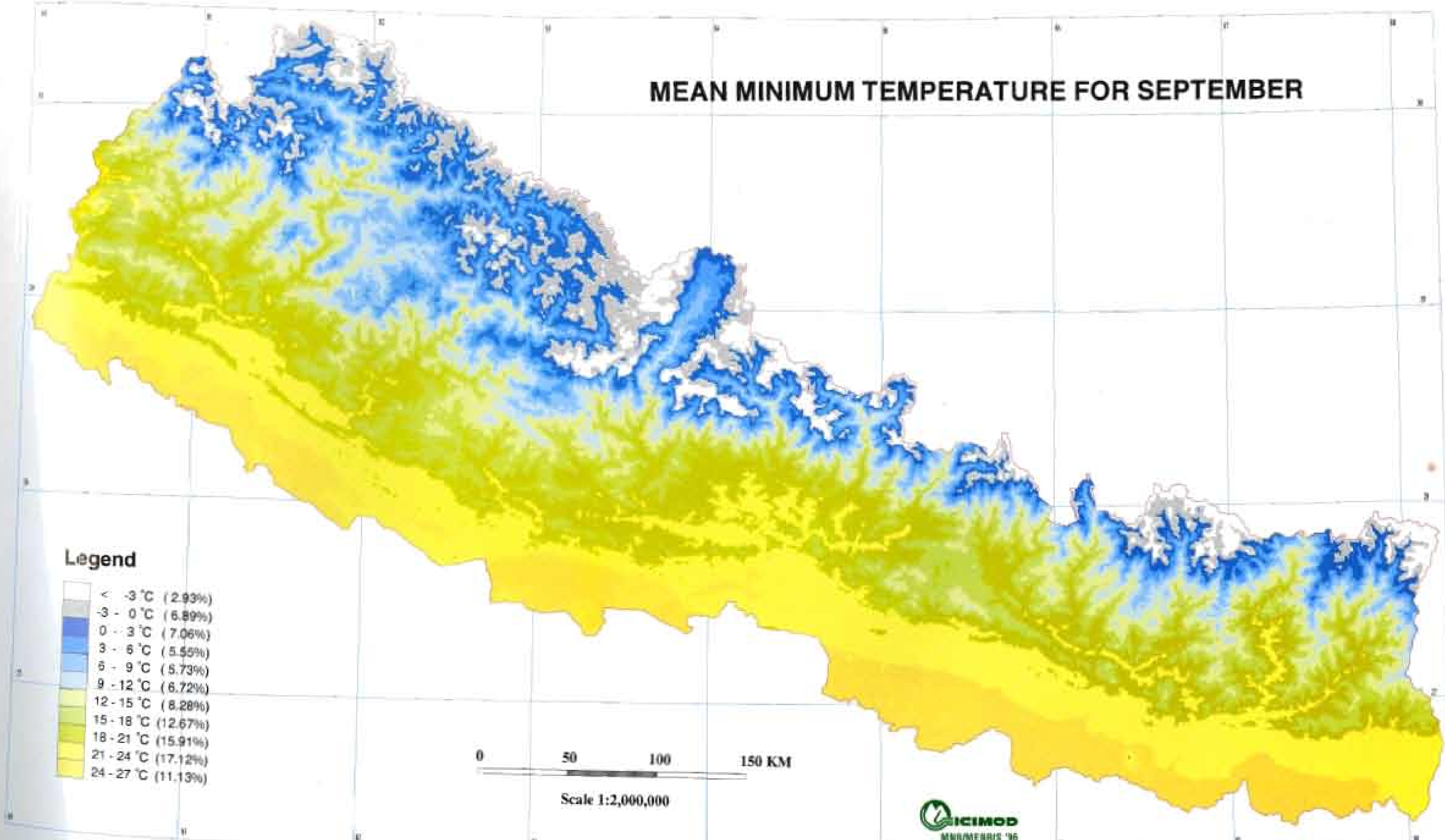

MEAN MINIMUM TEMPERATURE FOR MAY
Legend
< -3 °C (10.95%)
-3 - 0 °C (6.42%)
0 - 3 °C (5.10%)
3 - 6 °C (5.30%)
6 - 9 °C (6.18%)
9 - 12 °C (7.00%)
12 - 15 °C (10.03%)
15 - 18 °C (14.07%)
18 - 21 °C (13.55%)
21 - 24 °C (19.59%)
24 - 27 °C (1.81%)
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN MINIMUM TEMPERATURE FOR JUNE
Legend
< -3 °C (2.00%)
-3 - 0 °C (6.17%)
0 - 3 °C (7.33%)
3 - 6 °C (5.84%)
6 - 9 °C (5.39%)
9 - 12 °C (6.60%)
12 - 15 °C (7.52%)
15 - 18 °C (11.23%)
18 - 21 °C (15.44%)
21 - 24 °C (14.87%)
24 - 27 °C (17.60%)
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

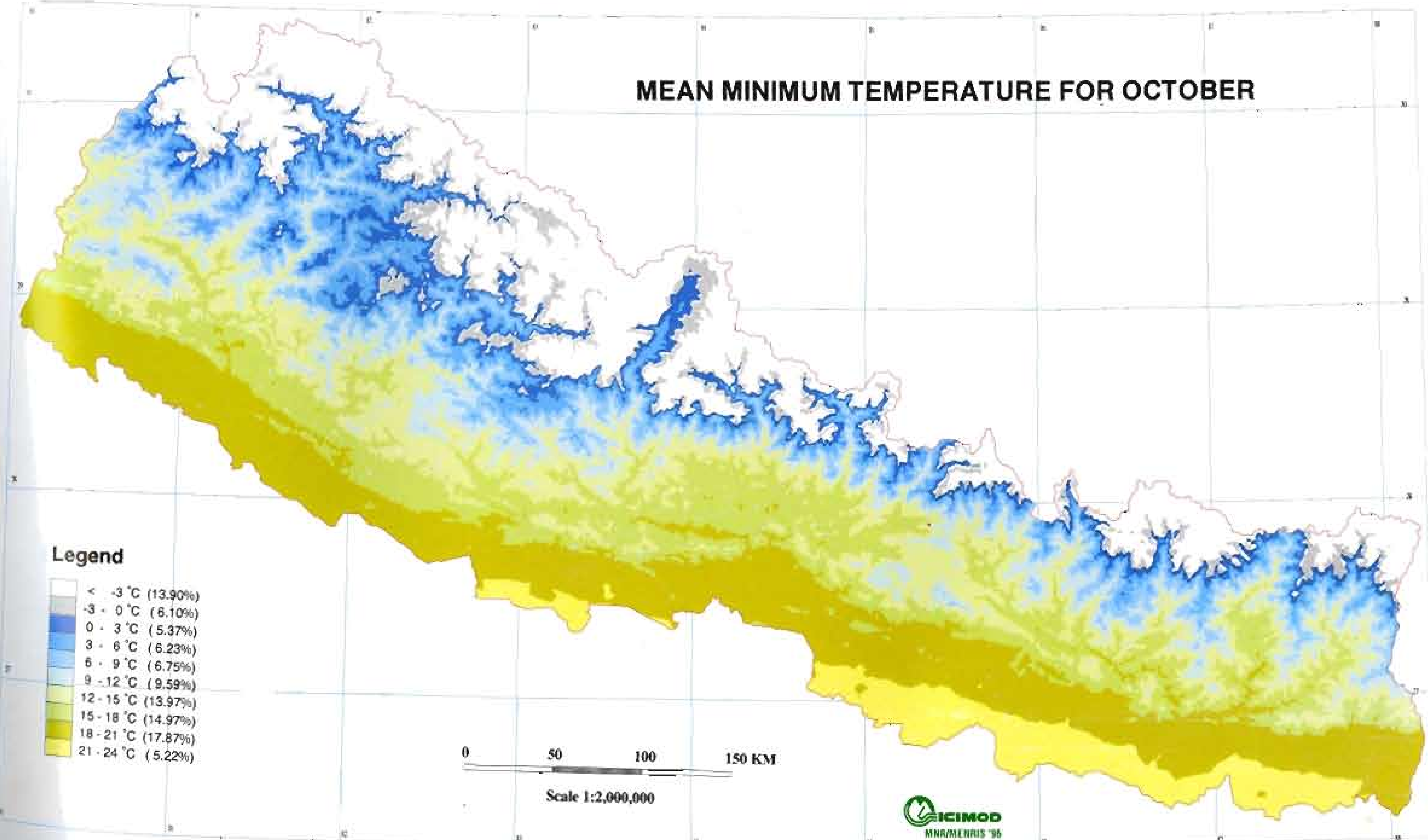

MEAN MINIMUM TEMPERATURE FOR JULY
Legend
< -3 °C (0.67%)
-3 - 0 °C (3.14%)
0 - 3 °C (7.29%)
3 - 6 °C (7.15%)
6 - 9 °C (5.59%)
9 - 12 °C (6.45%)
12 - 15 °C (7.45%)
15 - 18 °C (10.58%)
18 - 21 °C (15.74%)
21 - 24 °C (17.32%)
24 - 27 °C (18.62%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal



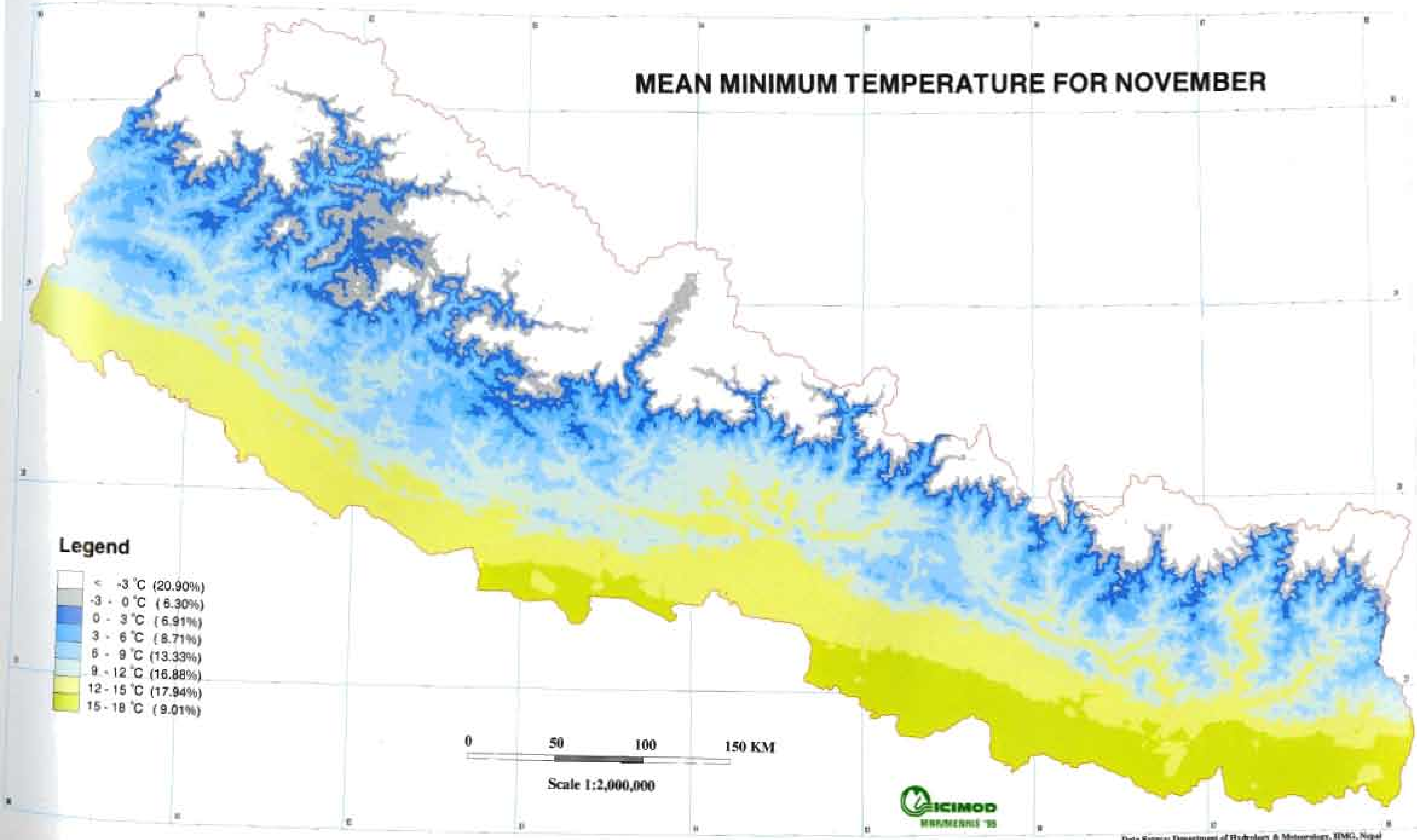
Data Source: Department of Hydrology & Meteorology, HMG, Nepal



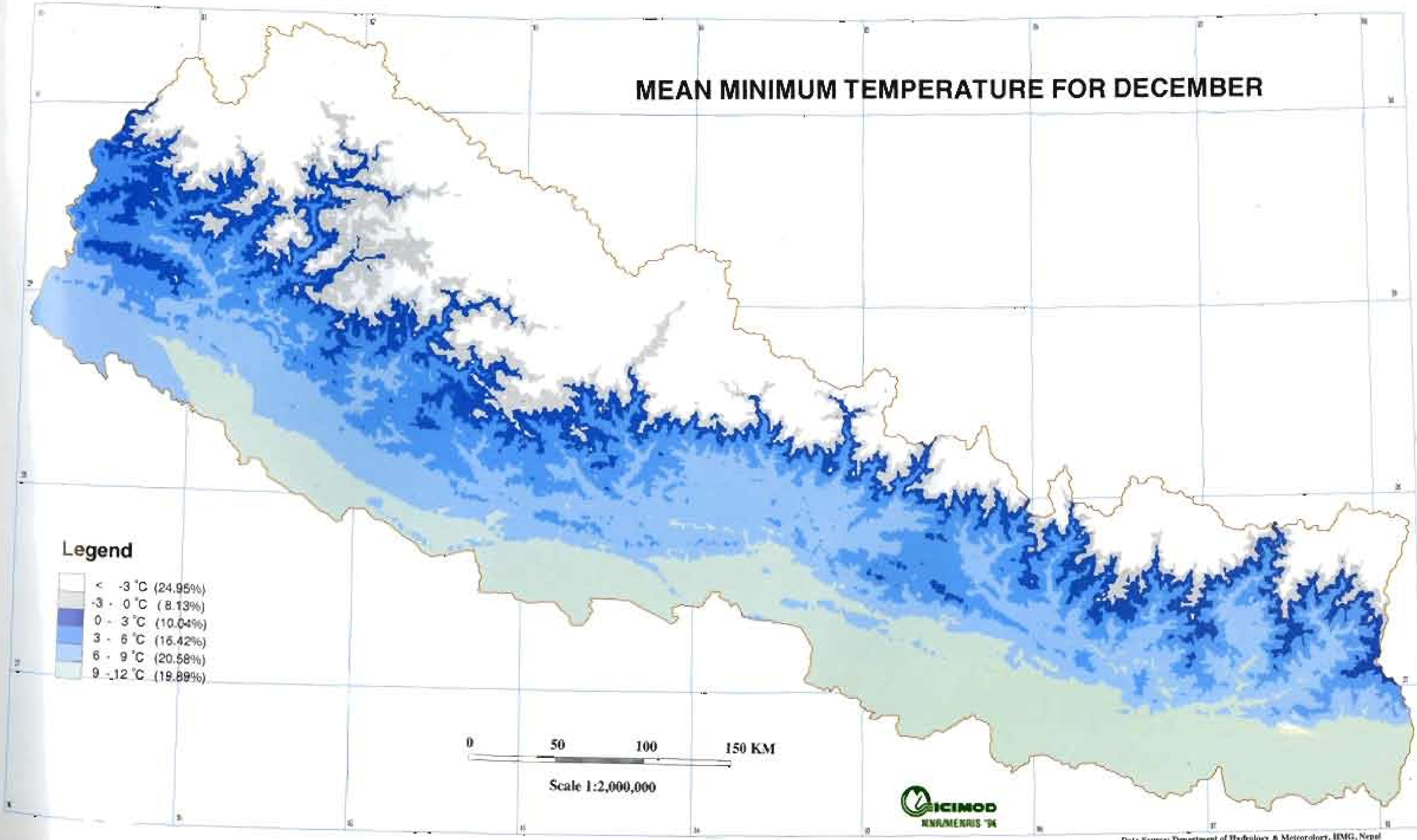
Data Source: Department of Hydrology & Meteorology, HMG, Nepal



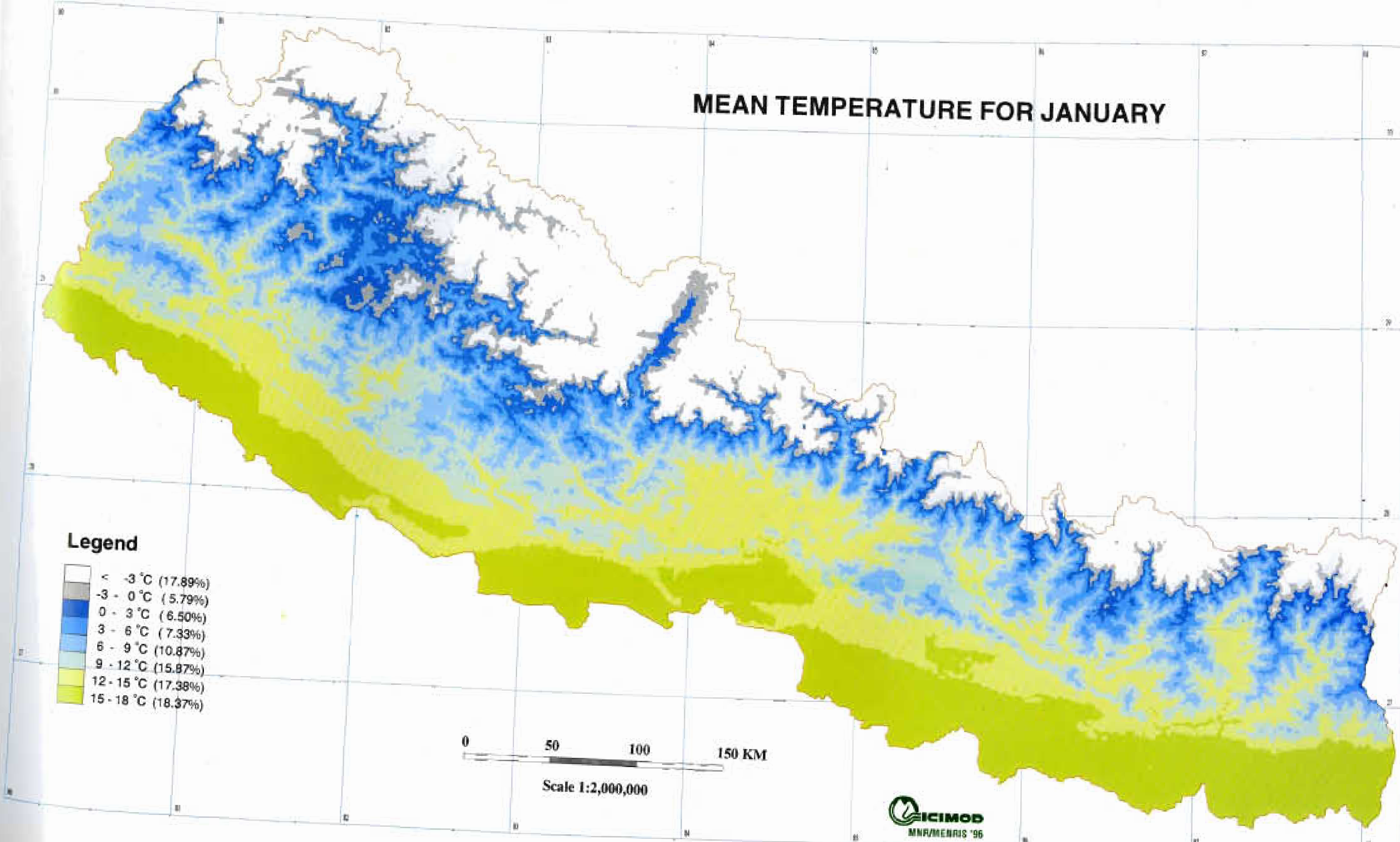
Data Source: Department of Hydrology & Meteorology, HMG, Nepal



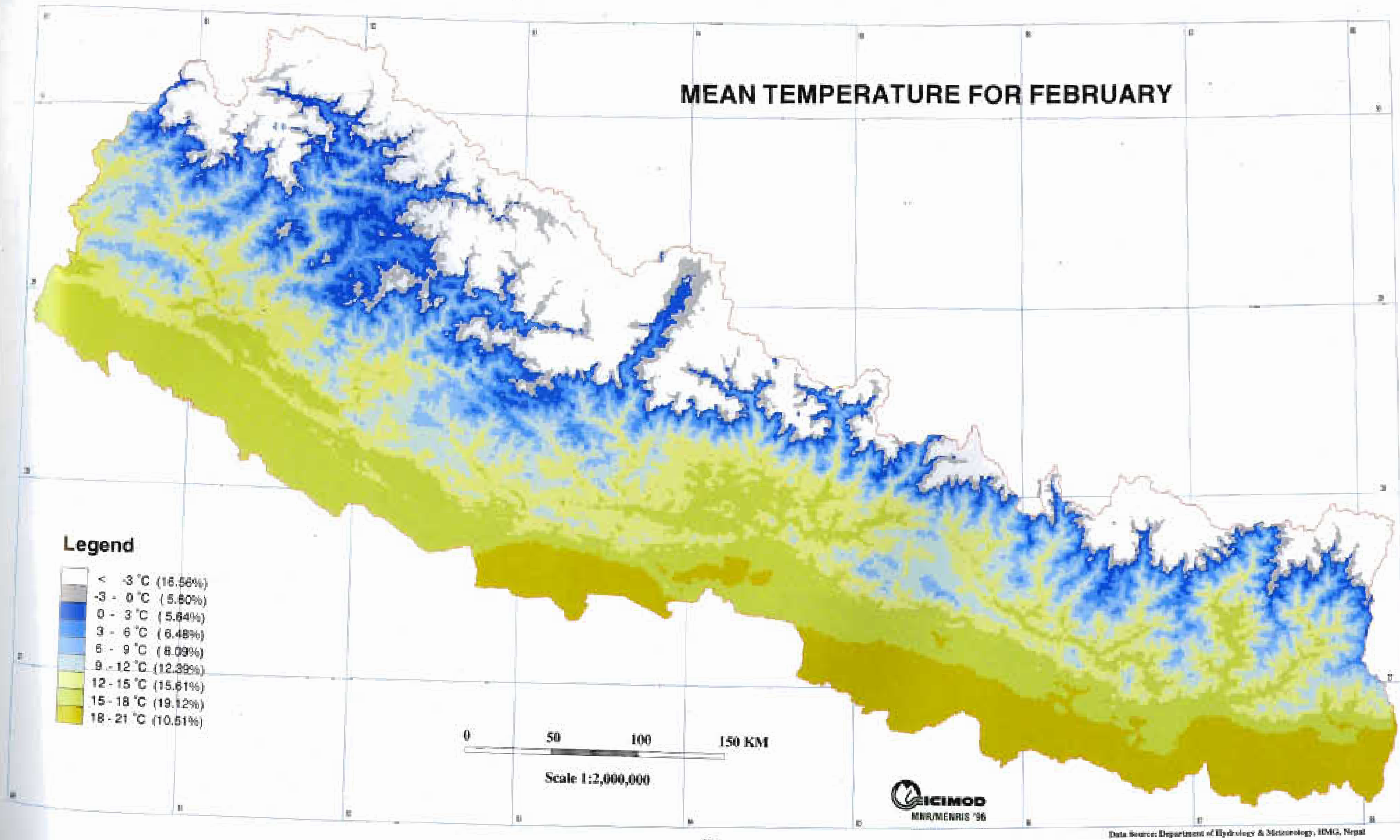
MEAN MINIMUM TEMPERATURE FOR NOVEMBER
Legend
< -3 °C (20.90%)
-3 - 0 °C (6.30%)
0 - 3 °C (6.91%)
3 - 6 °C (8.71%)
6 - 9 °C (13.33%)
9 - 12 °C (16.88%)
12 - 15 °C (17.94%)
15 - 18 °C (9.01%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

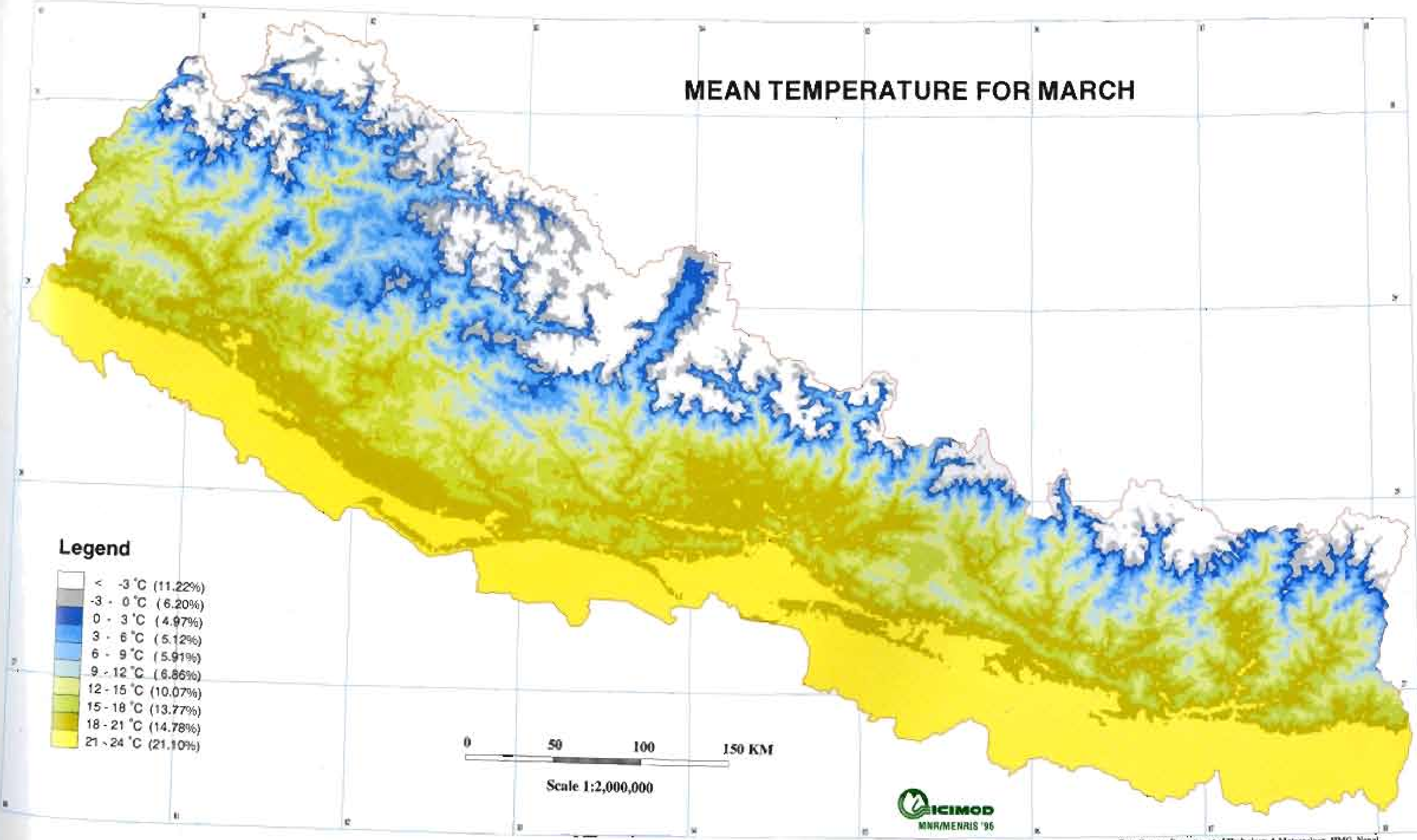

MEAN MINIMUM TEMPERATURE FOR DECEMBER
Legend
< -3 °C (24.95%)
-3 - 0 °C (8.13%)
0 - 3 °C (10.04%)
3 - 6 °C (16.42%)
6 - 9 °C (20.58%)
9 - 12 °C (19.89%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

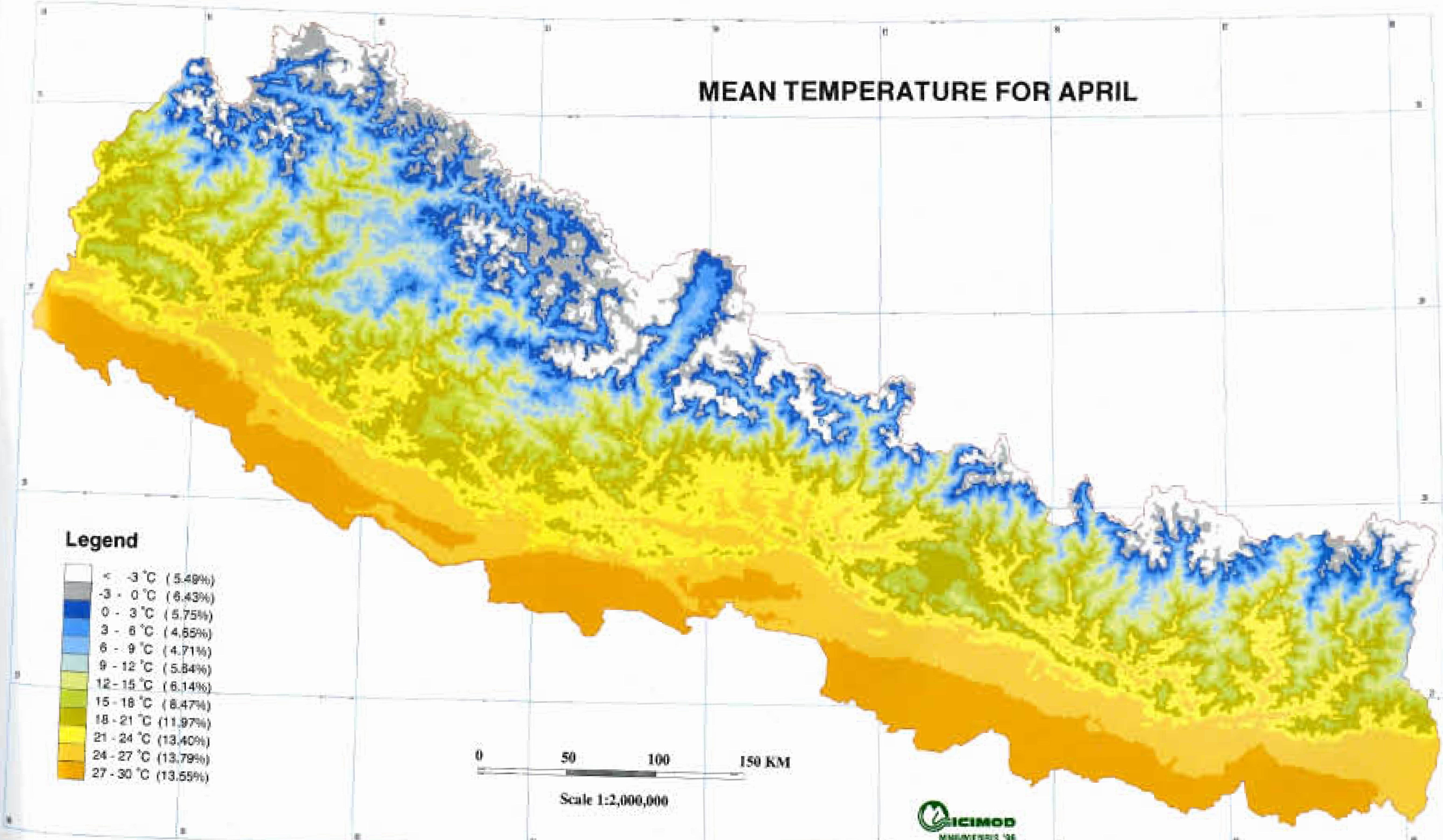
MEAN TEMPERATURE FOR JANUARY



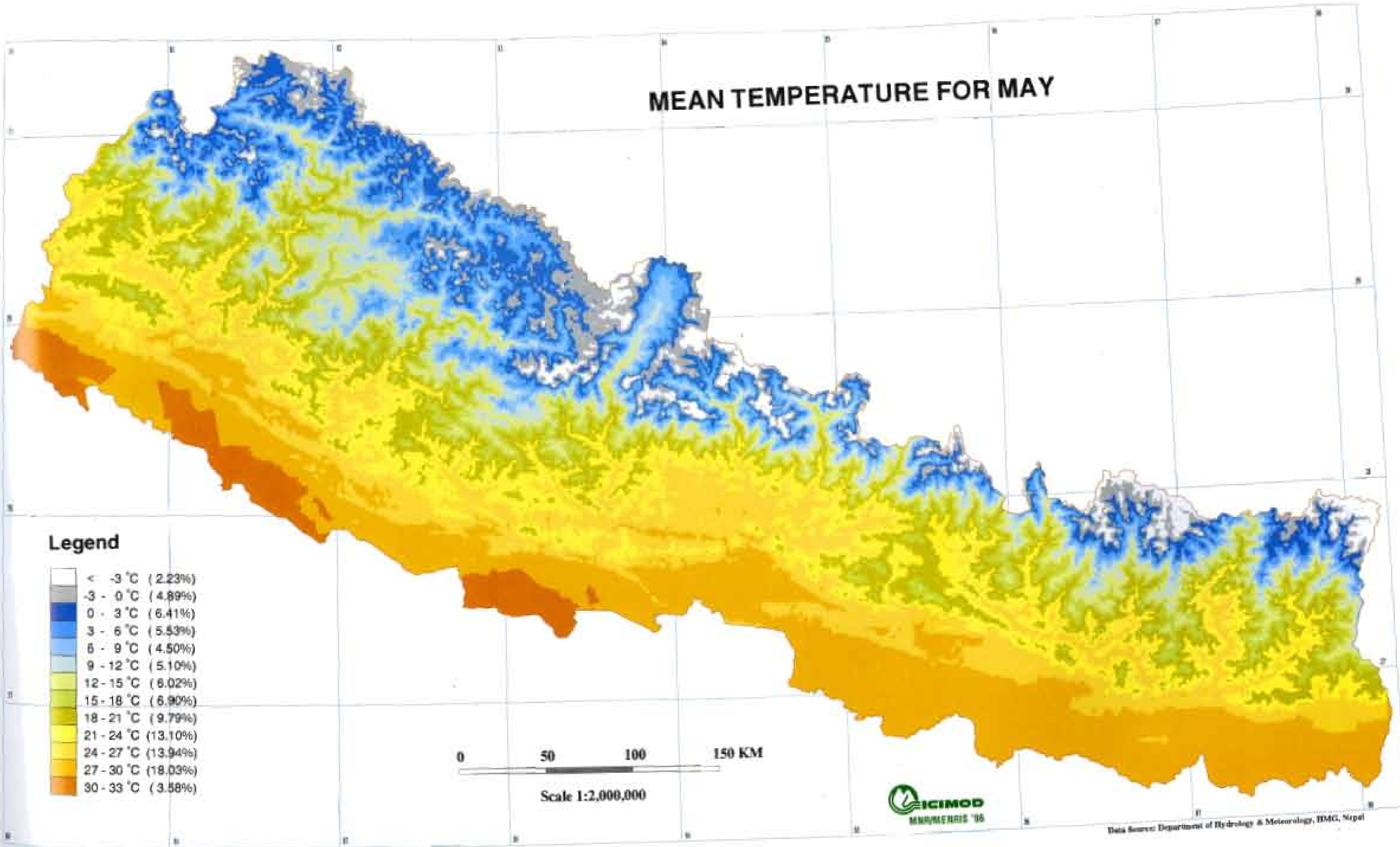
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

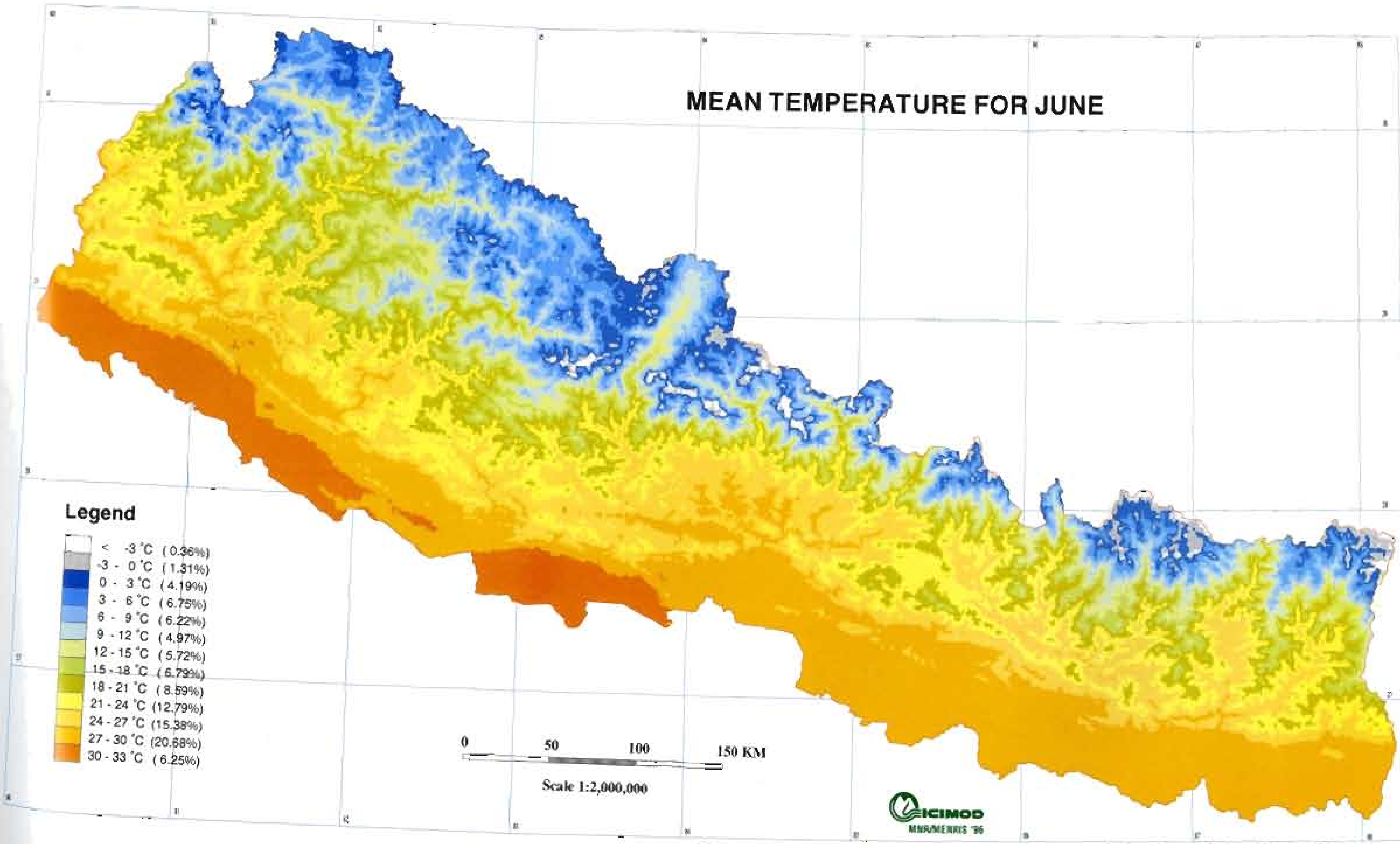

MEAN TEMPERATURE FOR FEBRUARY
Legend
< -3 °C (16.56%)
-3 - 0 °C (5.60%)
0 - 3 °C (5.64%)
3 - 6 °C (6.48%)
6 - 9 °C (8.09%)
9 - 12 °C (12.39%)
12 - 15 °C (15.61%)
15 - 18 °C (19.12%)
18 - 21 °C (10.51%)
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN TEMPERATURE FOR MARCH
Legend
< -3 °C (11.22%)
-3 - 0 °C (6.20%)
0 - 3 °C (4.97%)
3 - 6 °C (5.12%)
6 - 9 °C (5.91%)
9 - 12 °C (6.86%)
12 - 15 °C (10.07%)
15 - 18 °C (13.77%)
18 - 21 °C (14.78%)
21 - 24 °C (21.10%)
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

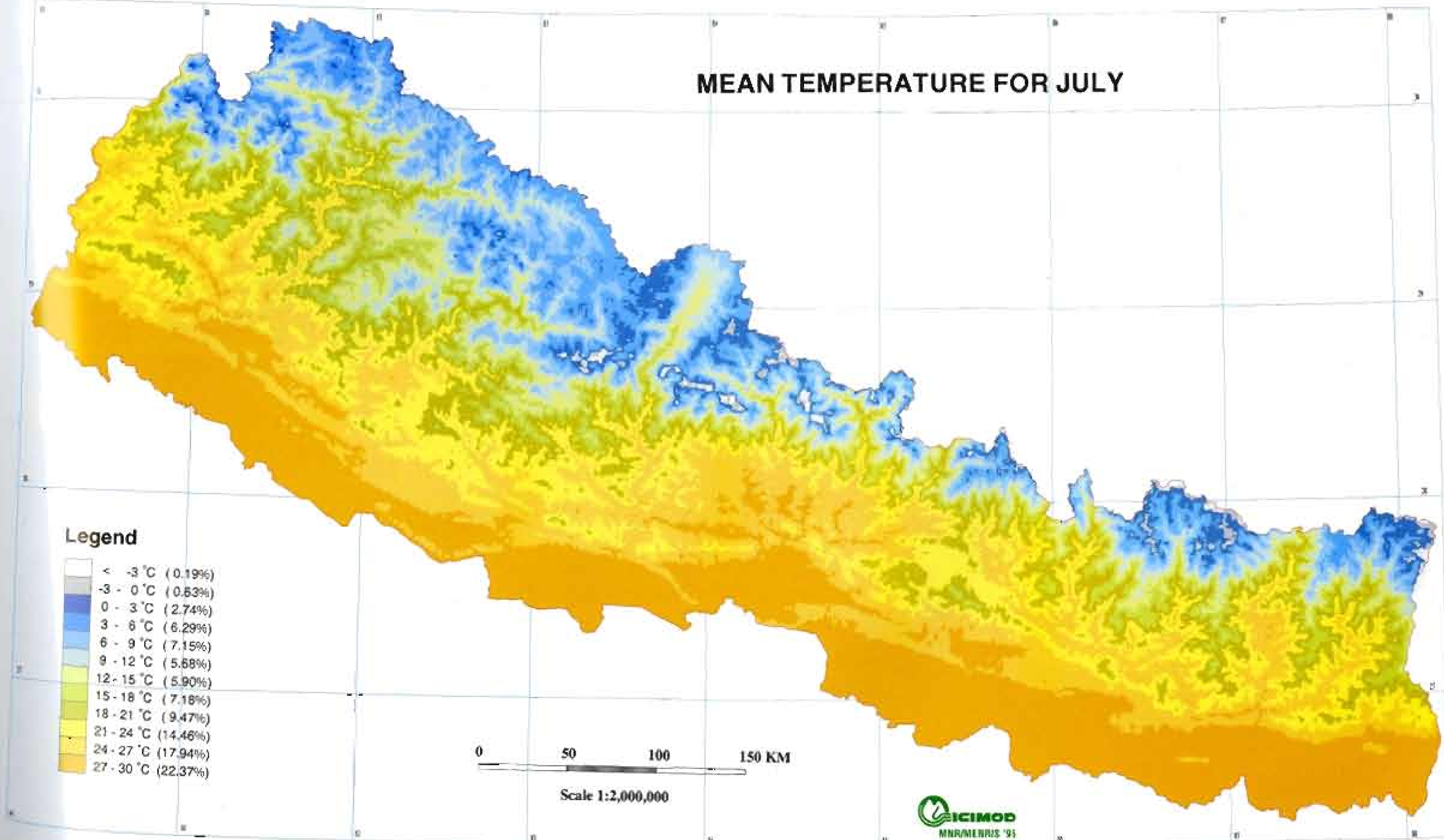


Data Source: Department of Hydrology & Meteorology, HMG, Nepal

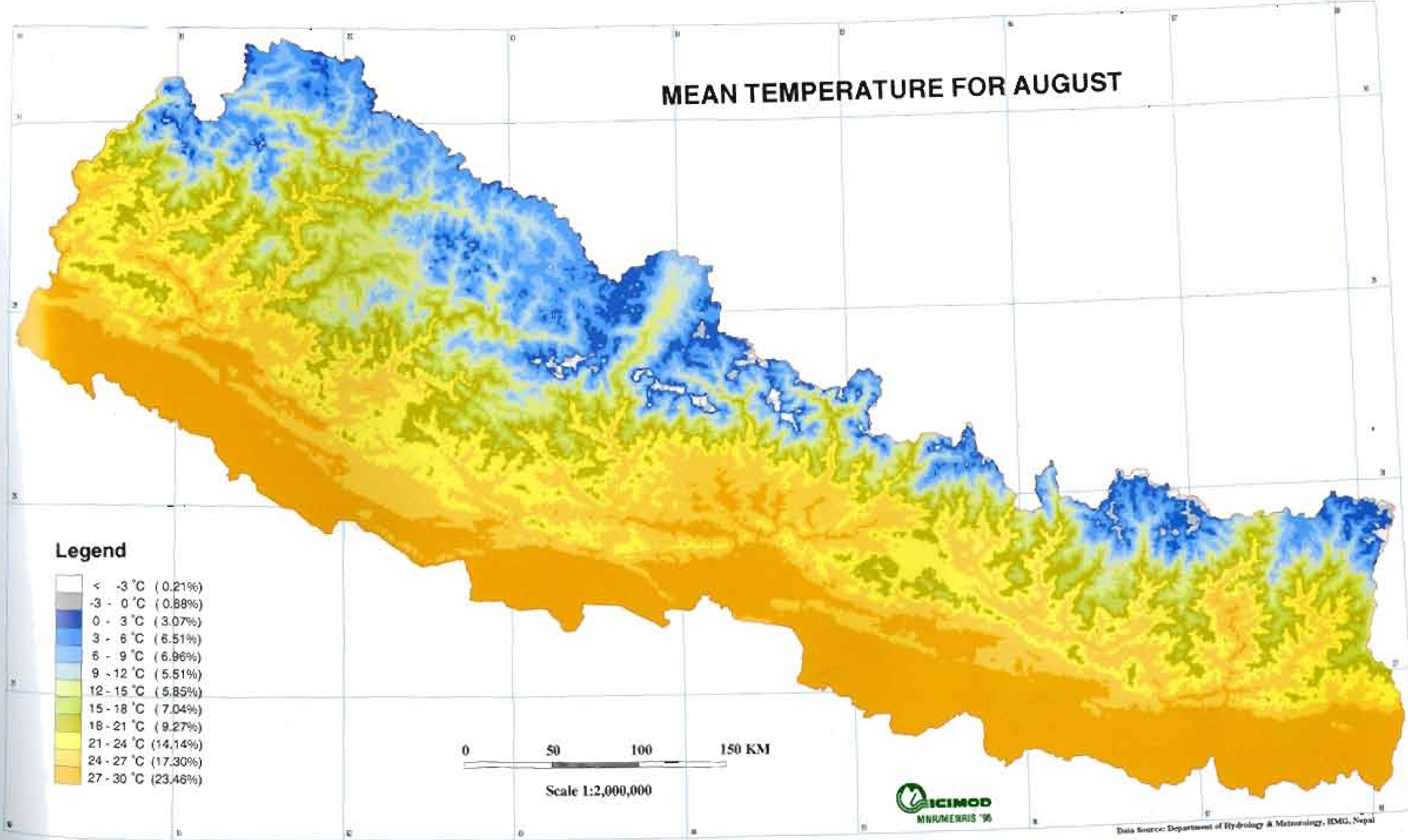

MEAN TEMPERATURE FOR MAY
Legend
< -3 °C (2.23%)
-3 - 0 °C (4.89%)
0 - 3 °C (6.41%)
3 - 6 °C (5.53%)
6 - 9 °C (4.50%)
9 - 12 °C (5.10%)
12 - 15 °C (6.02%)
15 - 18 °C (6.90%)
18 - 21 °C (9.79%)
21 - 24 °C (13.10%)
24 - 27 °C (13.94%)
27 - 30 °C (18.03%)
30 - 33 °C (3.58%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

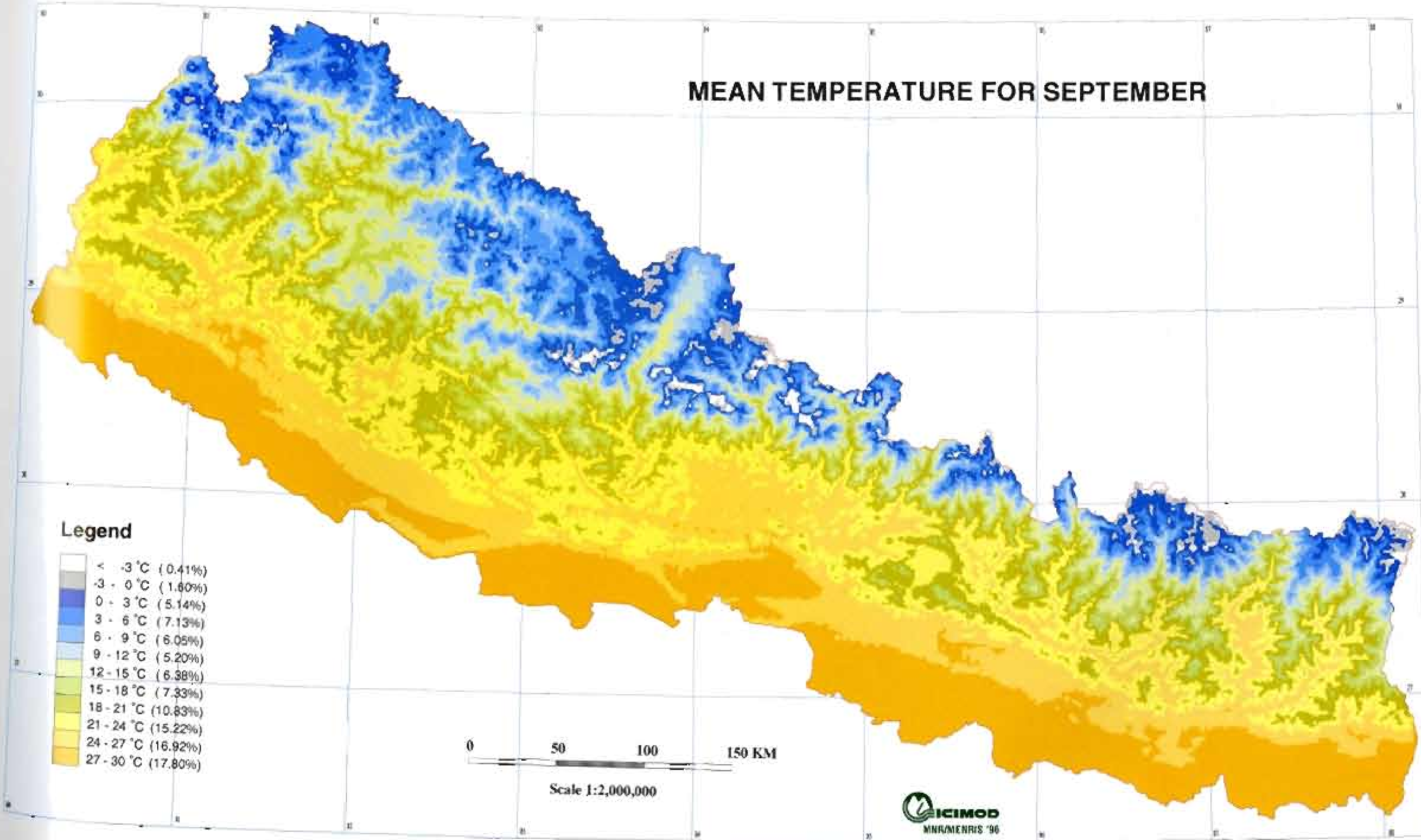


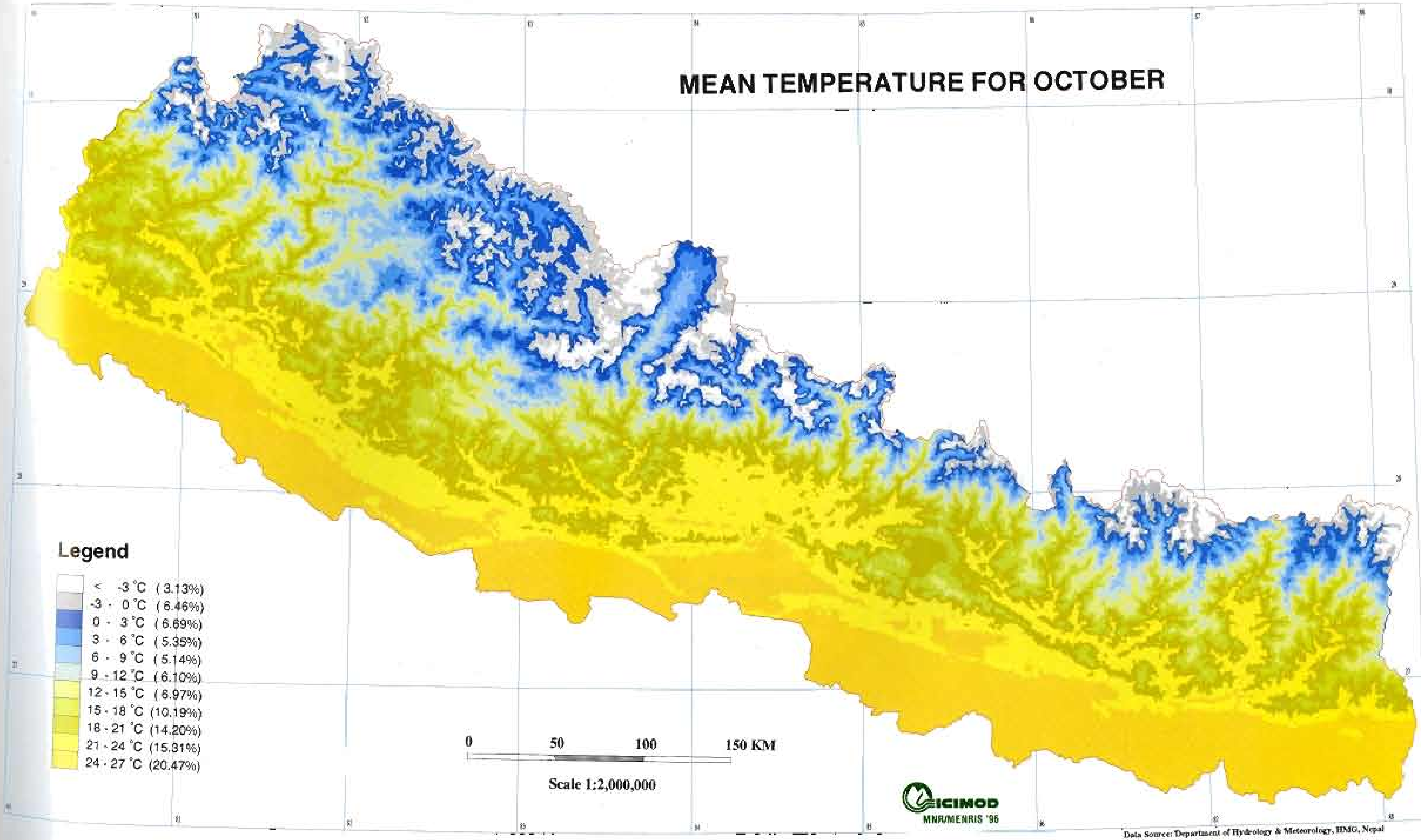
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

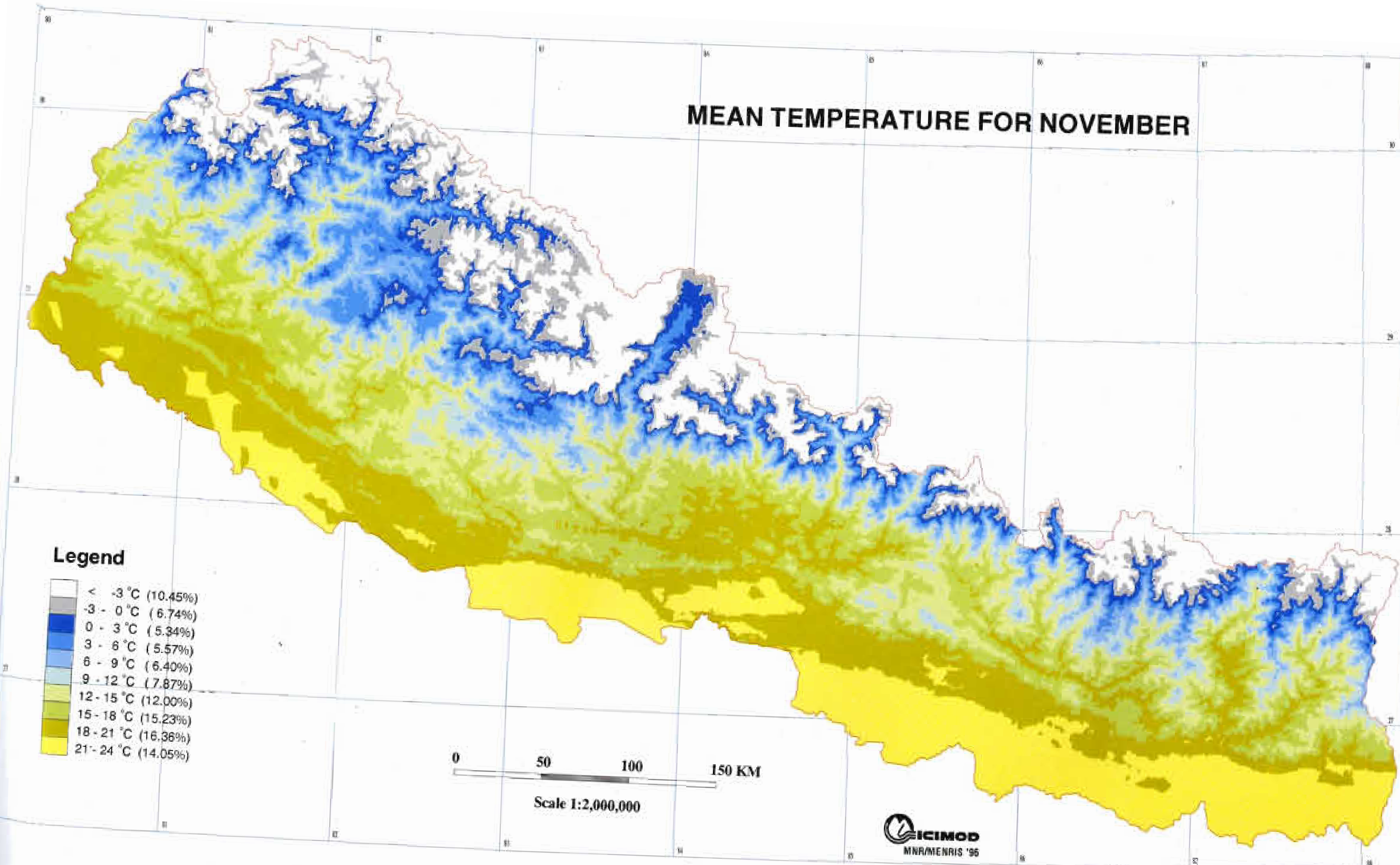


Data Source: Department of Hydrology & Meteorology, HMG, Nepal

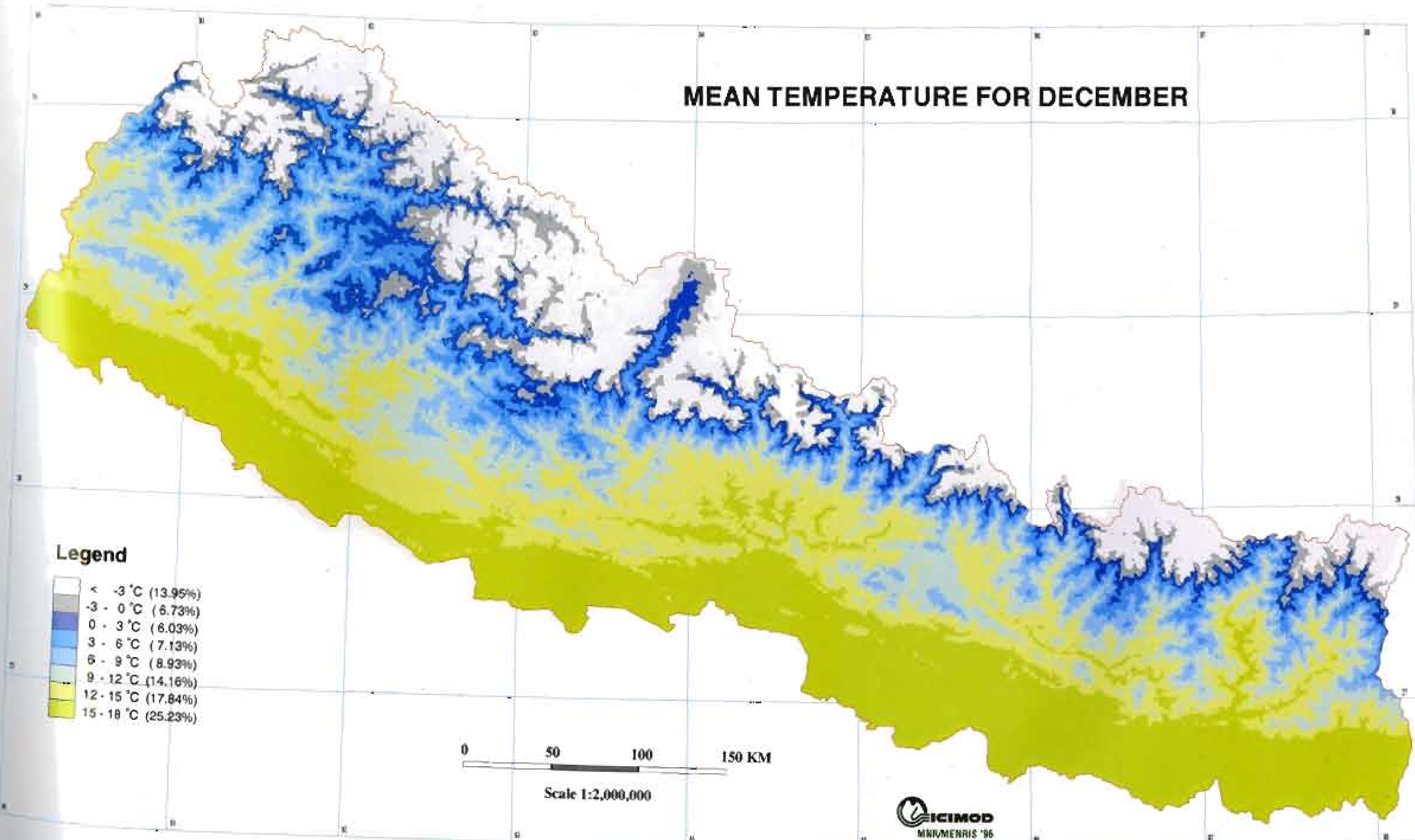

MEAN TEMPERATURE FOR AUGUST
Legend
< -3 °C (0.21%)
-3 - 0 °C (0.88%)
0 - 3 °C (3.07%)
3 - 6 °C (6.51%)
6 - 9 °C (6.96%)
9 - 12 °C (5.51%)
12 - 15 °C (5.85%)
15 - 18 °C (7.04%)
18 - 21 °C (9.27%)
21 - 24 °C (14.14%)
24 - 27 °C (17.30%)
27 - 30 °C (23.46%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

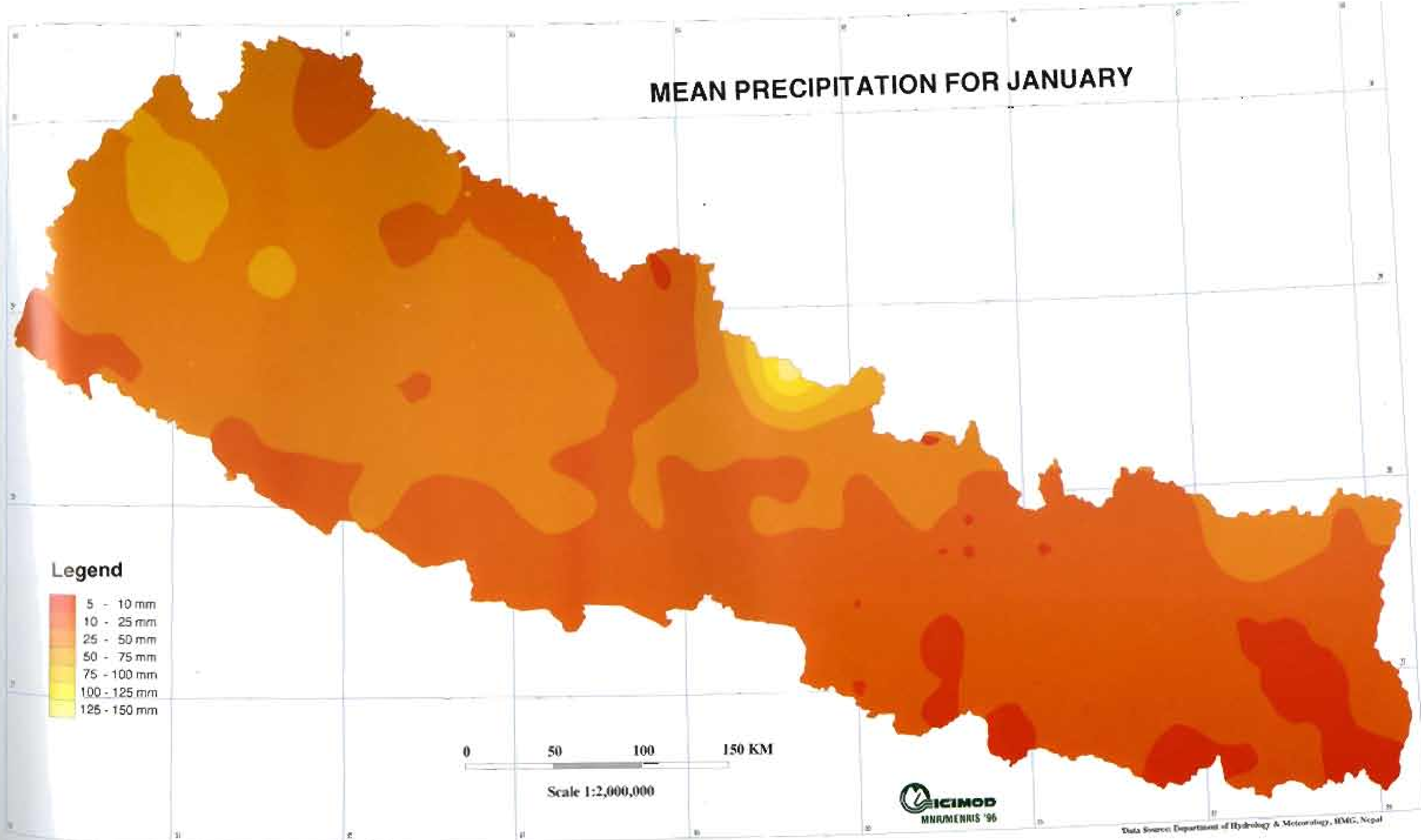

MEAN TEMPERATURE FOR SEPTEMBER
Legend
< -3 °C (0.41%)
-3 - 0 °C (1.60%)
0 - 3 °C (5.14%)
3 - 6 °C (7.13%)
6 - 9 °C (6.05%)
9 - 12 °C (5.20%)
12 - 15 °C (6.38%)
15 - 18 °C (7.33%)
18 - 21 °C (10.83%)
21 - 24 °C (15.22%)
24 - 27 °C (16.92%)
27 - 30 °C (17.80%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

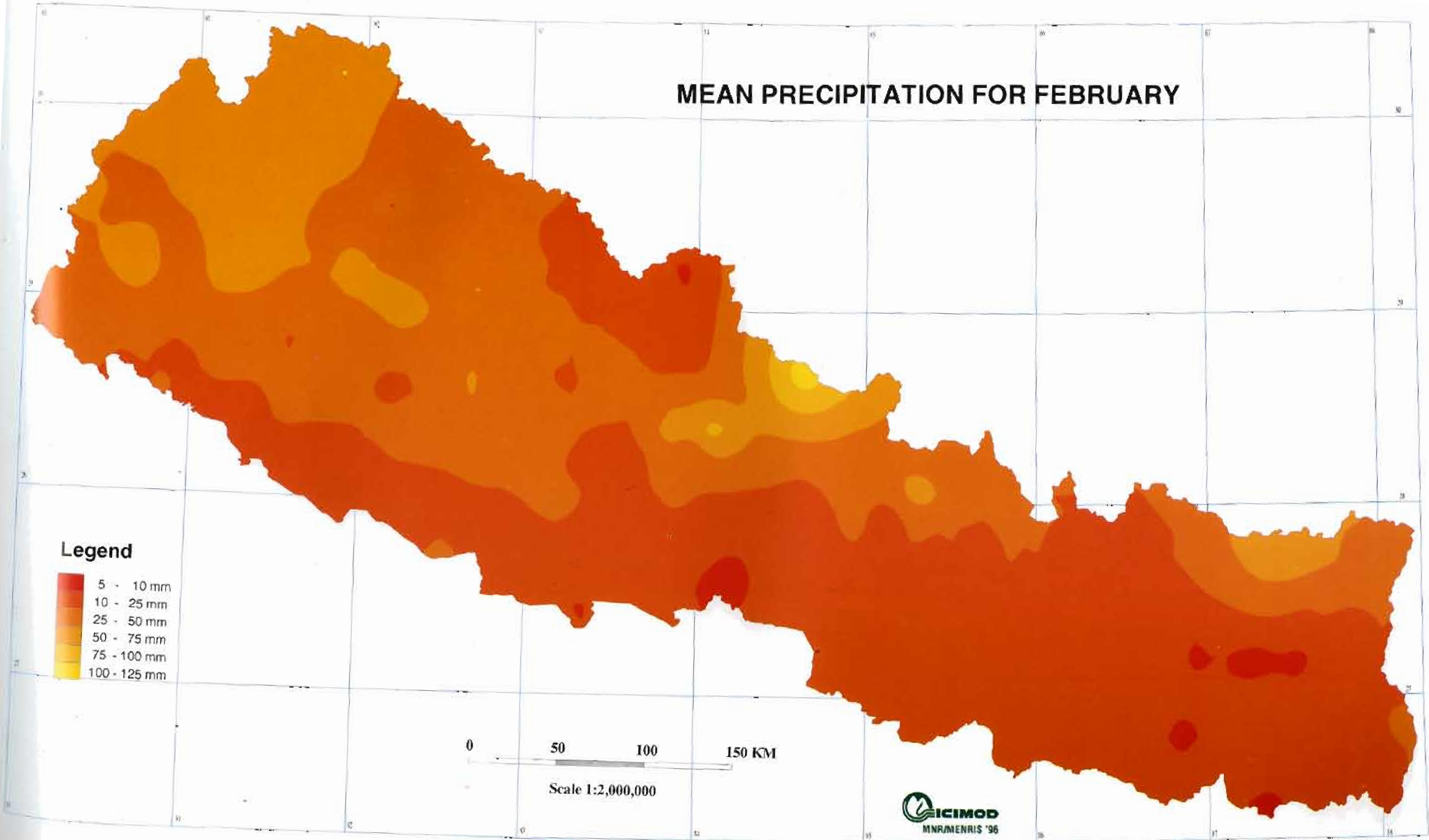

MEAN TEMPERATURE FOR OCTOBER
Legend
< -3 °C (3.13%)
-3 - 0 °C (6.46%)
0 - 3 °C (6.69%)
3 - 6 °C (5.35%)
6 - 9 °C (5.14%)
9 - 12 °C (6.10%)
12 - 15 °C (6.97%)
15 - 18 °C (10.19%)
18 - 21 °C (14.20%)
21 - 24 °C (15.31%)
24 - 27 °C (20.47%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

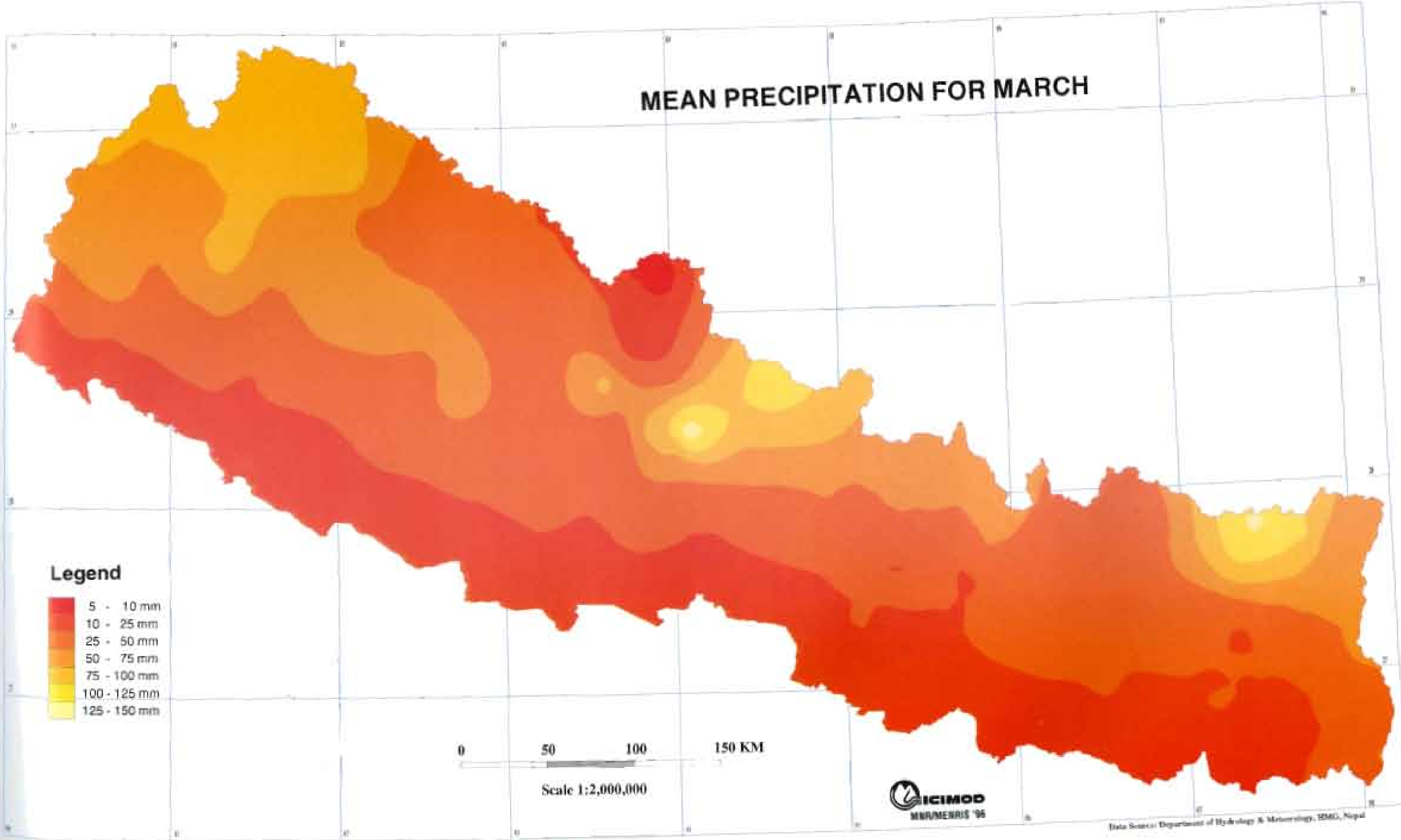


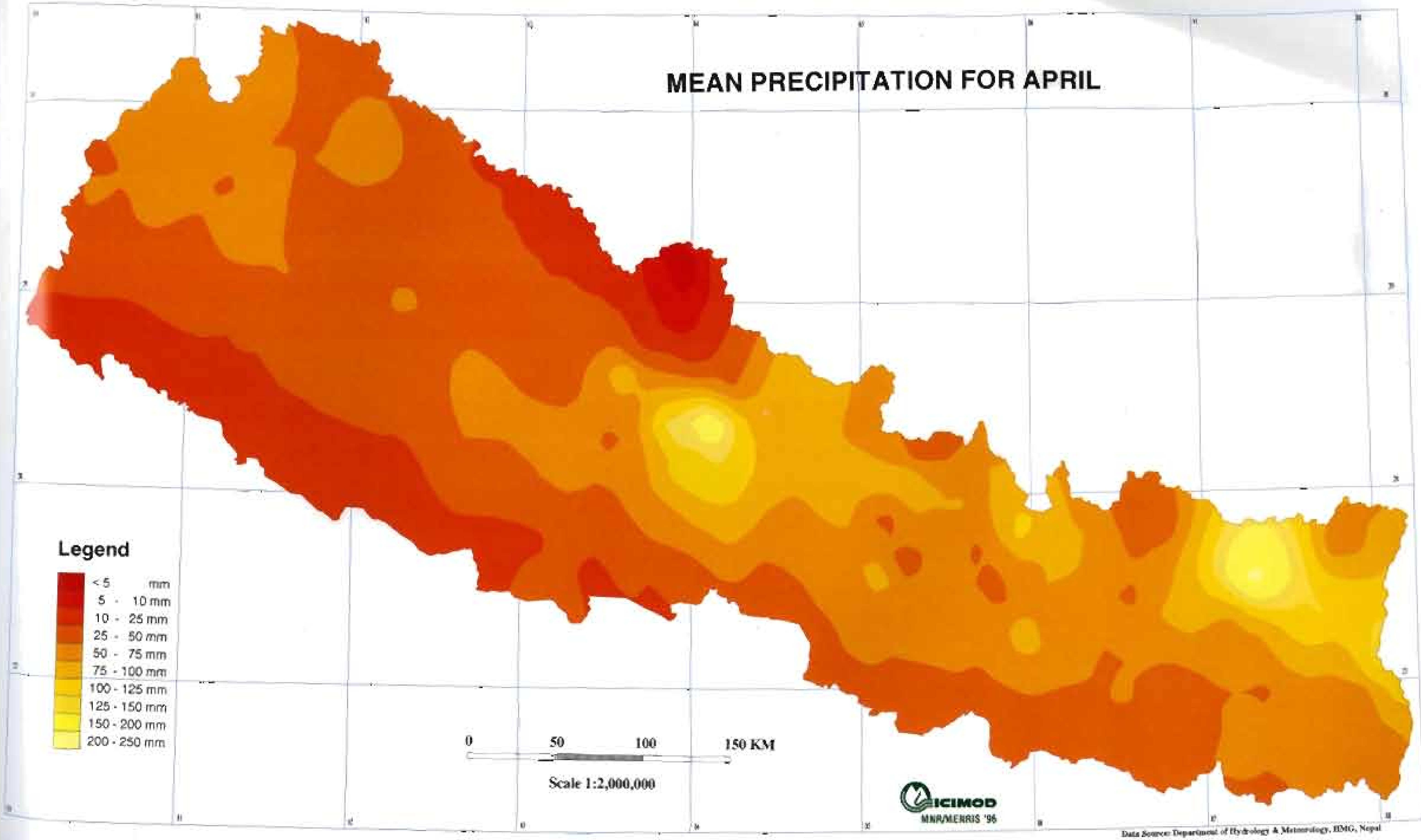
MEAN TEMPERATURE FOR NOVEMBER
Legend
< -3 °C (10.45%)
-3 - 0 °C (6.74%)
0 - 3 °C (5.34%)
3 - 6 °C (5.57%)
6 - 9 °C (6.40%)
9 - 12 °C (7.87%)
12 - 15 °C (12.00%)
15 - 18 °C (15.23%)
18 - 21 °C (16.36%)
21 - 24 °C (14.05%)
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

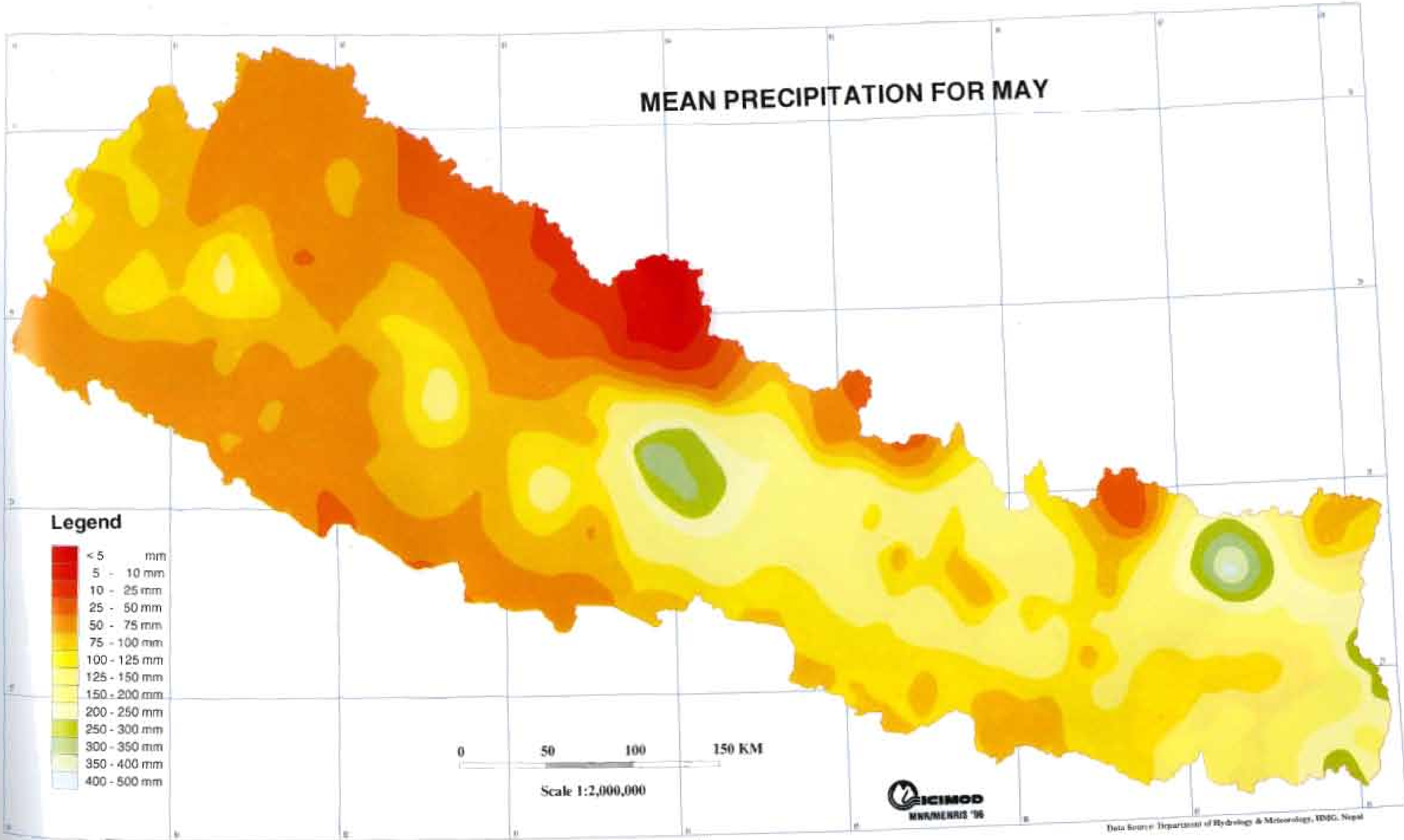

MEAN TEMPERATURE FOR DECEMBER
Legend
< -3 °C (13.95%)
-3 - 0 °C (6.73%)
0 - 3 °C (6.03%)
3 - 6 °C (7.13%)
6 - 9 °C (8.93%)
9 - 12 °C (14.16%)
12 - 15 °C (17.84%)
15 - 18 °C (25.23%)
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

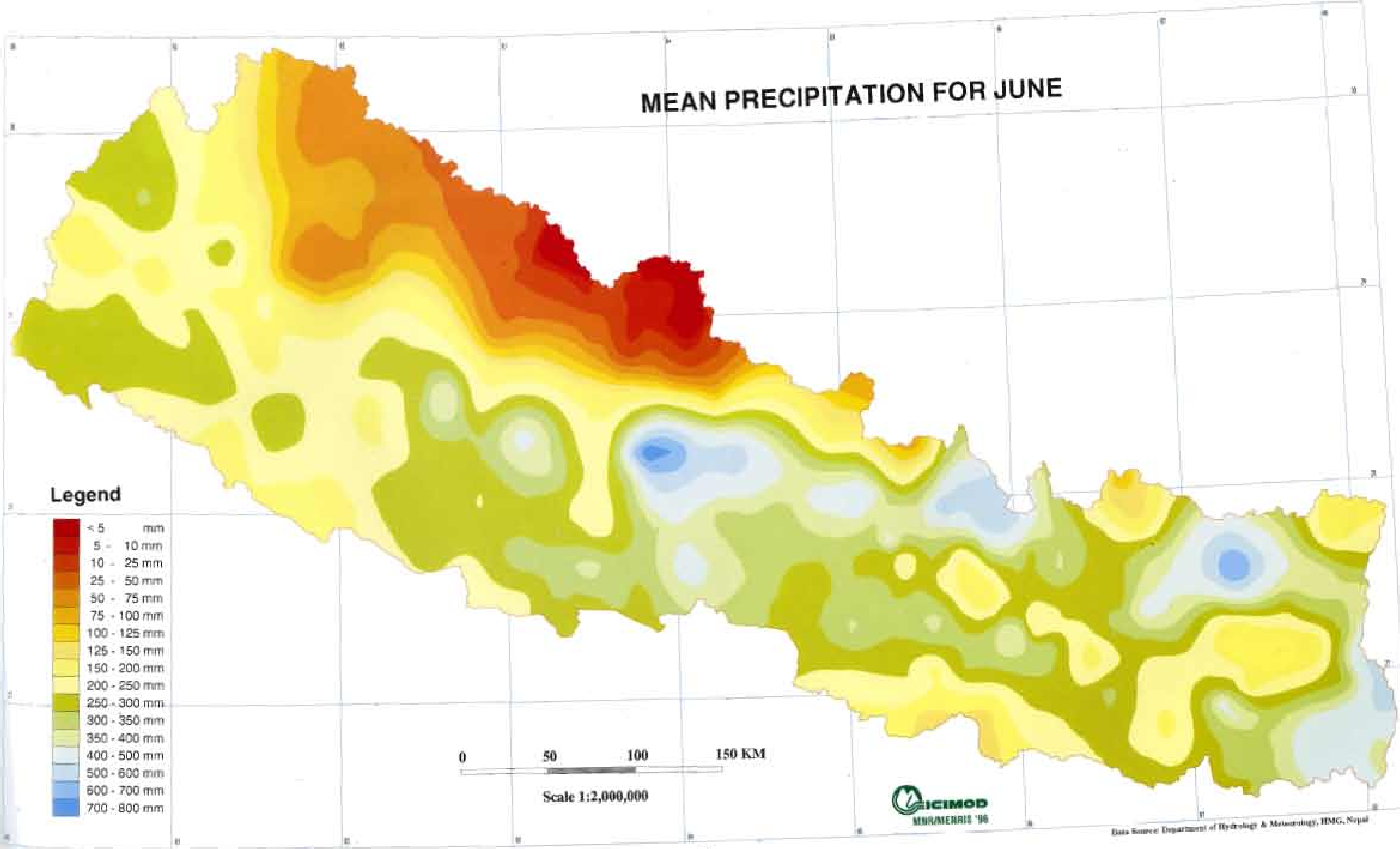

MEAN PRECIPITATION FOR JANUARY
Legend
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
125 - 150 mm
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNRMENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

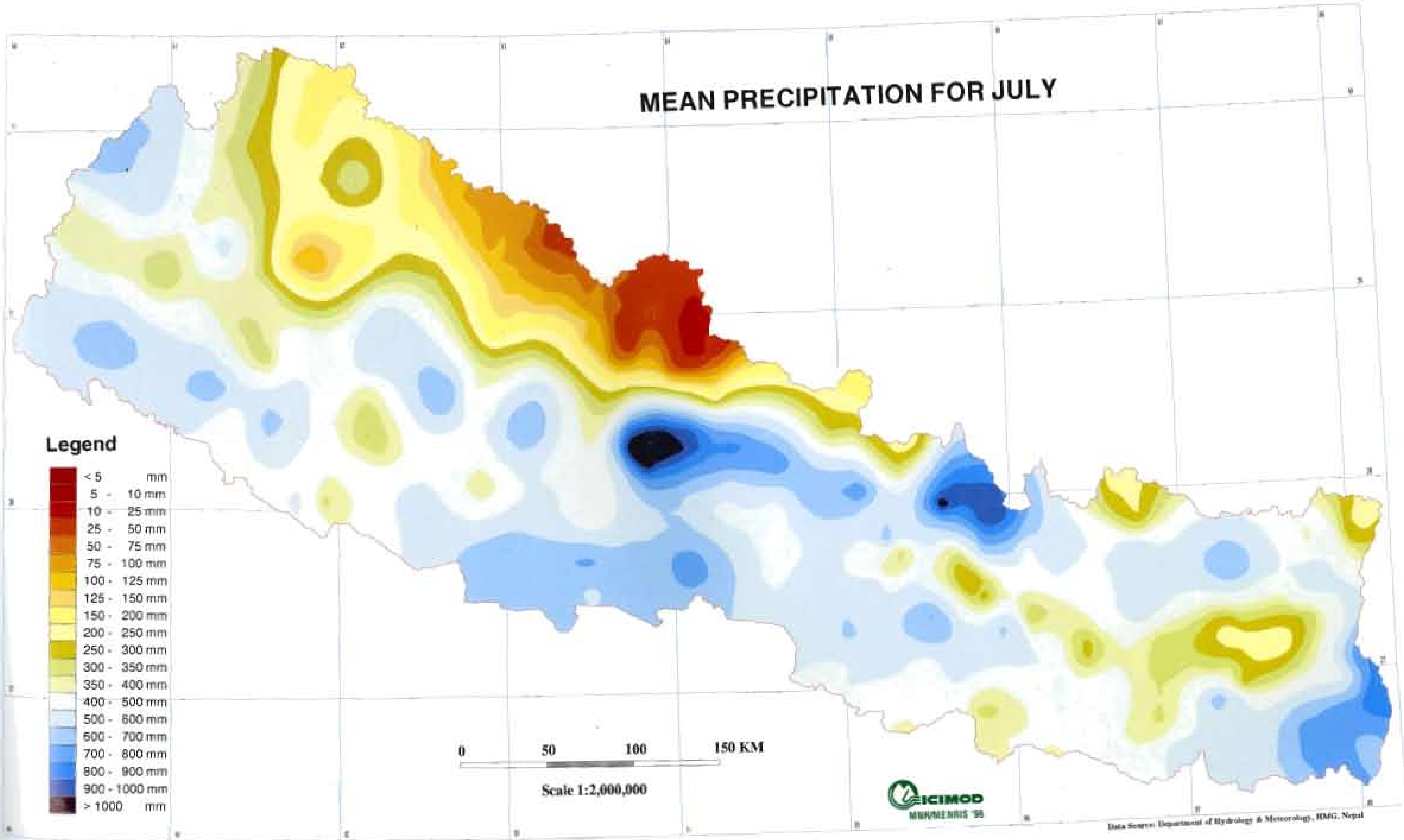

MEAN PRECIPITATION FOR FEBRUARY
Legend
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

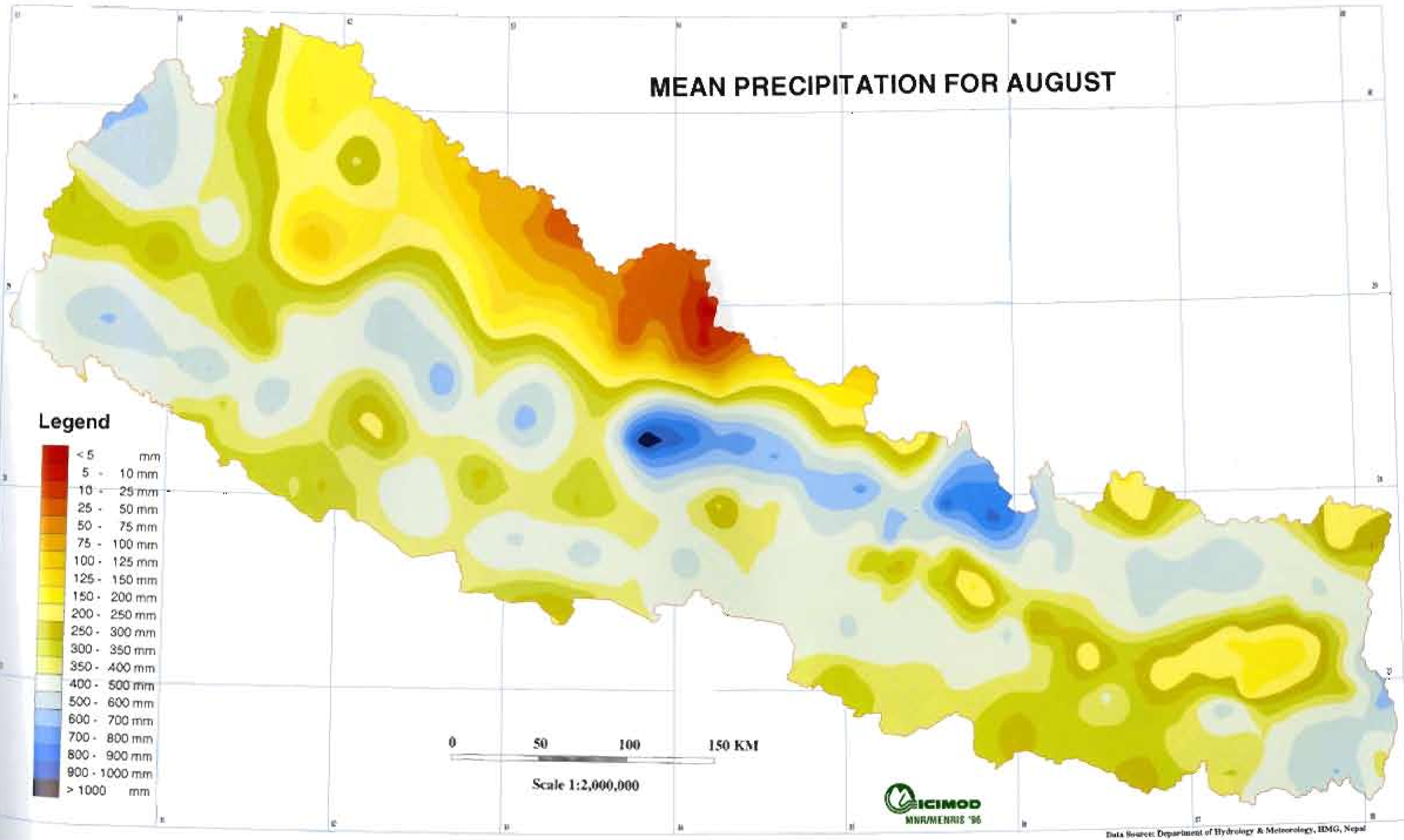

MEAN PRECIPITATION FOR MARCH
Legend
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
125 - 150 mm
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN PRECIPITATION FOR APRIL
Legend
< 5 mm
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
125 - 150 mm
150 - 200 mm
200 - 250 mm
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

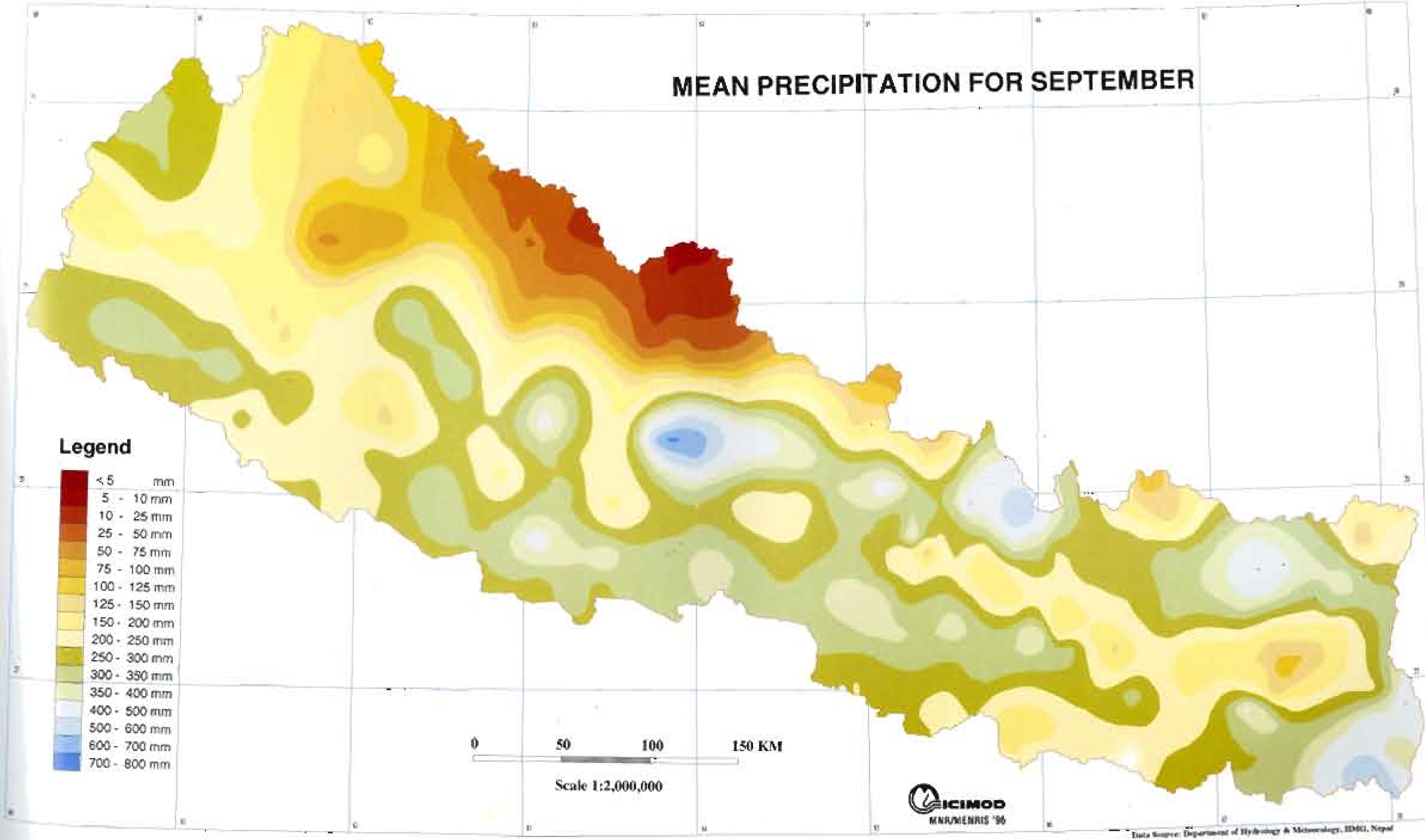

MEAN PRECIPITATION FOR MAY
Legend
< 5 mm
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
125 - 150 mm
150 - 200 mm
200 - 250 mm
250 - 300 mm
300 - 350 mm
350 - 400 mm
400 - 500 mm
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

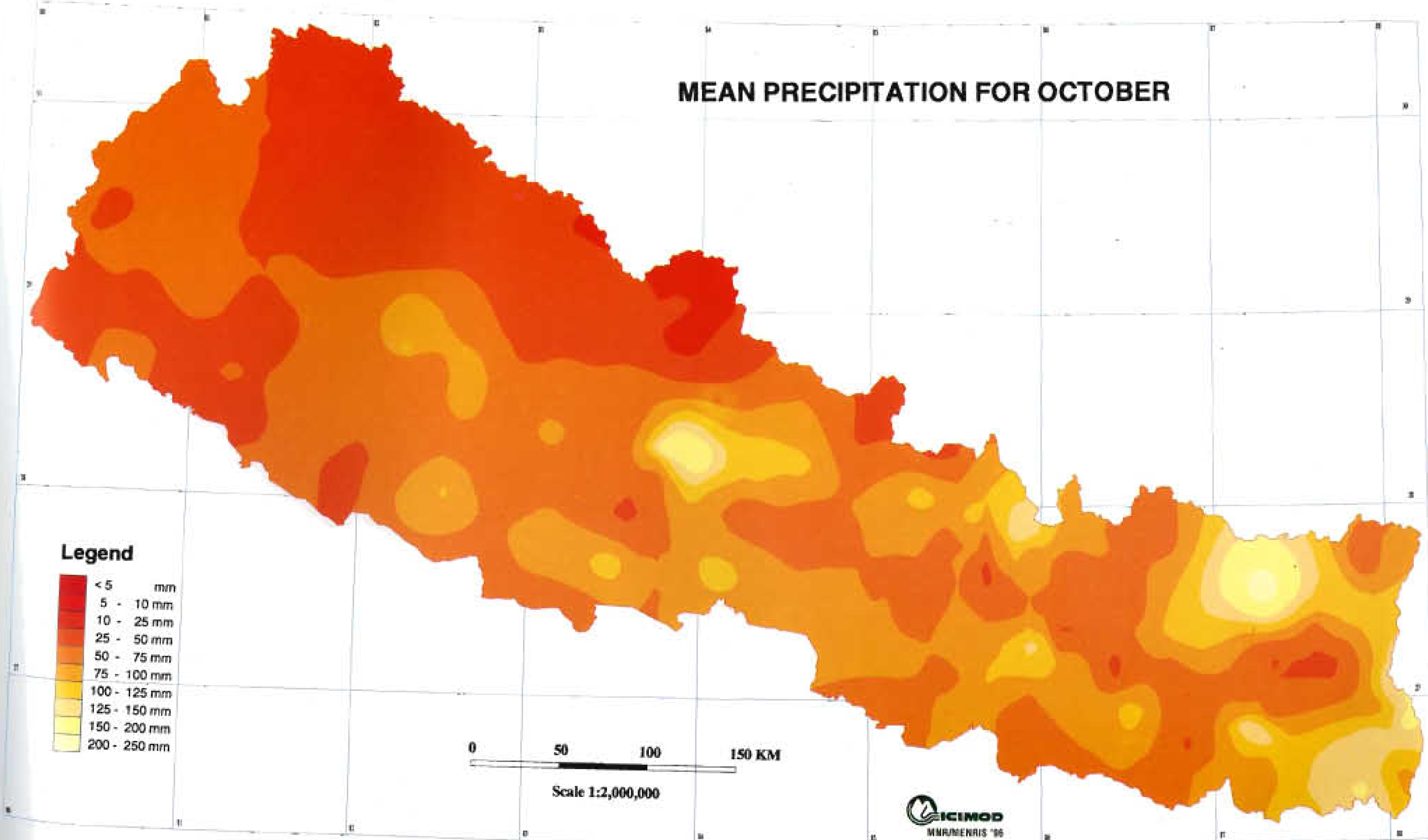

MEAN PRECIPITATION FOR JUNE
Legend
< 5 mm
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
125 - 150 mm
150 - 200 mm
200 - 250 mm
250 - 300 mm
300 - 350 mm
350 - 400 mm
400 - 500 mm
500 - 600 mm
600 - 700 mm
700 - 800 mm
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN PRECIPITATION FOR JULY
Legend
< 5 mm
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
125 - 150 mm
150 - 200 mm
200 - 250 mm
250 - 300 mm
300 - 350 mm
350 - 400 mm
400 - 500 mm
500 - 600 mm
600 - 700 mm
700 - 800 mm
800 - 900 mm
900 - 1000 mm
> 1000 mm
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

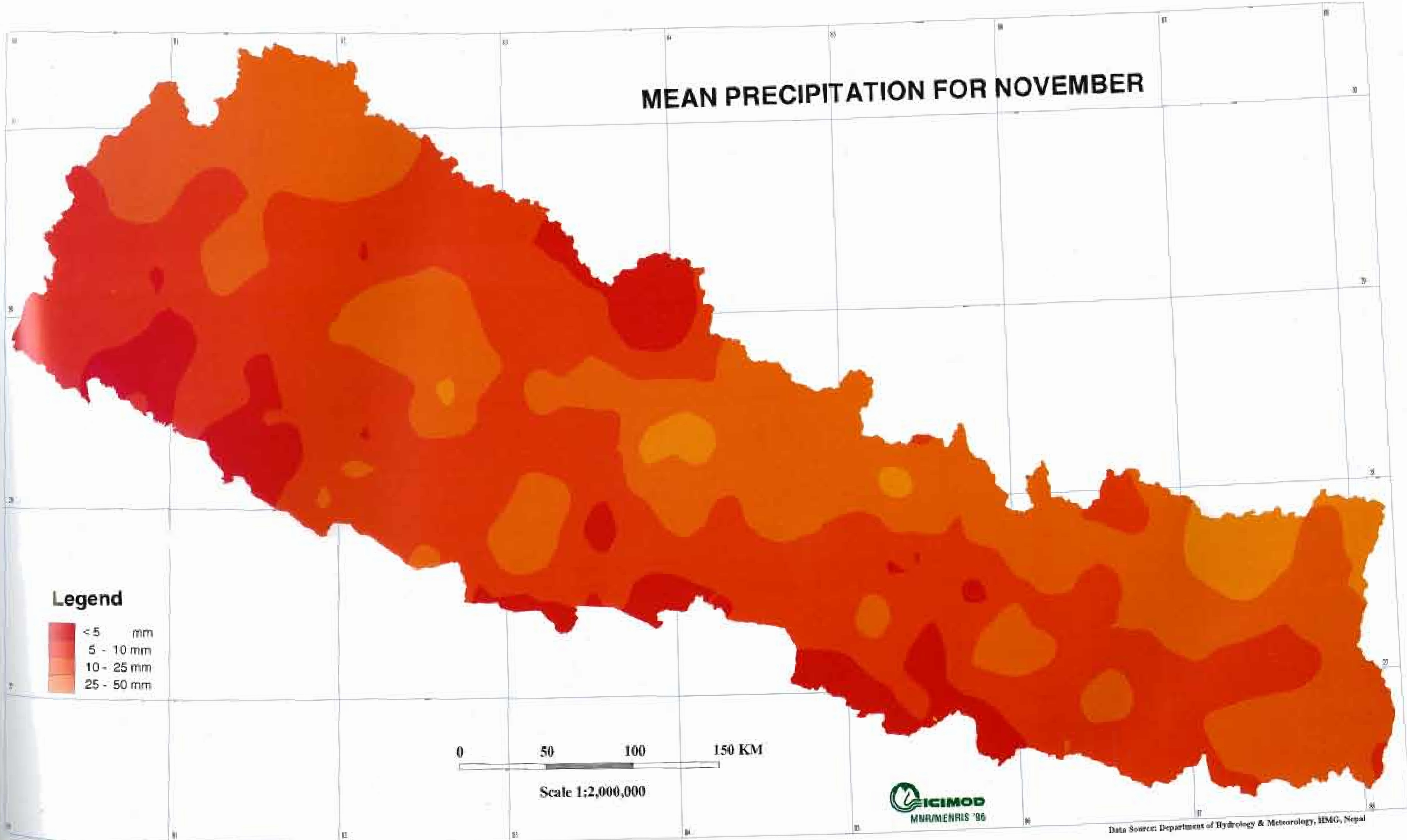


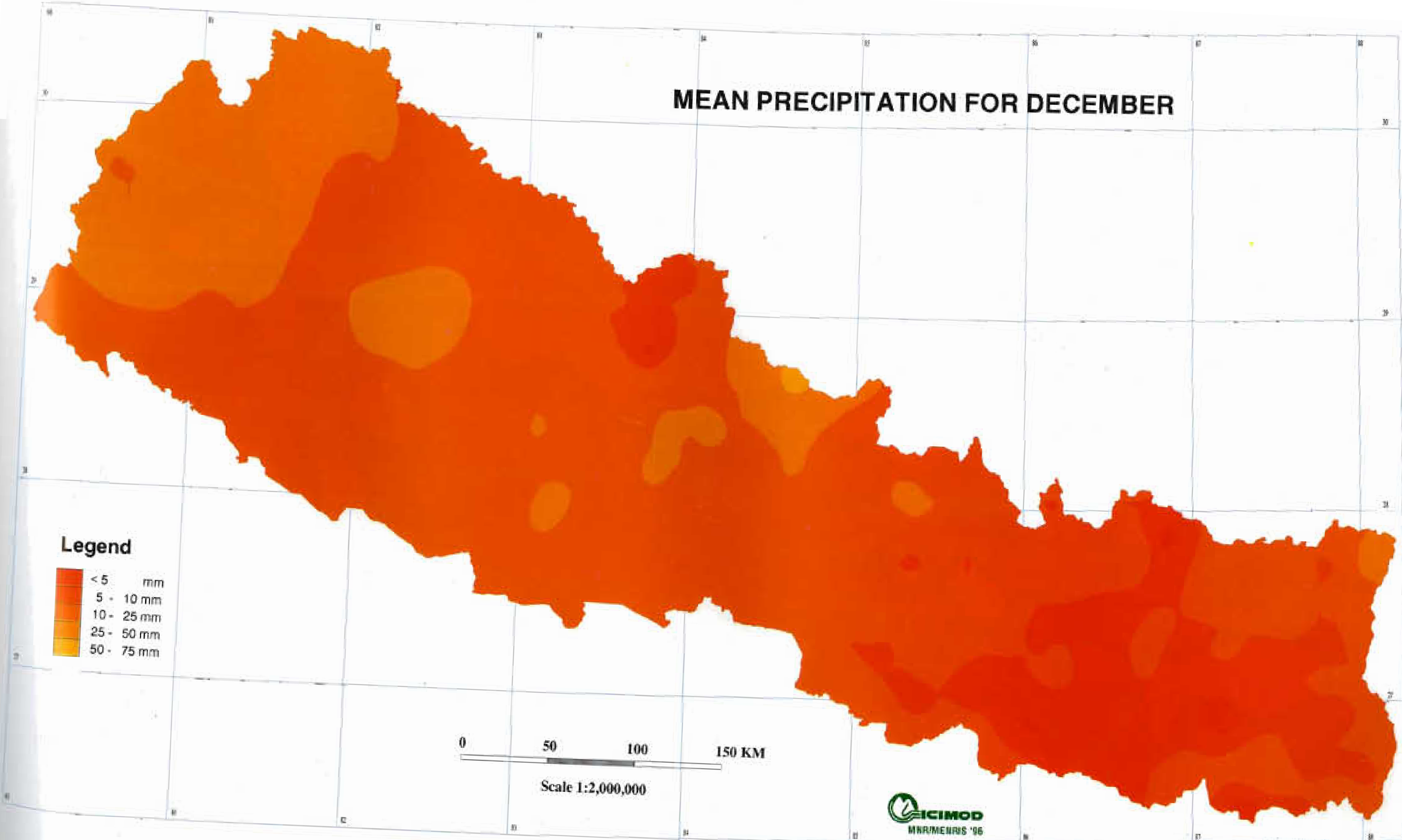
MEAN PRECIPITATION FOR AUGUST
Legend
< 5 mm
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
125 - 150 mm
150 - 200 mm
200 - 250 mm
250 - 300 mm
300 - 350 mm
350 - 400 mm
400 - 500 mm
500 - 600 mm
600 - 700 mm
700 - 800 mm
800 - 900 mm
900 - 1000 mm
> 1000 mm
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

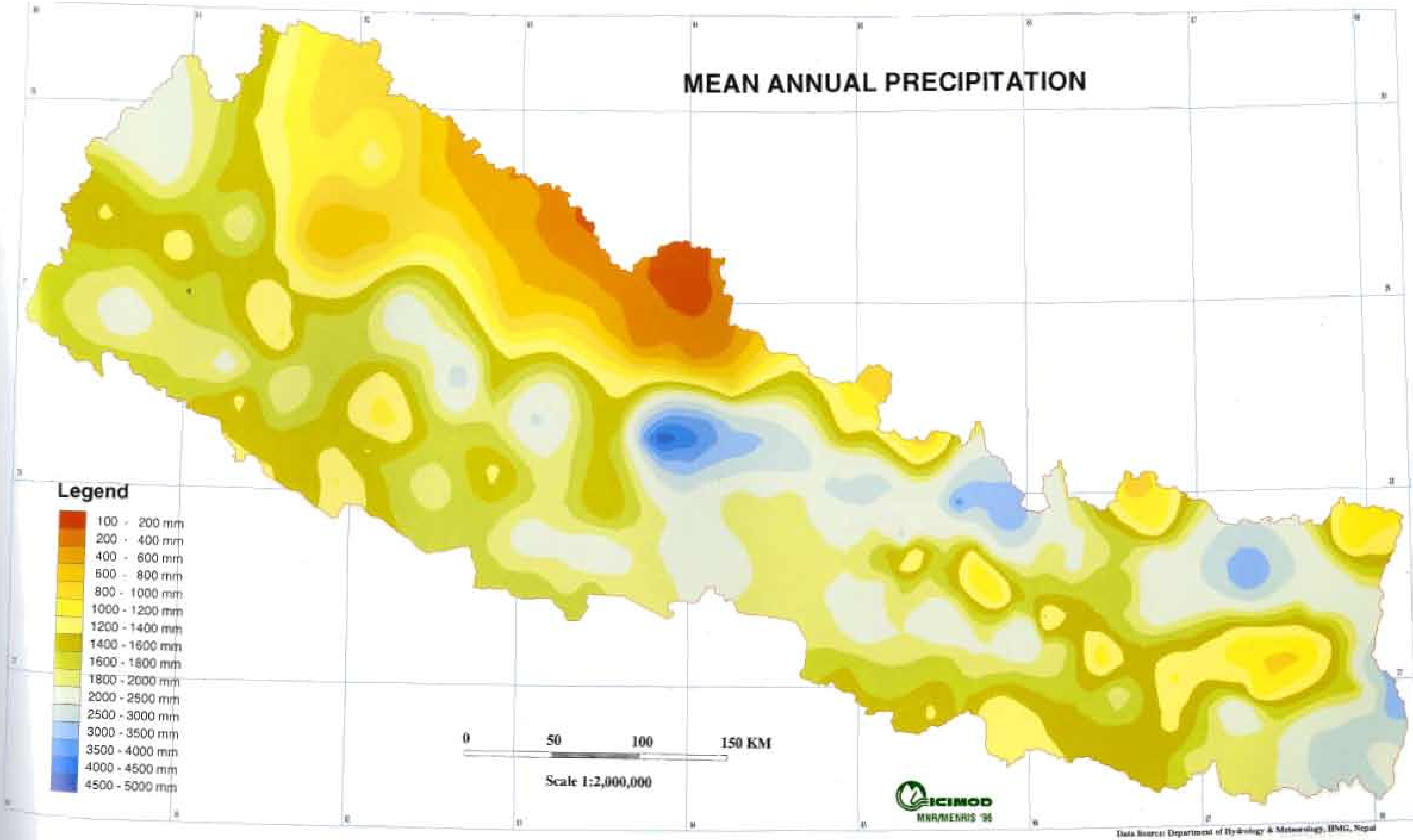

MEAN PRECIPITATION FOR SEPTEMBER
Legend
< 5 mm
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
125 - 150 mm
150 - 200 mm
200 - 250 mm
250 - 300 mm
300 - 350 mm
350 - 400 mm
400 - 500 mm
500 - 600 mm
600 - 700 mm
700 - 800 mm
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

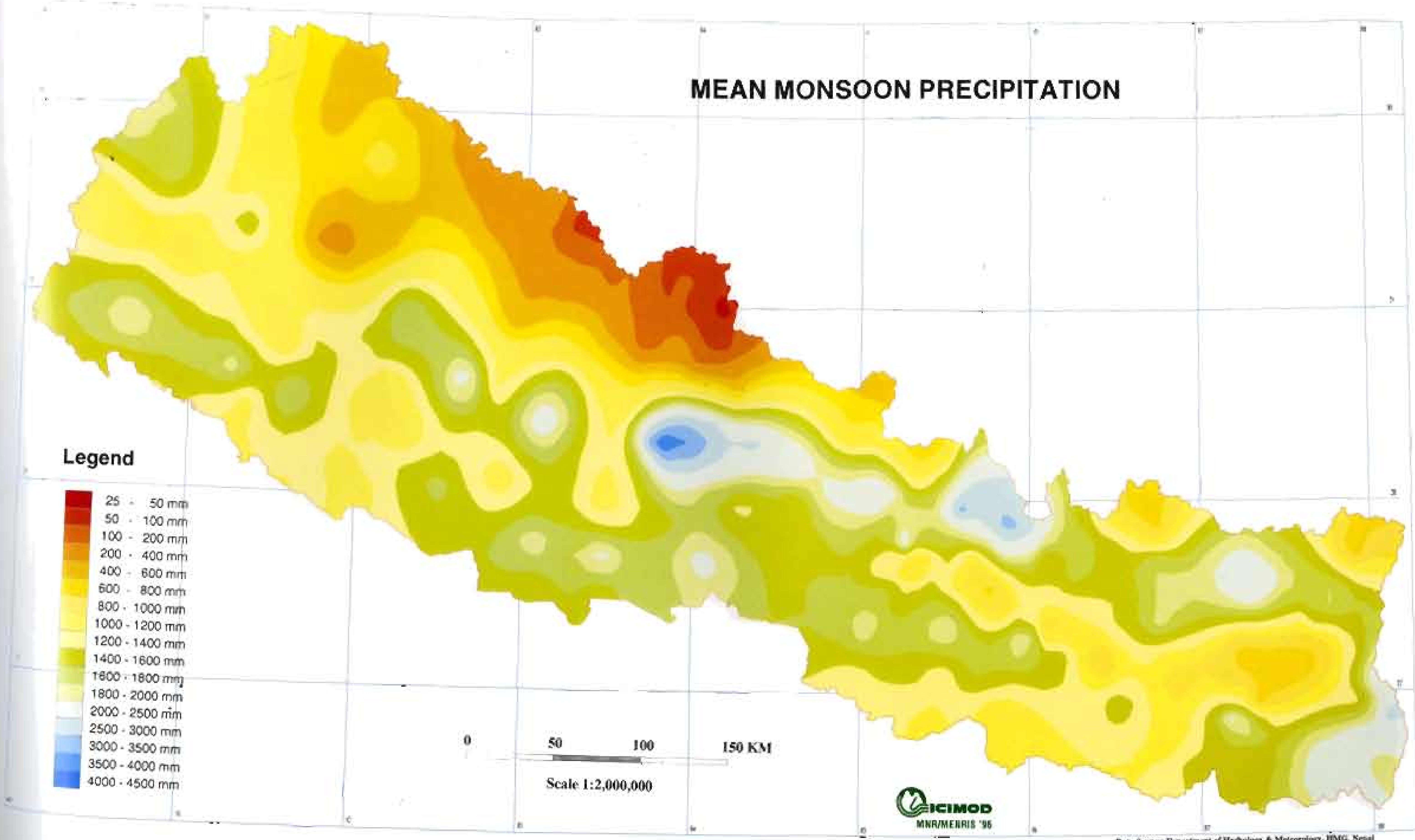


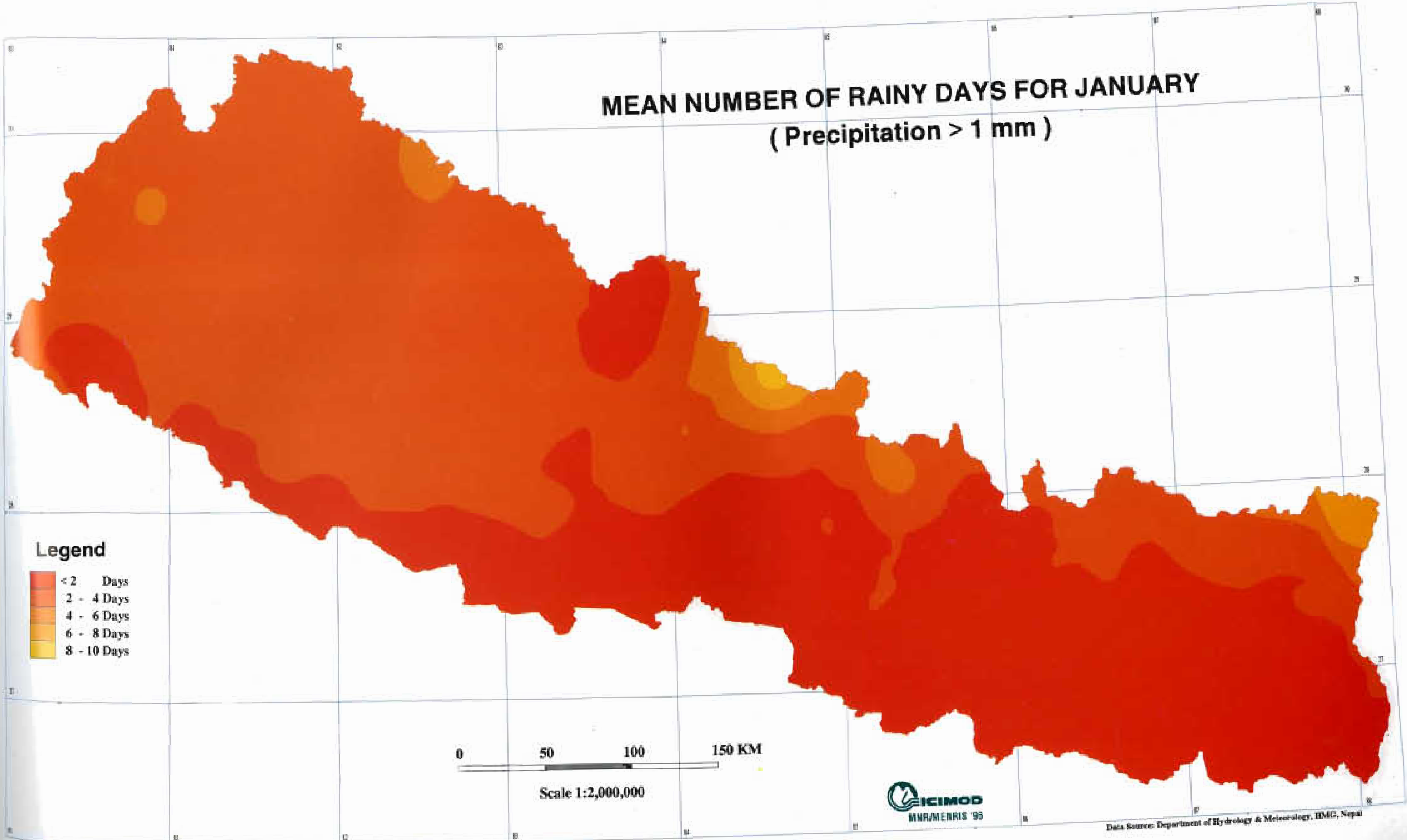
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

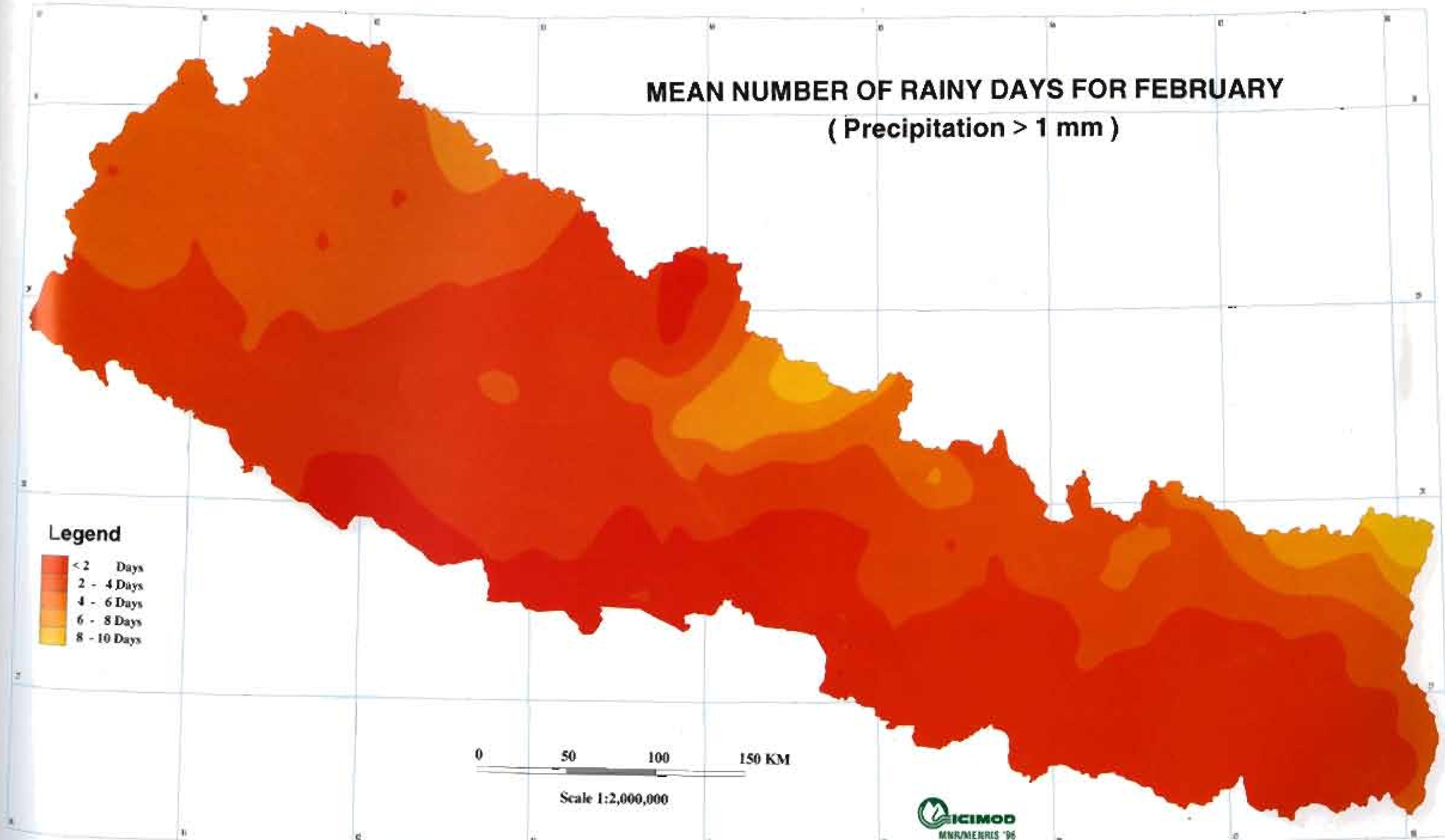

MEAN PRECIPITATION FOR NOVEMBER
Legend
< 5 mm
5 - 10 mm
10 - 25 mm
25 - 50 mm
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN PRECIPITATION FOR DECEMBER
Legend
< 5 mm
5 - 10 mm
10 - 25 mm
25 - 50 mm
50 - 75 mm
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

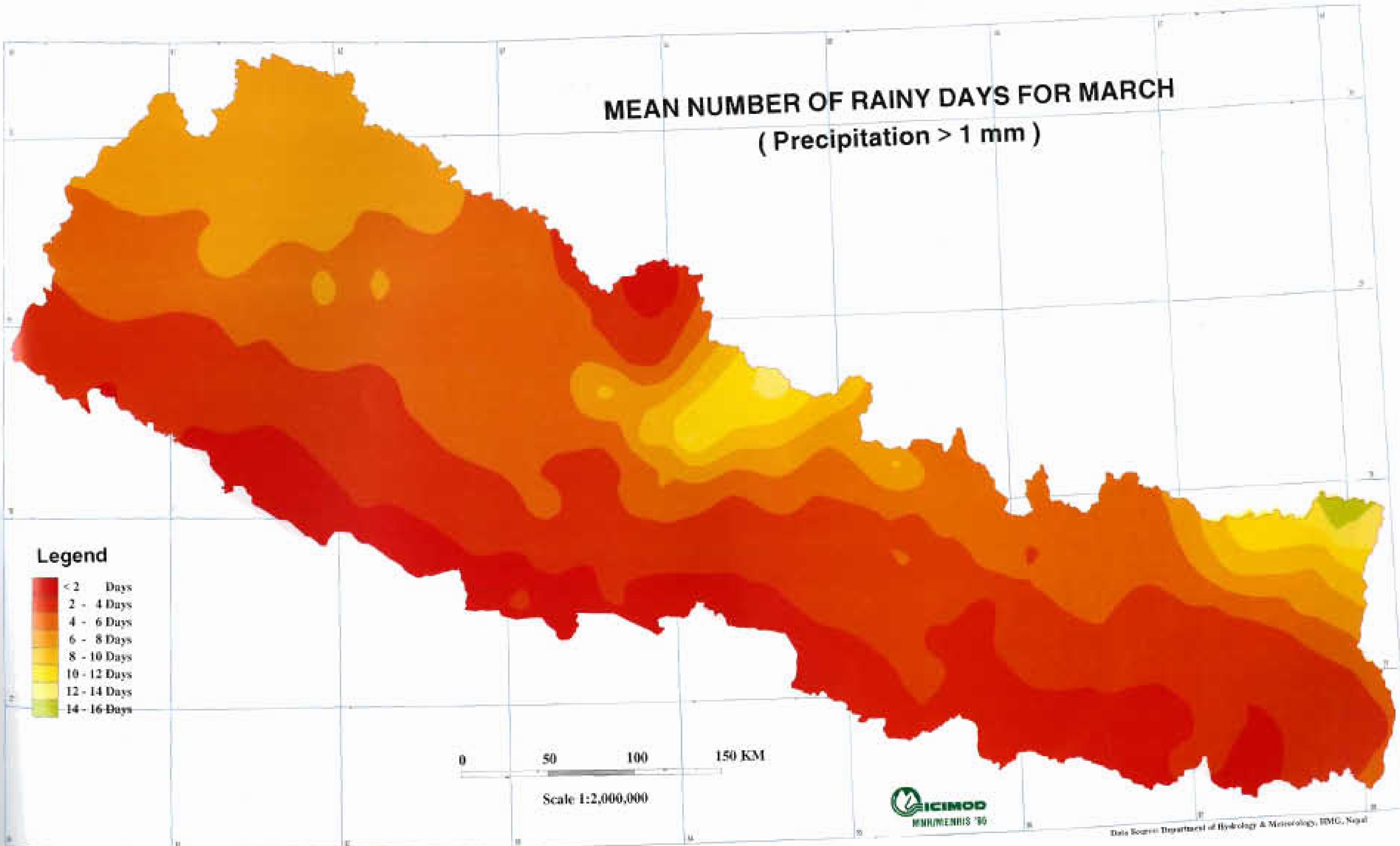

MEAN ANNUAL PRECIPITATION
Legend
100 - 200 mm
200 - 400 mm
400 - 600 mm
600 - 800 mm
800 - 1000 mm
1000 - 1200 mm
1200 - 1400 mm
1400 - 1600 mm
1600 - 1800 mm
1800 - 2000 mm
2000 - 2500 mm
2500 - 3000 mm
3000 - 3500 mm
3500 - 4000 mm
4000 - 4500 mm
4500 - 5000 mm
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN MONSOON PRECIPITATION
Legend
25 - 50 mm
50 - 100 mm
100 - 200 mm
200 - 400 mm
400 - 600 mm
600 - 800 mm
800 - 1000 mm
1000 - 1200 mm
1200 - 1400 mm
1400 - 1600 mm
1600 - 1800 mm
1800 - 2000 mm
2000 - 2500 mm
2500 - 3000 mm
3000 - 3500 mm
3500 - 4000 mm
4000 - 4500 mm
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

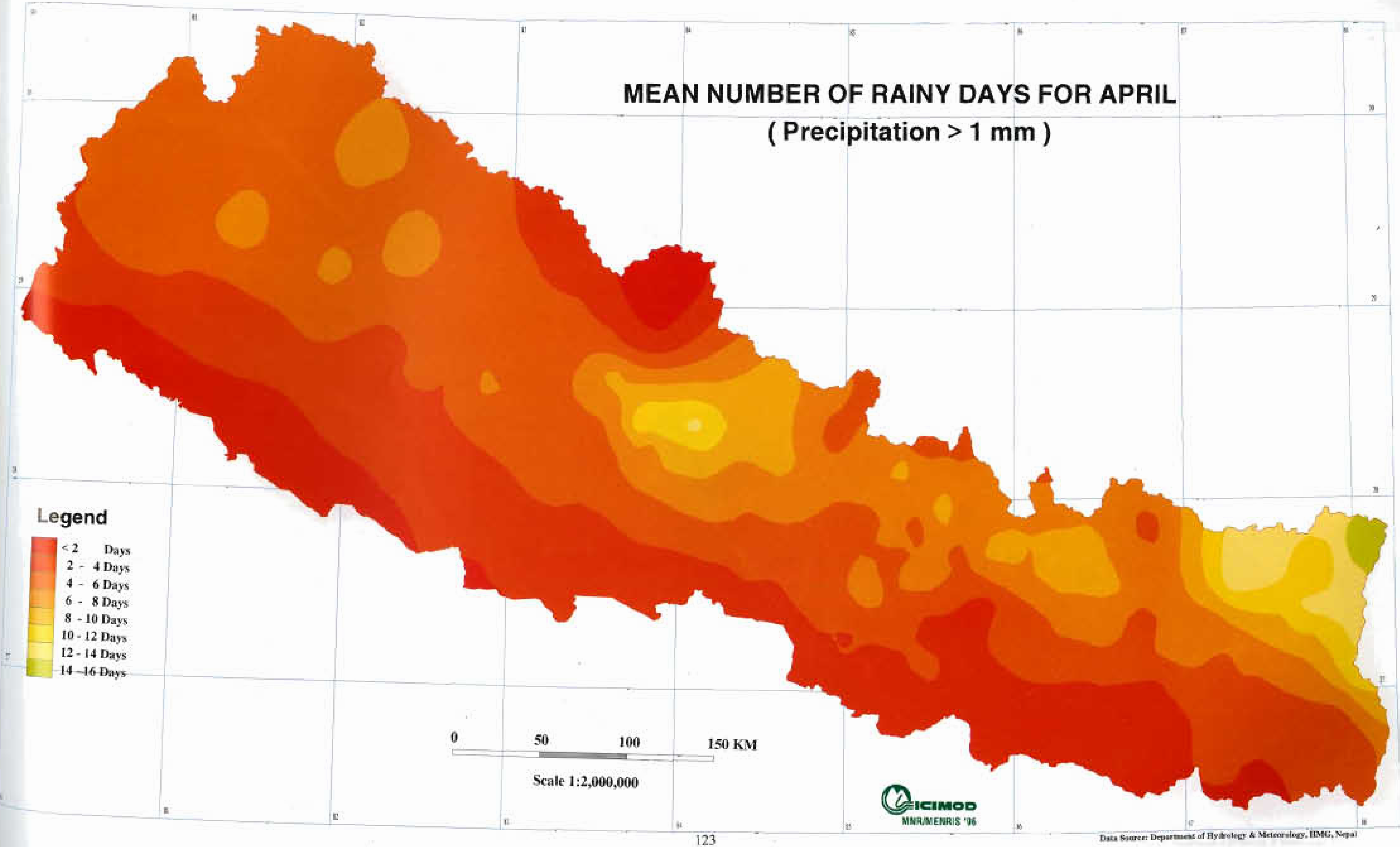

MEAN NUMBER OF RAINY DAYS FOR JANUARY
(Precipitation > 1 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '95
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

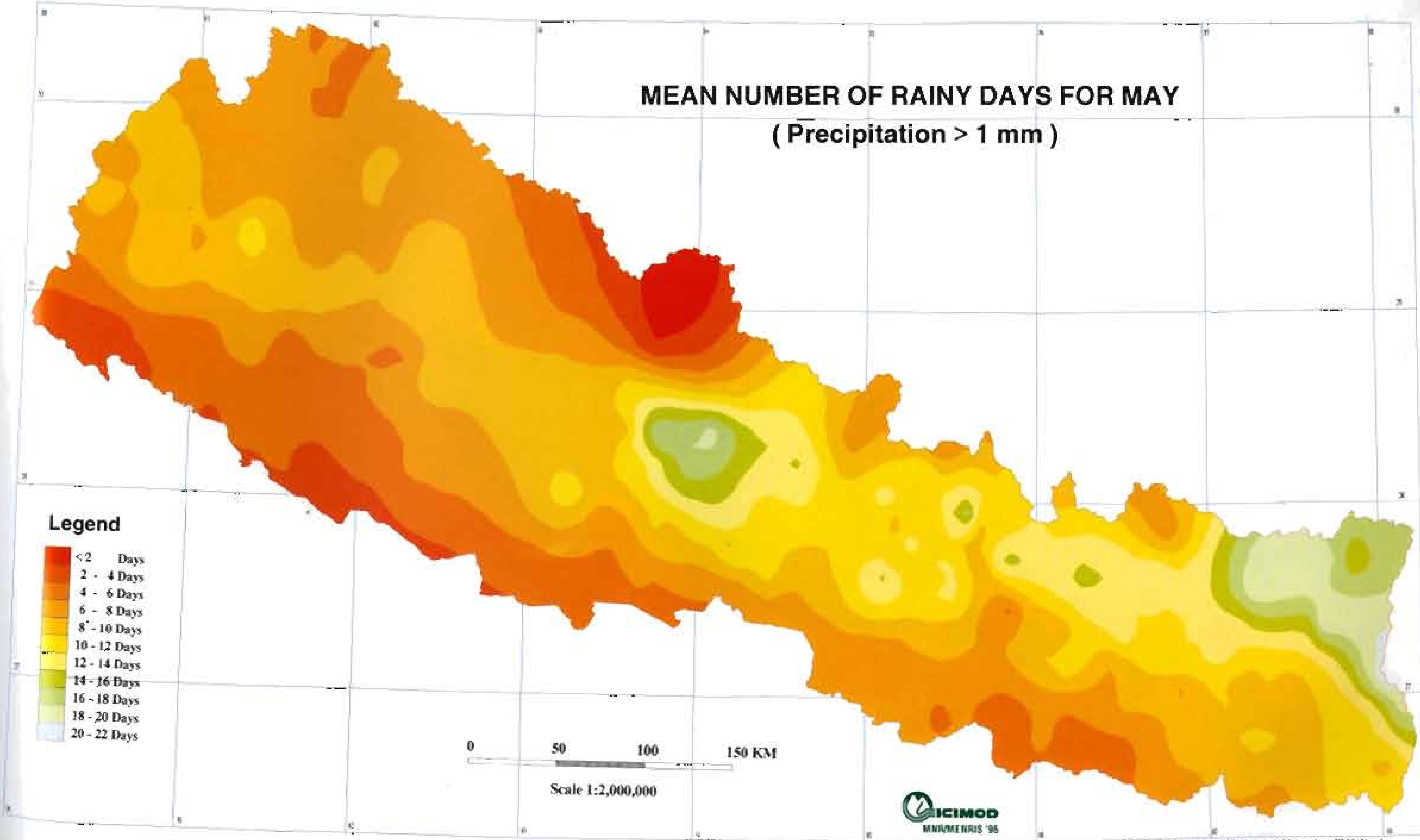


Data Source: Department of Hydrology & Meteorology, HMG, Nepal

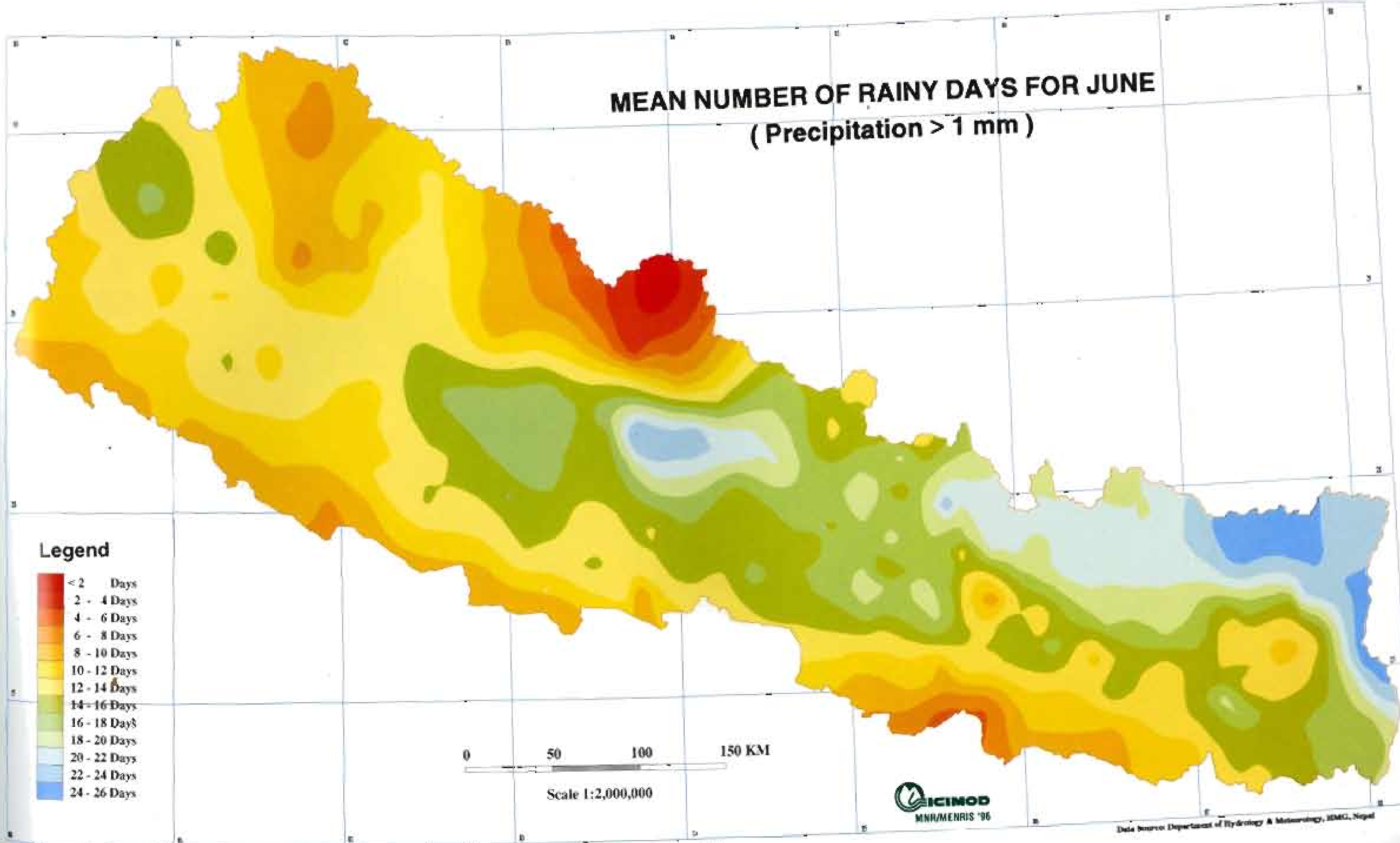

MEAN NUMBER OF RAINY DAYS FOR MARCH
(Precipitation > 1 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
14 - 16 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '90
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

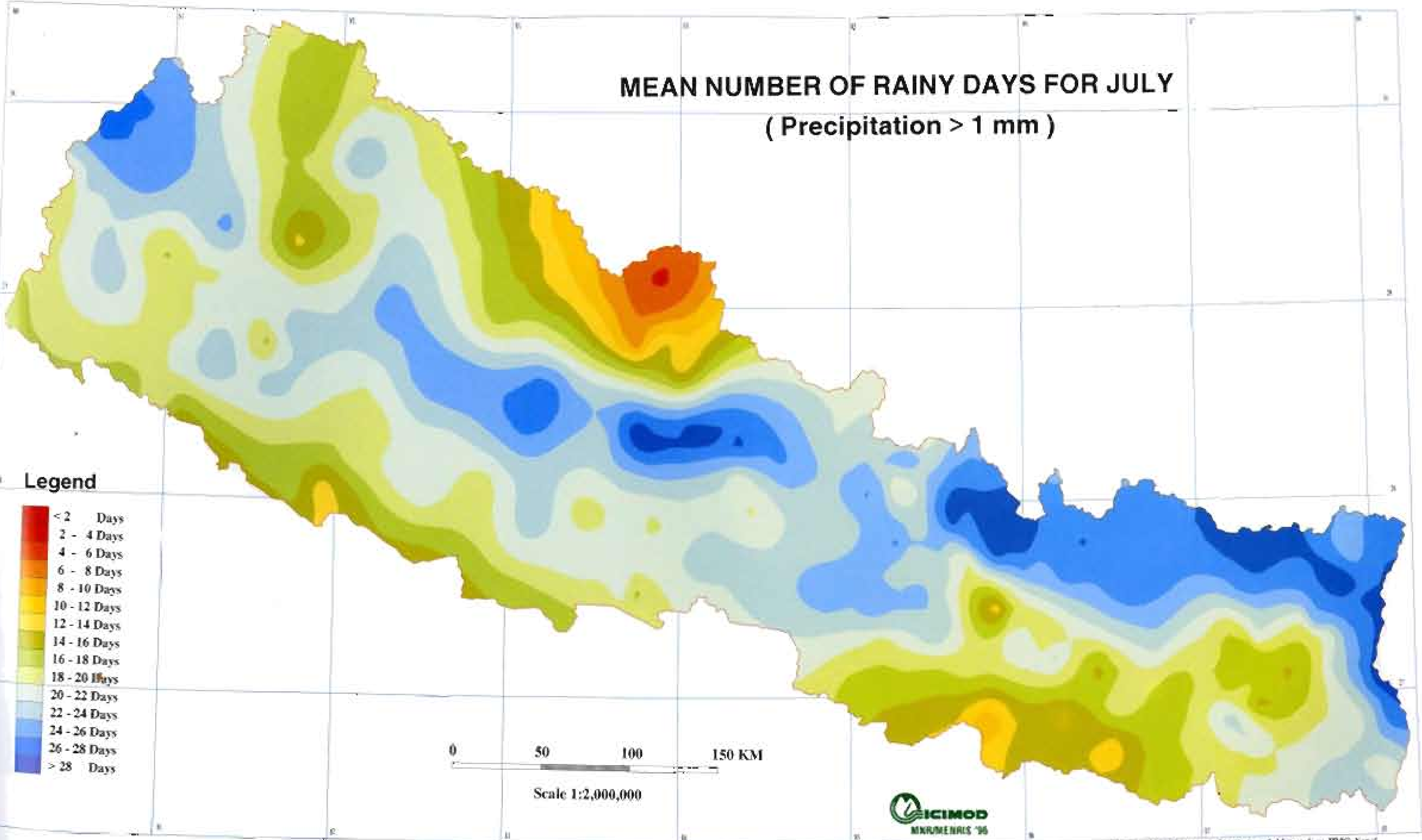
MEAN NUMBER OF RAINY DAYS FOR APRIL
(Precipitation > 1 mm)



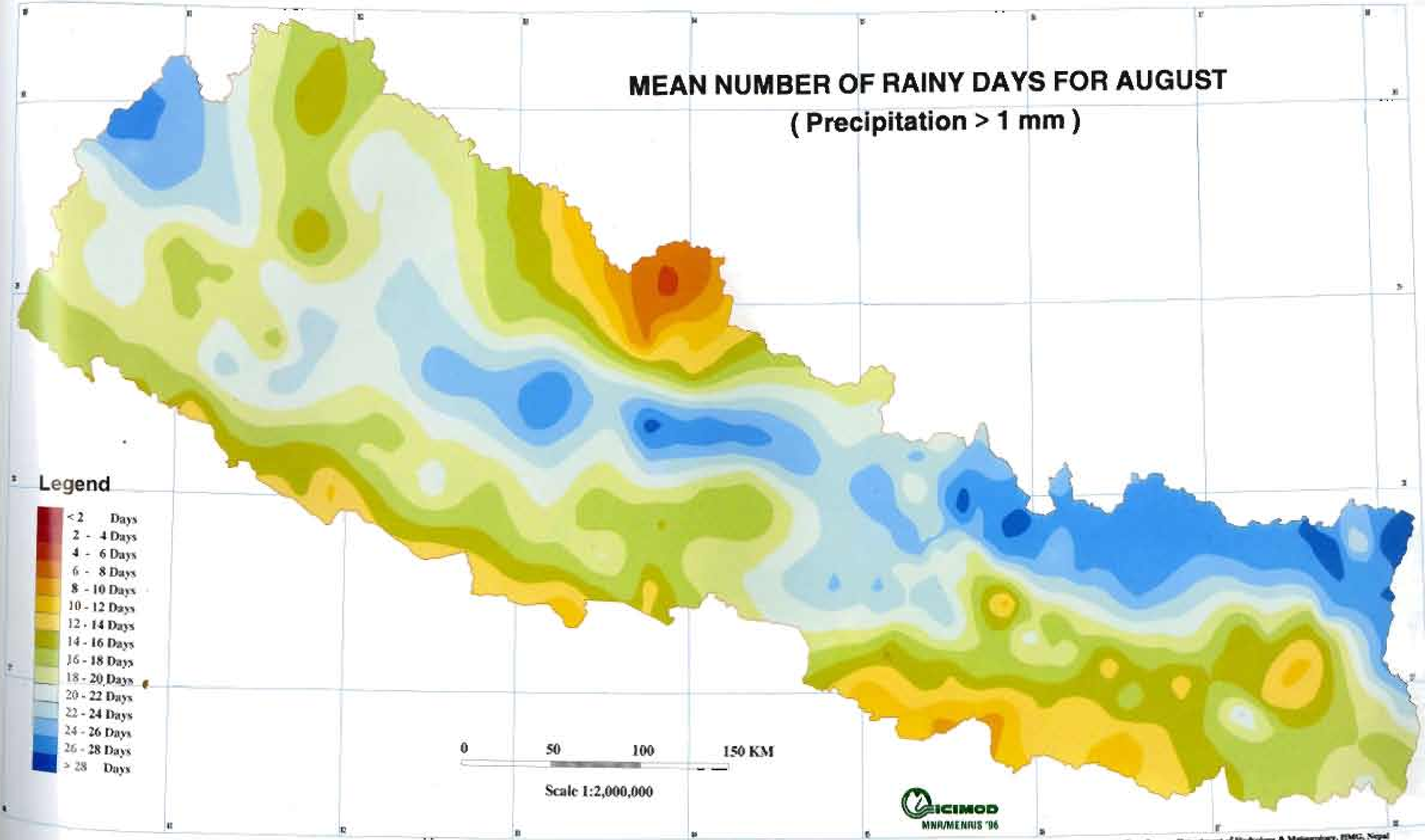


Data Source: Department of Hydrology & Meteorology, HMG, Nepal

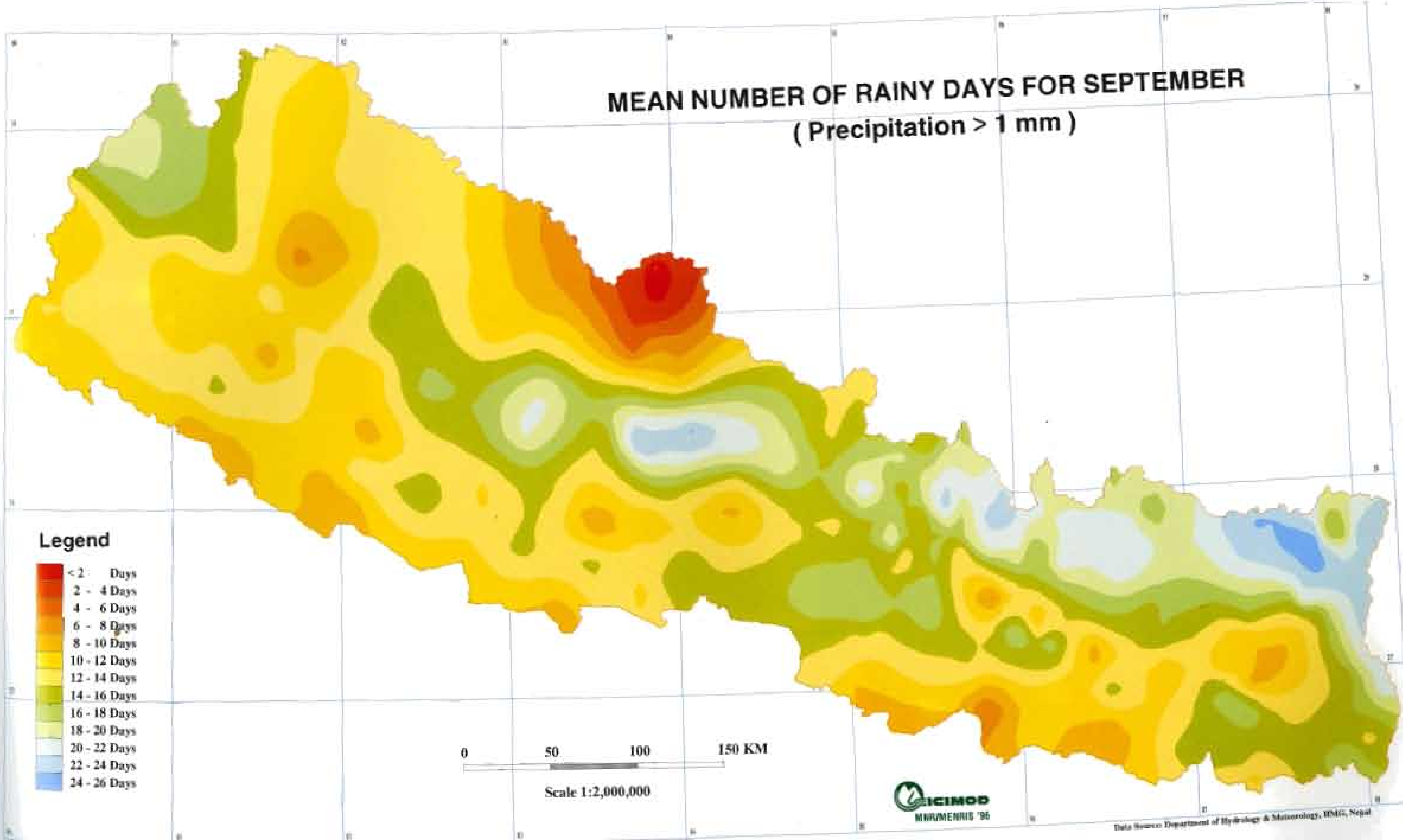

MEAN NUMBER OF RAINY DAYS FOR JUNE
(Precipitation > 1 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
14 - 16 Days
16 - 18 Days
18 - 20 Days
20 - 22 Days
22 - 24 Days
24 - 26 Days
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

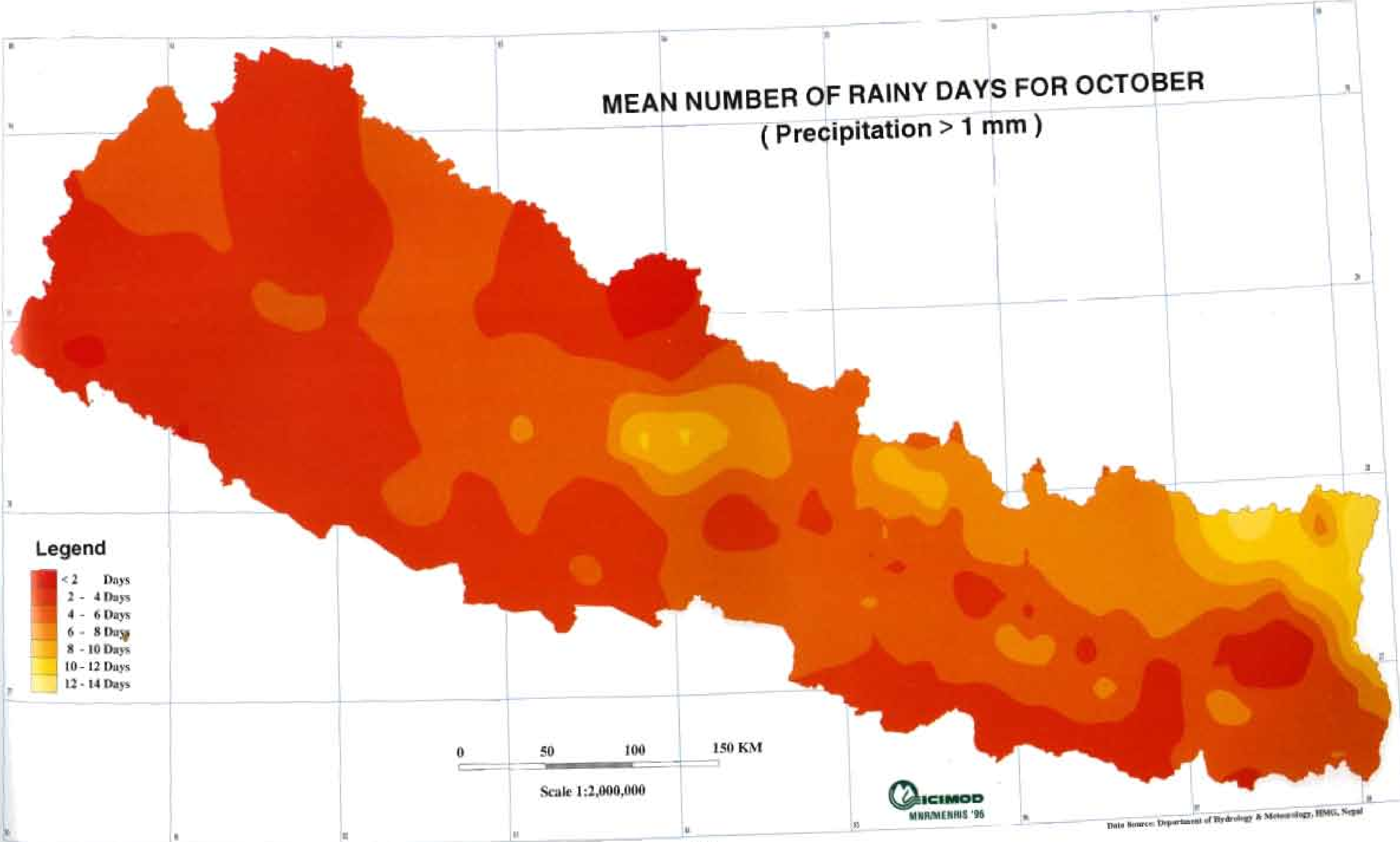


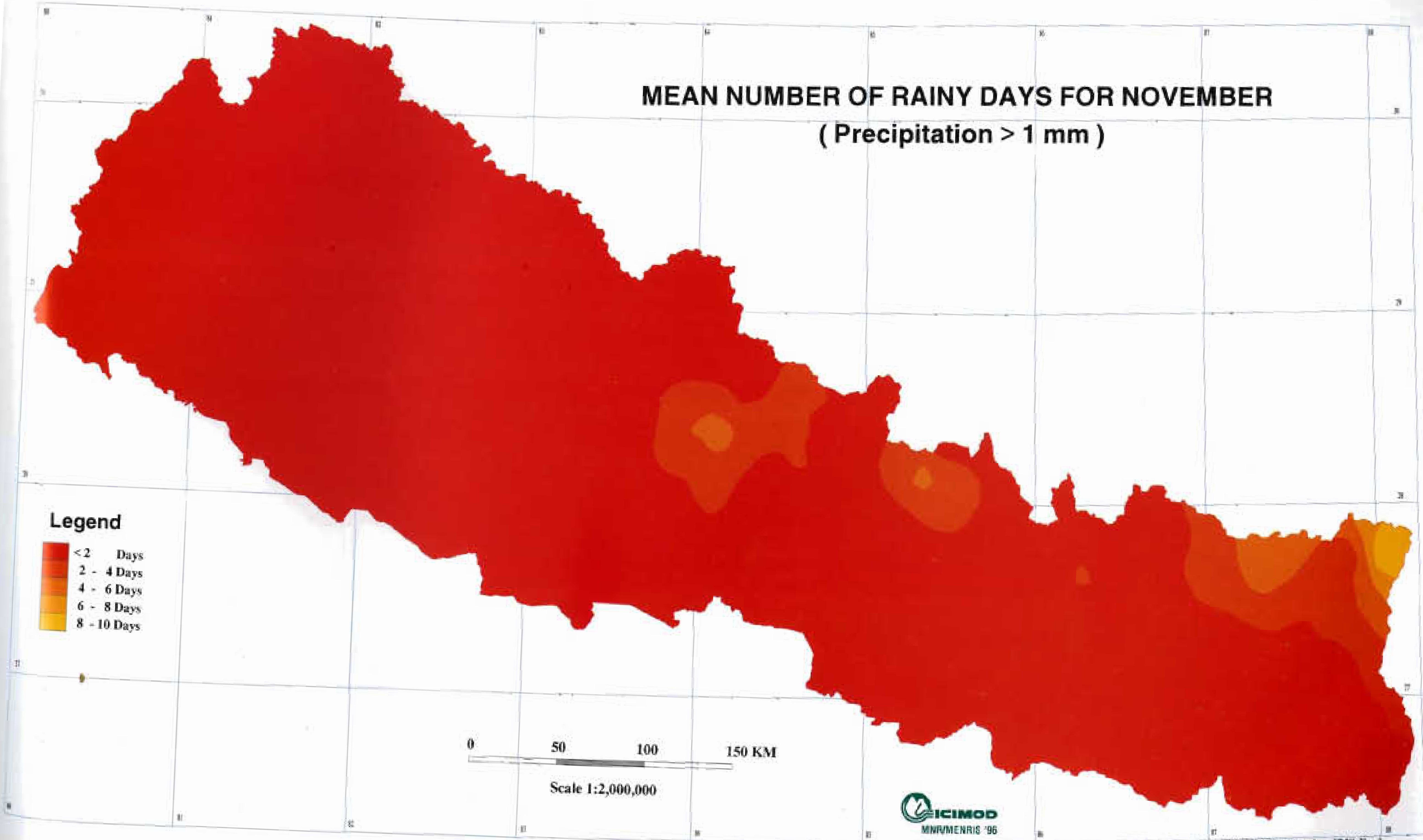
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

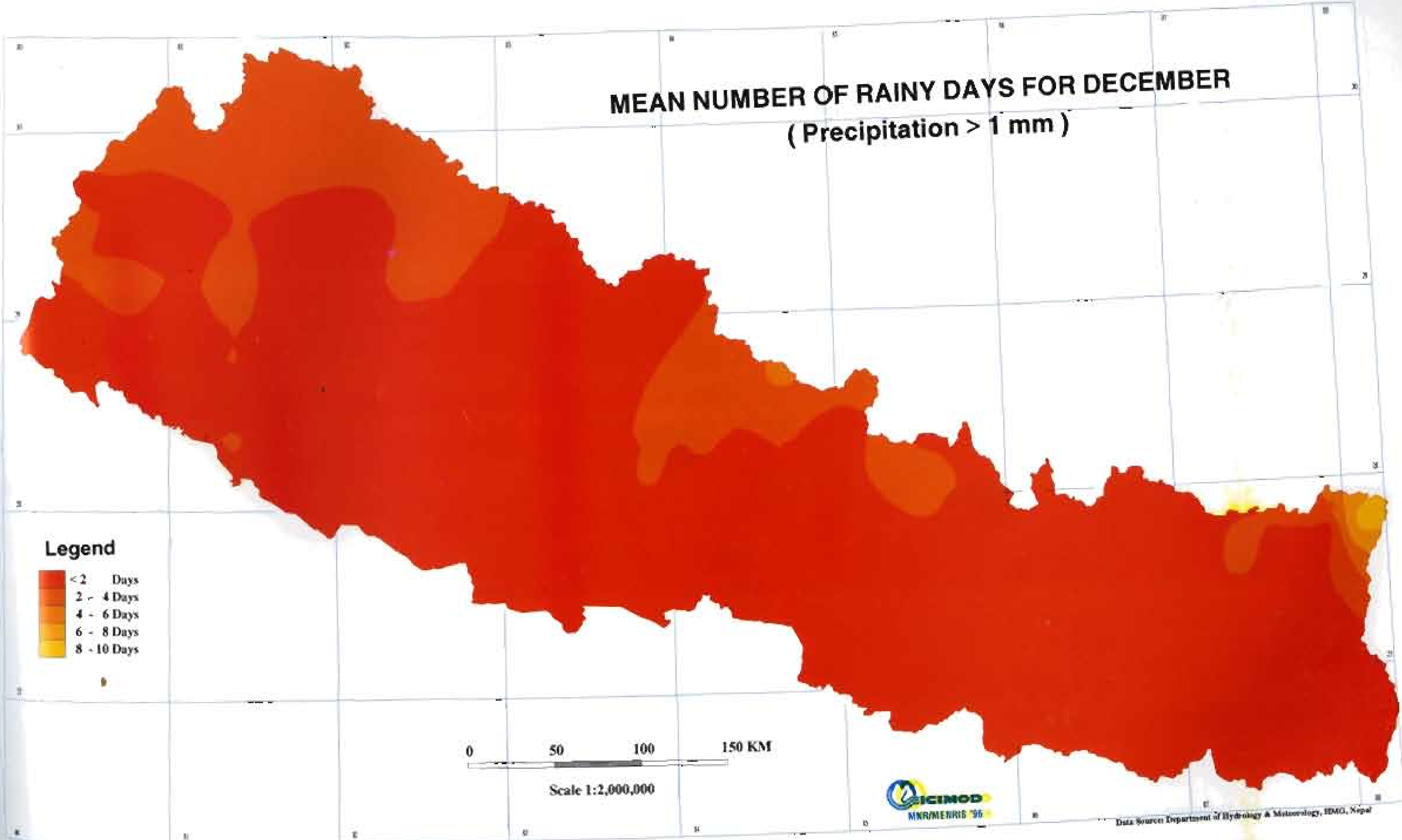


MEAN NUMBER OF RAINY DAYS FOR AUGUST
(Precipitation > 1 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
14 - 16 Days
16 - 18 Days
18 - 20 Days
20 - 22 Days
22 - 24 Days
24 - 26 Days
26 - 28 Days
> 28 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96

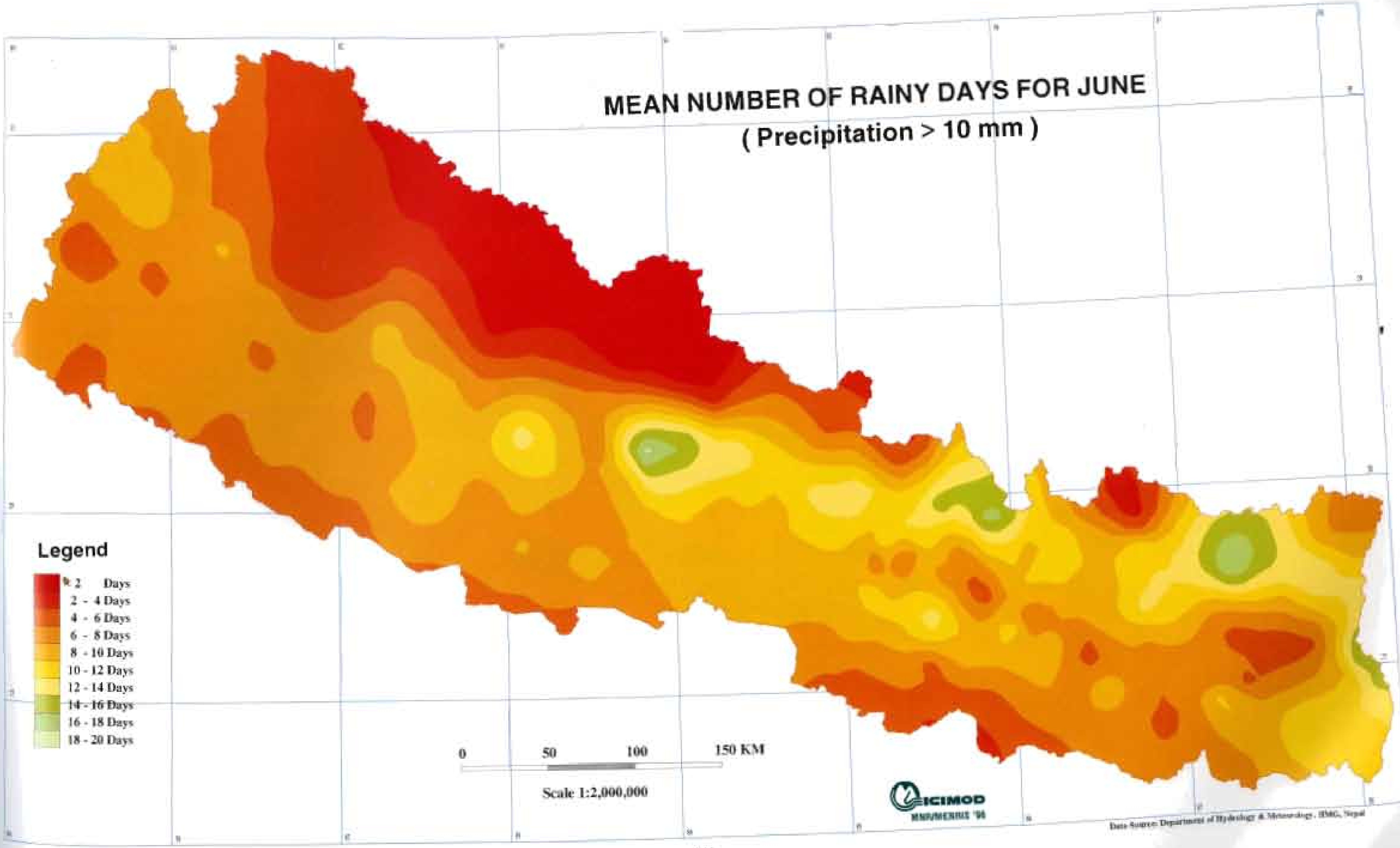

MEAN NUMBER OF RAINY DAYS FOR SEPTEMBER
(Precipitation > 1 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
14 - 16 Days
16 - 18 Days
18 - 20 Days
20 - 22 Days
22 - 24 Days
24 - 26 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

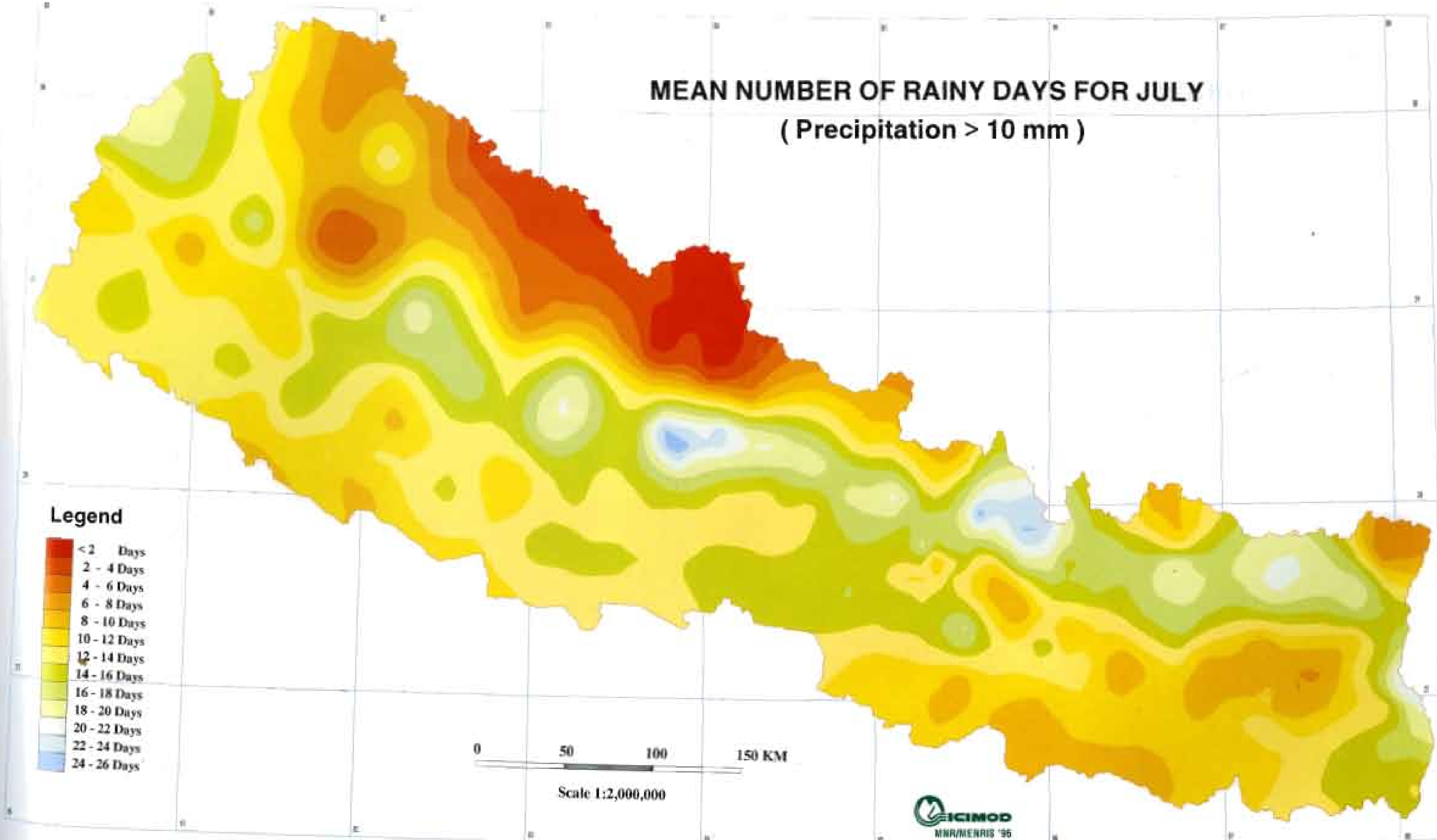

MEAN NUMBER OF RAINY DAYS FOR OCTOBER
(Precipitation > 1 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN NUMBER OF RAINY DAYS FOR NOVEMBER
(Precipitation > 1 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

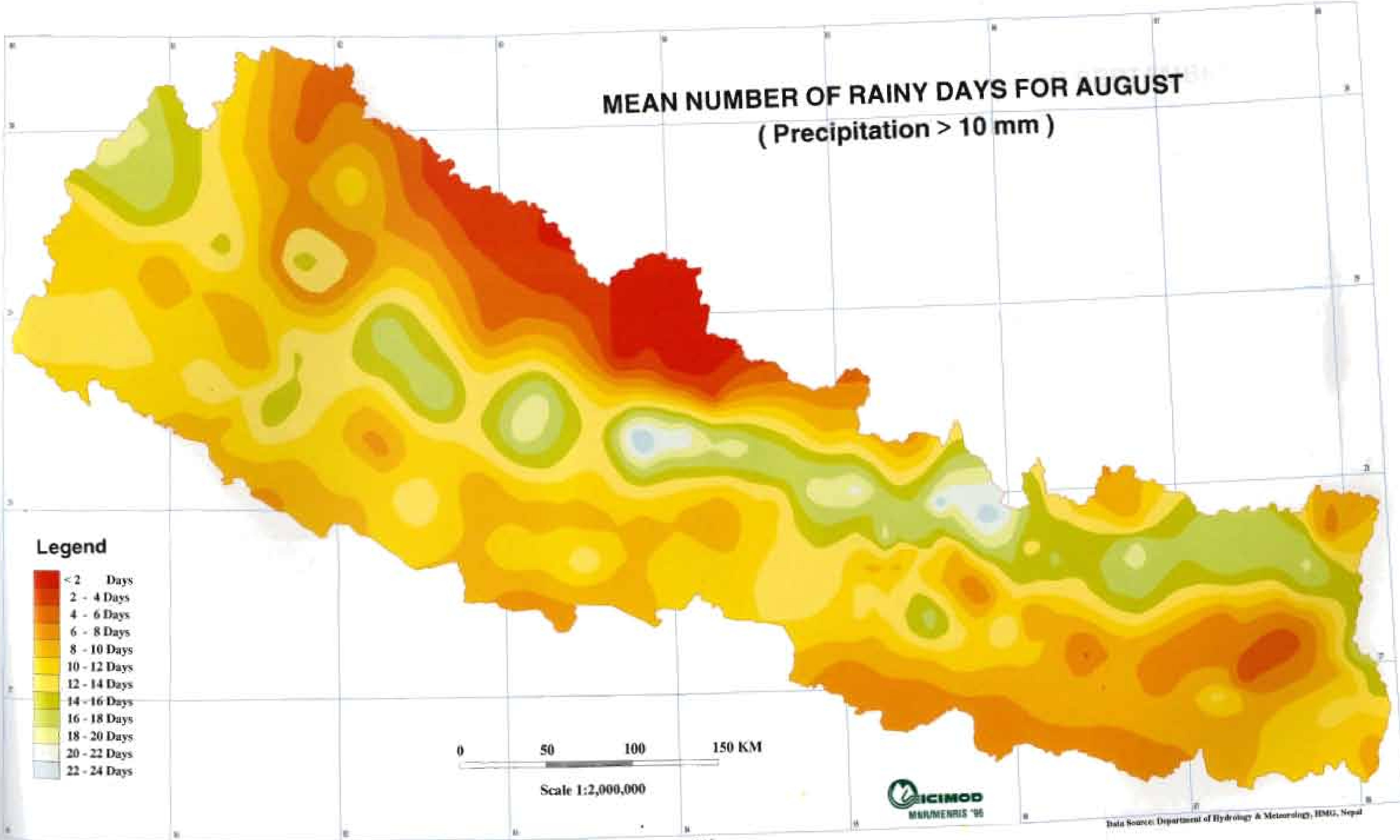


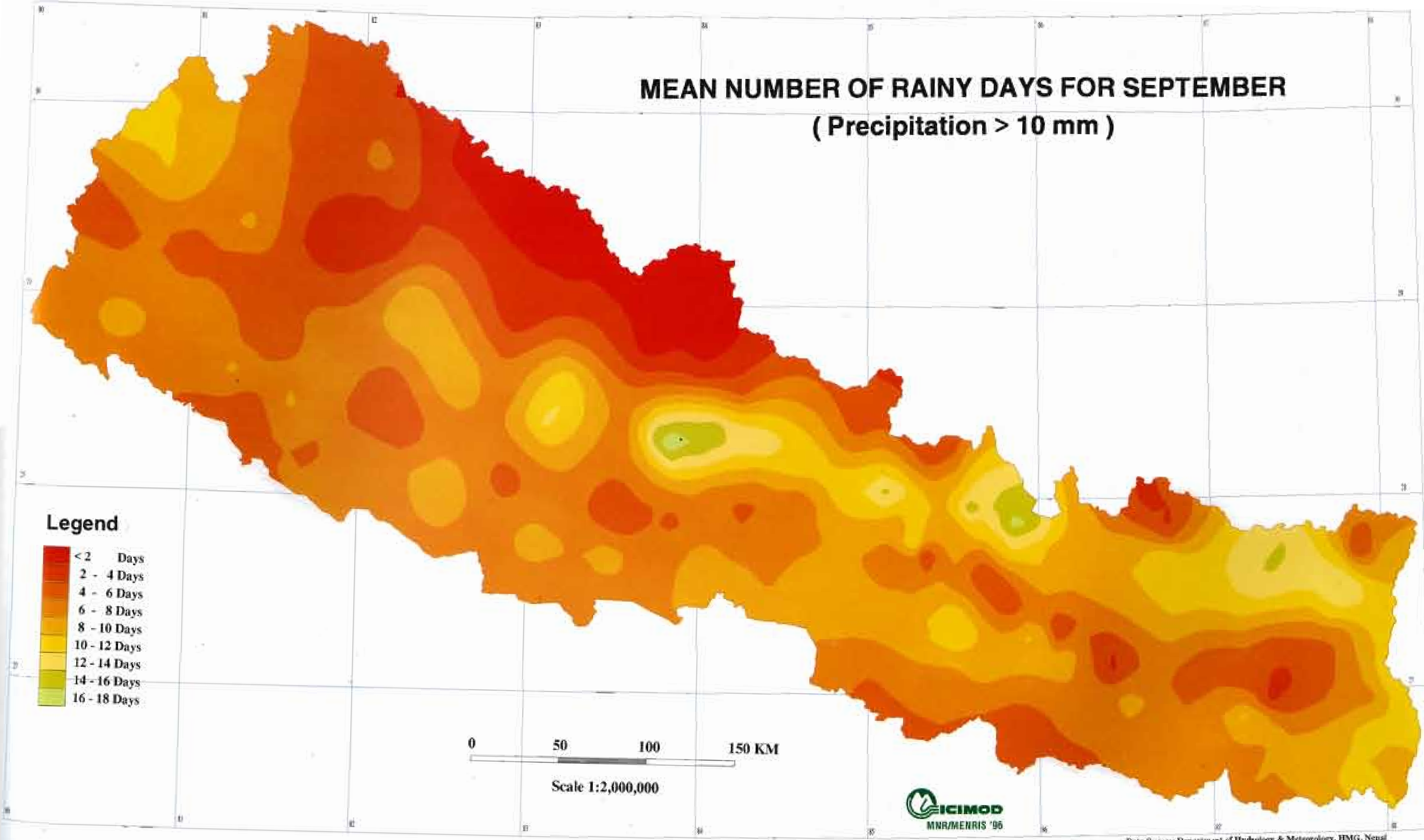
MEAN NUMBER OF RAINY DAYS FOR DECEMBER
(Precipitation > 1 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

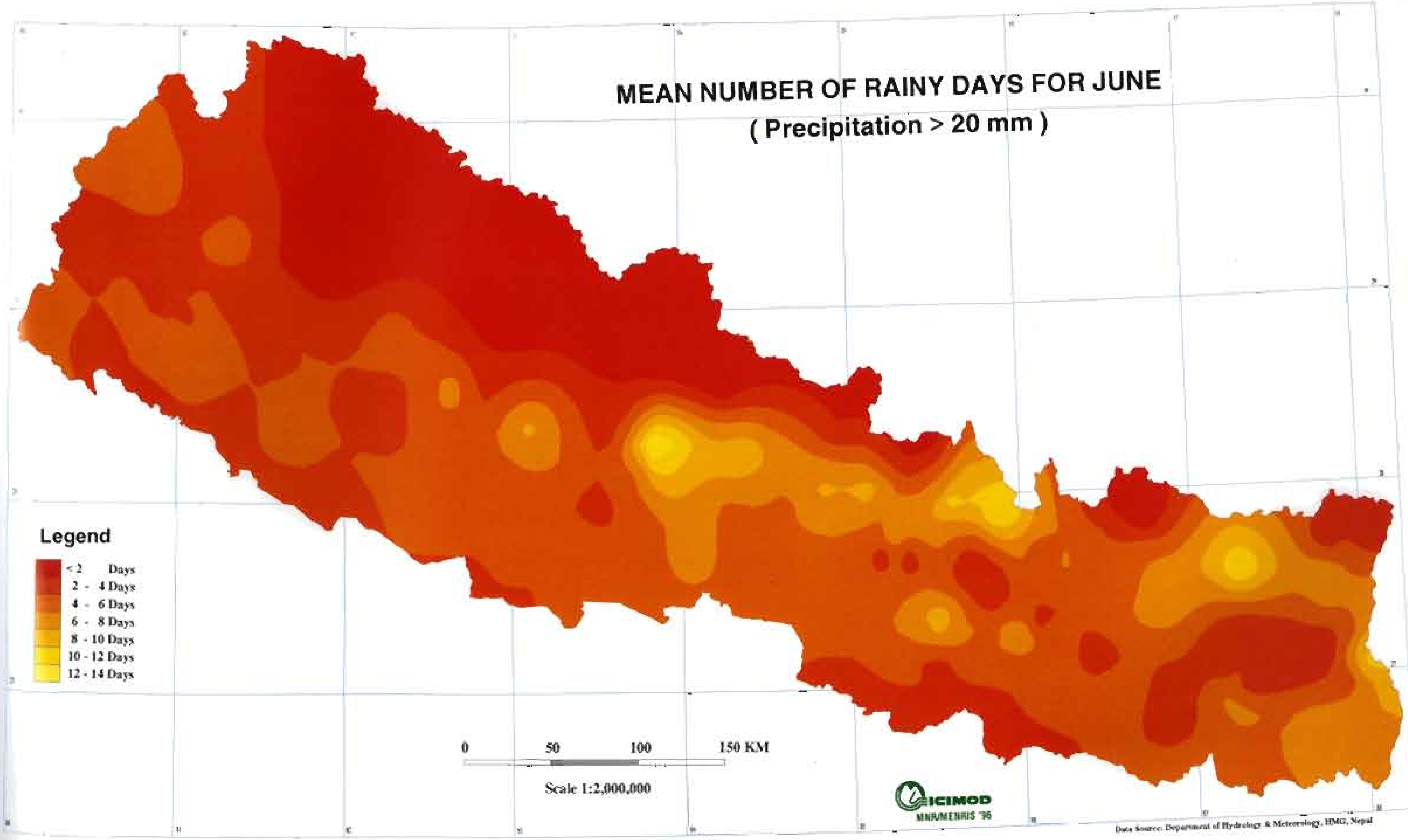

MEAN NUMBER OF RAINY DAYS FOR JUNE
(Precipitation > 10 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
14 - 16 Days
16 - 18 Days
18 - 20 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

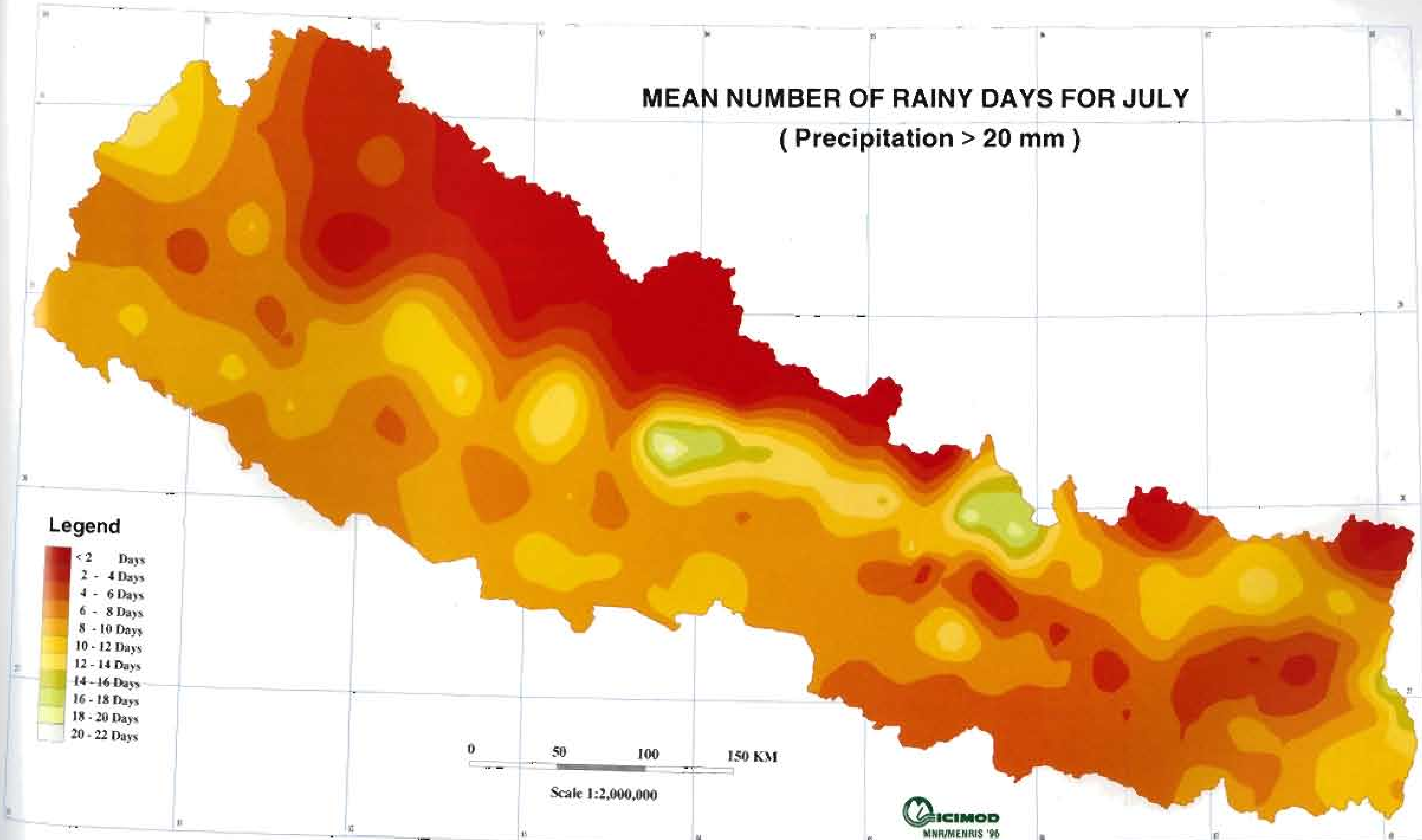


Data Source: Department of Hydrology & Meteorology, HMG, Nepal

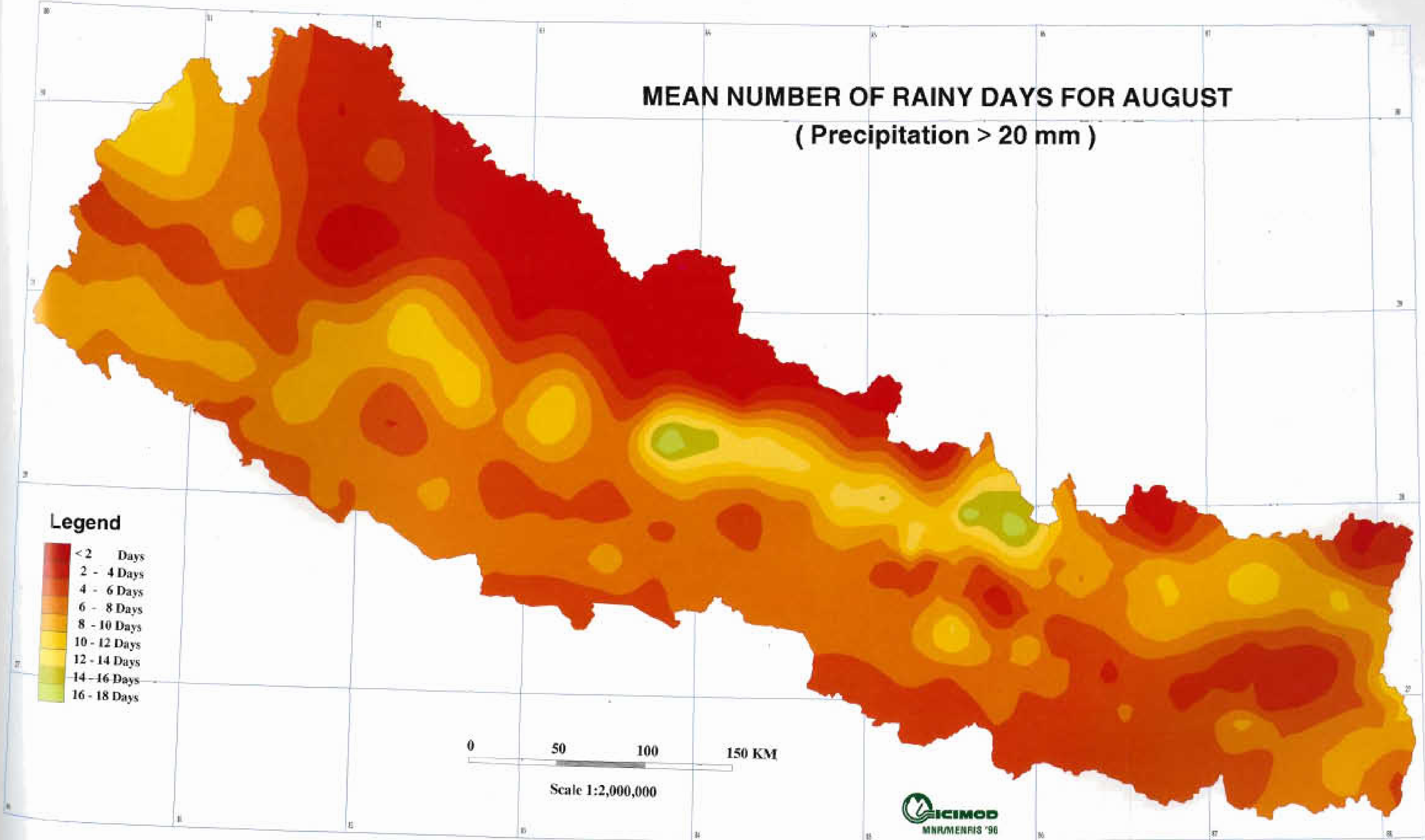

MEAN NUMBER OF RAINY DAYS FOR AUGUST
(Precipitation > 10 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
14 - 16 Days
16 - 18 Days
18 - 20 Days
20 - 22 Days
22 - 24 Days
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN NUMBER OF RAINY DAYS FOR SEPTEMBER
(Precipitation > 10 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
14 - 16 Days
16 - 18 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

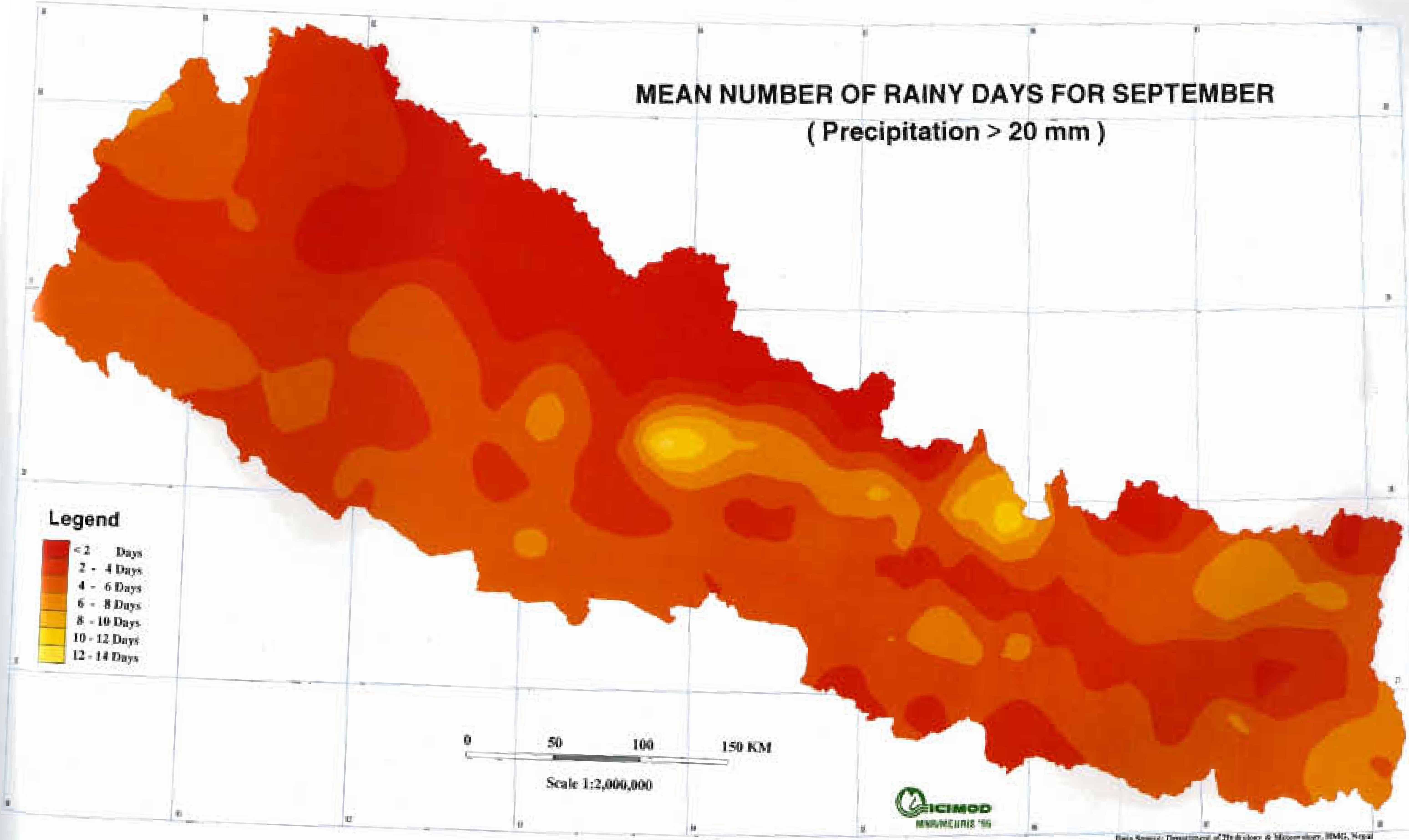

MEAN NUMBER OF RAINY DAYS FOR JUNE
(Precipitation > 20 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

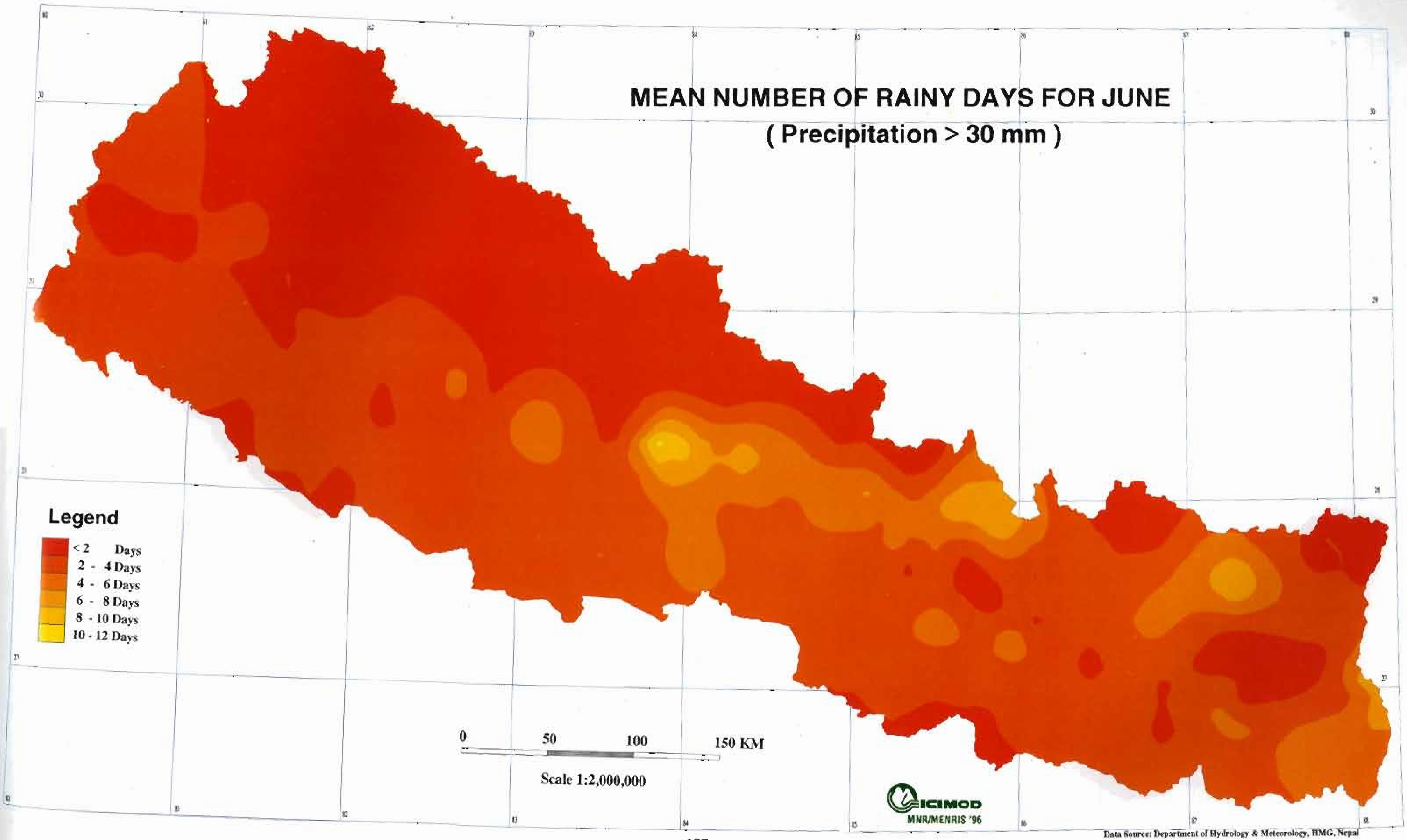


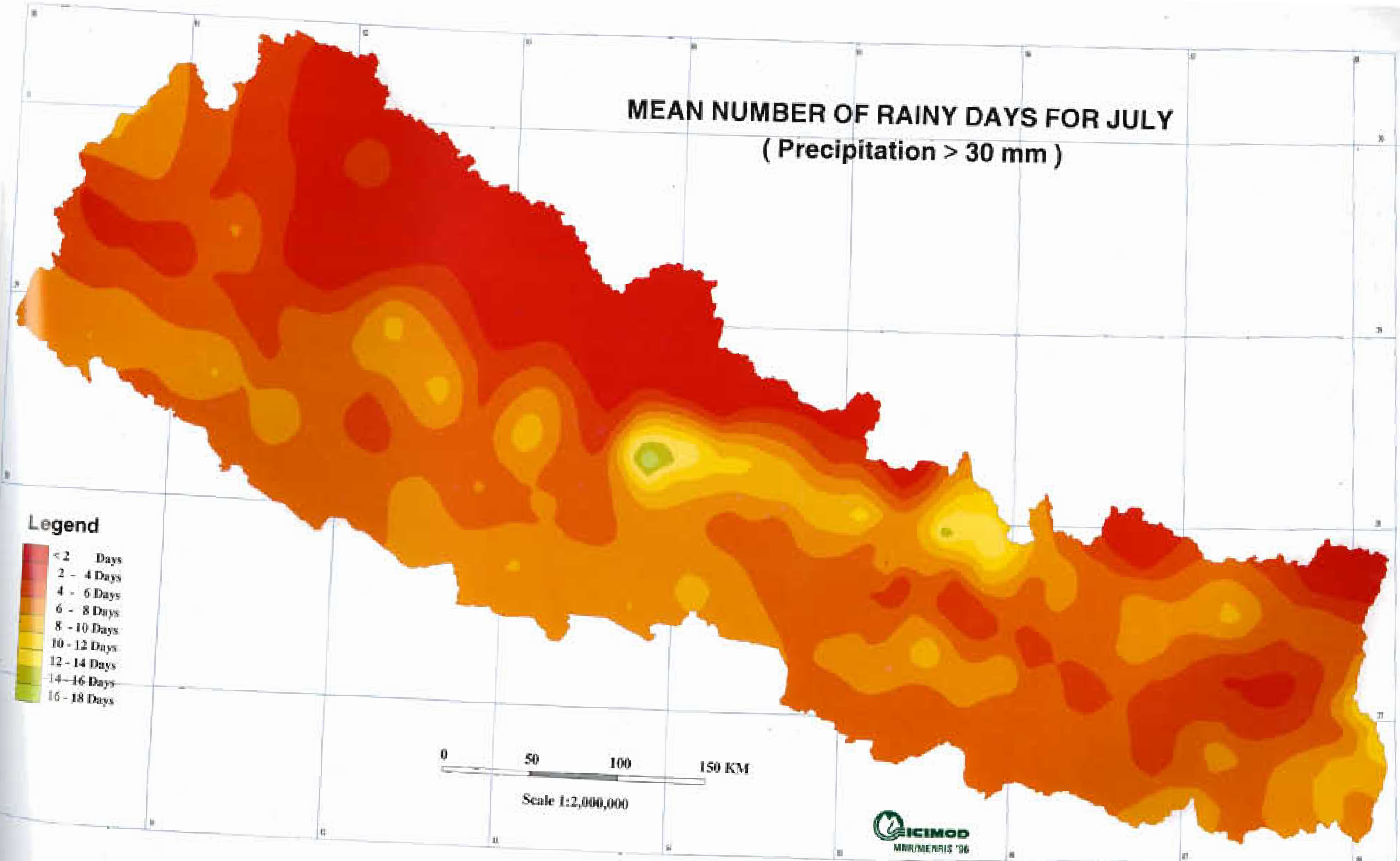
Data Source: Department of Hydrology & Meteorology, HMG, Nepal



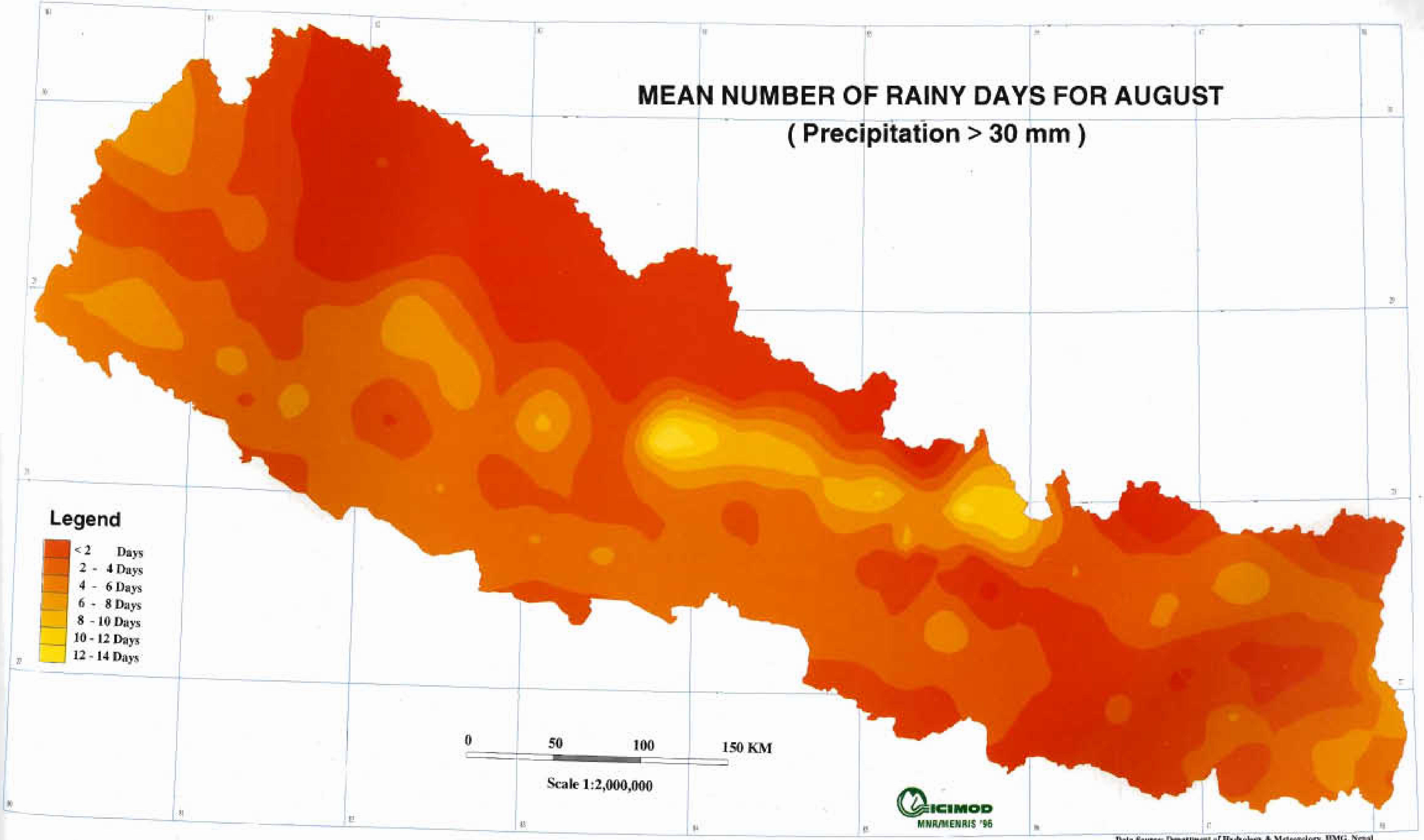
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

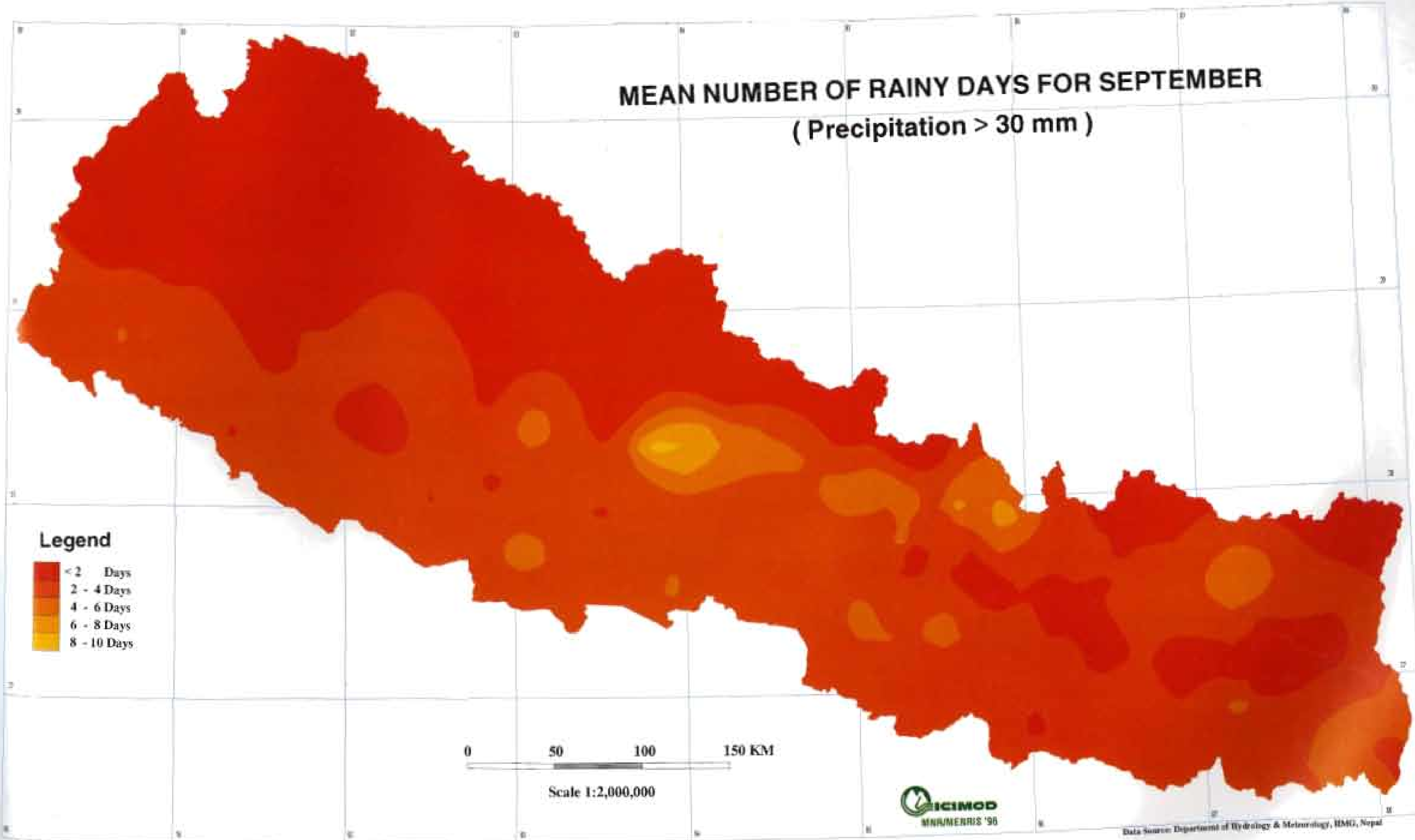

MEAN NUMBER OF RAINY DAYS FOR SEPTEMBER
(Precipitation > 20 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

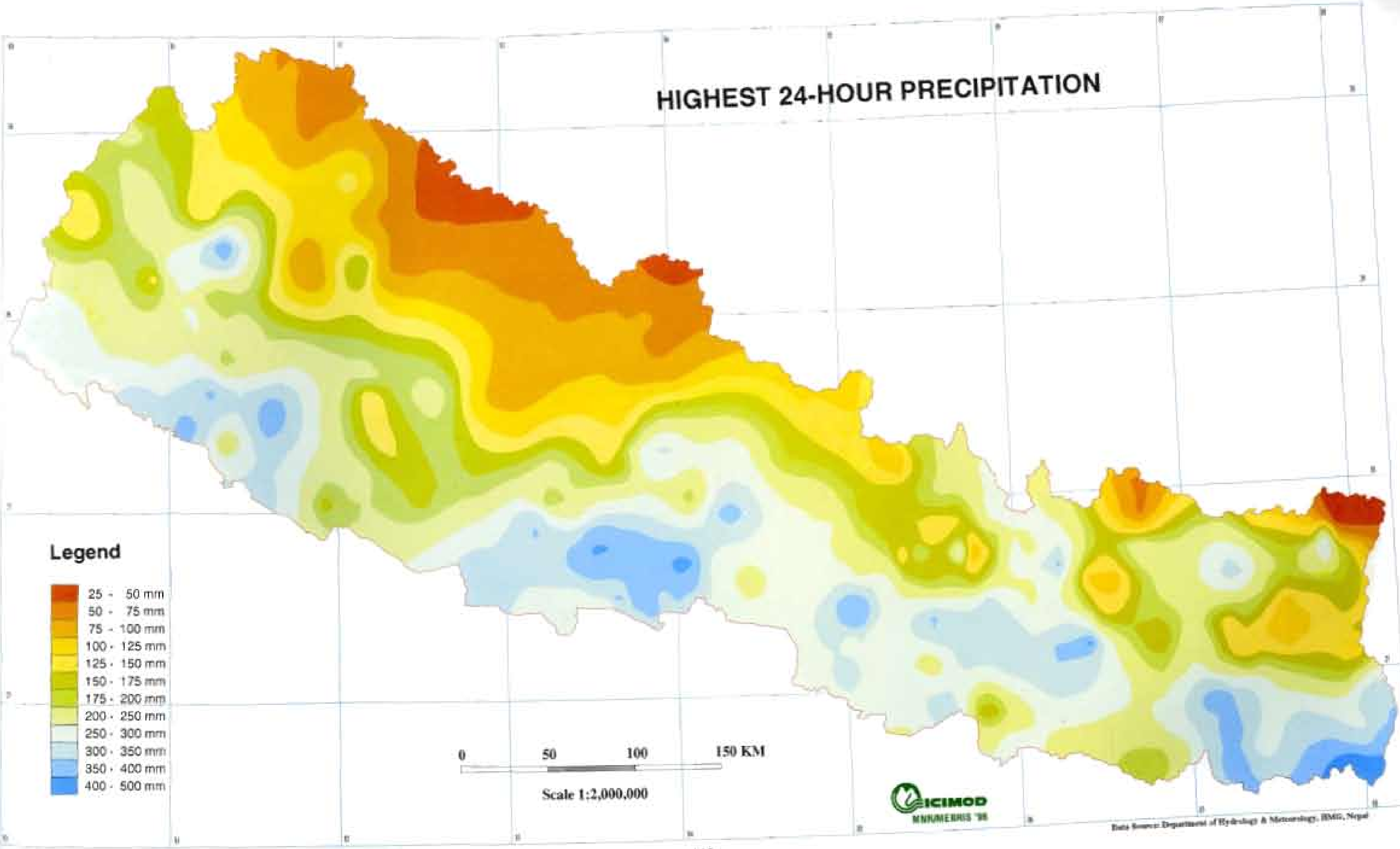

MEAN NUMBER OF RAINY DAYS FOR JUNE
(Precipitation > 30 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

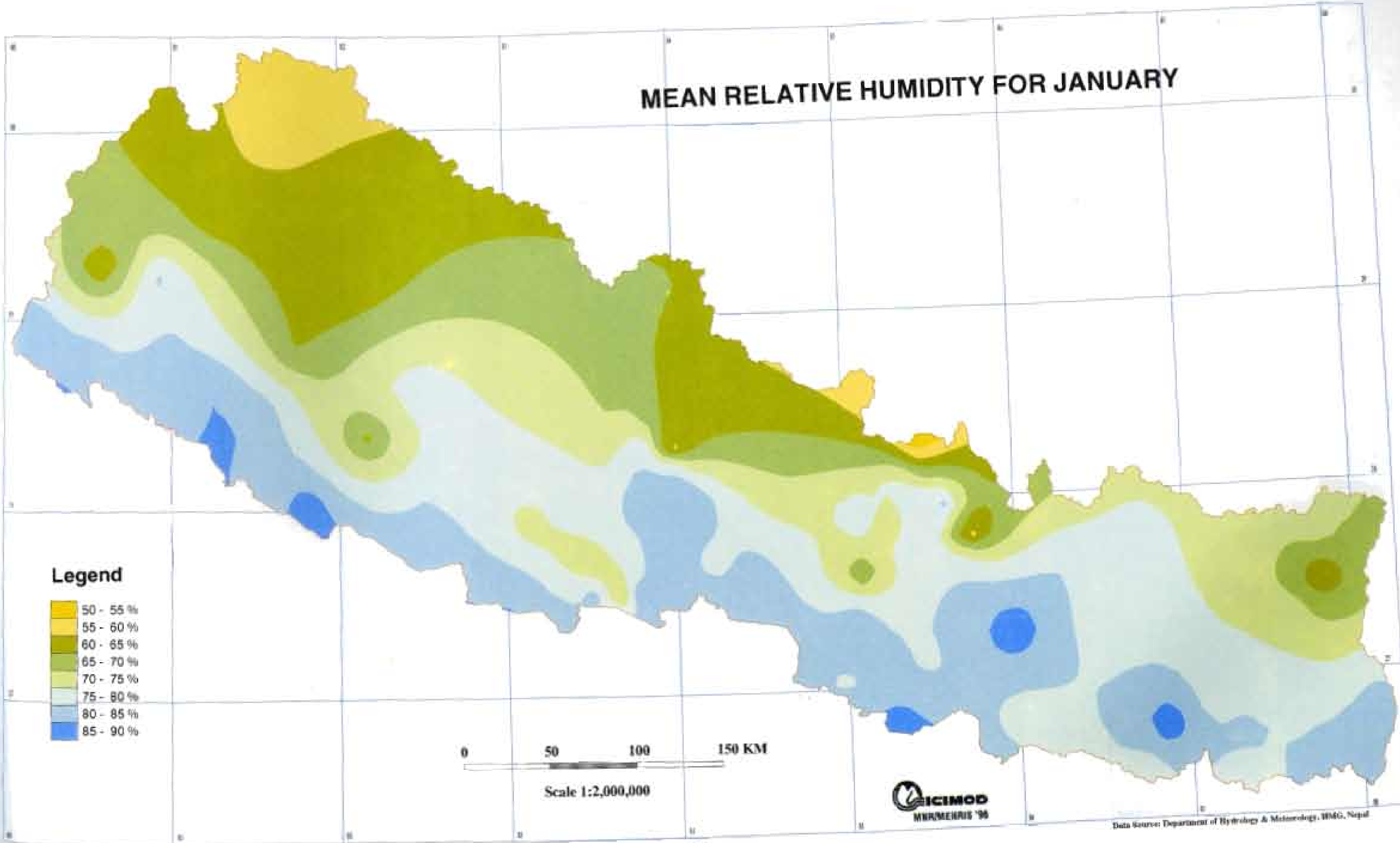


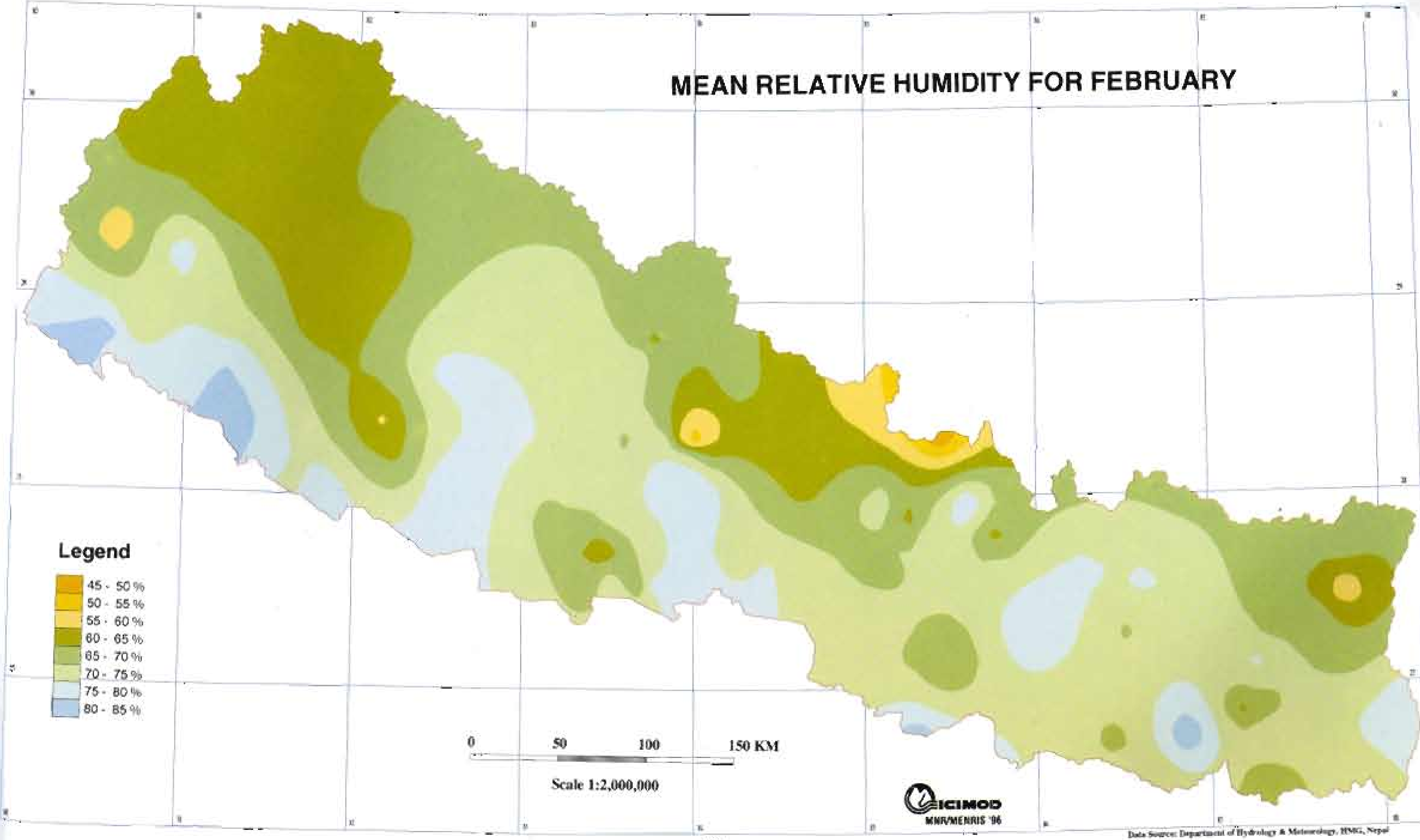
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN NUMBER OF RAINY DAYS FOR AUGUST
(Precipitation > 30 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
10 - 12 Days
12 - 14 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

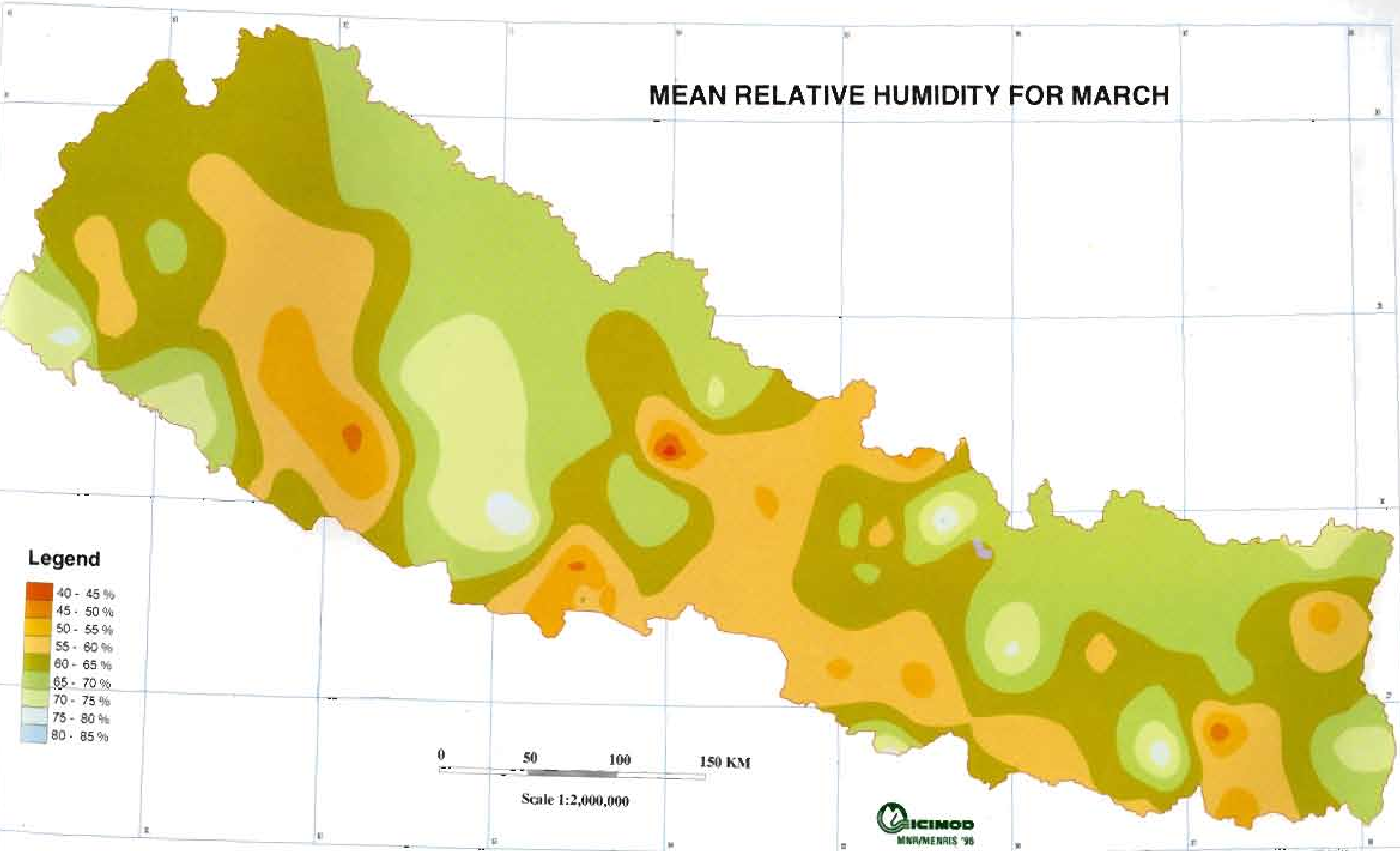

MEAN NUMBER OF RAINY DAYS FOR SEPTEMBER
(Precipitation > 30 mm)
Legend
< 2 Days
2 - 4 Days
4 - 6 Days
6 - 8 Days
8 - 10 Days
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

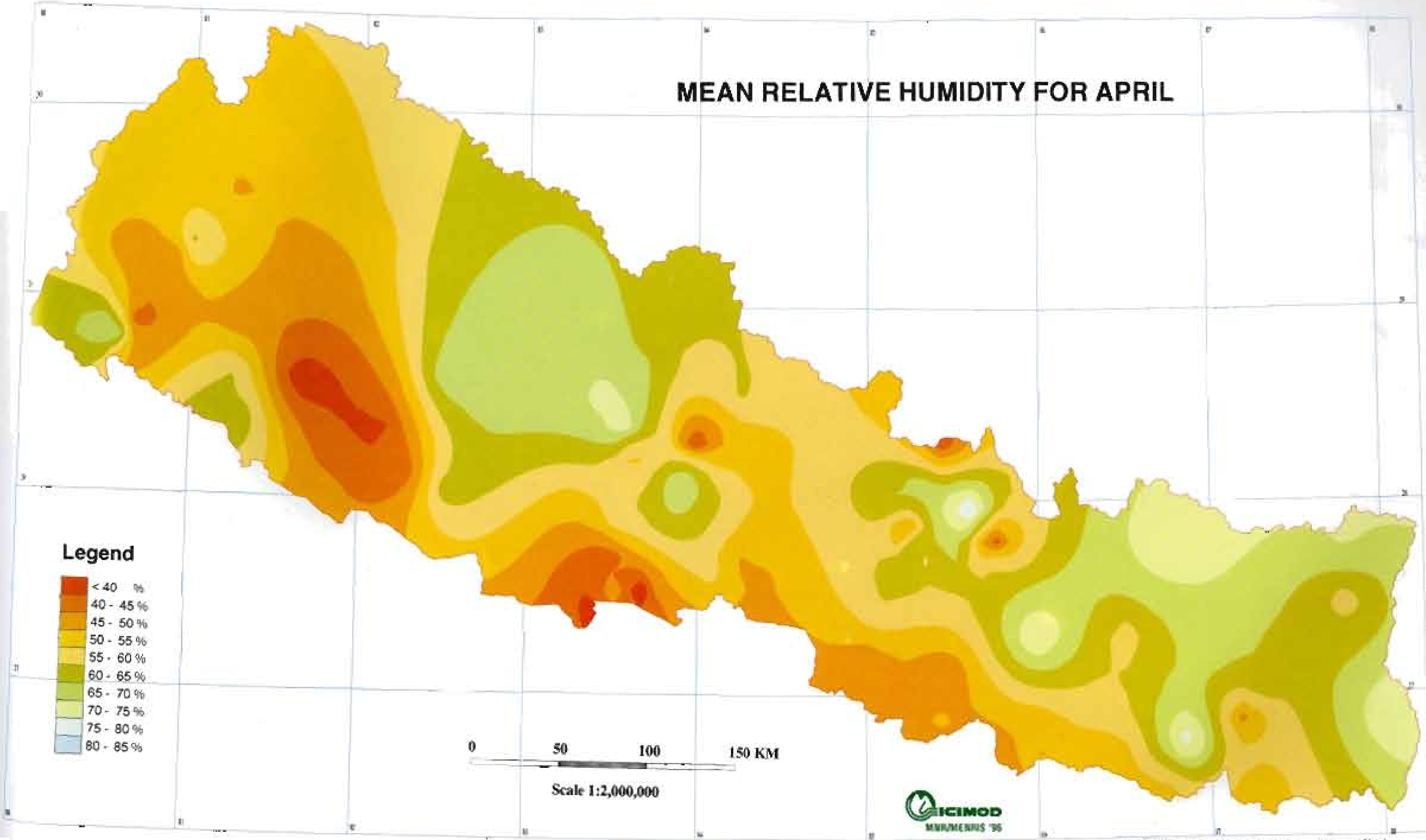

HIGHEST 24-HOUR PRECIPITATION
Legend
25 - 50 mm
50 - 75 mm
75 - 100 mm
100 - 125 mm
125 - 150 mm
150 - 175 mm
175 - 200 mm
200 - 250 mm
250 - 300 mm
300 - 350 mm
350 - 400 mm
400 - 500 mm
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

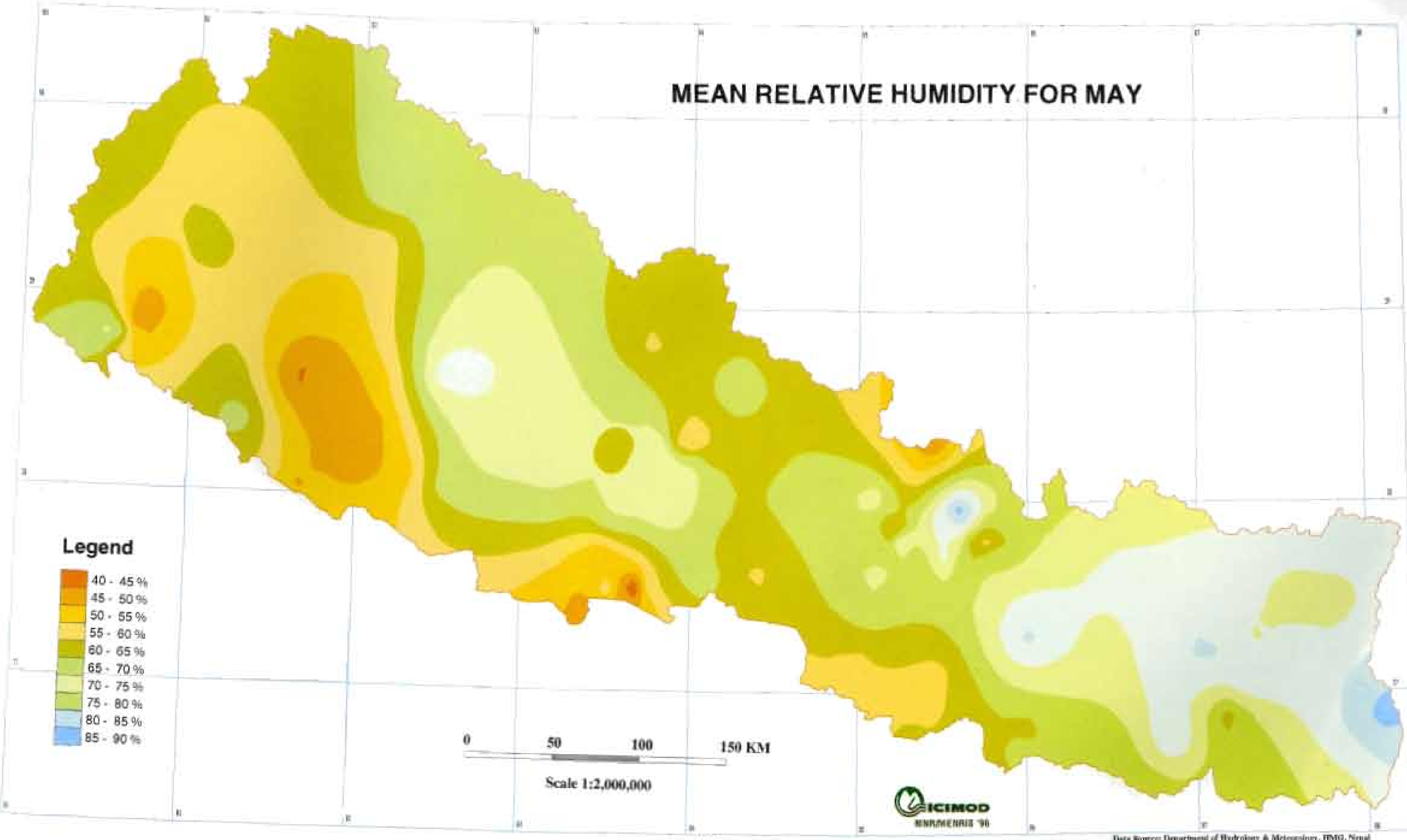

MEAN RELATIVE HUMIDITY FOR JANUARY
Legend
50 - 55 %
55 - 60 %
60 - 65 %
65 - 70 %
70 - 75 %
75 - 80 %
80 - 85 %
85 - 90 %
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

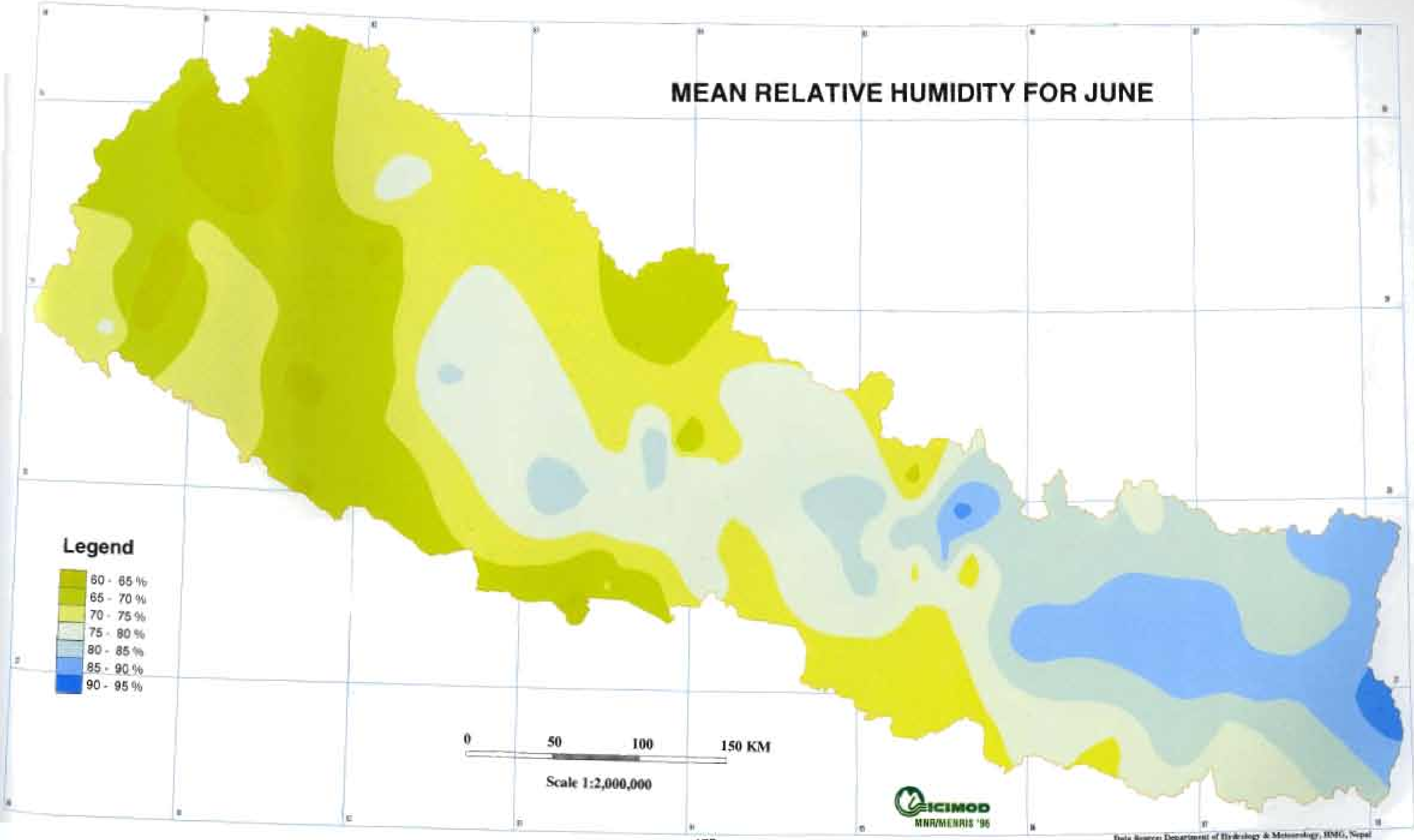

MEAN RELATIVE HUMIDITY FOR FEBRUARY
Legend
45 - 50 %
50 - 55 %
55 - 60 %
60 - 65 %
65 - 70 %
70 - 75 %
75 - 80 %
80 - 85 %
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

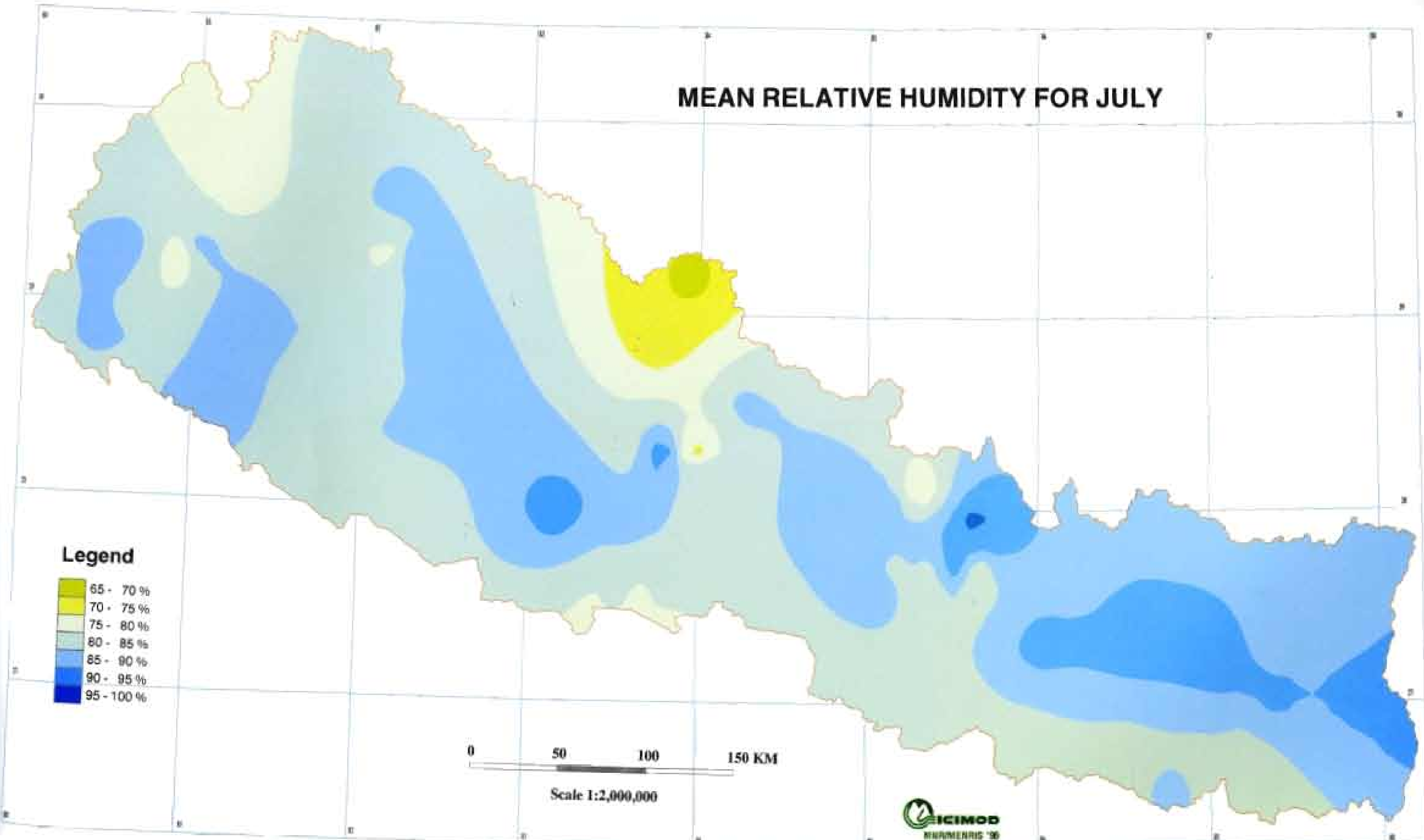
MEAN RELATIVE HUMIDITY FOR MARCH



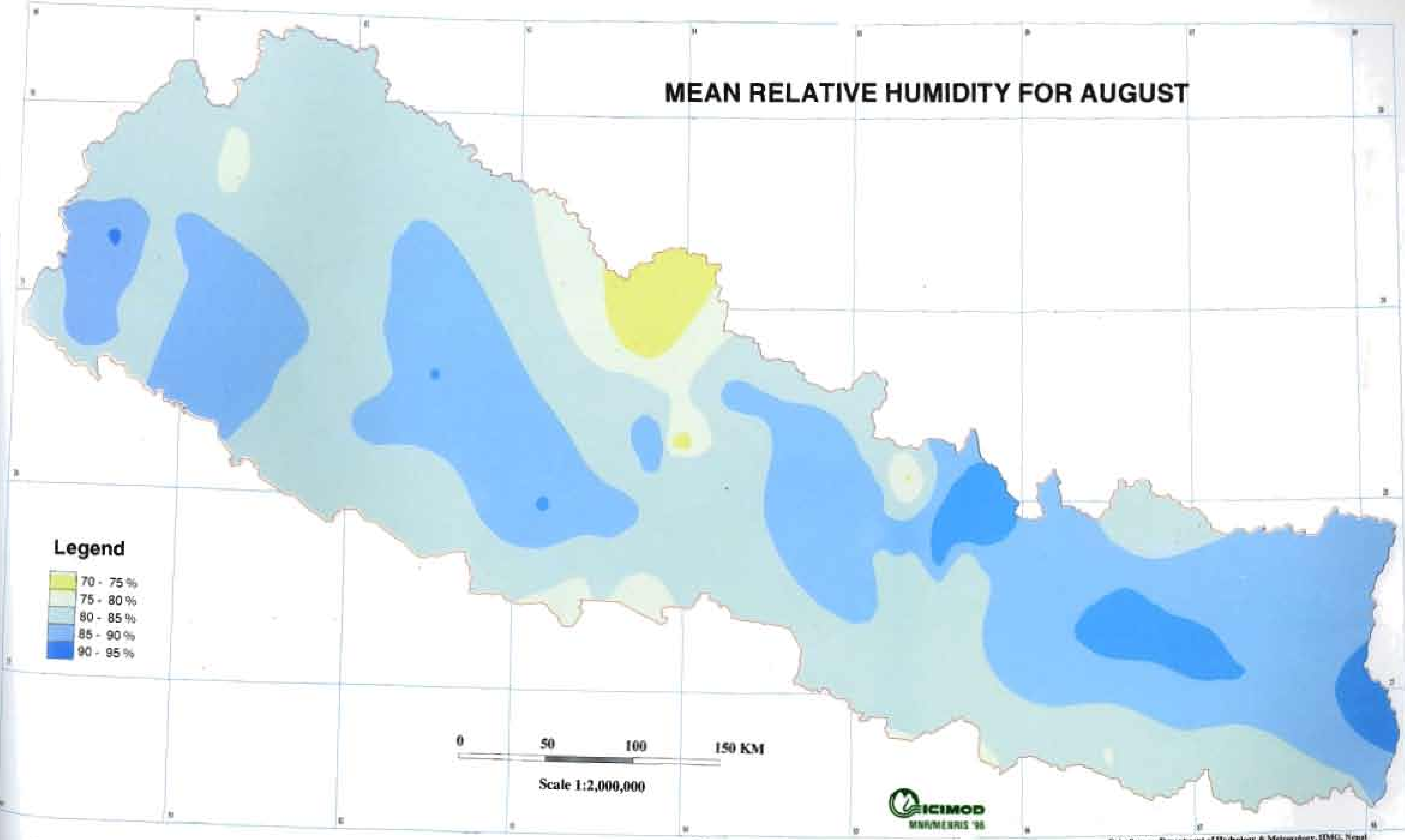

MEAN RELATIVE HUMIDITY FOR APRIL
Legend
< 40 %
40 - 45 %
45 - 50 %
50 - 55 %
55 - 60 %
60 - 65 %
65 - 70 %
70 - 75 %
75 - 80 %
80 - 85 %
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

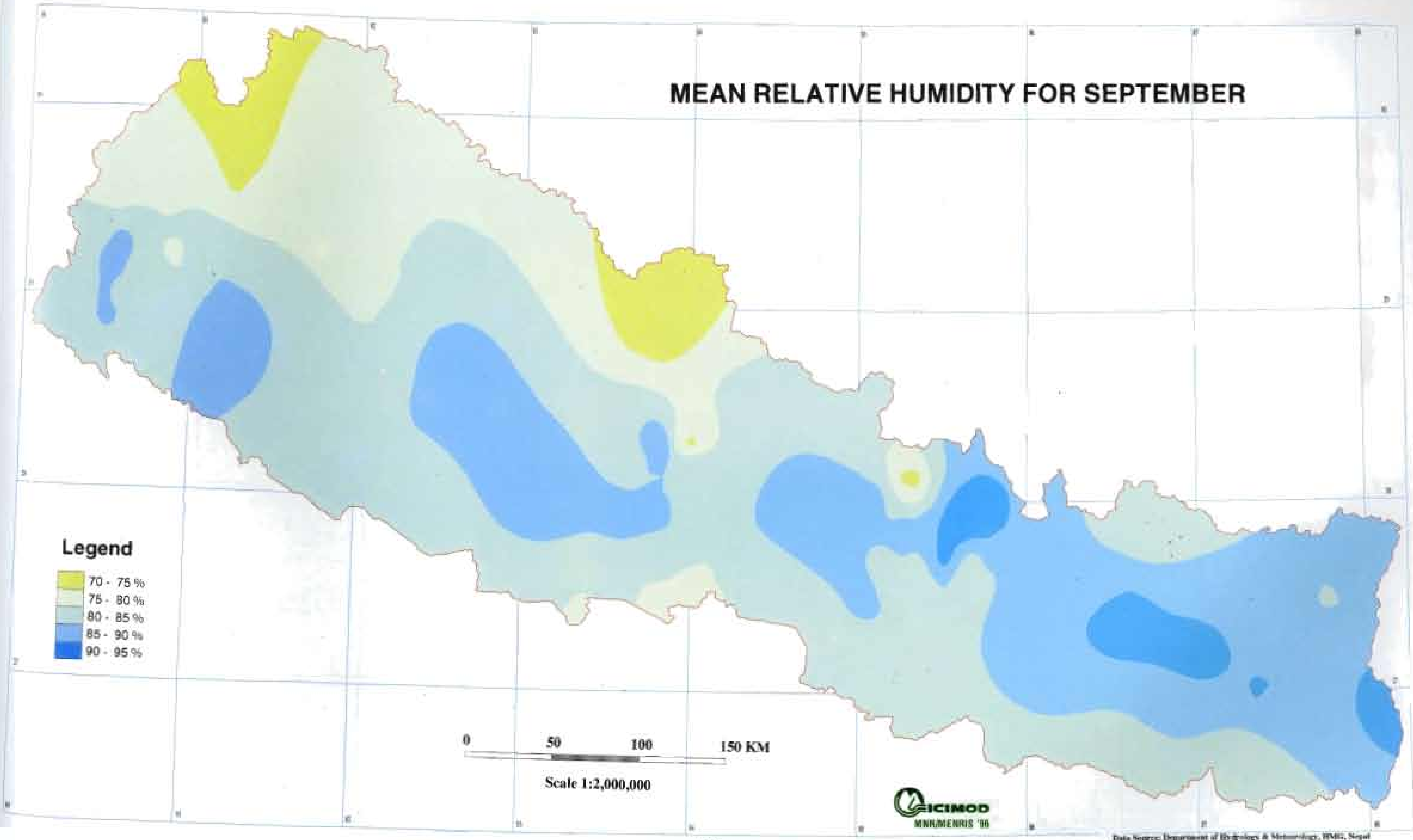

MEAN RELATIVE HUMIDITY FOR MAY
Legend
40 - 45 %
45 - 50 %
50 - 55 %
55 - 60 %
60 - 65 %
65 - 70 %
70 - 75 %
75 - 80 %
80 - 85 %
85 - 90 %
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

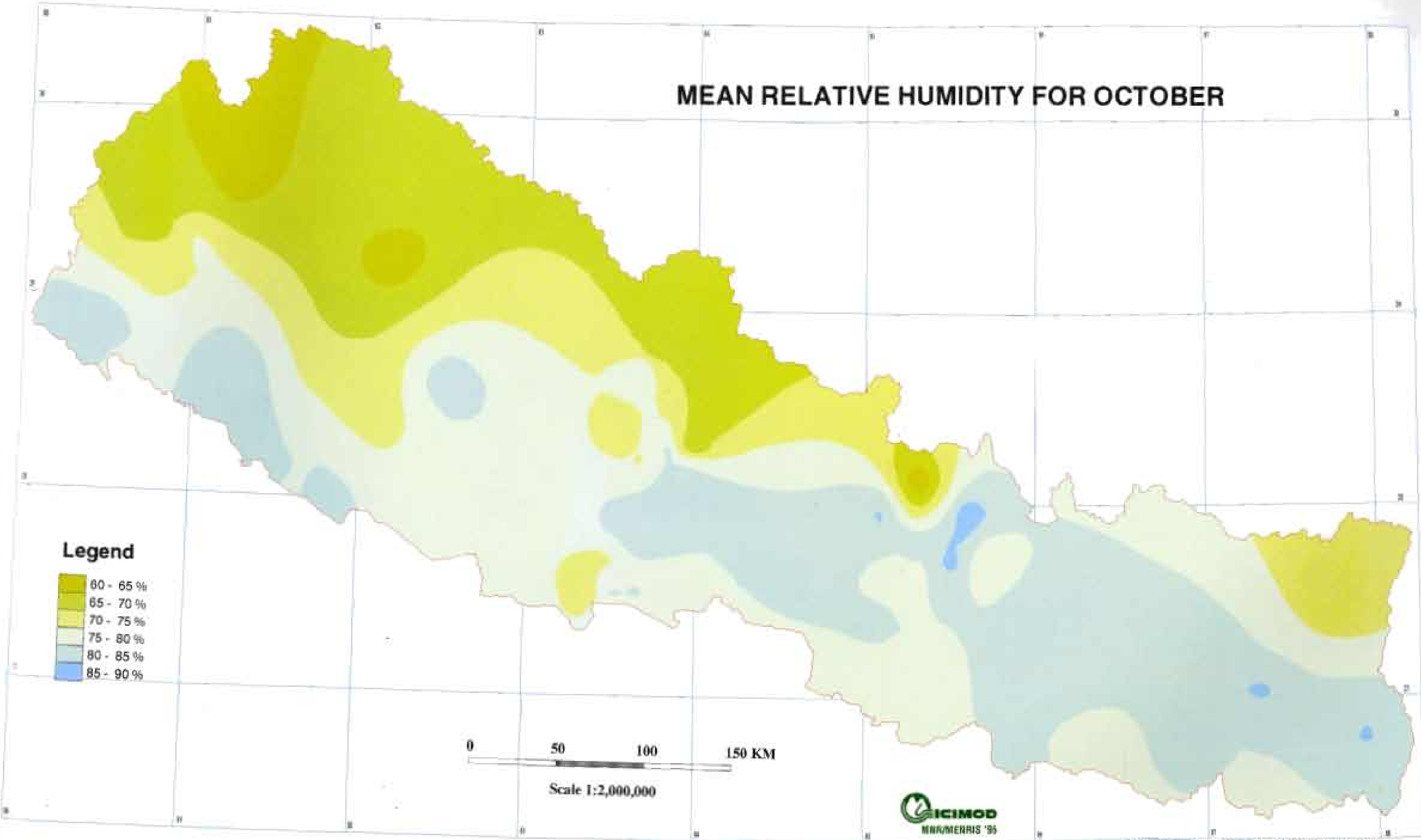

MEAN RELATIVE HUMIDITY FOR JUNE
Legend
60 - 65 %
65 - 70 %
70 - 75 %
75 - 80 %
80 - 85 %
85 - 90 %
90 - 95 %
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

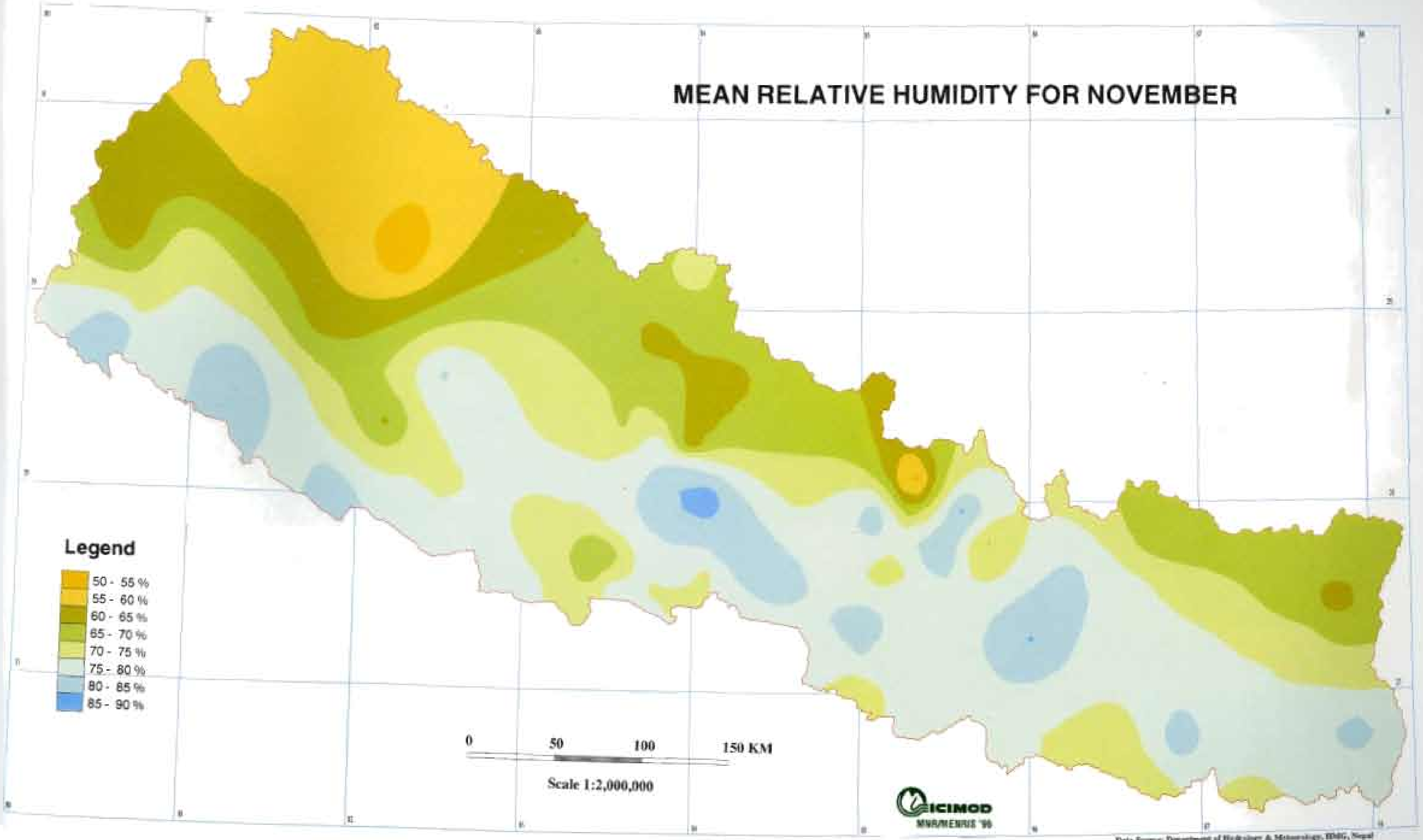


Data Source: Department of Hydrology & Meteorology, HMG, Nepal

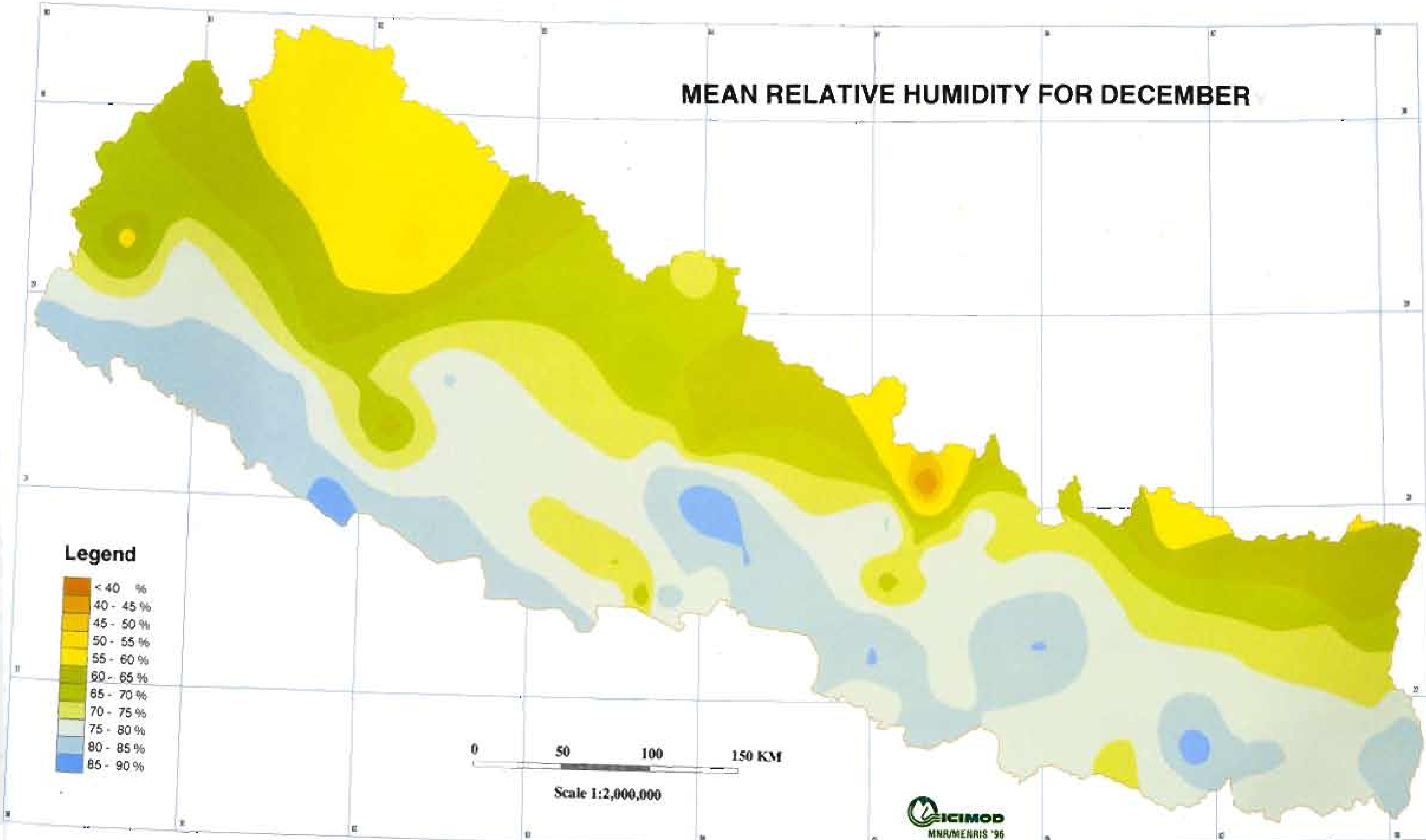

MEAN RELATIVE HUMIDITY FOR AUGUST
Legend
70 - 75 %
75 - 80 %
80 - 85 %
85 - 90 %
90 - 95 %
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN RELATIVE HUMIDITY FOR SEPTEMBER
Legend
70 - 75 %
75 - 80 %
80 - 85 %
85 - 90 %
90 - 95 %
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

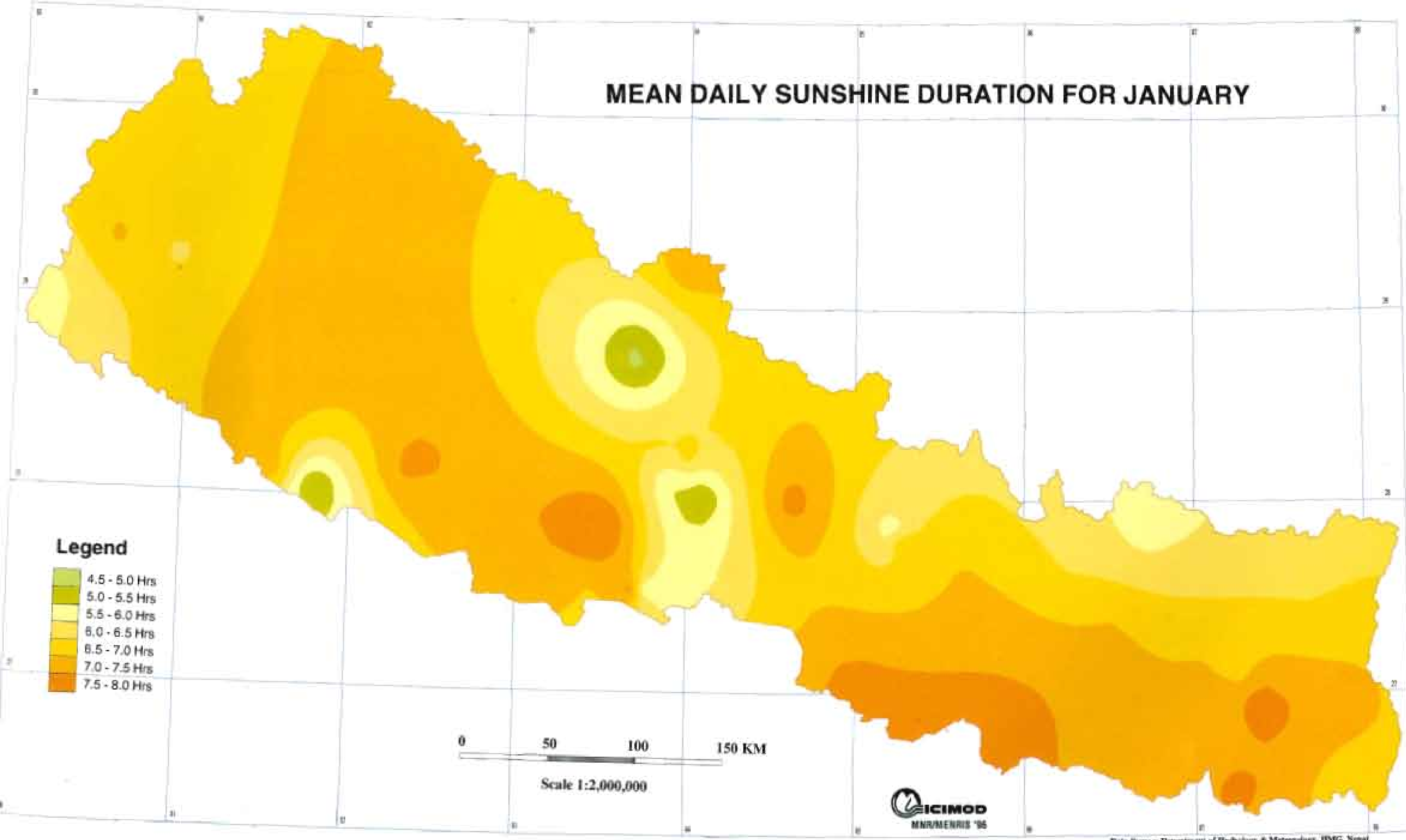

MEAN RELATIVE HUMIDITY FOR OCTOBER
Legend
60 - 65 %
65 - 70 %
70 - 75 %
75 - 80 %
80 - 85 %
85 - 90 %
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '95
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

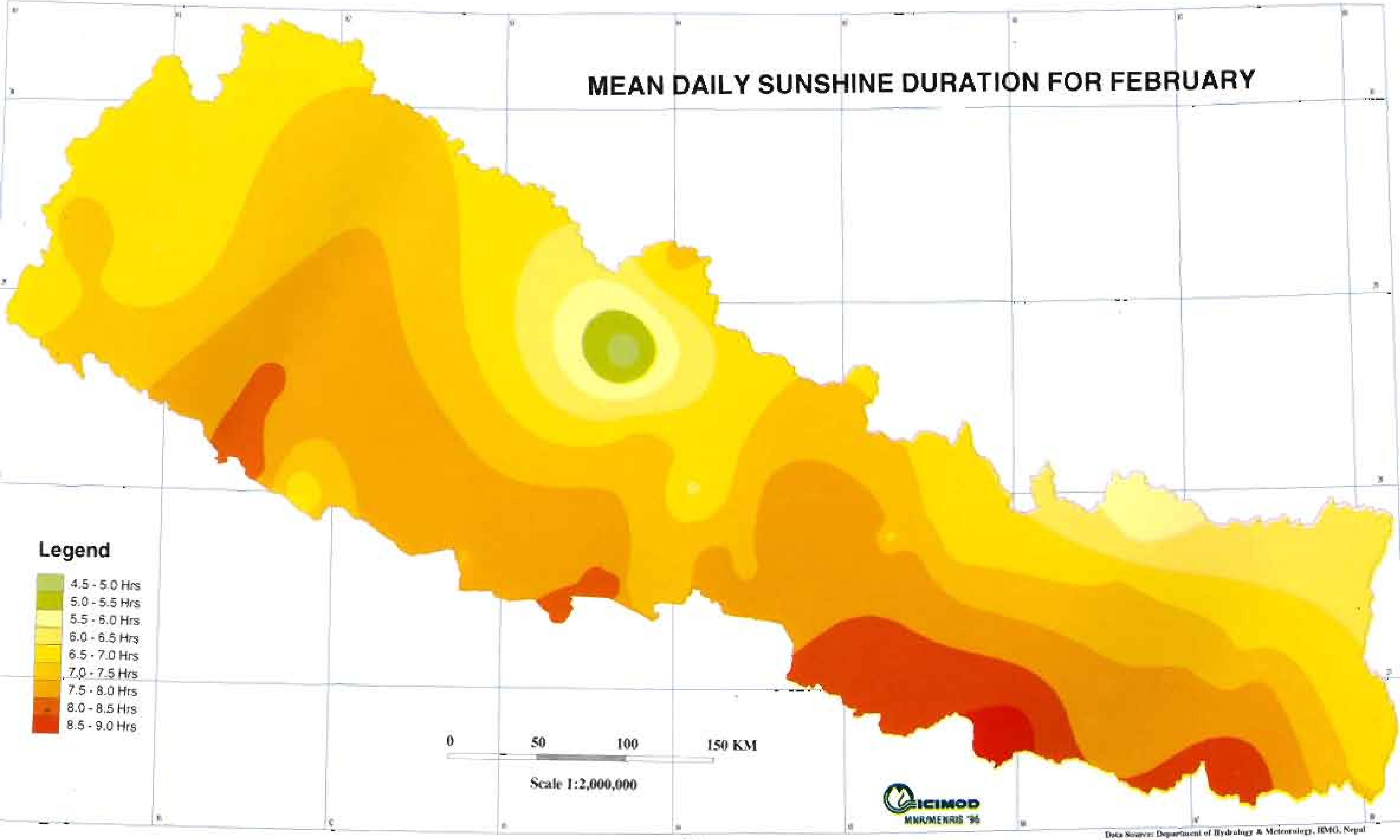


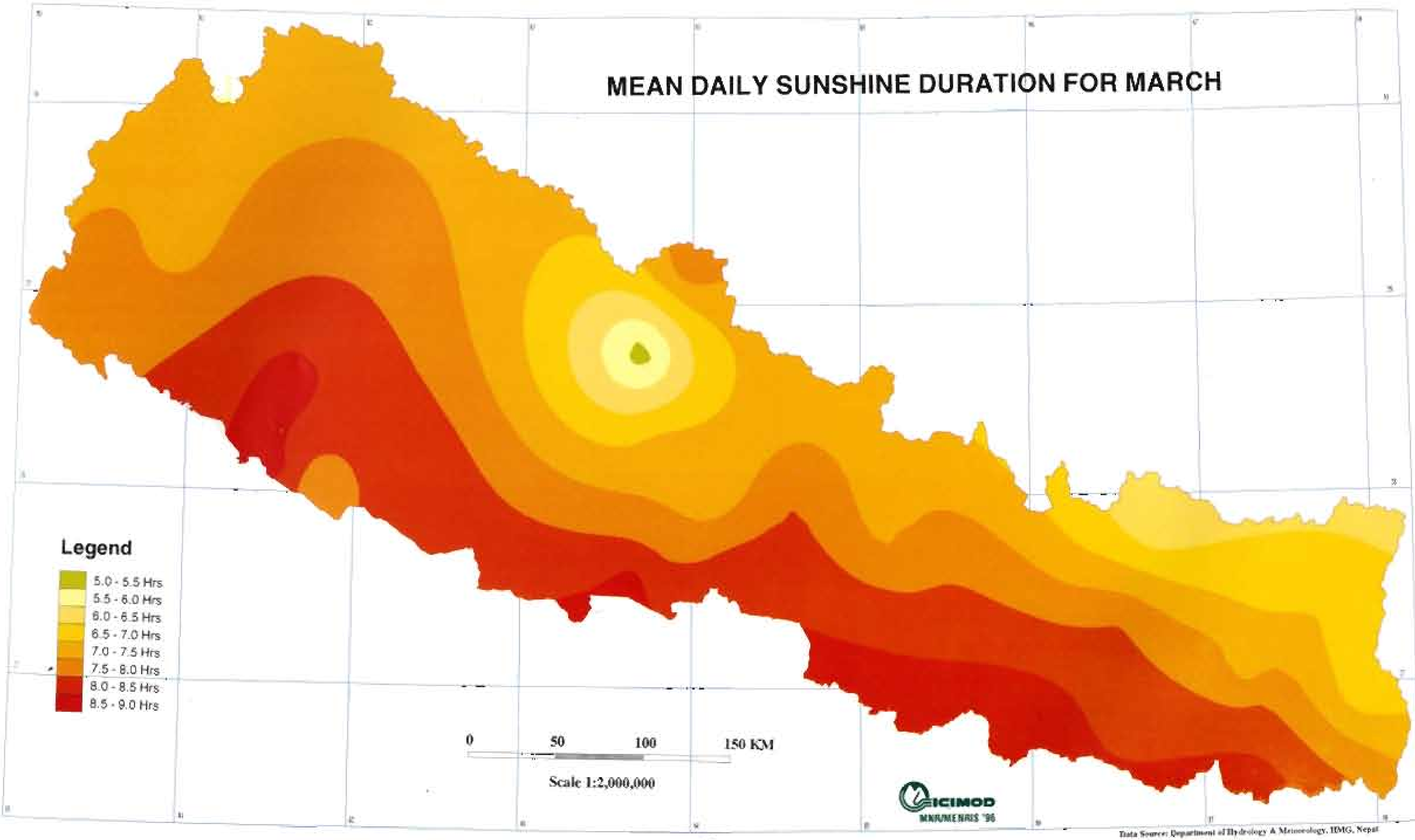
MEAN RELATIVE HUMIDITY FOR NOVEMBER
Legend
50 - 55 %
55 - 60 %
60 - 65 %
65 - 70 %
70 - 75 %
75 - 80 %
80 - 85 %
85 - 90 %
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

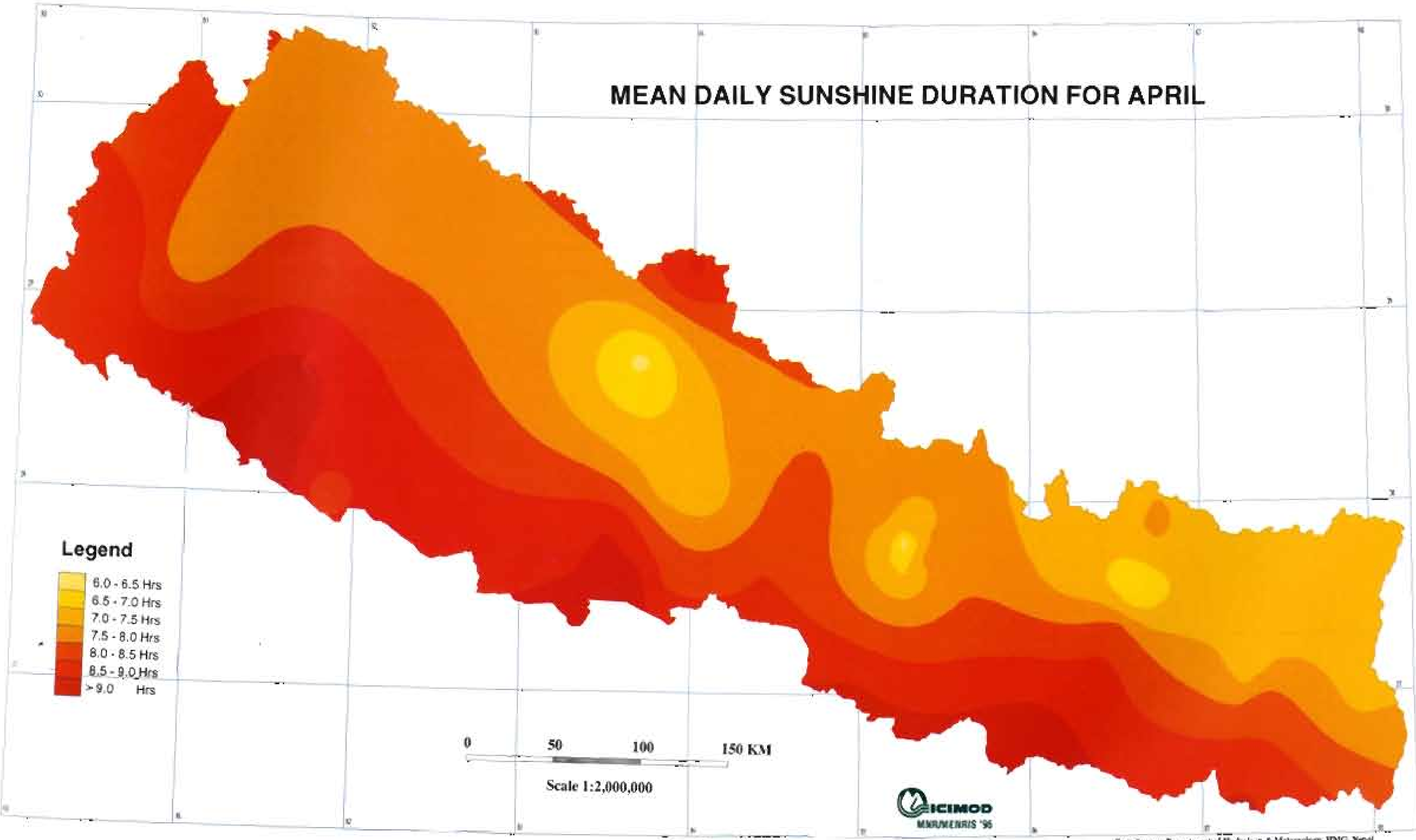


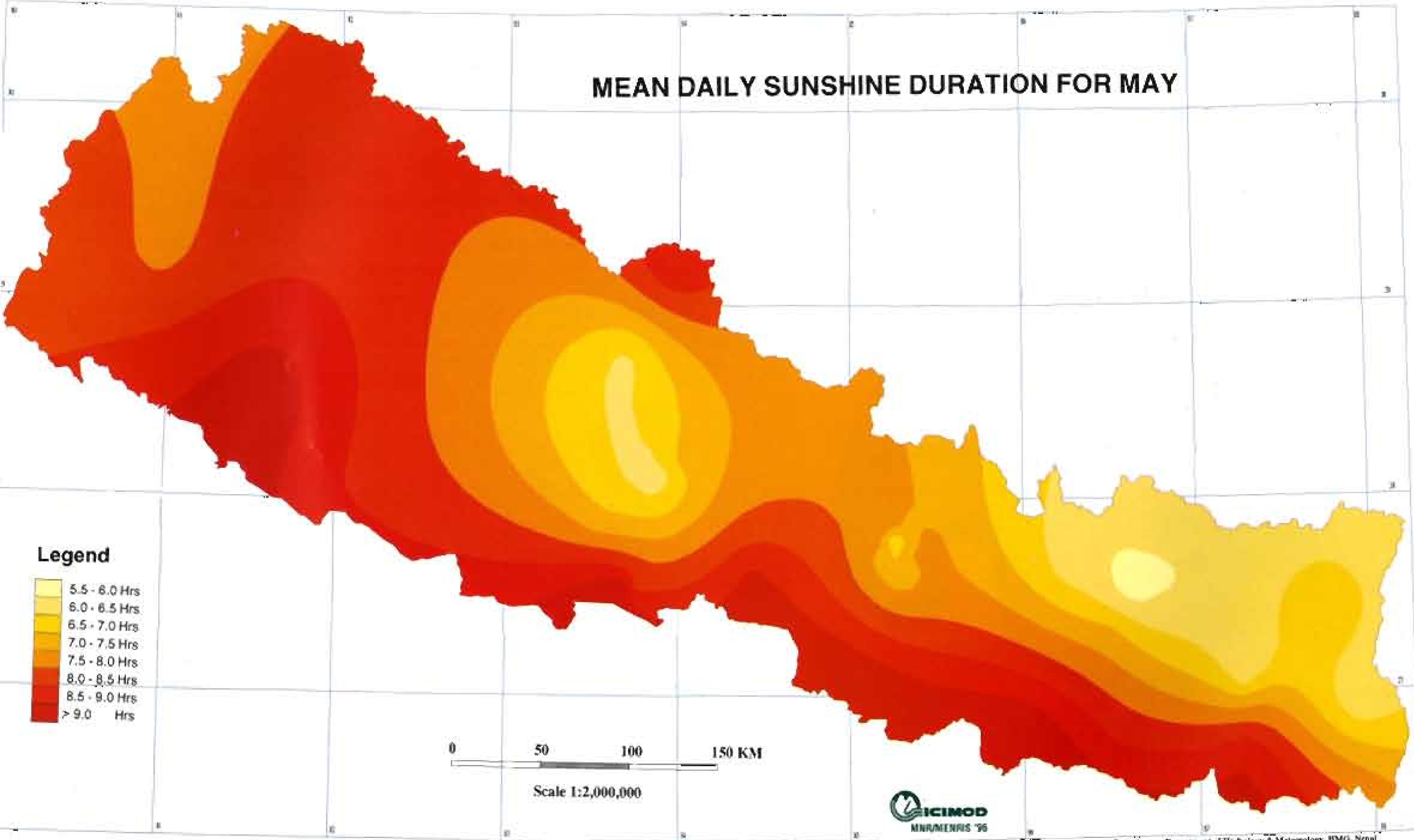
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

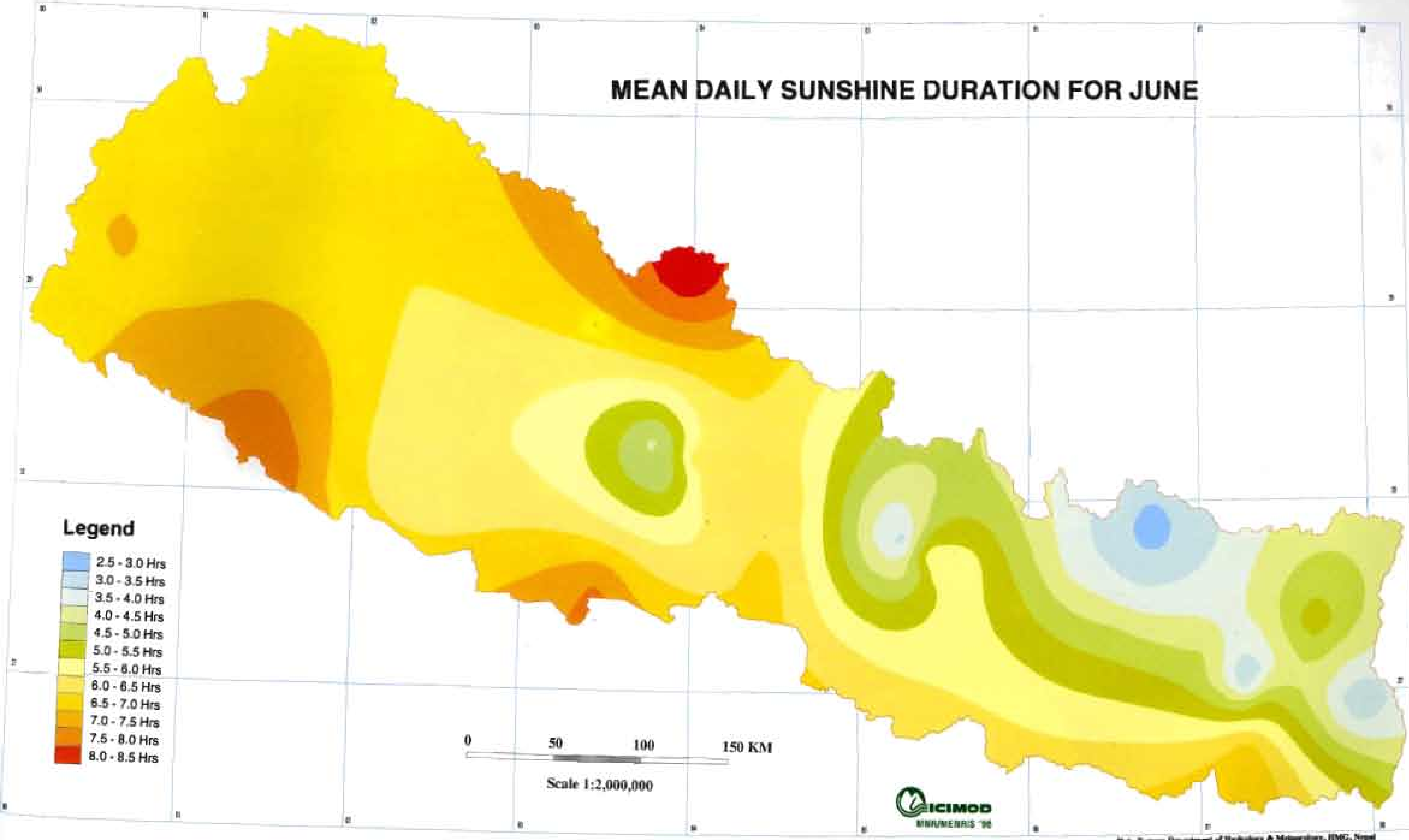

MEAN DAILY SUNSHINE DURATION FOR JANUARY
Legend
4.5 - 5.0 Hrs
5.0 - 5.5 Hrs
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
7.0 - 7.5 Hrs
7.5 - 8.0 Hrs
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

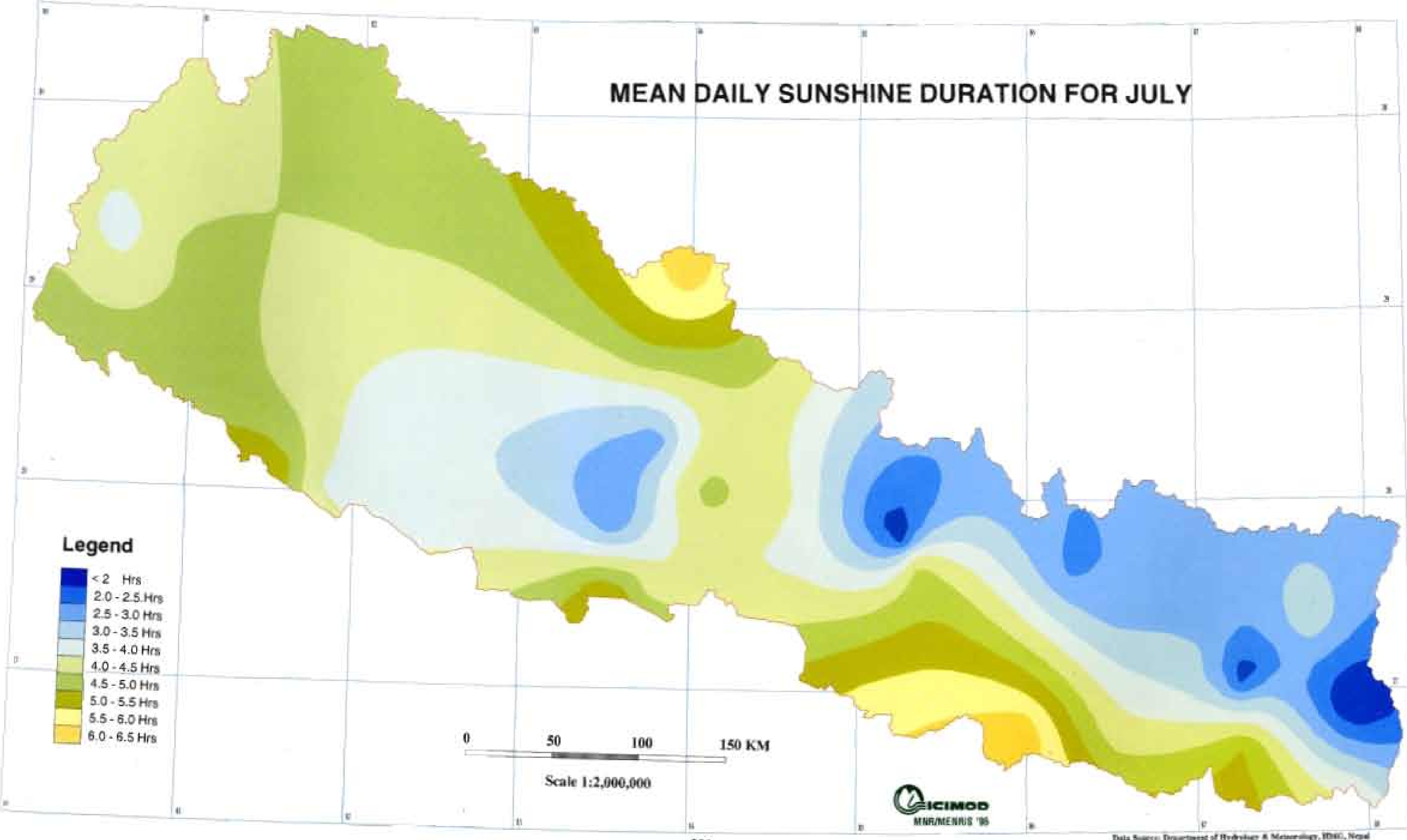

MEAN DAILY SUNSHINE DURATION FOR FEBRUARY
Legend
4.5 - 5.0 Hrs
5.0 - 5.5 Hrs
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
7.0 - 7.5 Hrs
7.5 - 8.0 Hrs
8.0 - 8.5 Hrs
8.5 - 9.0 Hrs
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

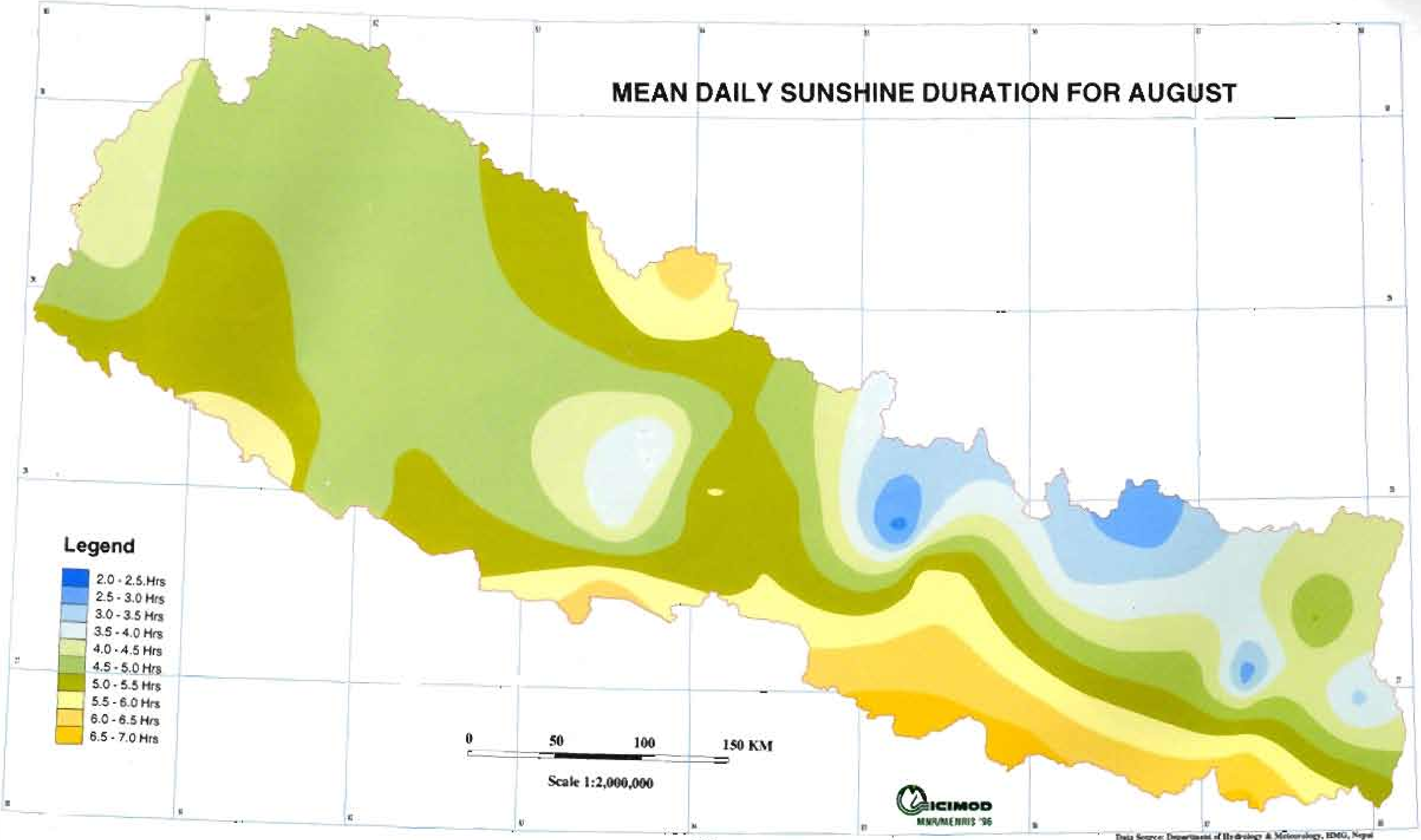

MEAN DAILY SUNSHINE DURATION FOR MARCH
Legend
5.0 - 5.5 Hrs
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
7.0 - 7.5 Hrs
7.5 - 8.0 Hrs
8.0 - 8.5 Hrs
8.5 - 9.0 Hrs
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN DAILY SUNSHINE DURATION FOR APRIL
Legend
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
7.0 - 7.5 Hrs
7.5 - 8.0 Hrs
8.0 - 8.5 Hrs
8.5 - 9.0 Hrs
> 9.0 Hrs
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

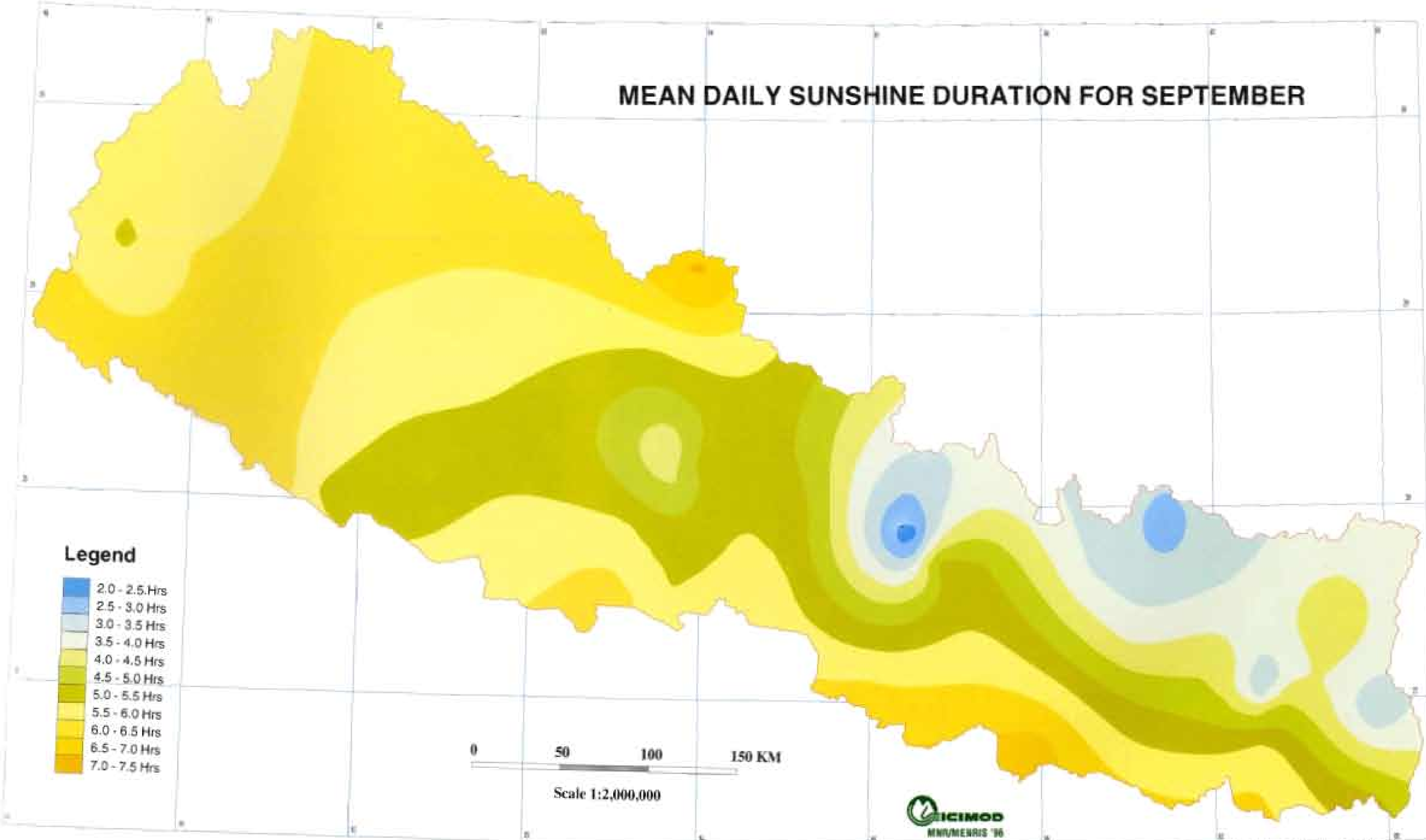

MEAN DAILY SUNSHINE DURATION FOR MAY
Legend
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
7.0 - 7.5 Hrs
7.5 - 8.0 Hrs
8.0 - 8.5 Hrs
8.5 - 9.0 Hrs
> 9.0 Hrs
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN DAILY SUNSHINE DURATION FOR JUNE
Legend
2.5 - 3.0 Hrs
3.0 - 3.5 Hrs
3.5 - 4.0 Hrs
4.0 - 4.5 Hrs
4.5 - 5.0 Hrs
5.0 - 5.5 Hrs
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
7.0 - 7.5 Hrs
7.5 - 8.0 Hrs
8.0 - 8.5 Hrs
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

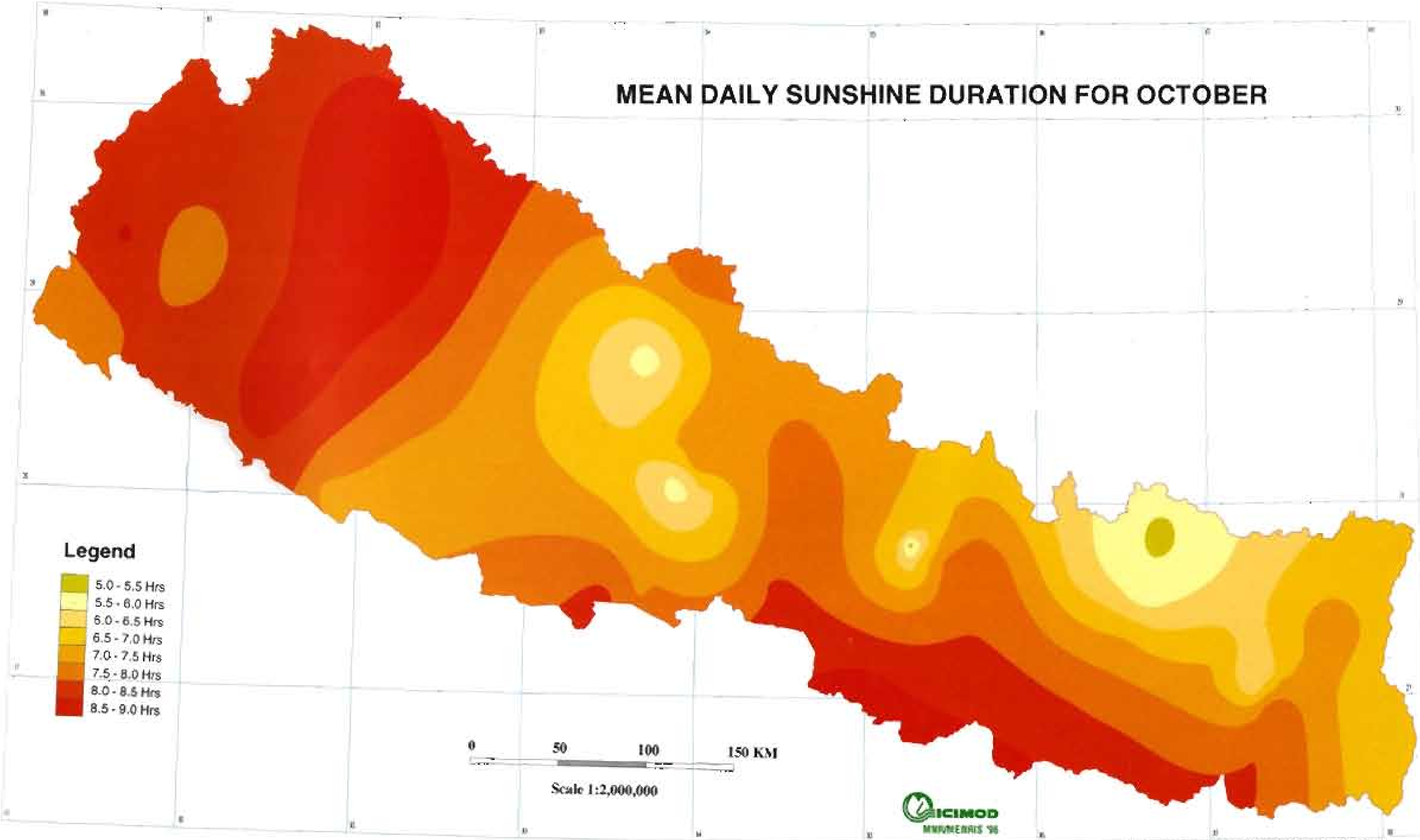

MEAN DAILY SUNSHINE DURATION FOR JULY
Legend
< 2 Hrs
2.0 - 2.5 Hrs
2.5 - 3.0 Hrs
3.0 - 3.5 Hrs
3.5 - 4.0 Hrs
4.0 - 4.5 Hrs
4.5 - 5.0 Hrs
5.0 - 5.5 Hrs
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal



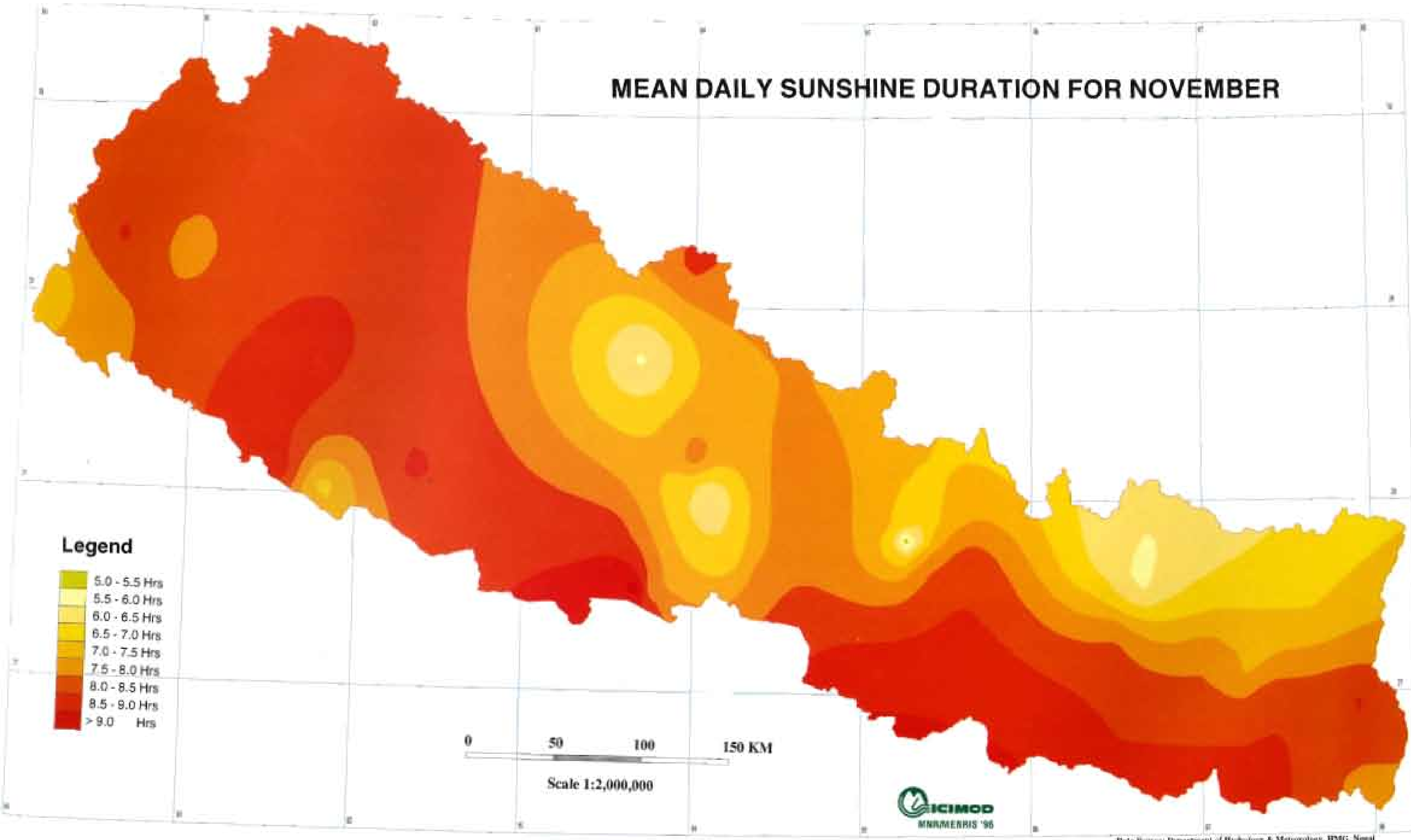
MEAN DAILY SUNSHINE DURATION FOR AUGUST
Legend
2.0 - 2.5 Hrs
2.5 - 3.0 Hrs
3.0 - 3.5 Hrs
3.5 - 4.0 Hrs
4.0 - 4.5 Hrs
4.5 - 5.0 Hrs
5.0 - 5.5 Hrs
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

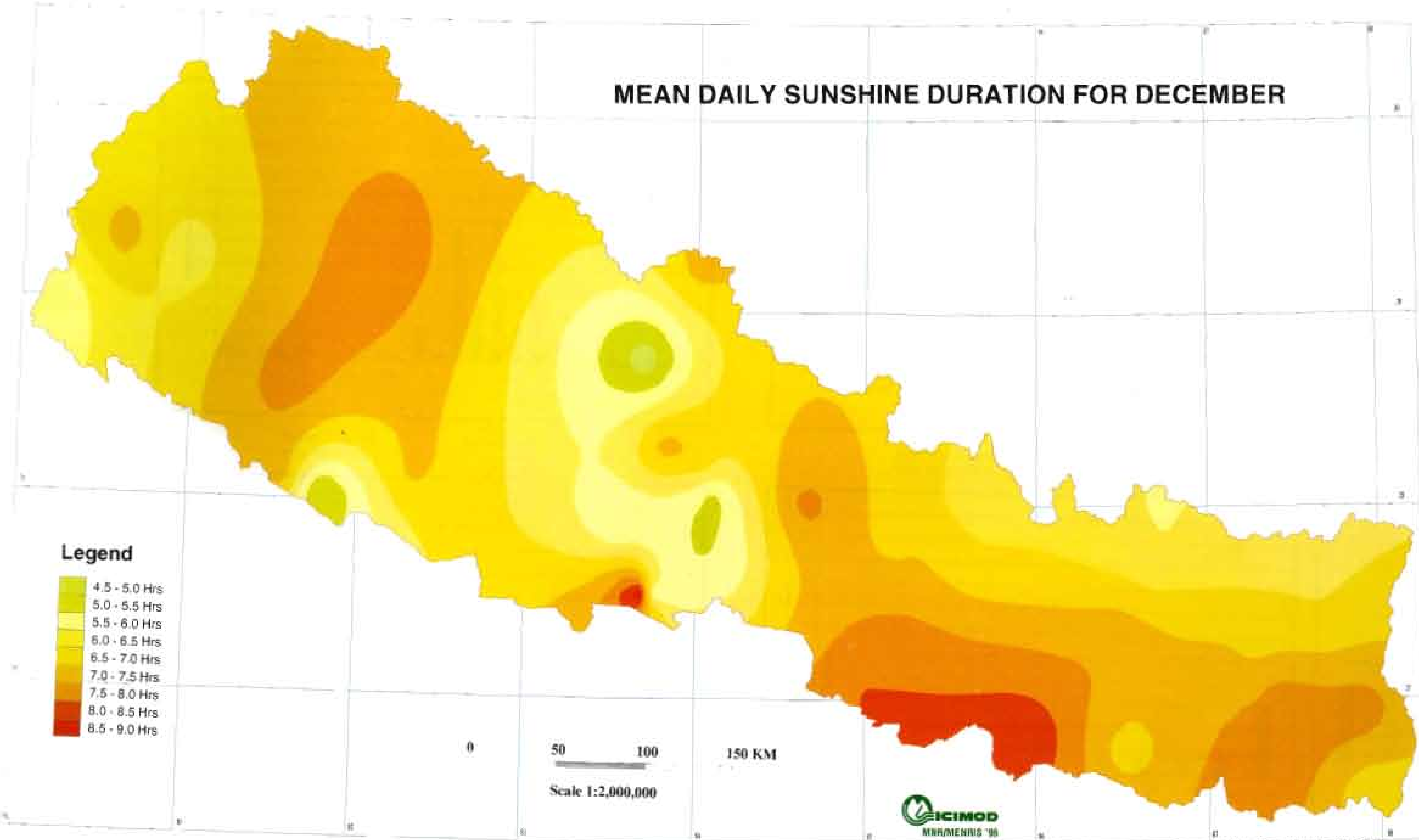


Data Source: Department of Hydrology & Meteorology, HMG, Nepal



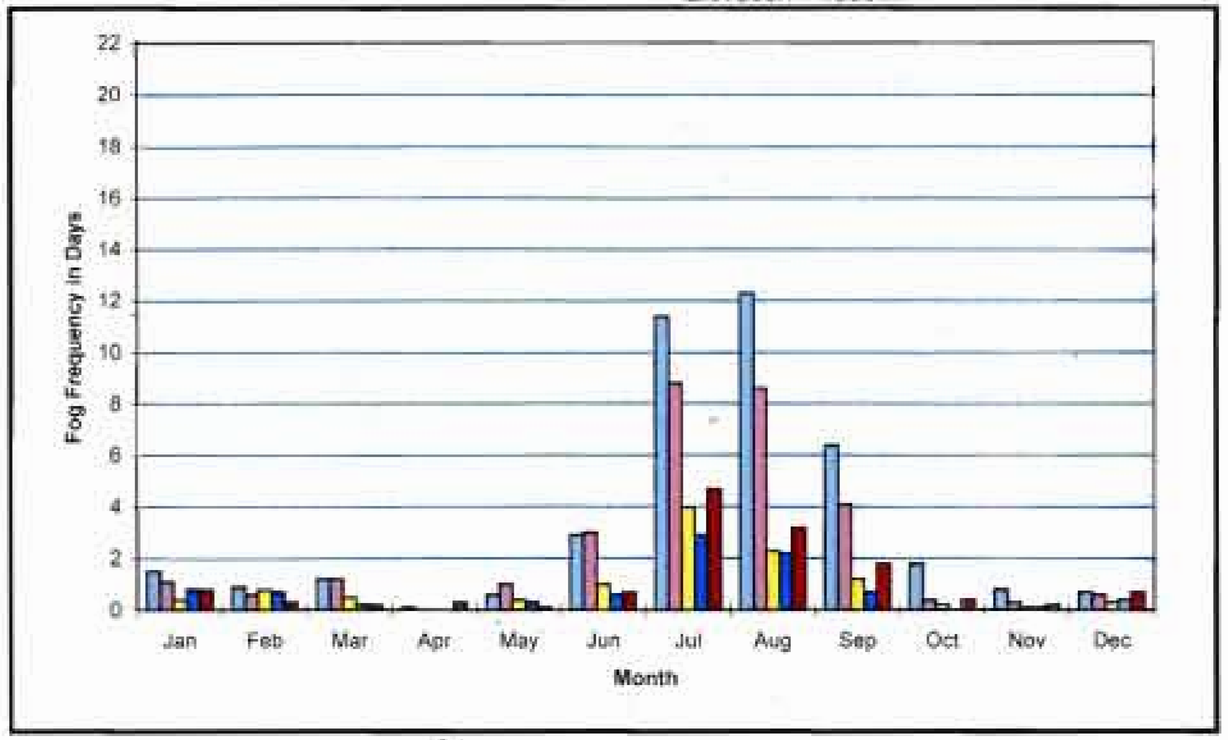
MEAN DAILY SUNSHINE DURATION FOR OCTOBER
Legend
5.0 - 5.5 Hrs
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
7.0 - 7.5 Hrs
7.5 - 8.0 Hrs
8.0 - 8.5 Hrs
8.5 - 9.0 Hrs
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal


MEAN DAILY SUNSHINE DURATION FOR NOVEMBER
Legend
5.0 - 5.5 Hrs
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
7.0 - 7.5 Hrs
7.5 - 8.0 Hrs
8.0 - 8.5 Hrs
8.5 - 9.0 Hrs
> 9.0 Hrs
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNRMENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

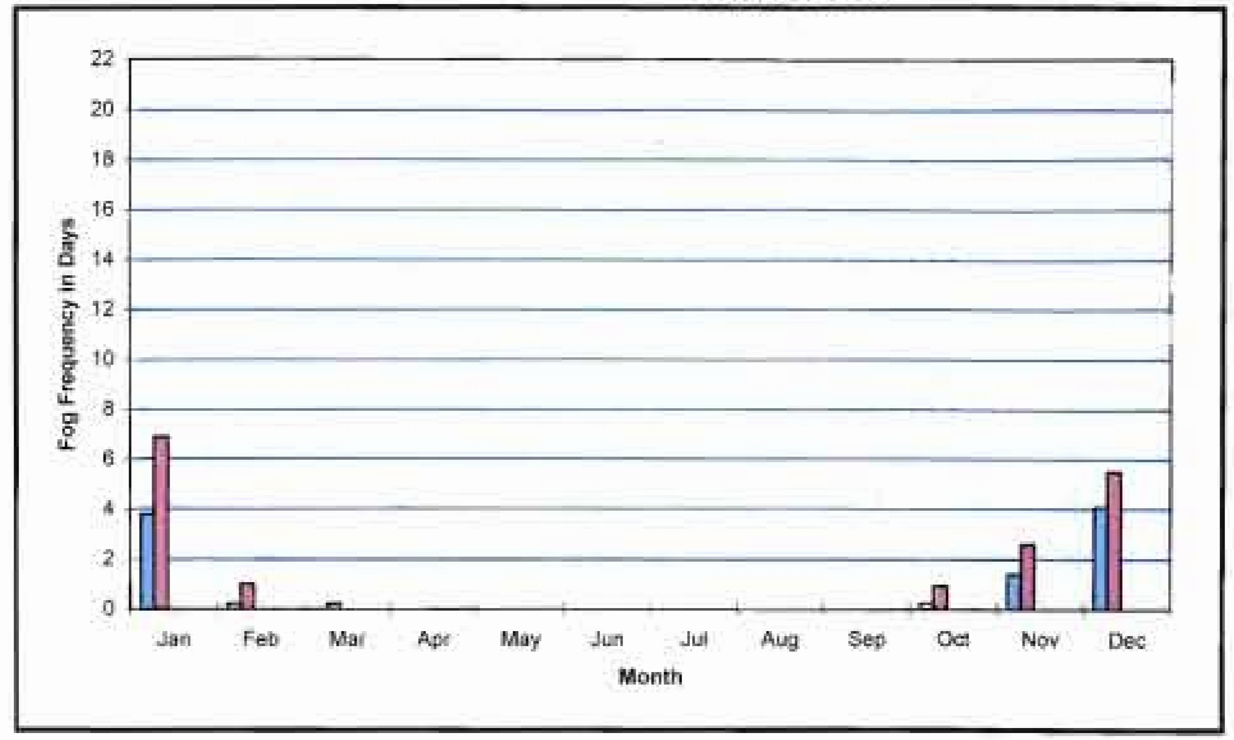

MEAN DAILY SUNSHINE DURATION FOR DECEMBER
Legend
4.5 - 5.0 Hrs
5.0 - 5.5 Hrs
5.5 - 6.0 Hrs
6.0 - 6.5 Hrs
6.5 - 7.0 Hrs
7.0 - 7.5 Hrs
7.5 - 8.0 Hrs
8.0 - 8.5 Hrs
8.5 - 9.0 Hrs
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '98
Data Source: Department of Hydrology & Meteorology, HMG, Nepal

MEAN FOG FREQUENCY

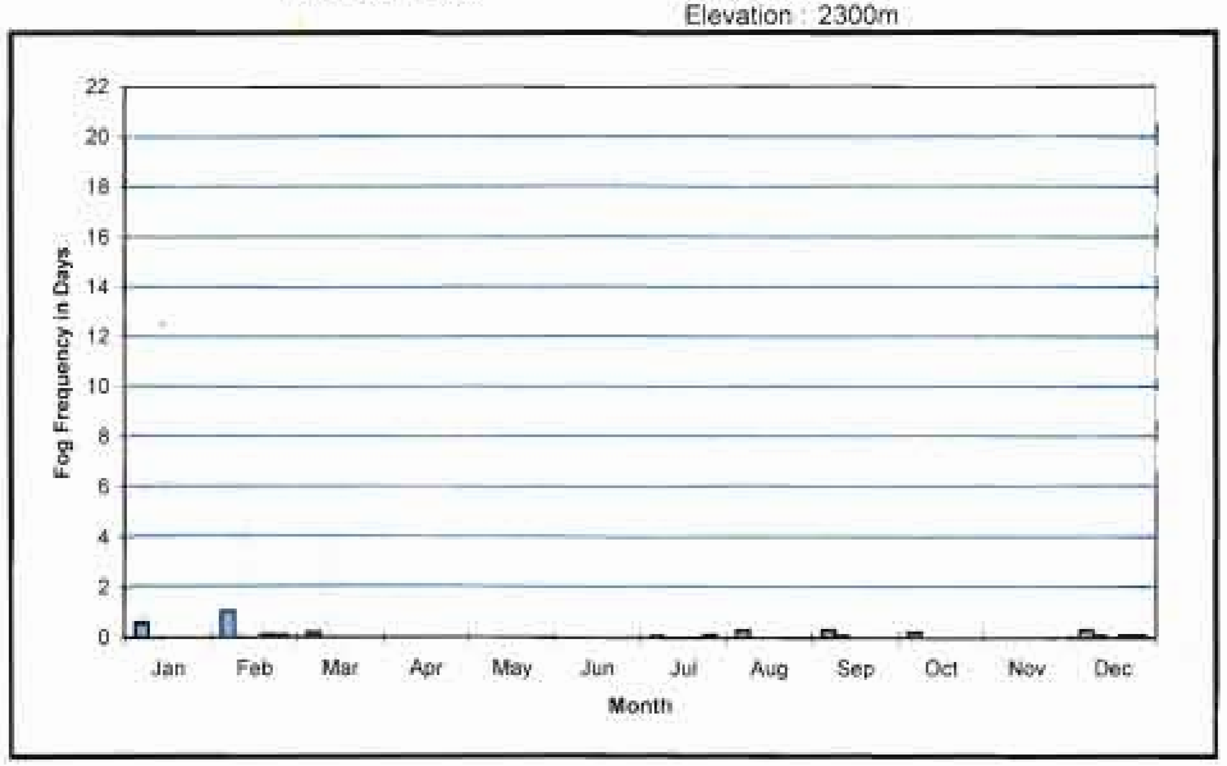
Station : Dadeldhura
Index No: 0104
Latitude : 29°18
Longitude: 80°35'
Elevation : 1865m



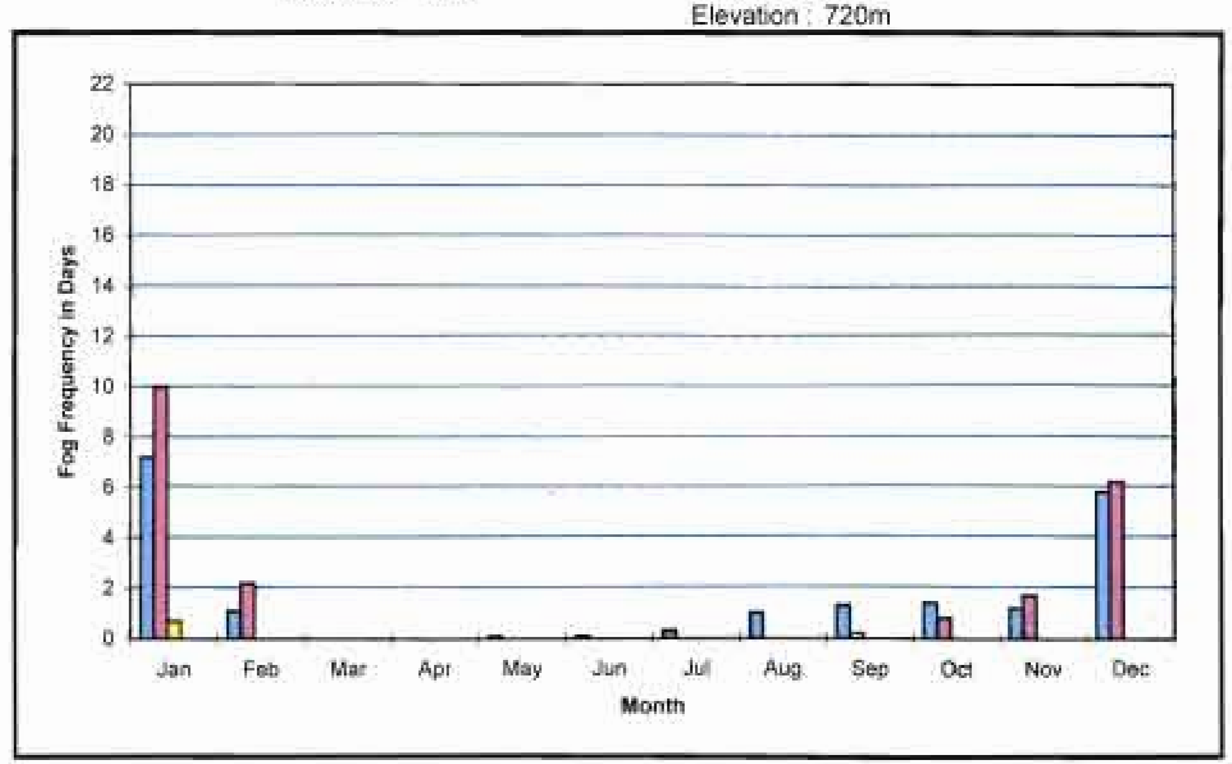
Station : Dipayal
Index No: 0218
Latitude : 29°15'
Longitude: 80°57'
Elevation : 617m



Station : Jumla
Index No: 0303
Latitude : 29°17'
Longitude: 82°10'
Elevation : 2300m



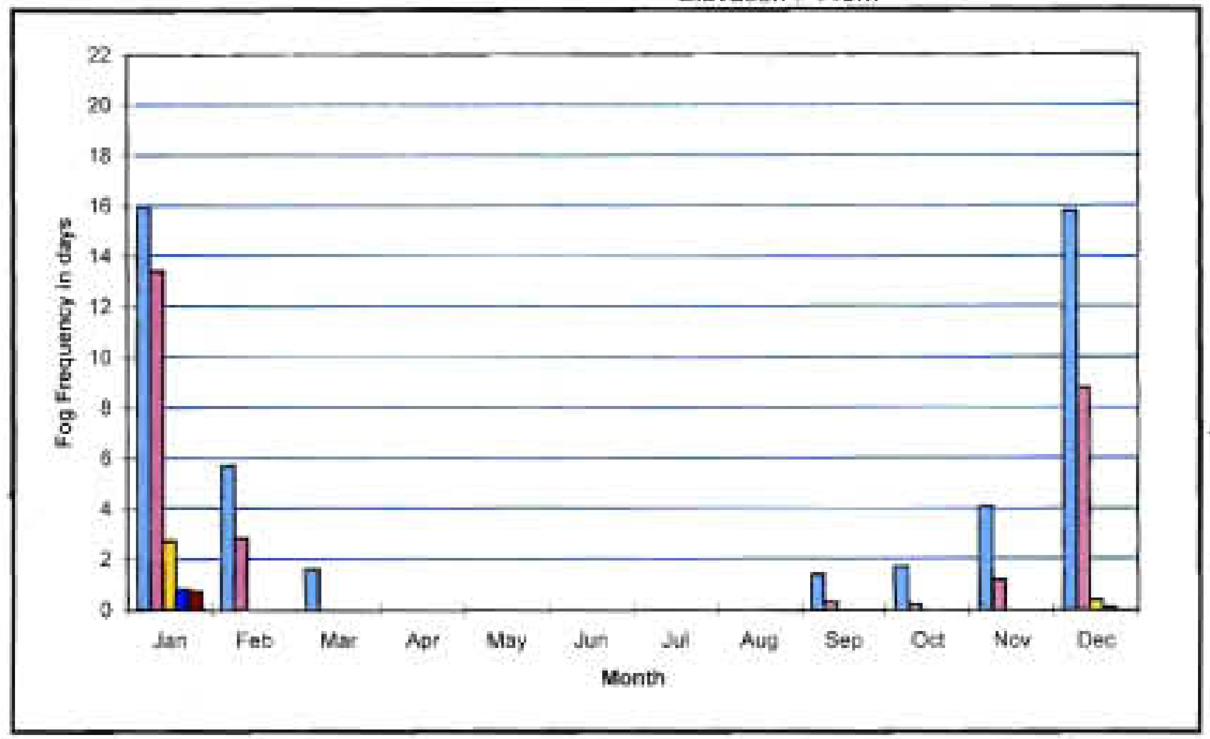
Station : Surkhet
Index No: 0406
Latitude : 28°36'
Longitude: 81°37'
Elevation : 720m



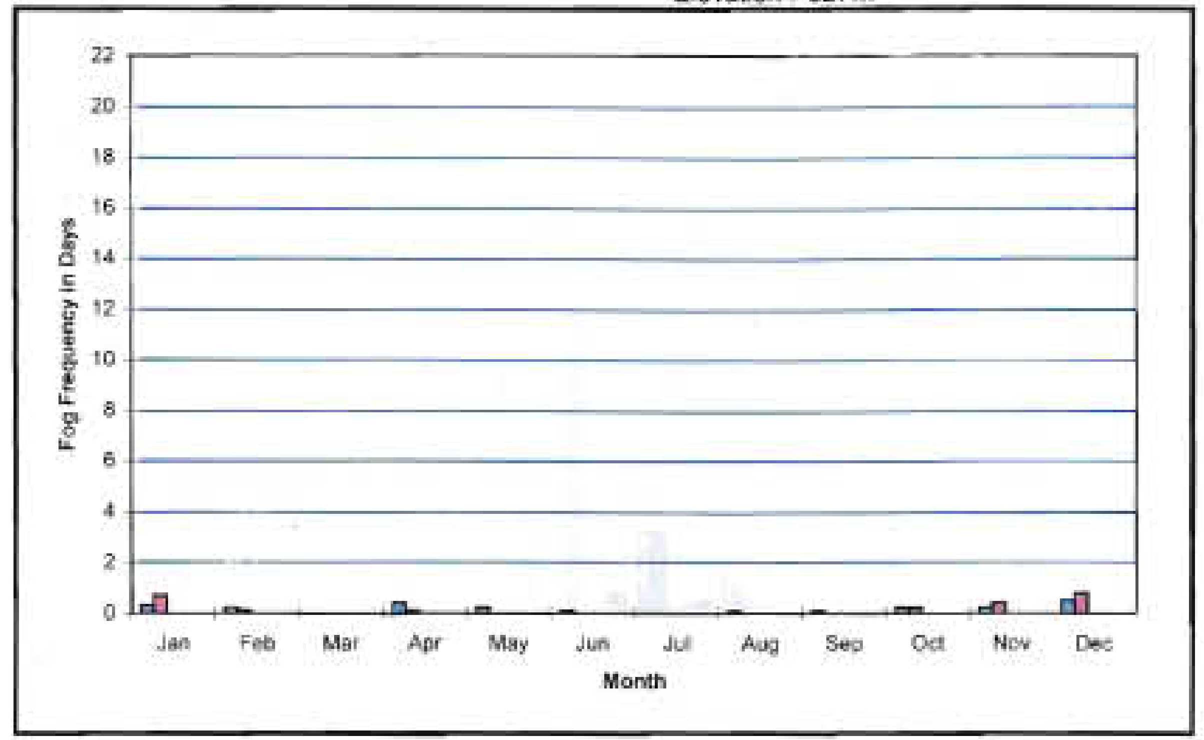
Source: Department of Hydrology & Meteorology, HMG, Nepal

MEAN FOG FREQUENCY

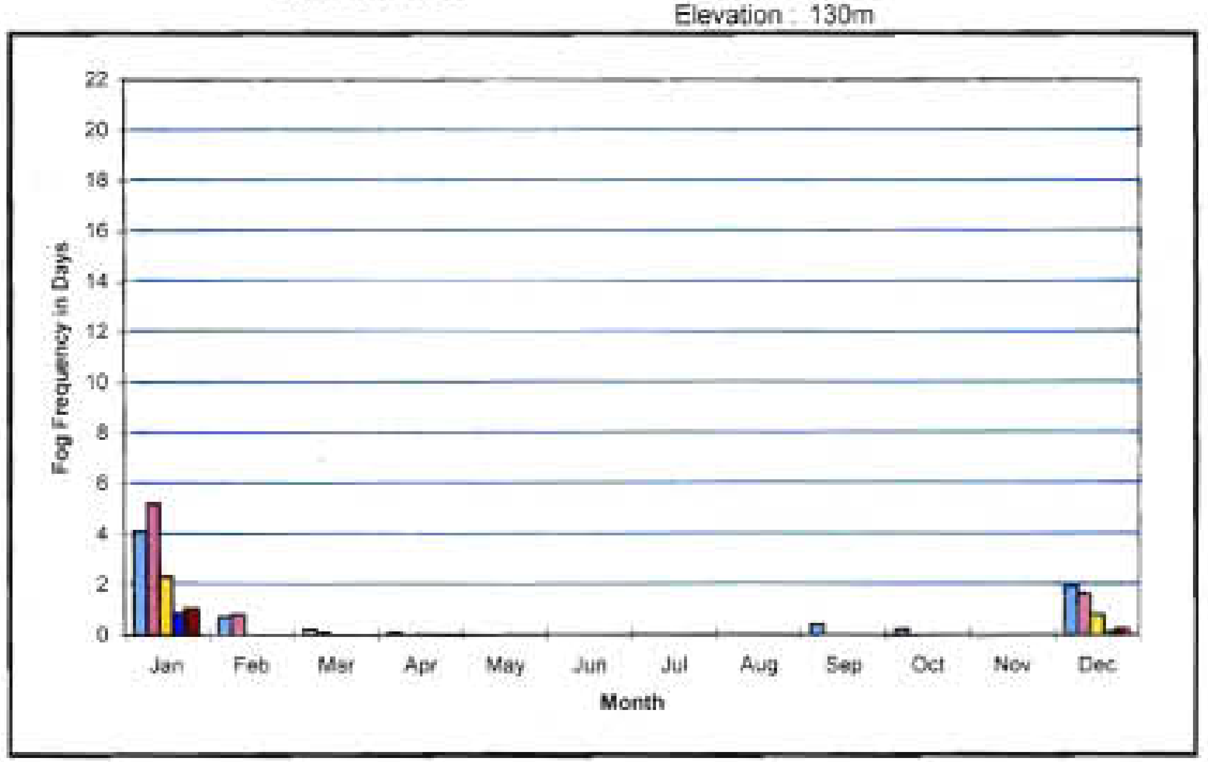
Station : Bhairahawa
Index No: 0705
Latitude : 27°31'
Longitude: 83°26'
Elevation : 110m



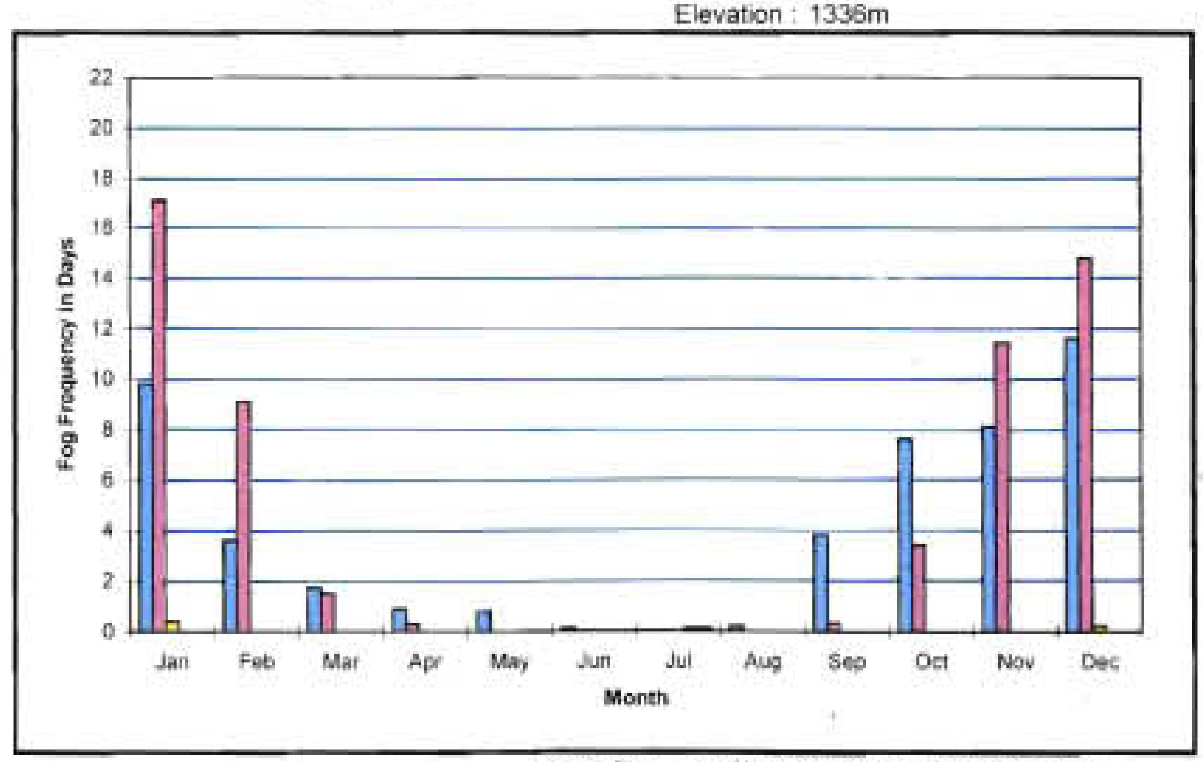
Station : Pokhara
Index No: 0804
Latitude : 28°13'
Longitude: 84°00'
Elevation : 827m



Station : Simara
Index No: 0909
Latitude : 27°10'
Longitude: 84°59'
Elevation : 130m



Station : Kathmandu
Index No: 1030
Latitude : 27°42'
Longitude: 85°22'
Elevation : 1336m



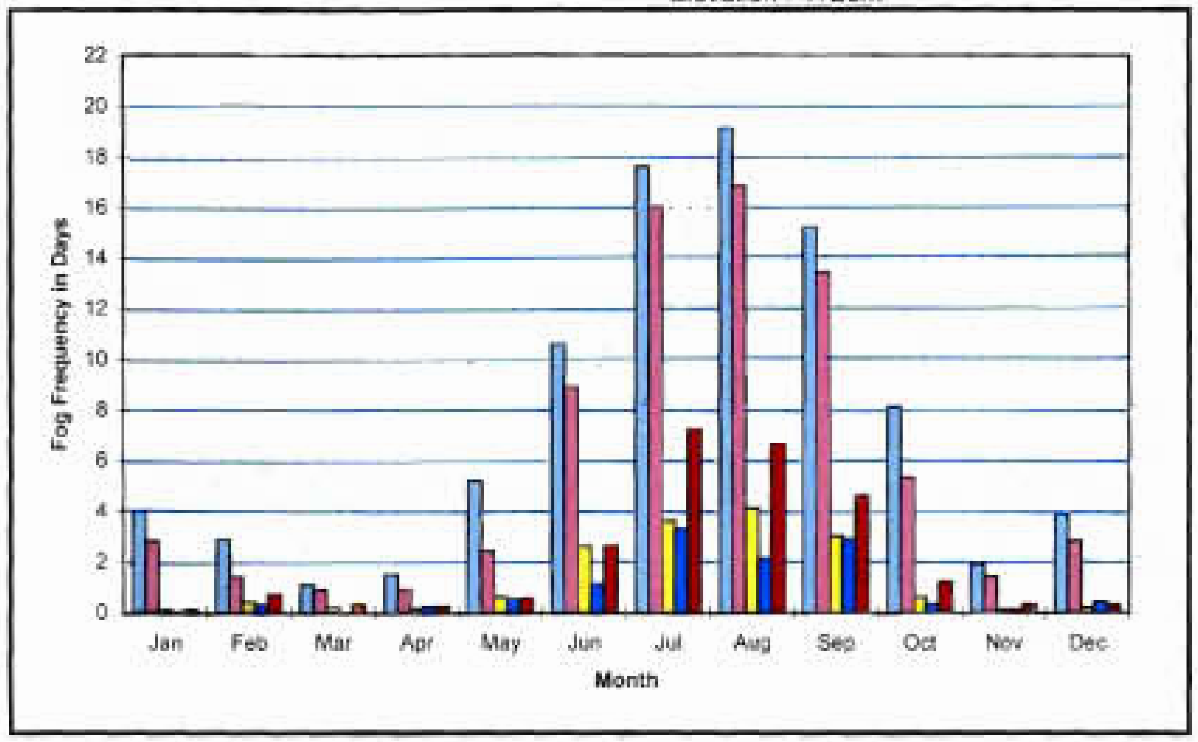
Legend

- 00 UTC
- 03 UTC
- 06 UTC
- 09 UTC
- 12 UTC

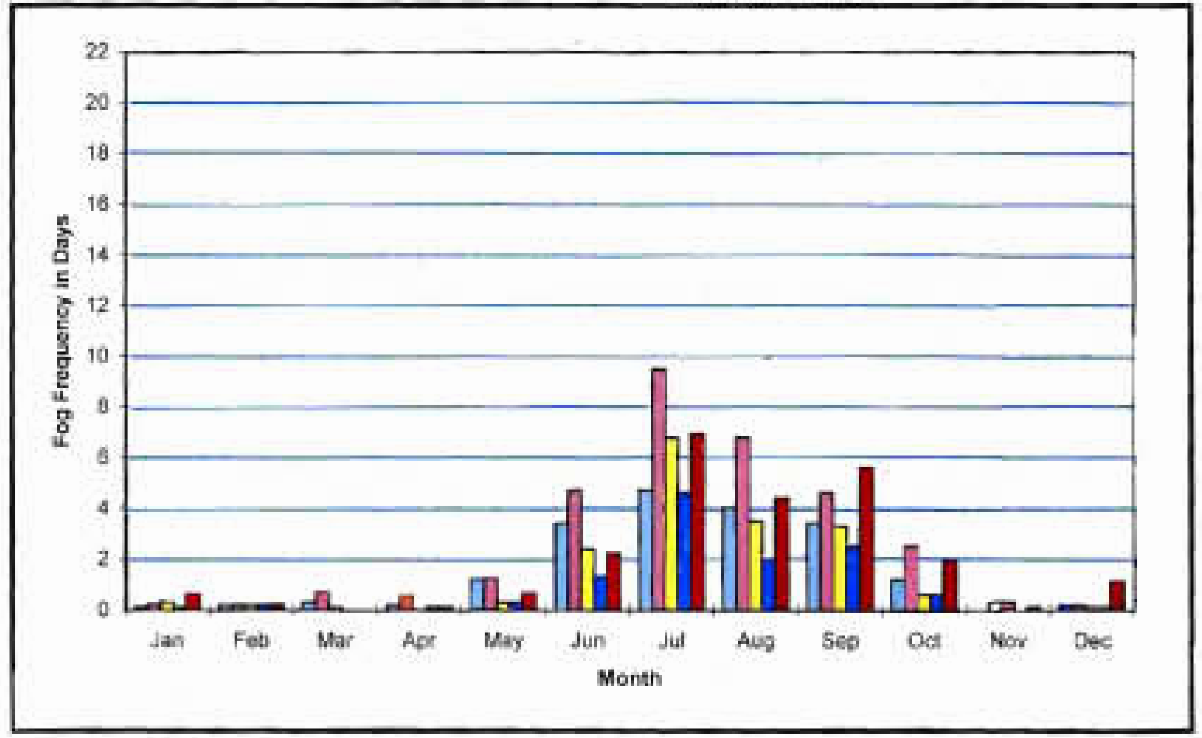
Source: Department of Hydrology & Meteorology, HMG, Nepal

MEAN FOG FREQUENCY

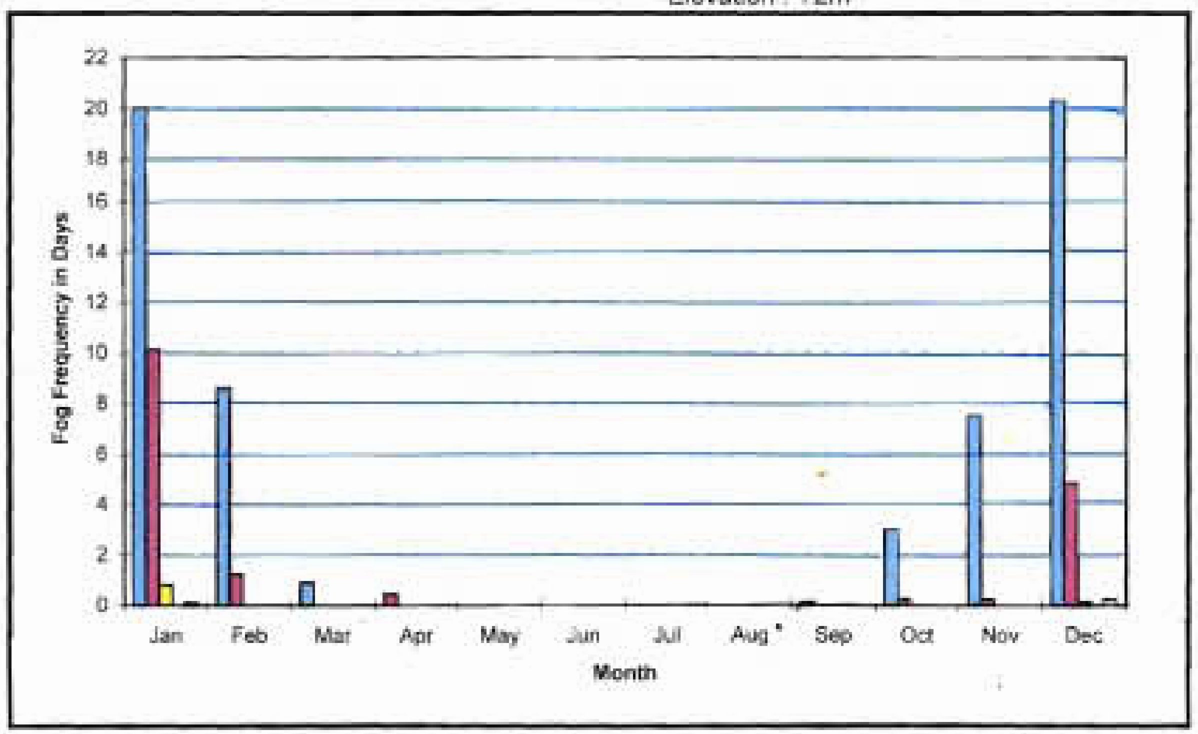
Station : Okhaldhunga
Index No: 1206
Latitude : 27°19'
Longitude: 86°30'
Elevation : 1720m



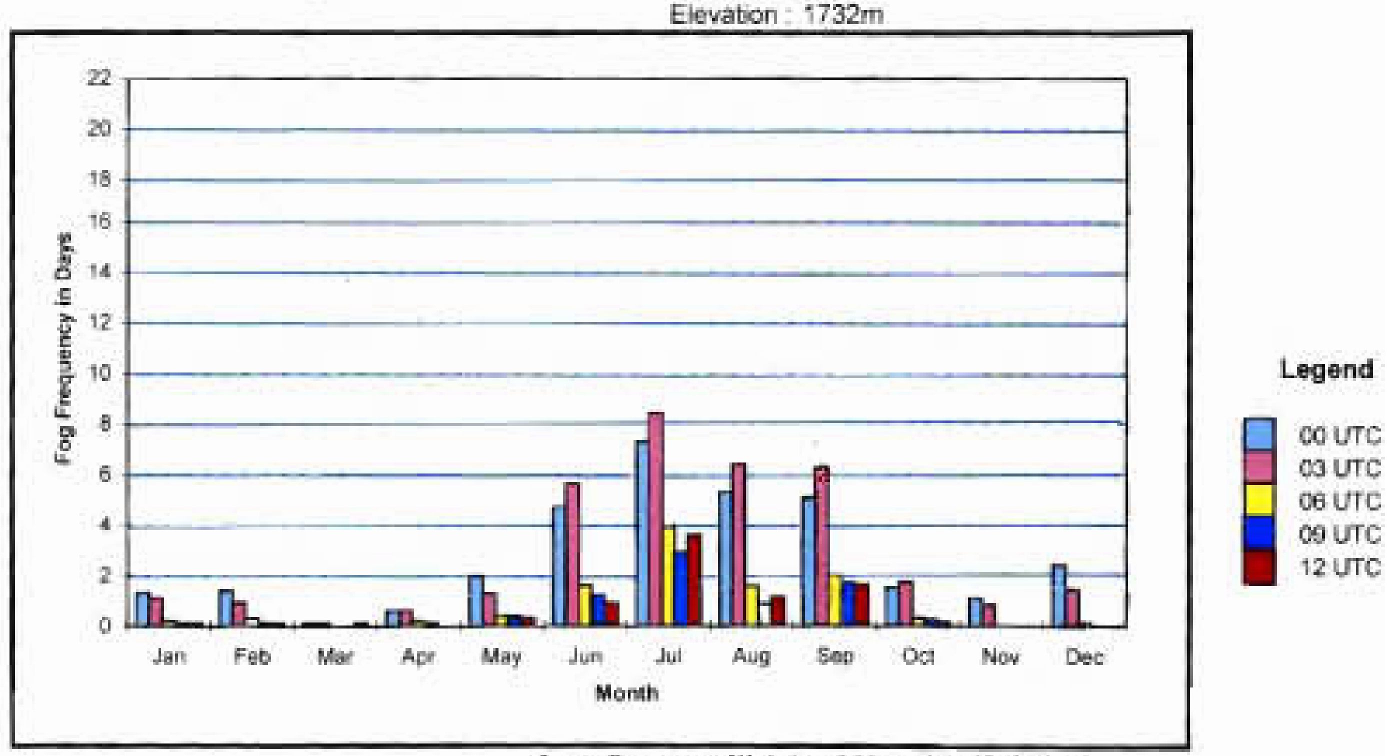
Station : Dhankuta
Index No: 1307
Latitude : 26°59'
Longitude: 87°21'
Elevation : 1445m



Station : Biratnagar
Index No: 1319
Latitude : 26°29'
Longitude: 87°16'
Elevation : 72m



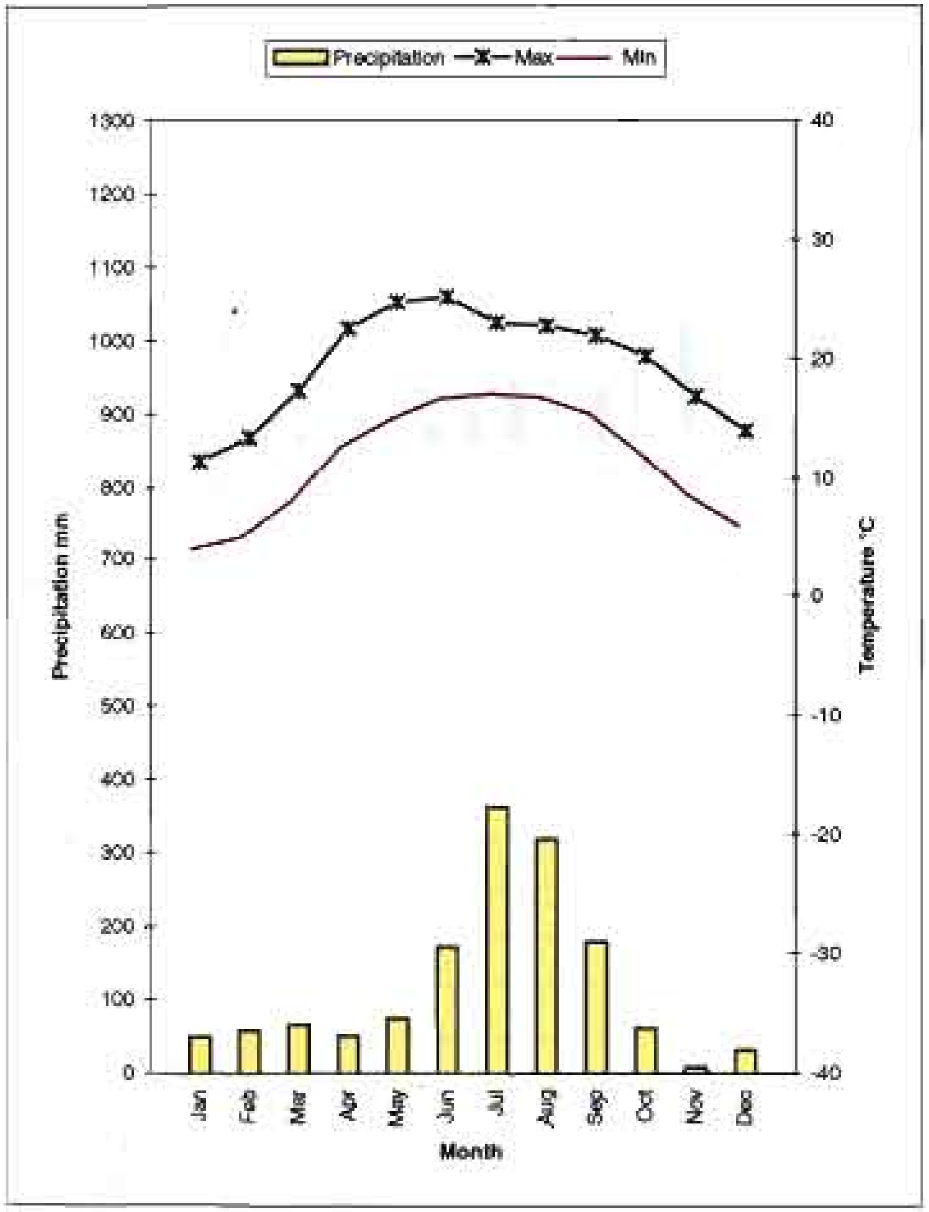
Station : Taplejung
Index No: 1405
Latitude : 27°21'
Longitude: 87°40'
Elevation : 1732m



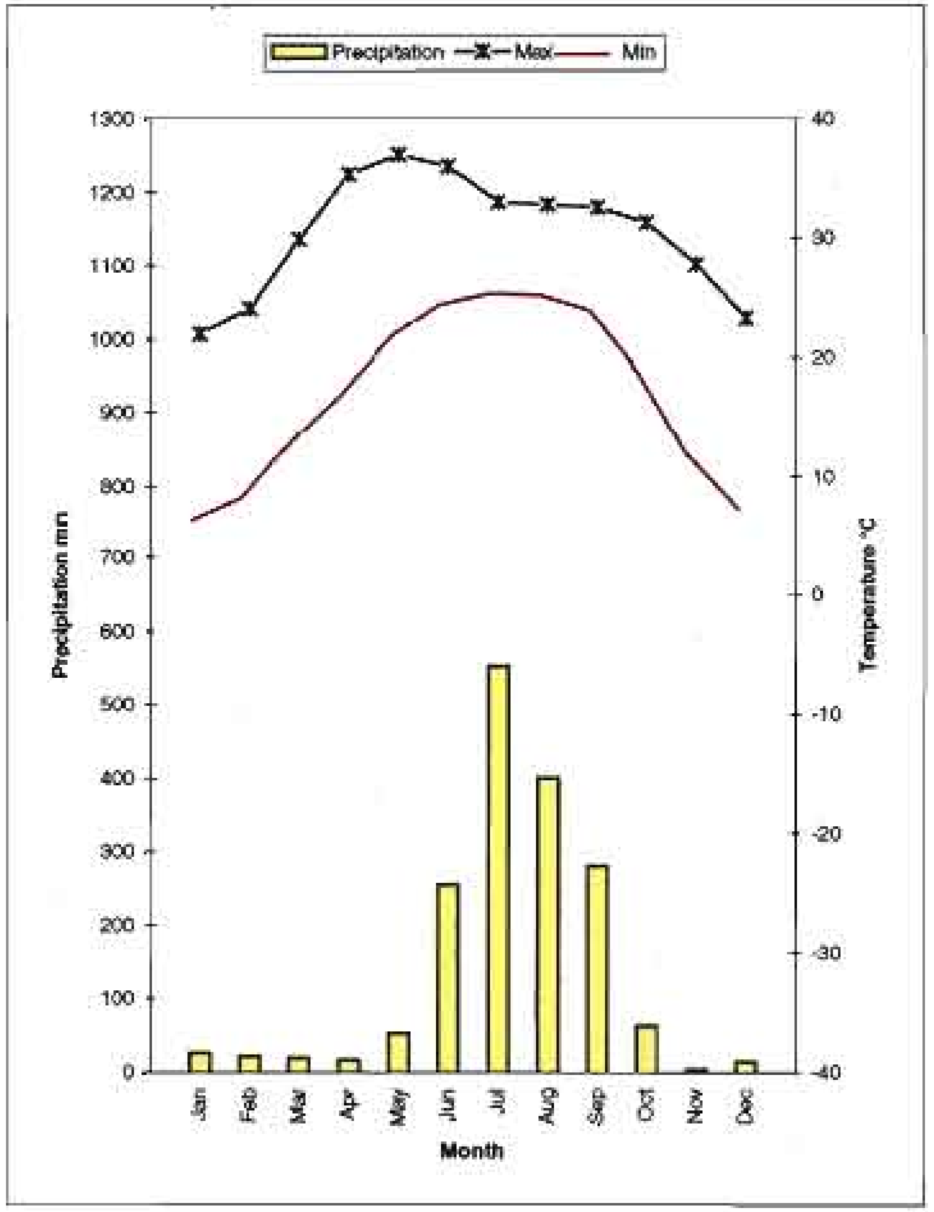
Source: Department of Hydrology & Meteorology, HMG, Nepal

AVERAGE MAXIMUM & MINIMUM TEMPERATURE AND PRECIPITATION

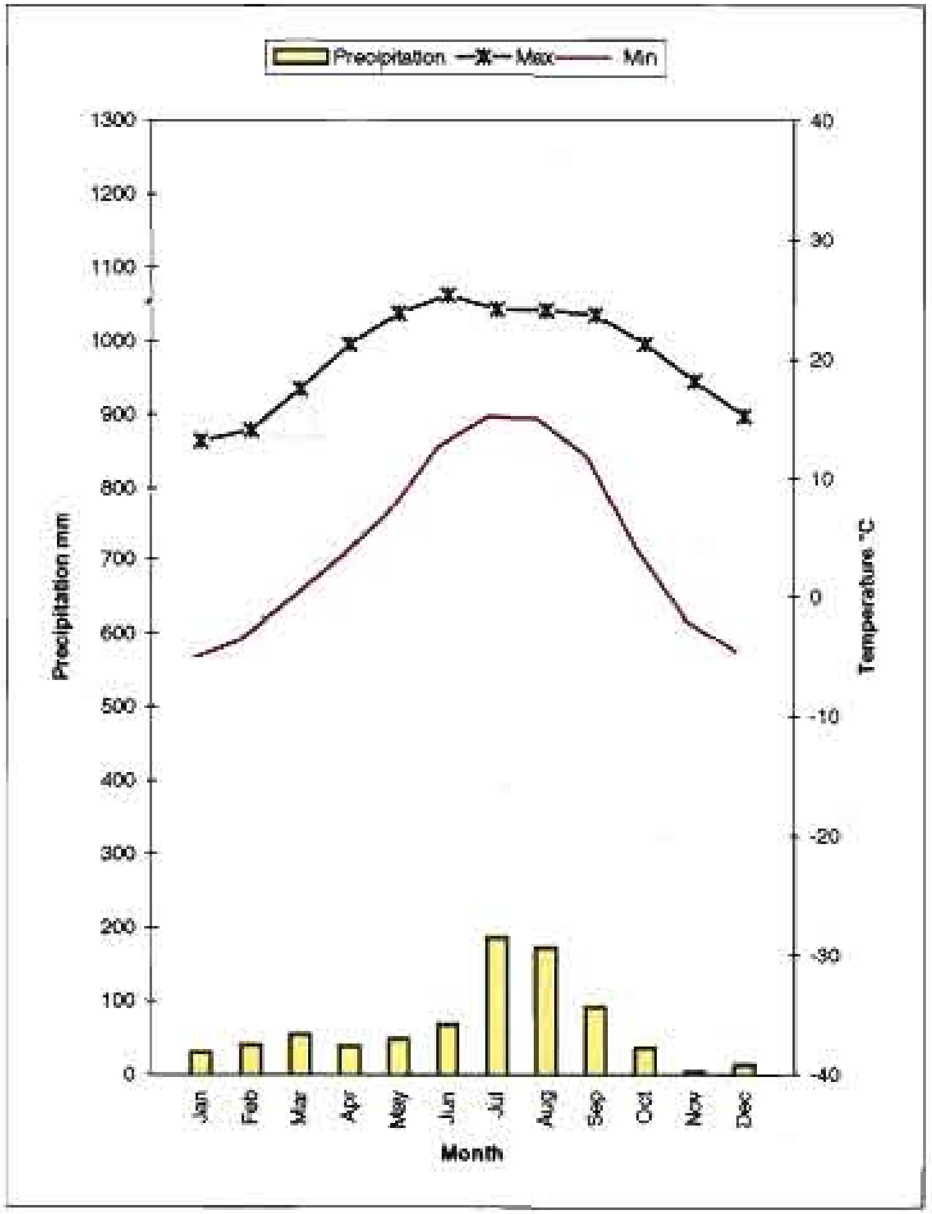
Station : **Dadeldhura**
Index No : 0104
Latitude : 29°18'
Longitude : 80°35'
Elevation : 1865m



Station : **Dhangadhi**
Index No : 0209
Latitude : 28°41'
Longitude : 80°36'
Elevation : 170m



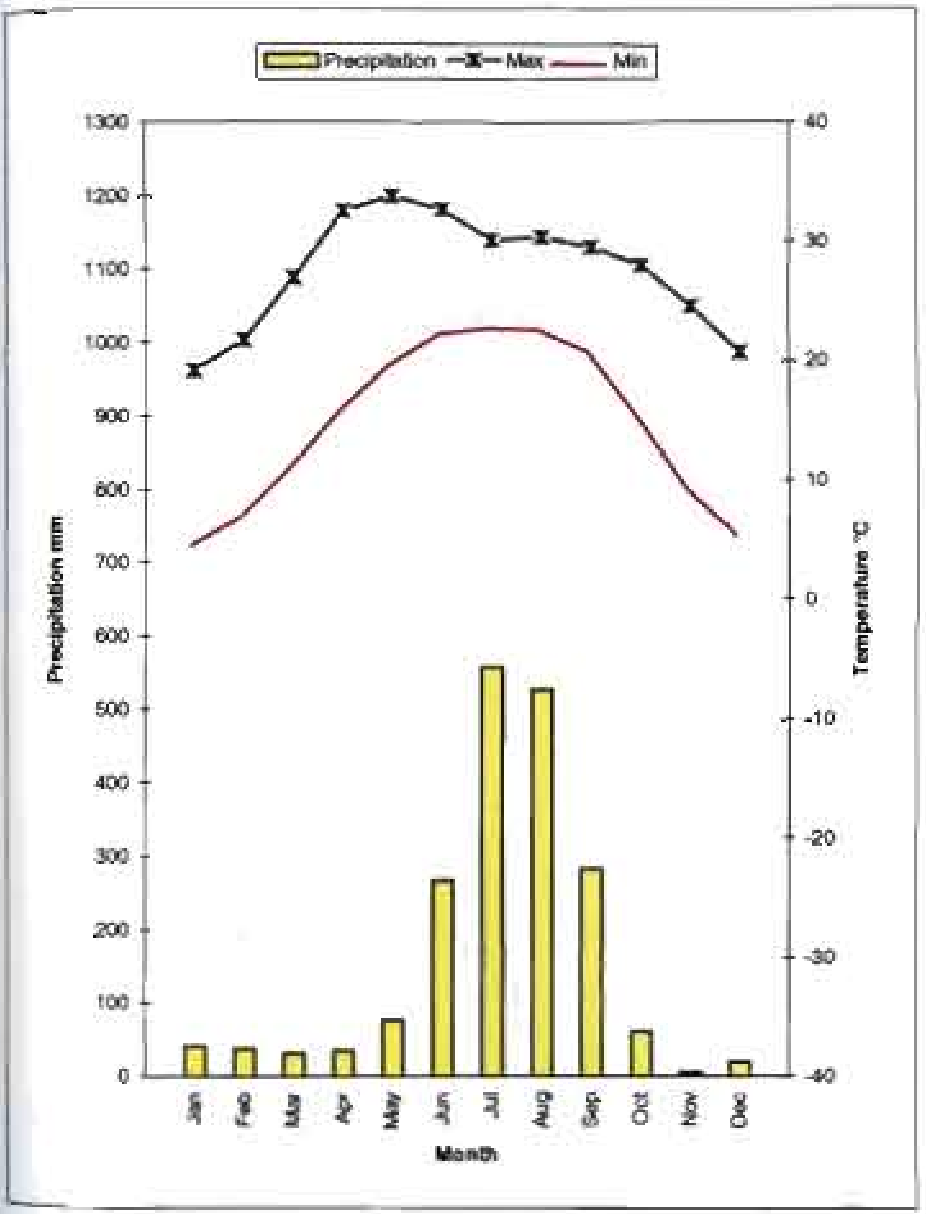
Station : **Jumla**
Index No : 0303
Latitude : 29°17'
Longitude : 82°10'
Elevation : 2300m



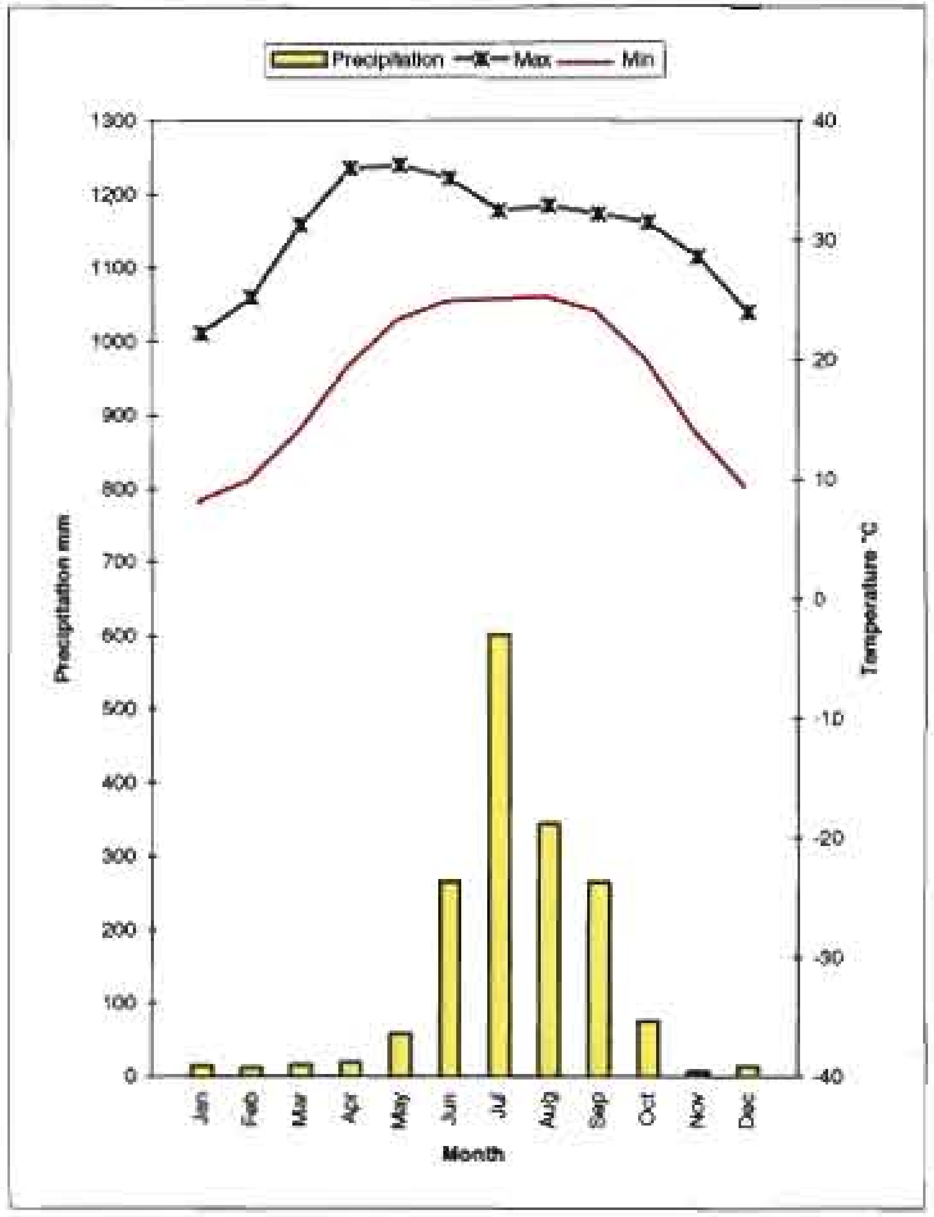
Source: Department of Hydrology & Meteorology, HMG, Nepal

AVERAGE MAXIMUM & MINIMUM TEMPERATURE AND PRECIPITATION

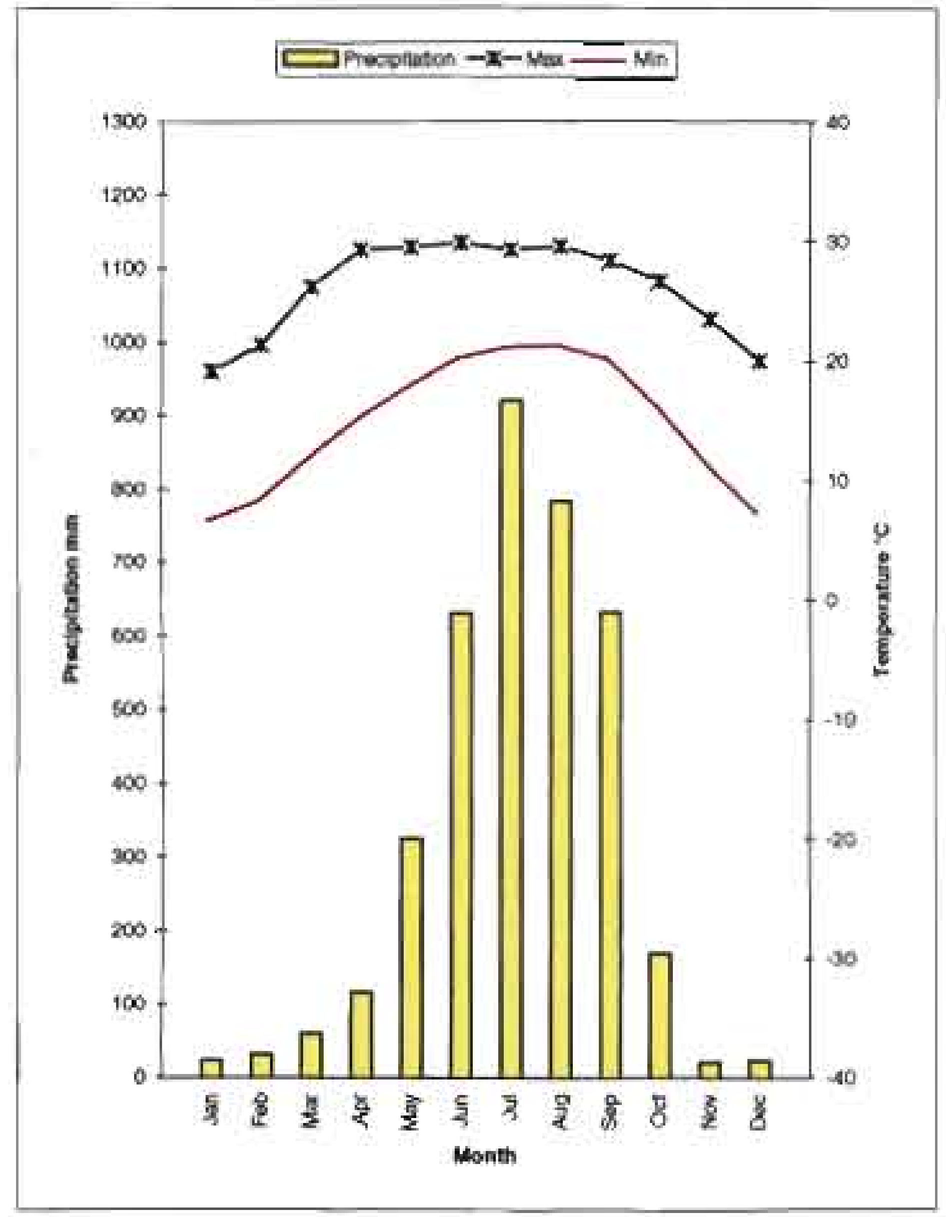
Station : **Surkhet**
Index No : 0406
Latitude : 28°36'
Longitude : 81°37'
Elevation : 720m



Station : **Bhairahawa**
Index No : 0705
Latitude : 27°31'
Longitude : 83°26'
Elevation : 110m



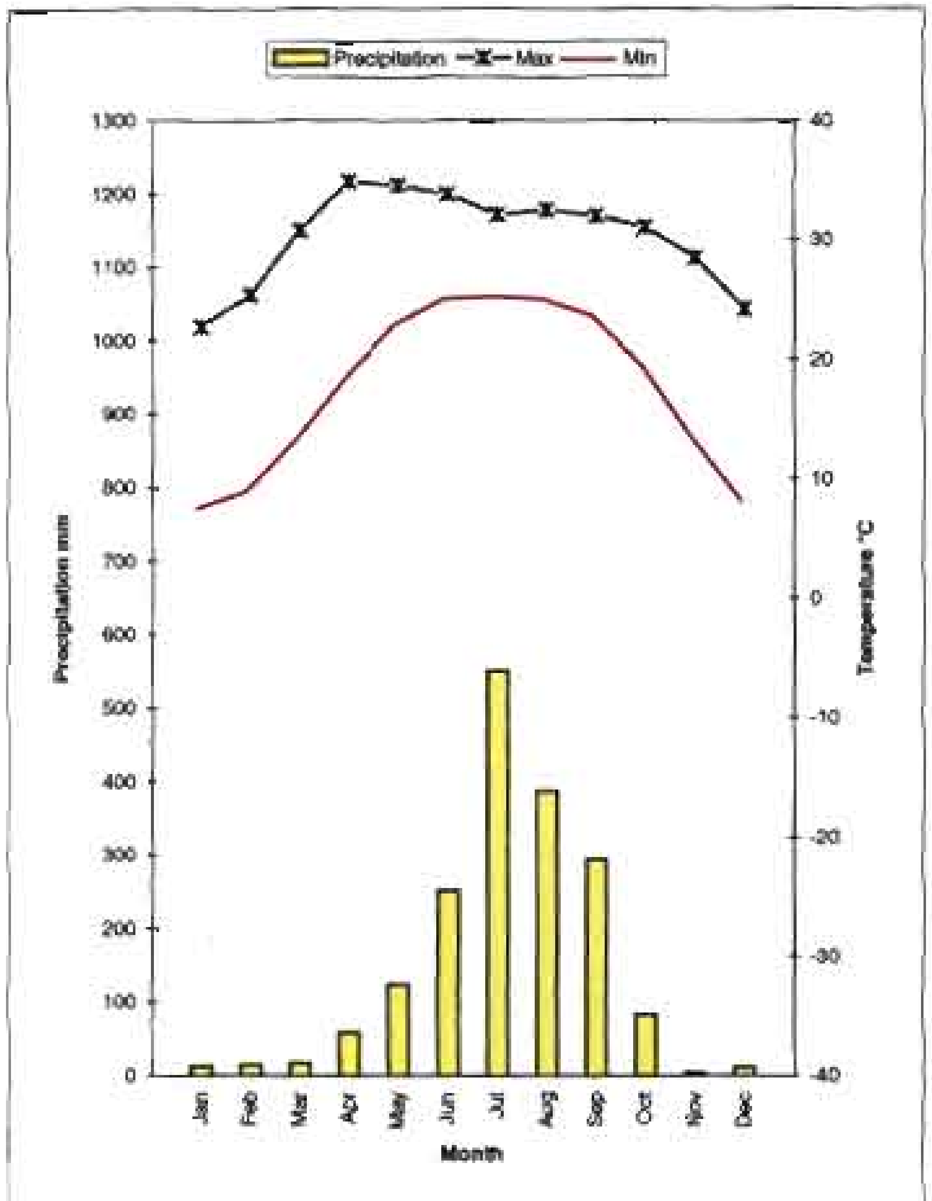
Station : **Pokhara**
Index No : 0804
Latitude : 28°13'
Longitude : 84°00'
Elevation : 827m



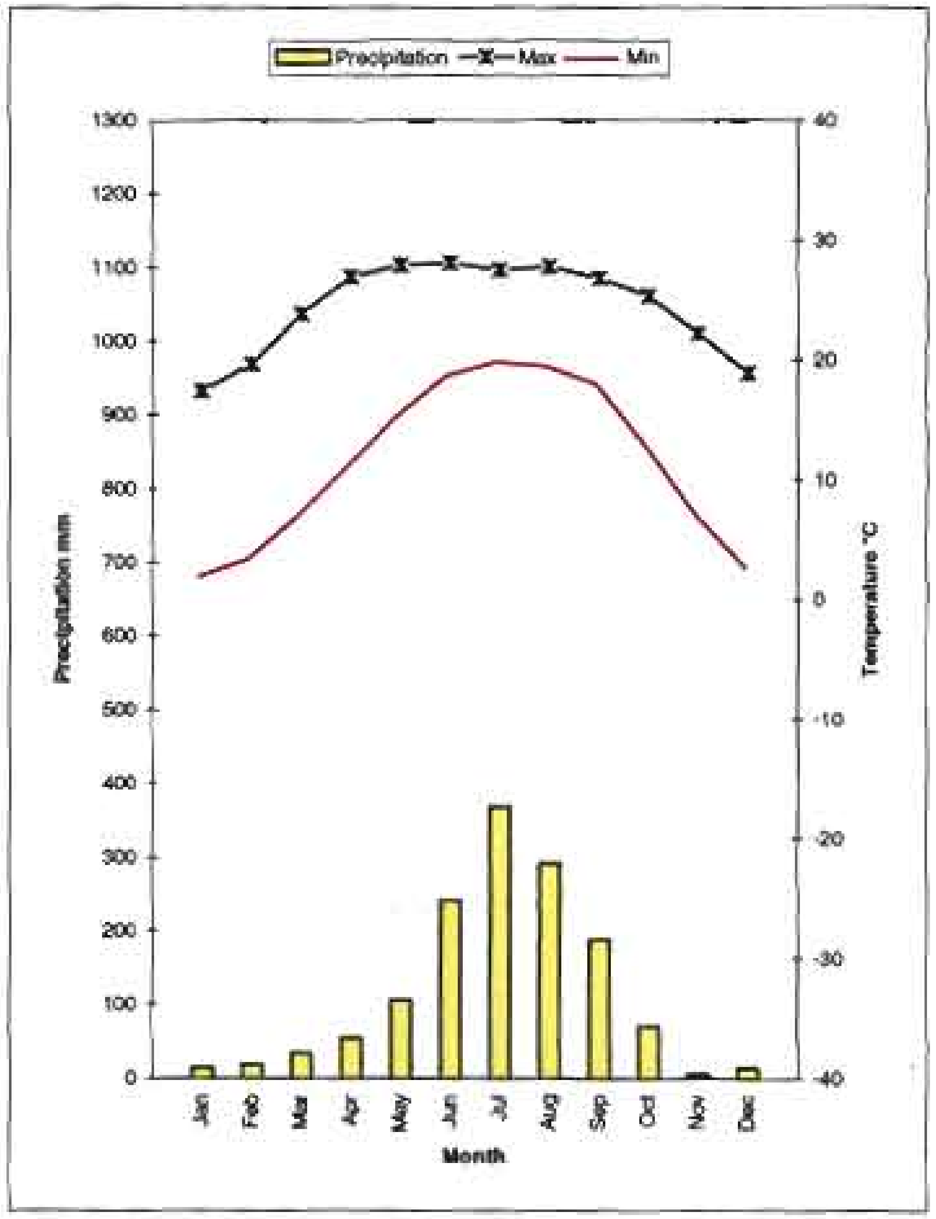
Source: Department of Hydrology & Meteorology, HMG, Nepal

AVERAGE MAXIMUM & MINIMUM TEMPERATURE AND PRECIPITATION

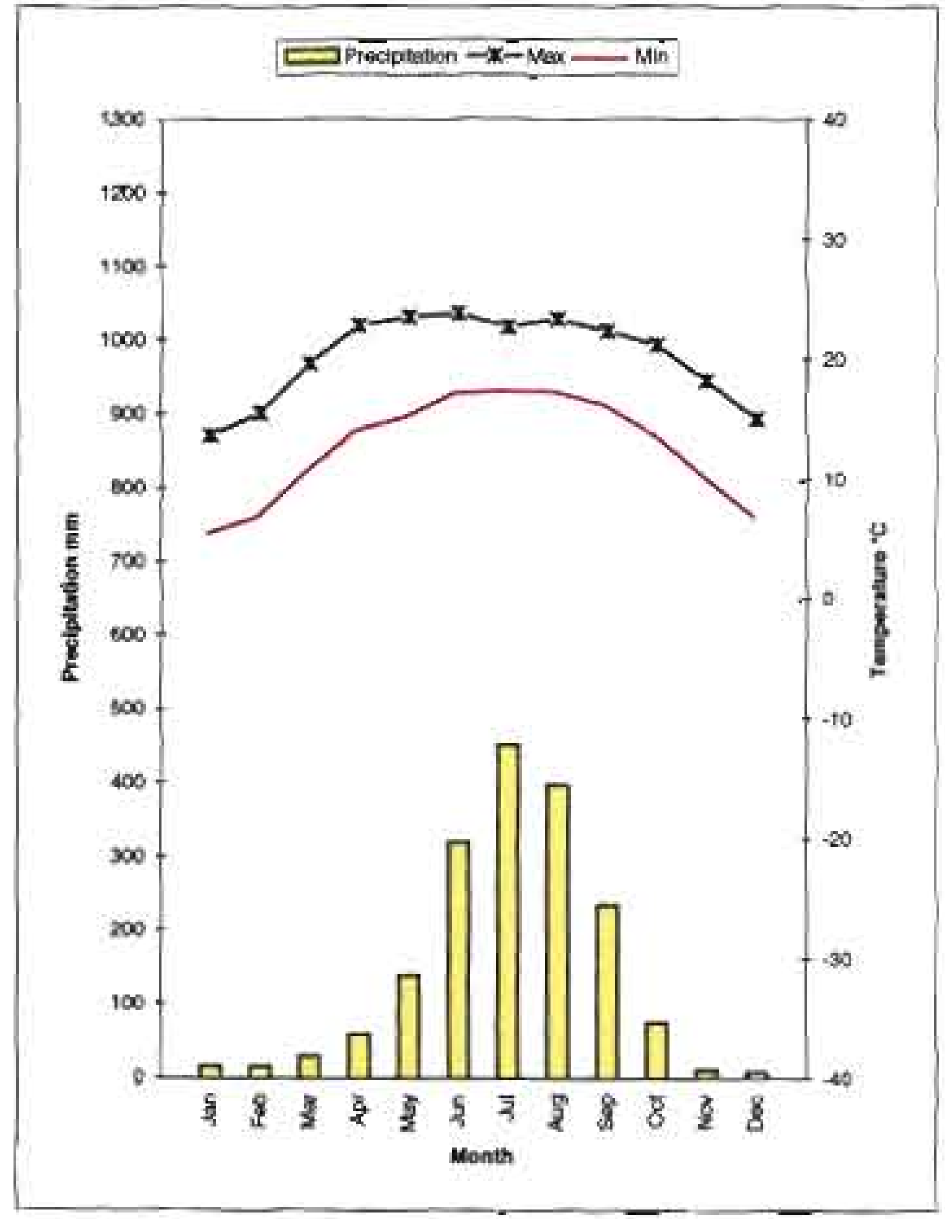
Station : **Simara** Index No : 0909
Latitude : 27°10' Longitude : 84°59' Elevation : 130m



Station : **Kathmandu** Index No : 1030
Latitude : 27°42' Longitude : 85°22' Elevation : 1336m



Station : **Okhaldhunga** Index No : 1206
Latitude : 27°19' Longitude : 86°30' Elevation : 1720m

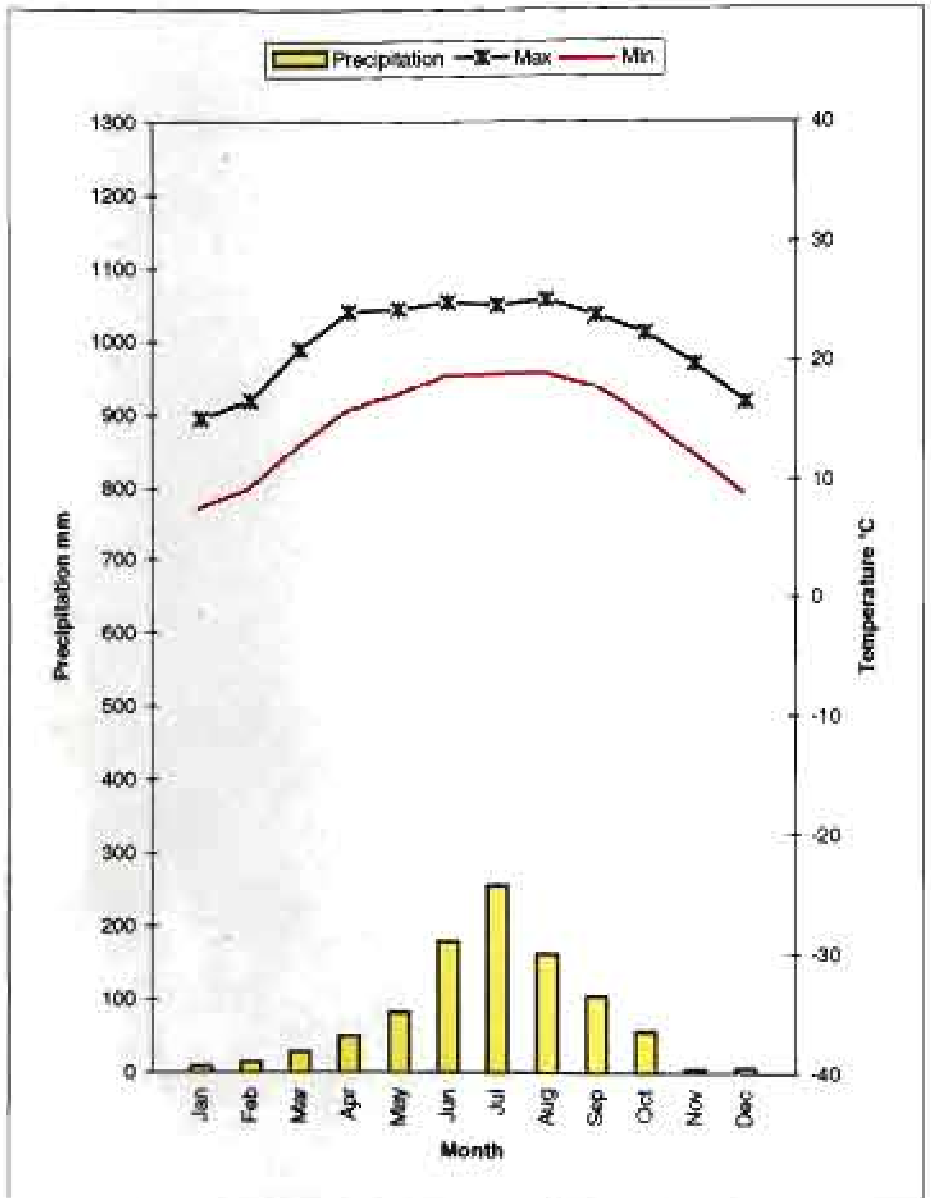


Source: Department of Hydrology & Meteorology, HMG, Nepal

AVERAGE MAXIMUM & MINIMUM TEMPERATURE AND PRECIPITATION

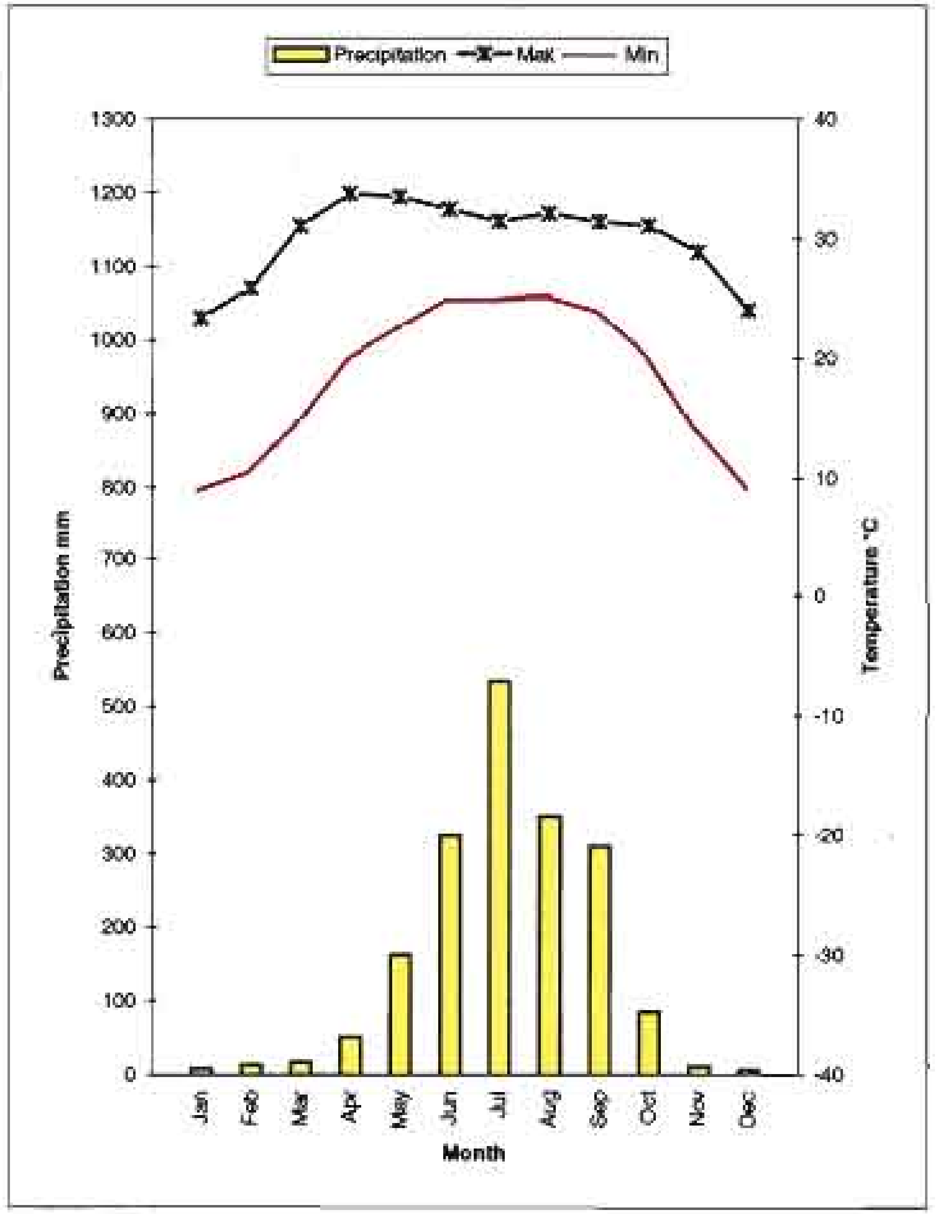
Station : **Dhankuta**
Index No : 1307

Latitude : 26°59'
Longitude : 87°21'
Elevation : 1445m



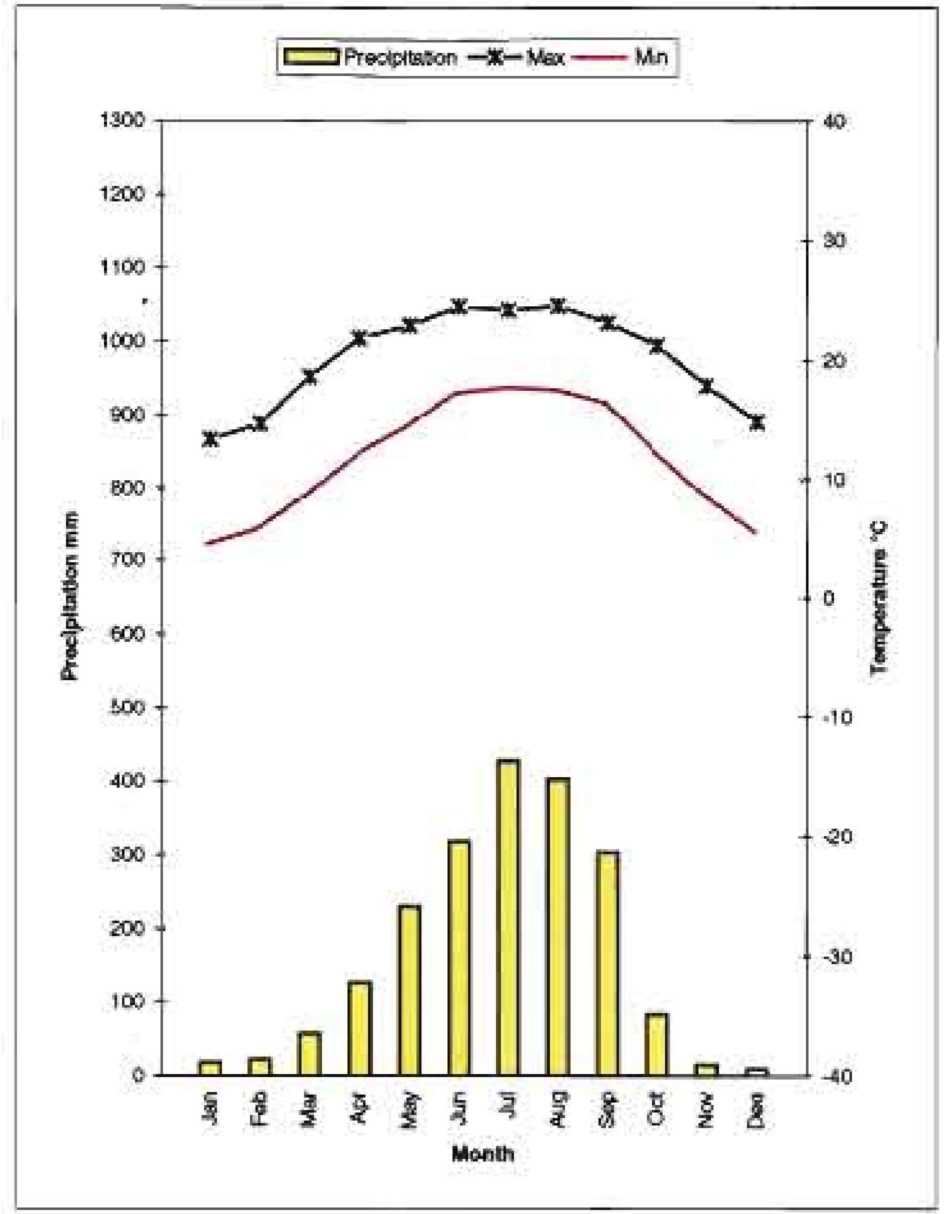
Station : **Biratnagar**
Index No : 1319

Latitude : 26°29'
Longitude : 87°16'
Elevation : 72m



Station : **Taplejung**
Index No : 1405

Latitude : 27°21'
Longitude : 87°40'
Elevation : 1732m



Source: Department of Hydrology & Meteorology, HMG, Nepal

Section 2
Hydrologic Maps/Figures

List of Hydrometric Stations

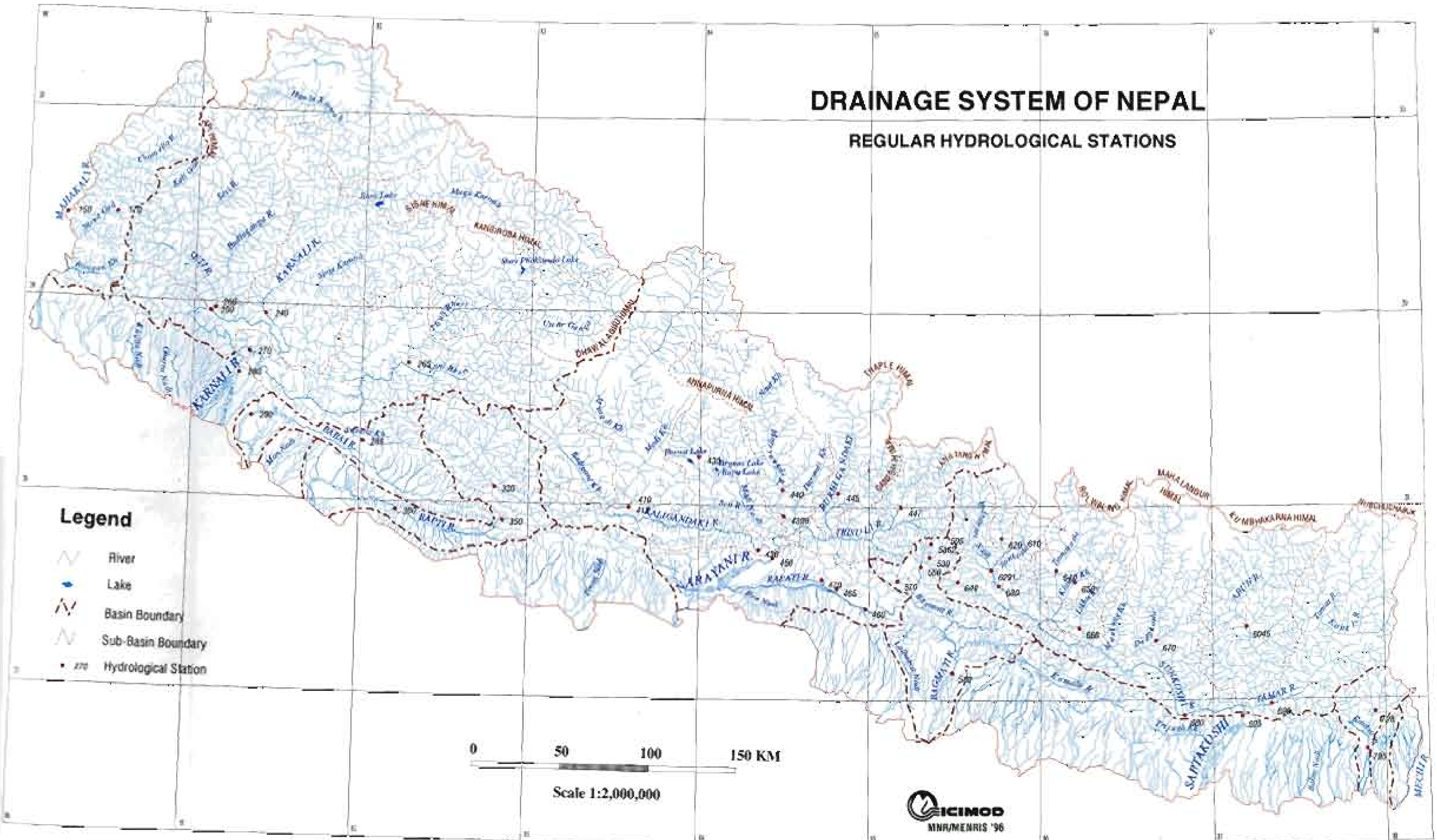
Stn No.	Name of river	Name of site	Latitude in ° ' "	Longitude in ° ' "	Elevation m.	Dr. Area sq. km.	Instru-ments	Start of records	End of records
150	Mahakali	Pancheshwor	29 26 45	80 15 30	430	12100	C,R,S	1/1/62	
170	Surnagad*	Patan near Baitadi	29 27 30	80 33 10	1110	188	C	01/01/66	–/04/88
240	Karnali River	Asara Ghat	28 57 10	81 26 30	629	19260	C,R,S	01/01/61	
250	Karnali River	Benighat	28 57 40	81 07 10	320	21240	C	01/02/63	
260	Seti River	Banga near Belgaon	28 58 40	81 08 40	328	7460	C,R,S	06/02/63	
265	Thulo Bheri	Rimna	28 42 30	82 17 30	-	-	C	18,06/72	
270	Bheri River	Jamu	28 45 20	81 21 00	246	12290	C,R,S	23/01/63	
280	Karnali River	Chisapani	28 38 40	81 17 30	191	42890	C,R,S	01/01/62	
286	Sarada Khola	Daradhunga	28 17 58	82 01 30	-	816	C,R,S	01/01/72	
290	Babai River*	Bargadha	28 25 20	81 22 10	192	3000	C,R	16/07/66	13/04/89
330	Mari Khola	Nayagaon	28 04 20	82 48 00	536	1980	C	01/01/64	
350	Rapti River	Bagasoti Gaon	27 54 00	82 51 00	381	3380	C,R,S	08/05/75	
360	Rapti River	Jalkundi	27 56 50	82 13 30	218	5150	C,R,S	08/04/64	
410	Kali Gandaki	Seti Beni	28 00 30	83 36 10	546	6630	C,R,S	21/02/64	
415	Andhi Khola	Dumrichaur Andhimuhan	27 58 20	83 35 20	543	476	C	06/04/64	
420	Kali Gandaki	Kotagaon Shringe	27 45 00	84 20 50	198	11400	C,R	15/04/64	
430	Seti River*	Phoolbari	28 14 00	84 00 00	830	582	C,R,S	01/01/64	27/08/92
439.8	Marsyangdi*	Gopling Ghat	27 55 35	84 29 42	320	3850	C,R,S	01/06/73	24/06/88
440	Chepe Khola	Garam Besi	28 03 41	84 29 23	442	308	C,R	20/11/63	
445	Budhi Gandaki	Arughat	28 02 37	84 48 59	485	4270	C,R,S	28/11/63	
446.8	Phalankhu Khola	Betrawati	27 58 25	85 11 15	630	162		24/04/69	
447	Trishuli	Betrawati	27 58 08	85 11 00	600	4110	C,R,S	01/04/67	
450	Narayani	Narayan Ghat	27 42 30	84 25 50	180	31100	C,R,S	10/02/62	
460	Rapti River	Rajaiya	27 26 30	84 58 15	332	579	C,R	01/01/63	
465	Manahari Khola	Manahari	27 33 00	84 48 10	305	427	C,R	13/06/63	

Stn No.	Name of river	Name of site	Latitude in ° ' "	Longitude in ° ' "	Elevation m.	Dr. Area sq. km.	Instru-ments	Start of records	End of records
470	Lothar Khola	Lothar	27 35 40	84 43 00	336	169	C,S	30/11/63	
505	Bagmati River	Sundarijal	27 46 30	85 25 40	1600	17	C,R	07/12/62	
530	Bagmati River	Gauri Ghat	27 42 30	85 21 00	1300	68		15/11/64	
536.2	Bishnumati Khola*	Budhanilkantha	27 46 49	85 21 32	1454	4		27/05/68	27/08/92
550	Bagmati River*	Chovar	27 39 40	85 17 50	1280	585	C,R,S	01/07/62	1980
570	Kulekhani Khola*	Kulekhani	27 35 10	85 09 30	1480	126	C,R,S	01/12/62	15/11/77
589	Bagmati River	Pandhera Dobhan	27 06 20	85 28 30	180	2700	C,R,S	28/01/79	
604.5	Arun River	Turkeghat	27 20 00	87 11 30	414	28200	C,R	23/05/75	
610	Bhote Koshi	Barhabise	27 47 10	85 53 20	840	2410		17/02/65	
620	Balephi Khola	Jalbire	27 48 20	85 46 10	793	629	C	25/12/63	
629.1	Indrawati River	Dolal Ghat	27 38 20	85 42 30	-	1225	C	1/9/72	
630	Sun Koshi	Pachuwar Ghat	27 33 30	85 45 10	589	4920	C,R	26/03/64	
640	Rosi Khola	Panauti	27 34 50	85 30 50	1480	87		17/10/63	
647	Tama Koshi	Busti	27 38 05	86 05 12	849	2753	C,R	14/01/70	
650	Khimti Khola	Rasnalu village	27 34 30	86 11 50	1520	313	C	06/04/64	
660	Likhu Khola	Sangutar	27 20 10	86 13 10	543	823	C	24/03/64	
670	Dudh Koshi	Rabuwa Bazar	27 16 00	86 39 50	460	4100	C,R	10/03/64	
680	Sun Koshi	Kampughat	26 52 30	86 49 20	200	17600	C,R,S	28/06/65	
690	Tamar river	Mulghat	26 55 50	87 19 45	276	5640	C,R,S	11/03/65	
695	Sapta Koshi	Chatara-Kothu	26 52 00	87 09 30	140	54100	C,R,S	01/01/77	
728	Mai Khola	Rajdwali	26 52 45	87 55 45	-	377	C,R,S	01/01/83	
795	Kankai Mai River	Mainachuli	26 41 12	87 52 44	125	1148	C,R,S	01/05/71	

Total No. of Stations: 47
* Stations Regularly Operating in the past

R = Water Level Recorder (total no.: 32)
S = Sediment Sampler (total no.: 23)
C = Cableway (total no.: 42)

All stations have a staff gauge
Data Source: DHM, Ministry of Water Resources, HMG/Nepal


DRAINAGE SYSTEM OF NEPAL
REGULAR HYDROLOGICAL STATIONS
Legend
River
Lake
Basin Boundary
Sub-Basin Boundary
Hydrological Station
0 50 100 150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
KARNALI R.
BABAI R.
RAPTI R.
KALIGANDAKI R.
NARAYANI R.
TRISULI R.
BUDHI GANDAKI
RAPATI R.
BAGMATI R.
SAPTAKOSHI
SUNKOSHI
ARUN R.
TAMAR R.
MECHI R.
MAHAKALI R.
SETI R.
DHAWALAGIRI HIMAL
ANNAPURNA HIMAL
KANJIROBA HIMAL
MAHALANGUR HIMAL
KUMBHAKARNA HIMAL
Data Source: DHM, Ministry of Water Resources, HMG/NEPAL

MAP-1

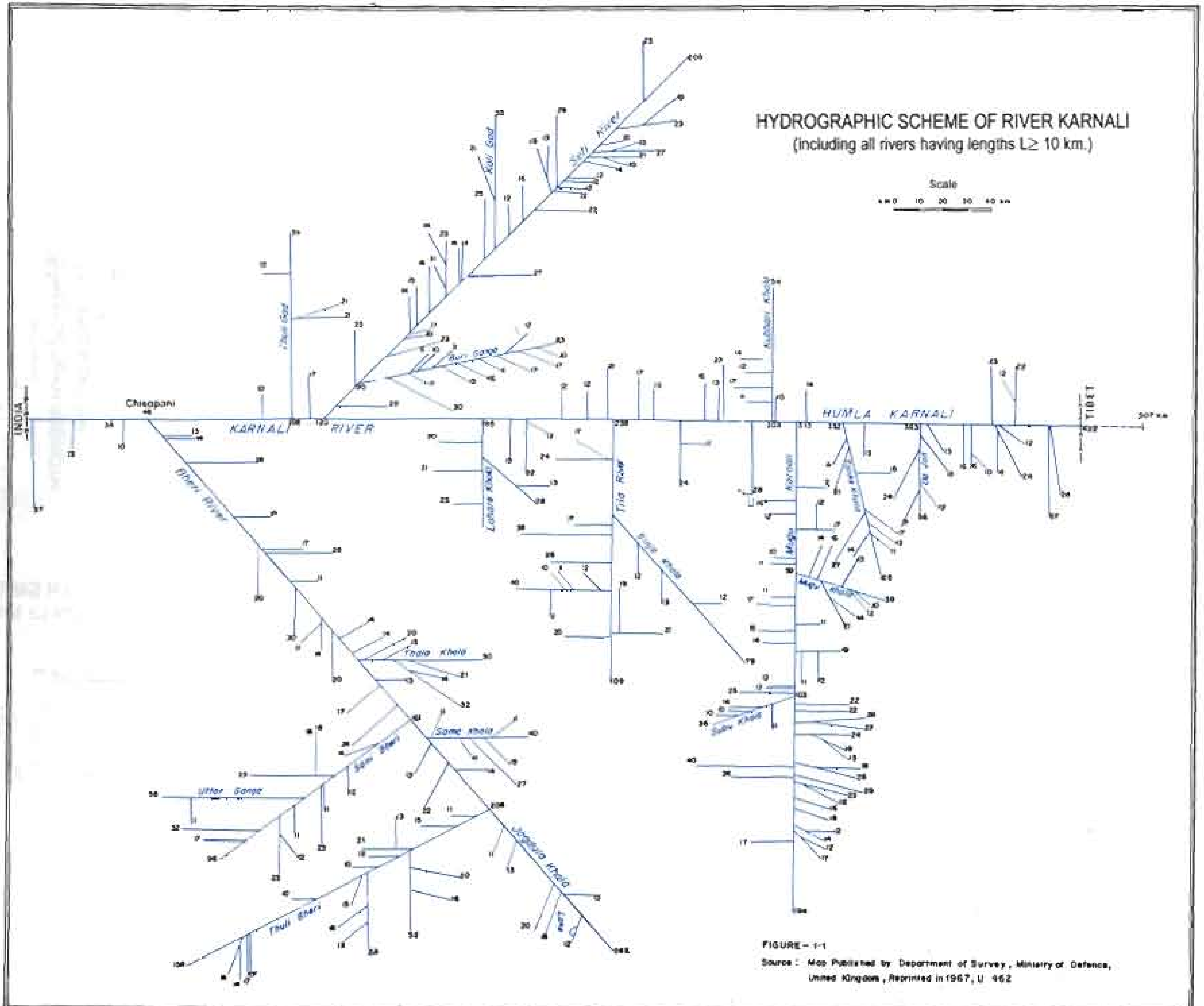
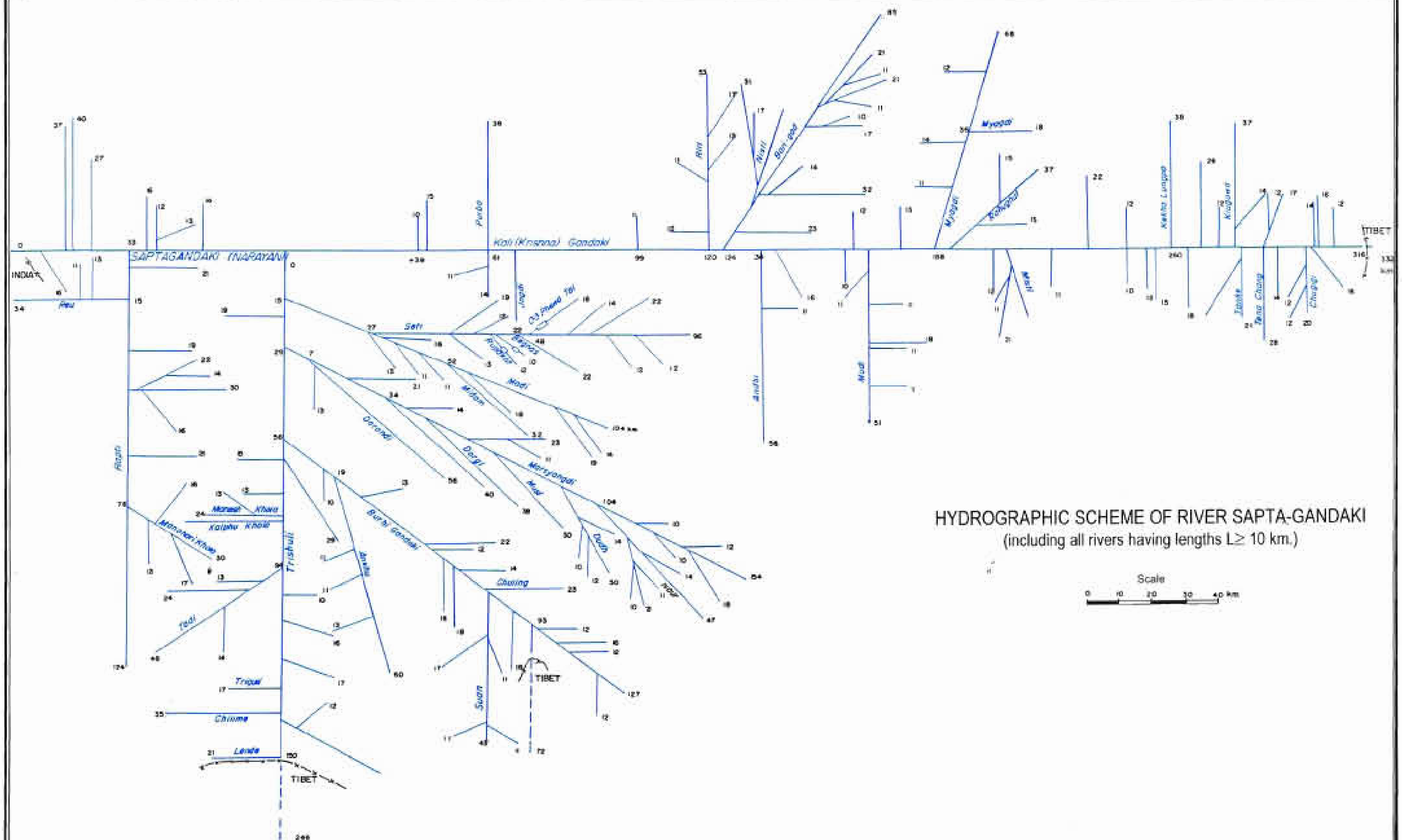


FIGURE – 1-1

Source : Map Published by Department of Survey, Ministry of Defence, United Kingdom, Reprinted in 1967, U 462



HYDROGRAPHIC SCHEME OF RIVER SAPTA-GANDAKI
(including all rivers having lengths L≥ 10 km.)

FIGURE – 1·2

Source : Map Published by Department of Survey, Ministry of Defence, United Kingdom, Reprinted in 1967, U 462.

HYDROGRAPHIC SCHEME OF RIVER SAPTA-KOSHI

(including all rivers having lengths L≥ 10 km.)

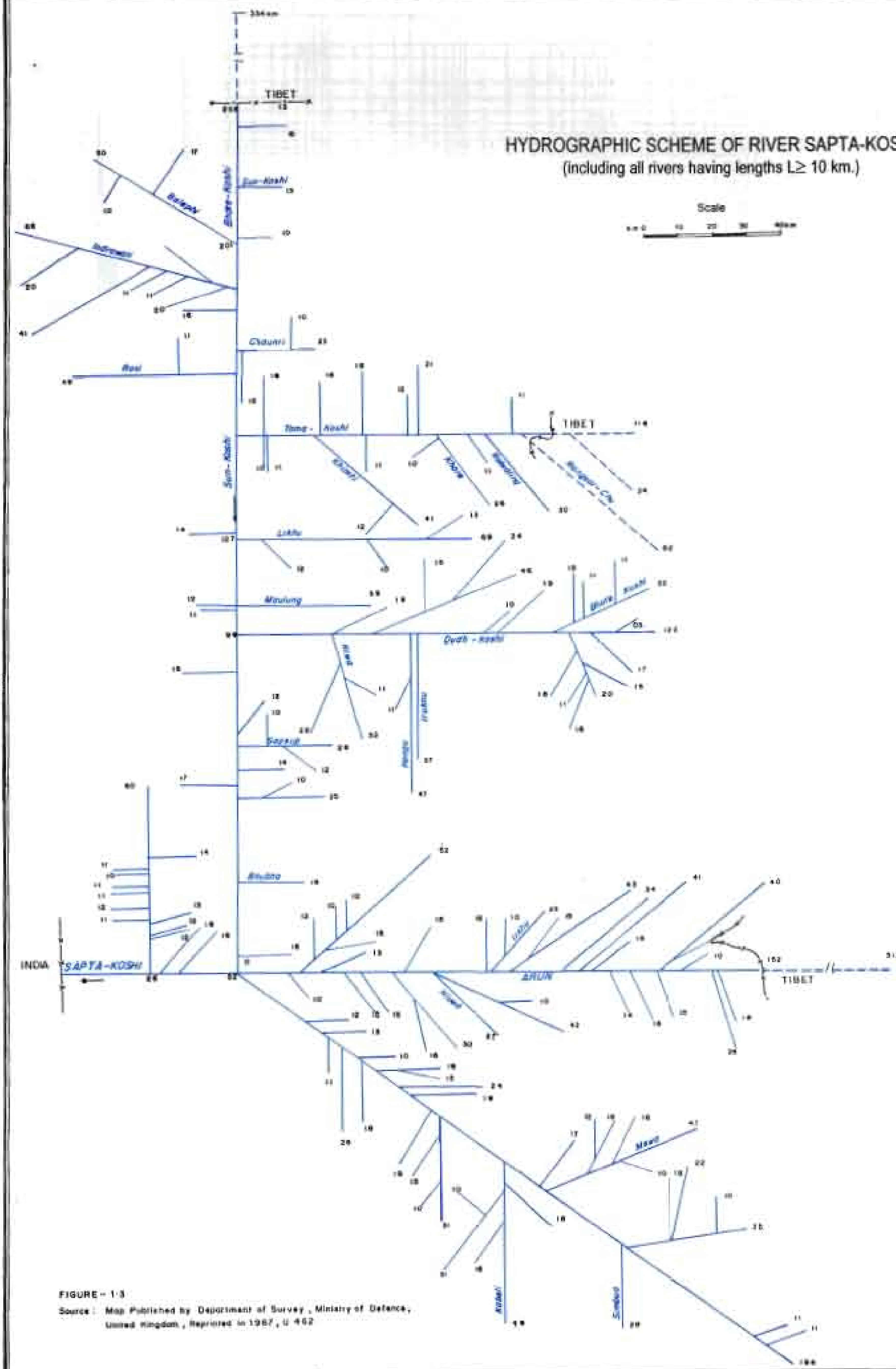


FIGURE - 1·3

Source : Map Published by Department of Survey, Ministry of Defence, United Kingdom, Reprinted in 1967, U 462

WATER AVAILABILITY FOR MAJOR RIVERS

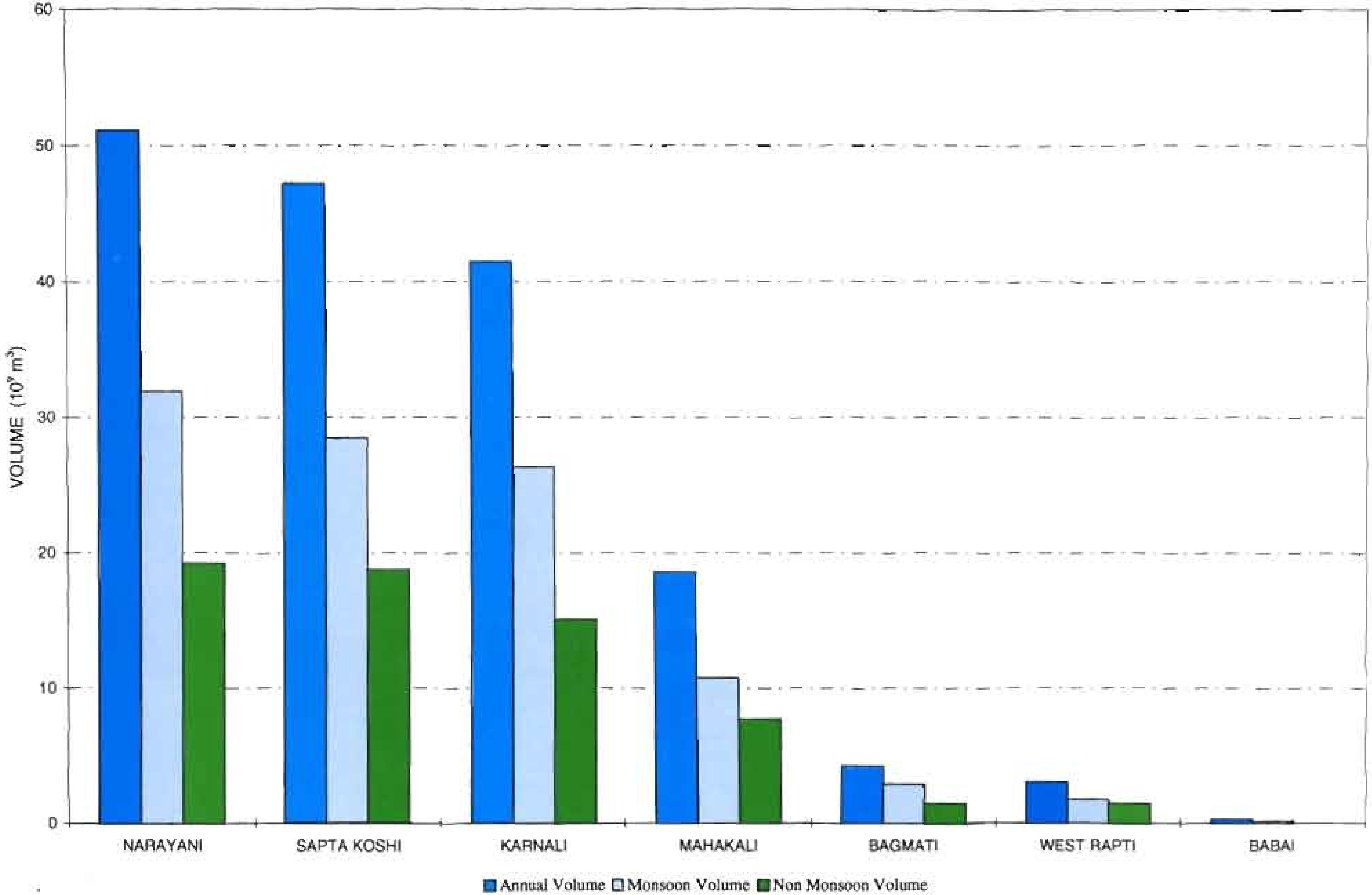


Figure -2

Source: Department of Hydrology and Meteorology, Ministry of Water Resources, HMG/Nepal.

COMPARISON OF FLOODS IN NEPAL AND SOME REGIONS OF THE WORLD

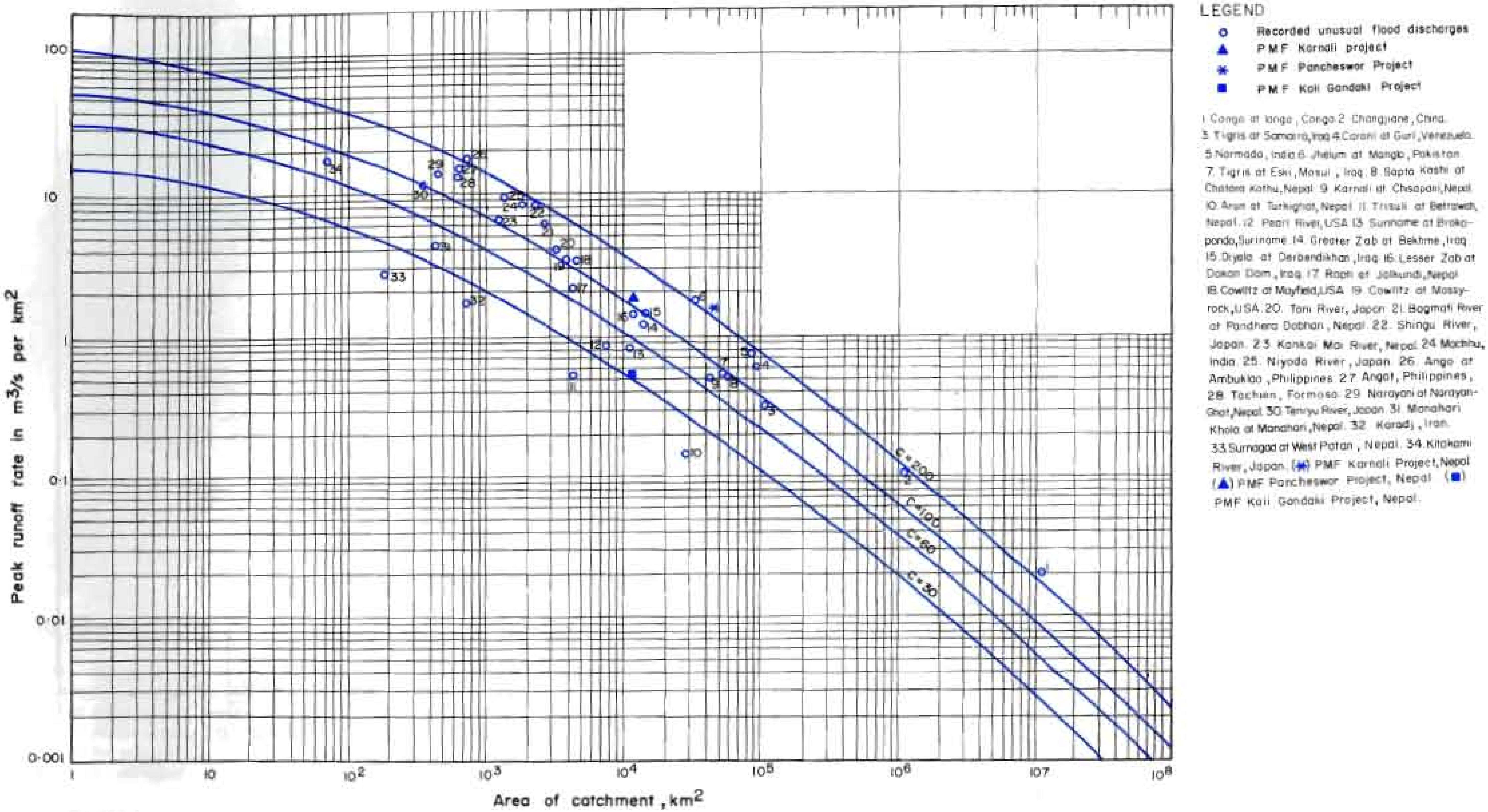


FIGURE-3

Sources: -Raudkivi, A.J., Hydrology, Pergamon Press, 1977, PP 288.

-DHM, Ministry of Water Resources, HMG/Nepal.

-Annual Disaster Review, 1993, Water Induced Disaster Prevention Technical Centre, June 1994

-Mutreja, K.N., Applied Hydrology, Tata Mc Graw Hill, New Delhi, 1986, PP 746.

-Ministry of Water Resources, HMG/Nepal, Pancheswar Multipurpose Project, 1985; Karnali (Chisapani) Multipurpose Project, 1989 Kaligandaki 'A' Hydroelectric Project 1990.

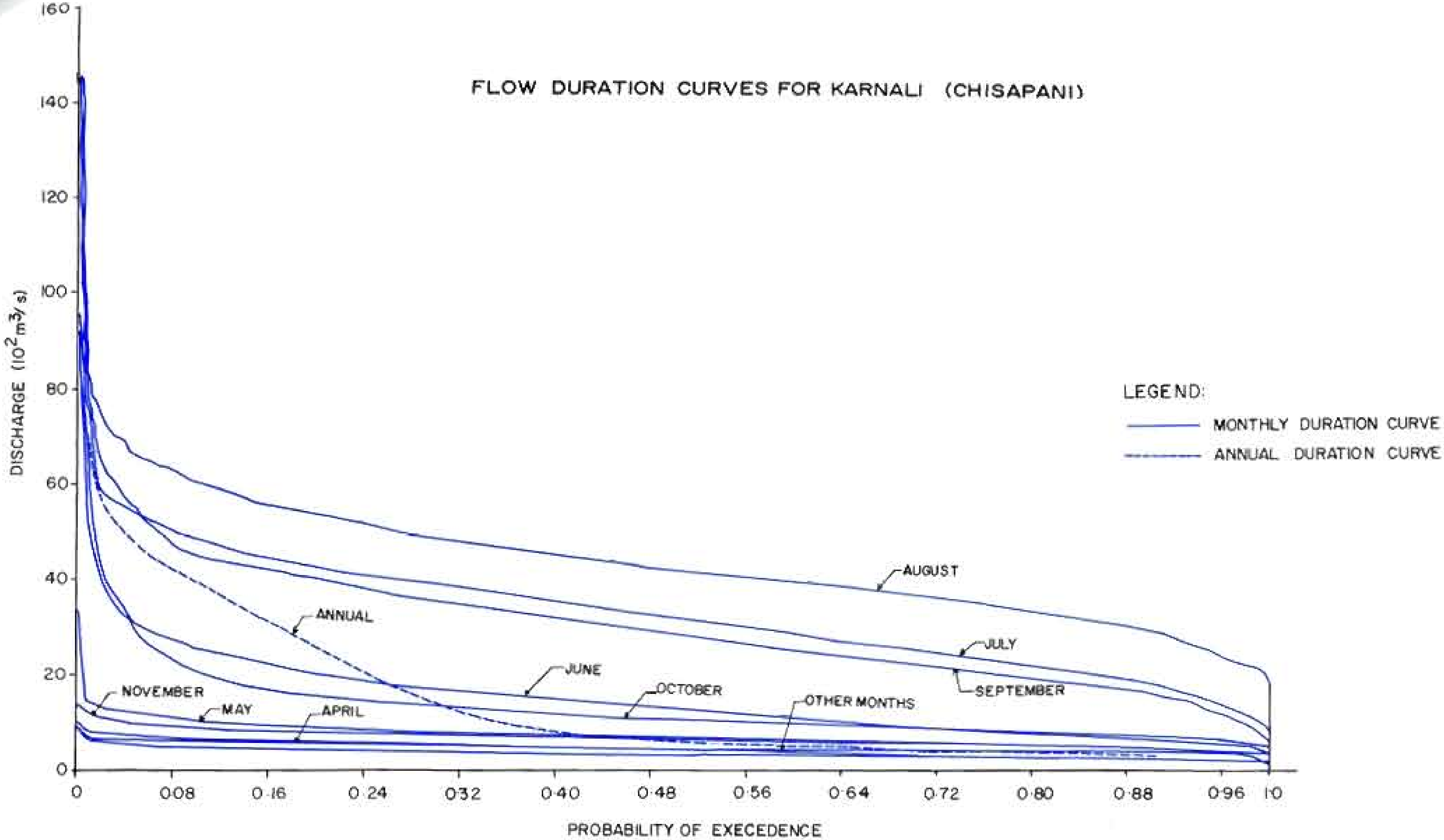
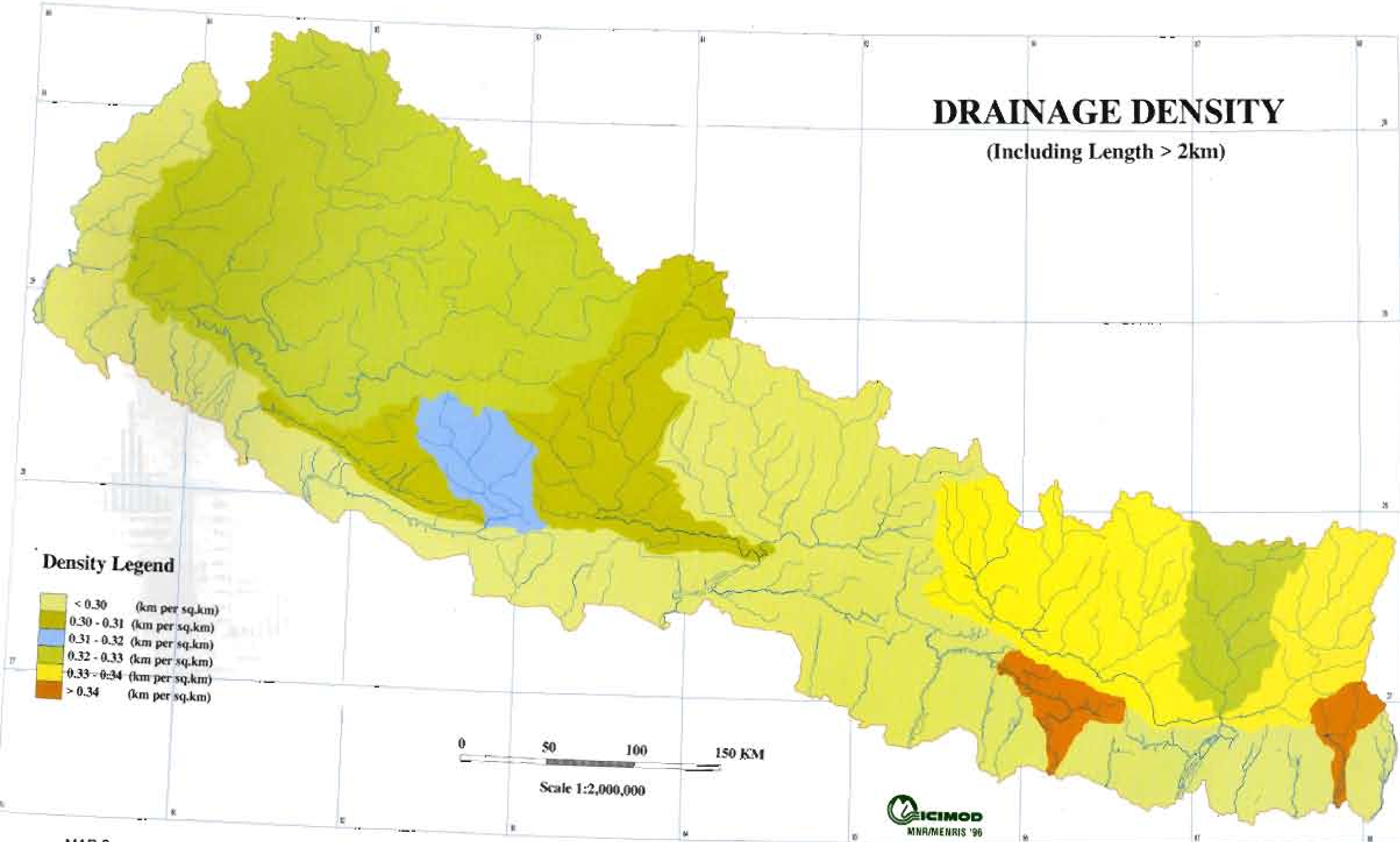


FIGURE-4

Source: Ministry of Water Resources, HMG/Nepal, Karnali (Chisapani) Multipurpose Project Report, Dec. 1989.


DRAINAGE DENSITY
(Including Length > 2km)
Density Legend
< 0.30 (km per sq.km)
0.30 - 0.31 (km per sq.km)
0.31 - 0.32 (km per sq.km)
0.32 - 0.33 (km per sq.km)
0.33 - 0.34 (km per sq.km)
> 0.34 (km per sq.km)
0
50
100
150 KM
Scale 1:2,000,000
ICIMOD
MNR/MENRIS '96
Data Source: Department of Hydrology & Meteorology, HMG, Nepal
MAP-2

MONTHLY AVERAGE FLOW OF MAJOR RIVERS

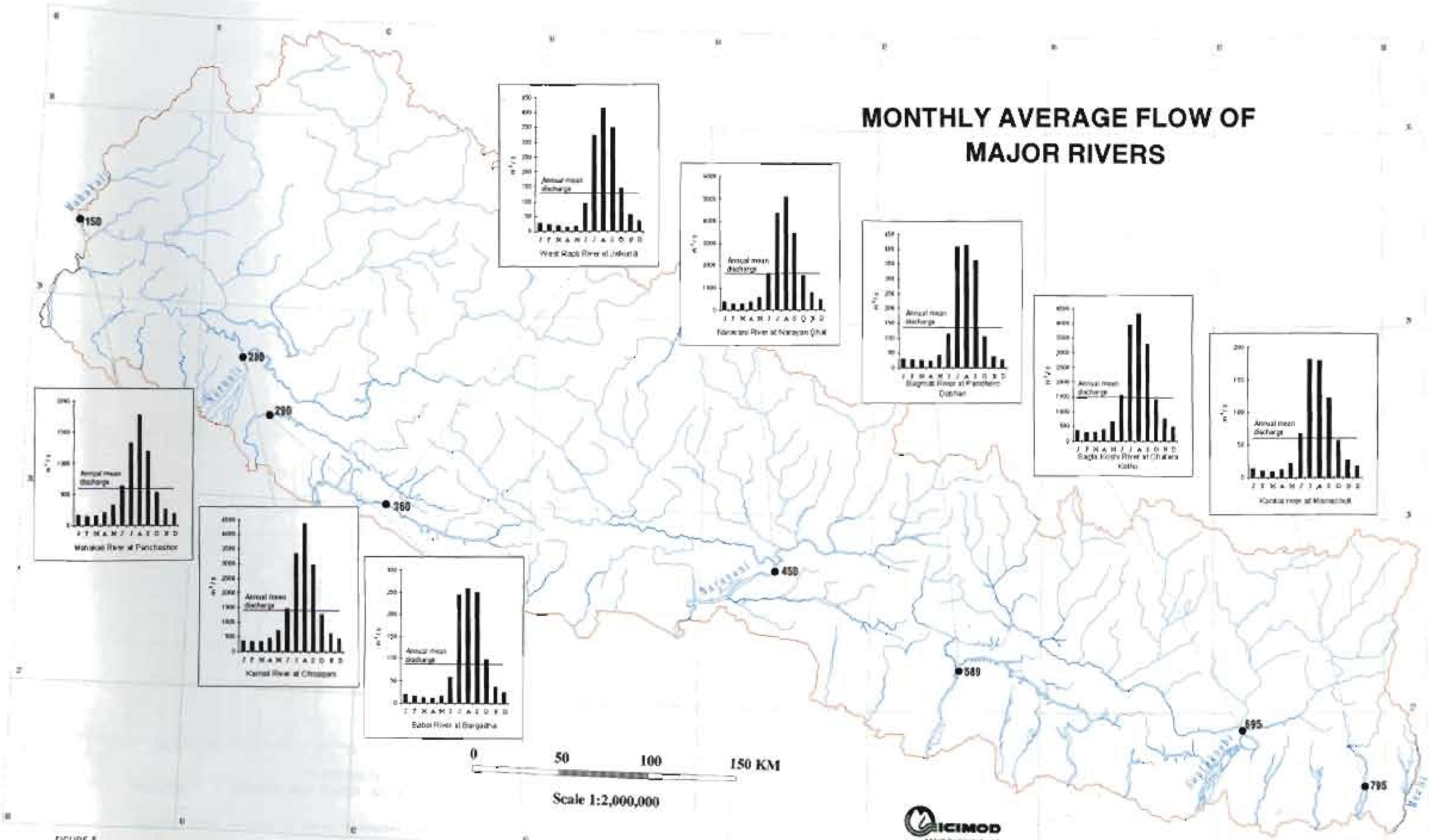


FIGURE-5

Data Source: DHM, Ministry of Water Resources, HMG/NEPAL

ANNUAL MAXIMUM DAILY FLOW OF KANKAI MAI RIVER

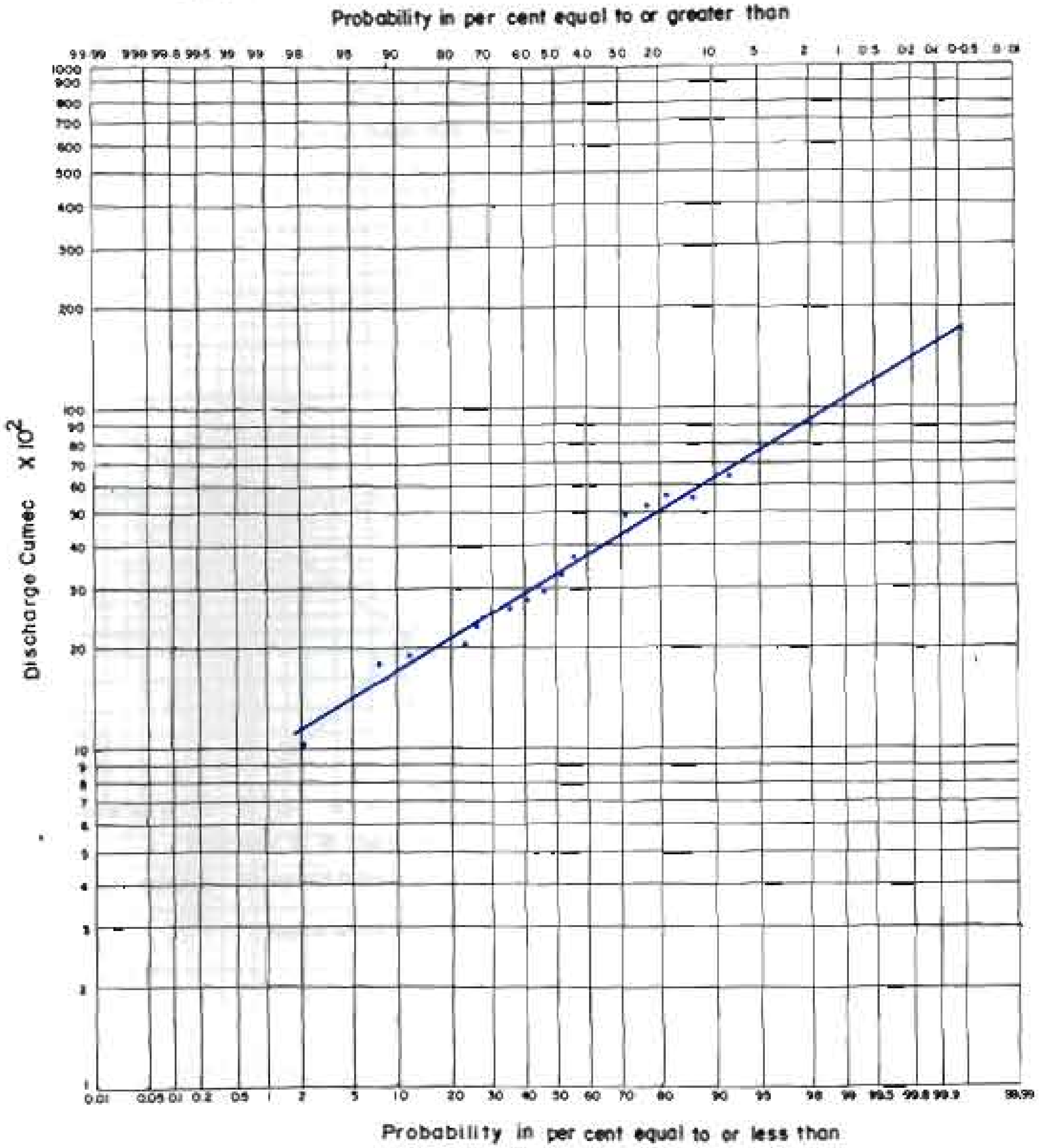


FIGURE - 6.1 KANKAI MAI RIVER AT MAINACHULI (Station No. 795)

Source: DHM, Ministry of Water Resources, HMG/Nepal

ANNUAL MAXIMUM DAILY FLOW OF ARUN RIVER

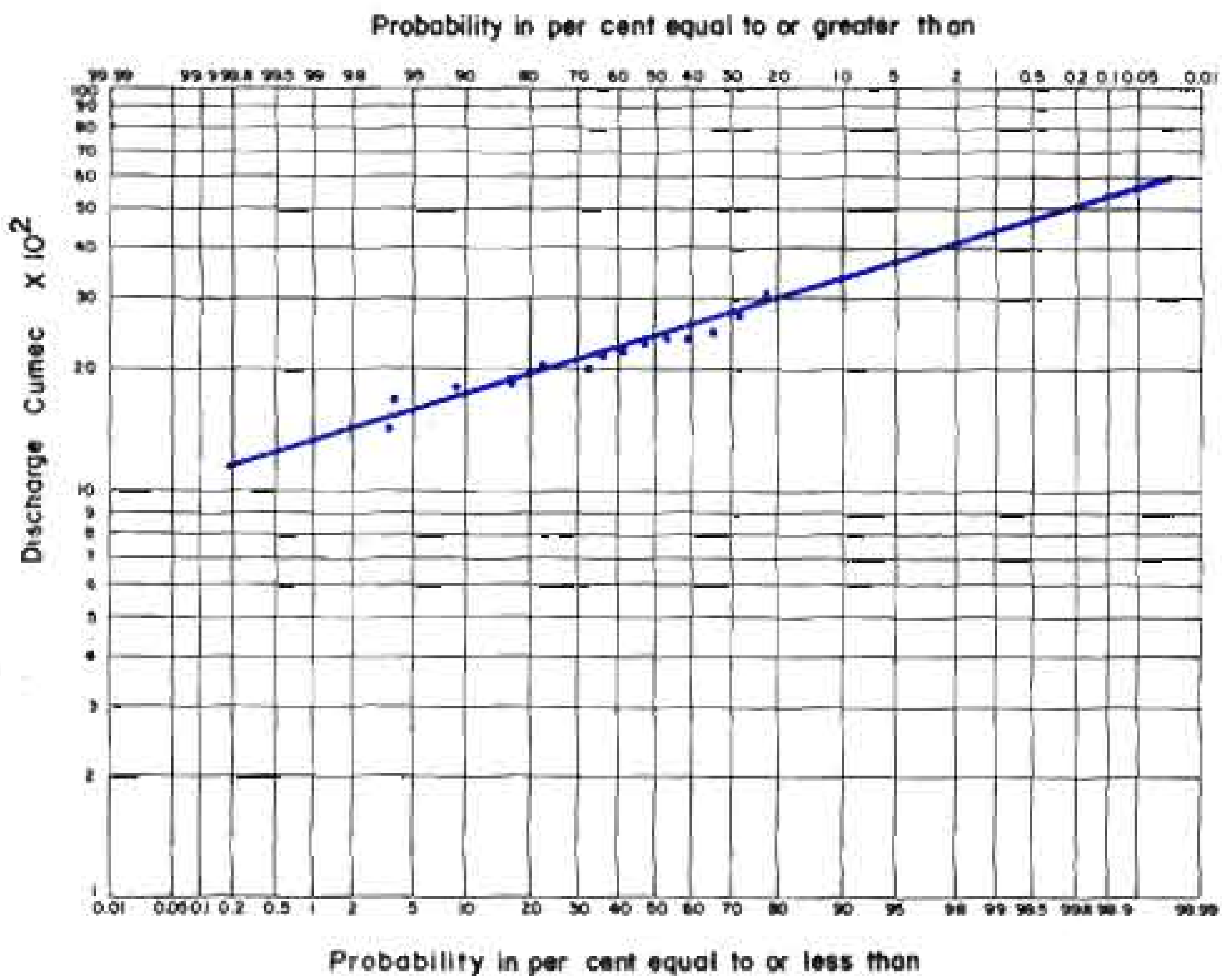


FIGURE - 6.2 ARUN RIVER AT TURKEGHAT (Station No. 604.5)

Source: DHM, Ministry of Water Resources, HMG/Nepal

ANNUAL MAXIMUM DAILY FLOW OF SAPTA KOSHI RIVER

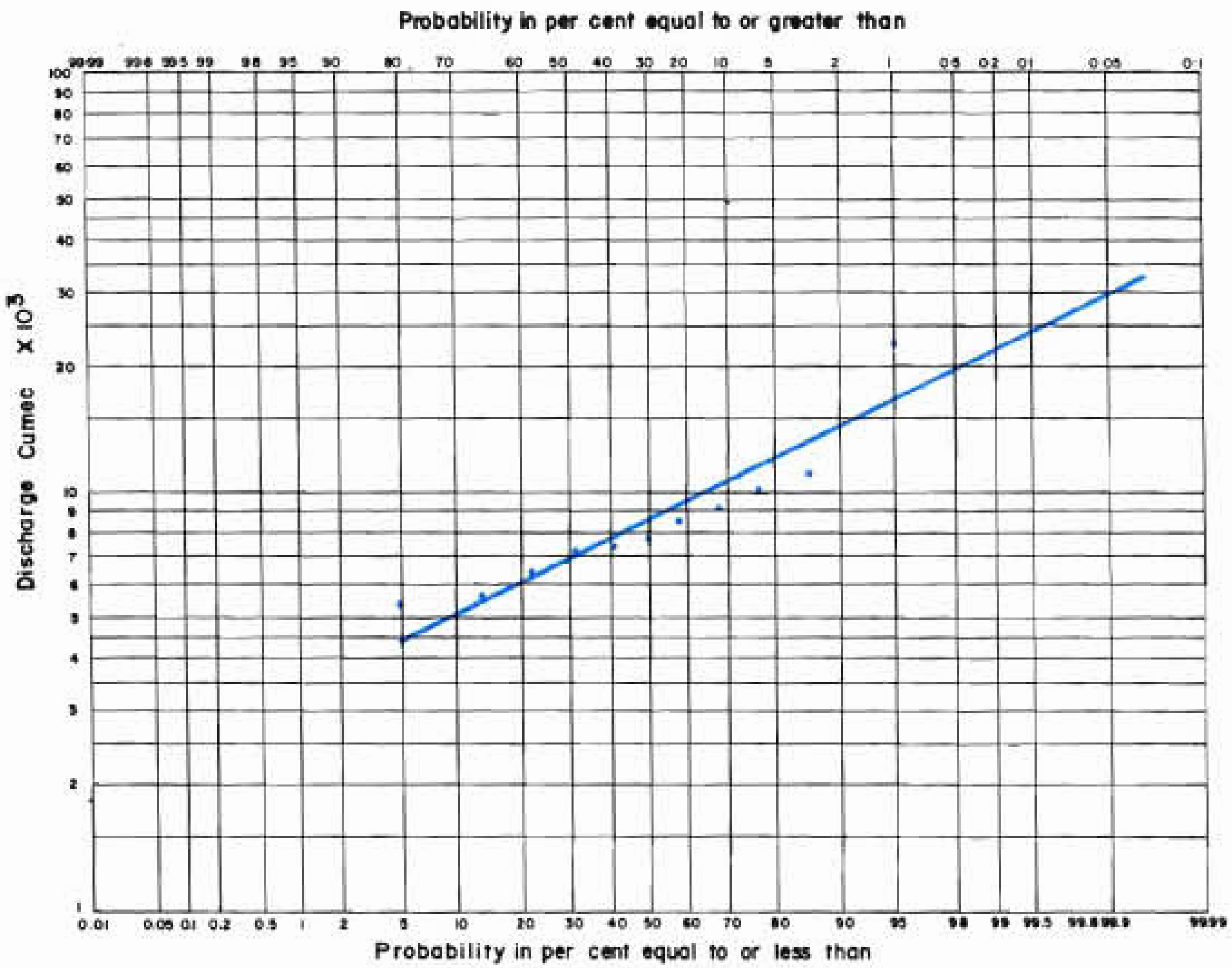


FIGURE 6.3 SAPTA KOSHI AT CHATARA – KOTHU (Station No. 695)

Source: DHM, Ministry of Water Resources, HMG/Nepal

ANNUAL MAXIMUM DAILY FLOW OF BAGMATI RIVER

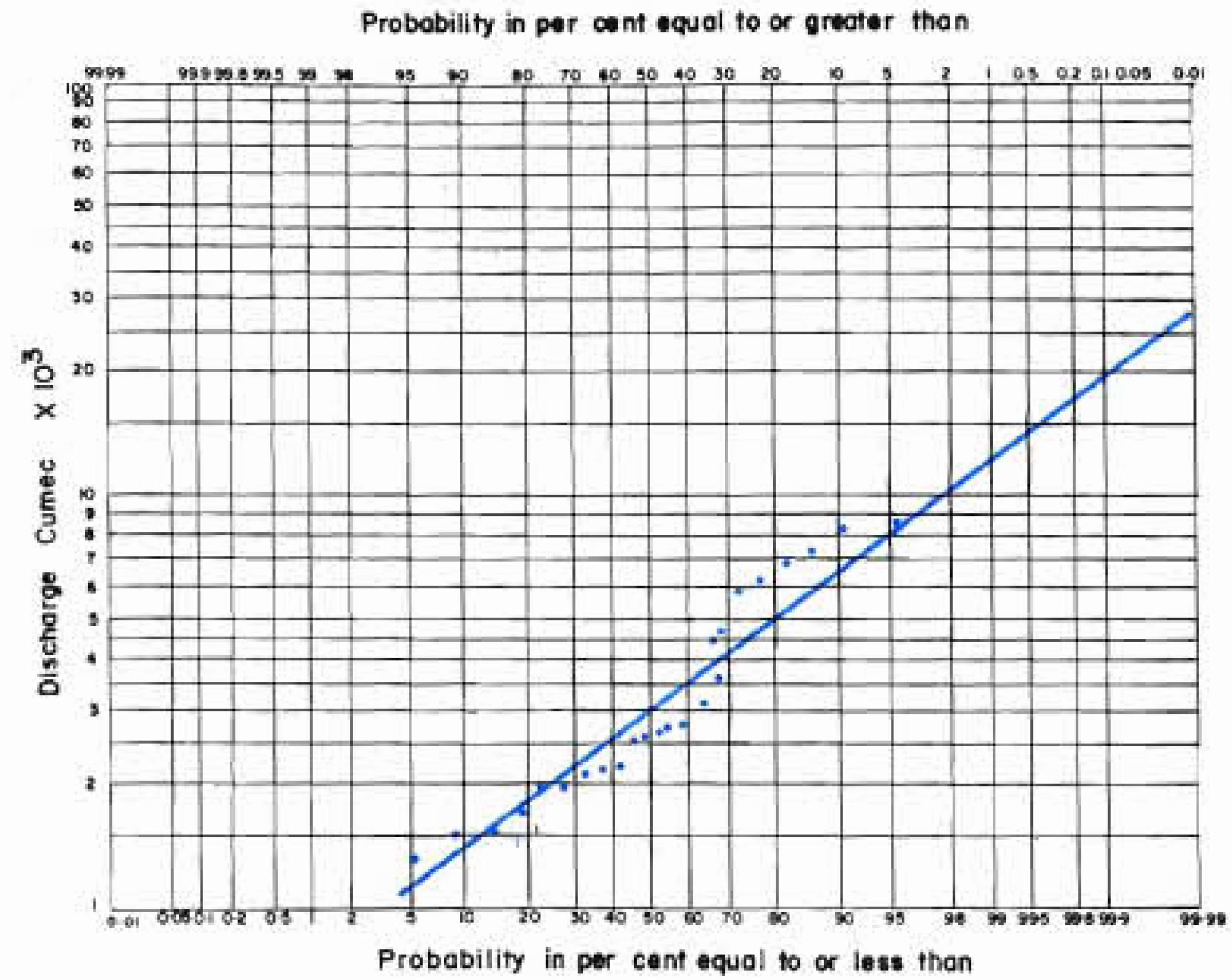


FIGURE - 6.4 BAGMATI RIVER AT PANDHERADOBHAN (Station No. 589)

Source: DHM, Ministry of Water Resources, HMG/Nepal

ANNUAL MAXIMUM DAILY FLOW OF MANAHARI KHOLA

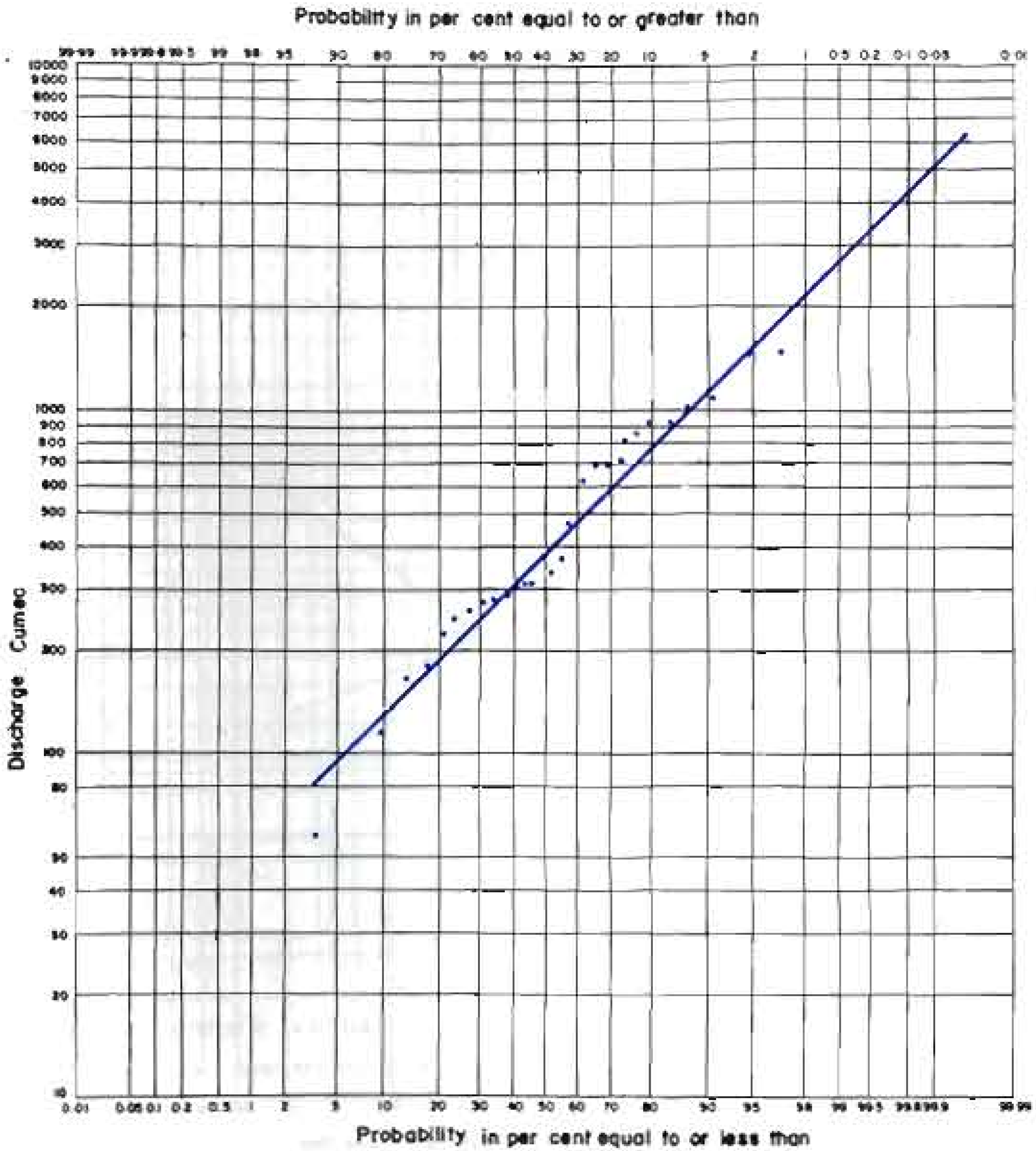


FIGURE - 6.5 MANAHARI KHOLA AT MANAHARI (Station No 465)

Source: DHM, Ministry of Water Resources, HMG/Nepal

ANNUAL MAXIMUM DAILY FLOW OF NARAYANI RIVER

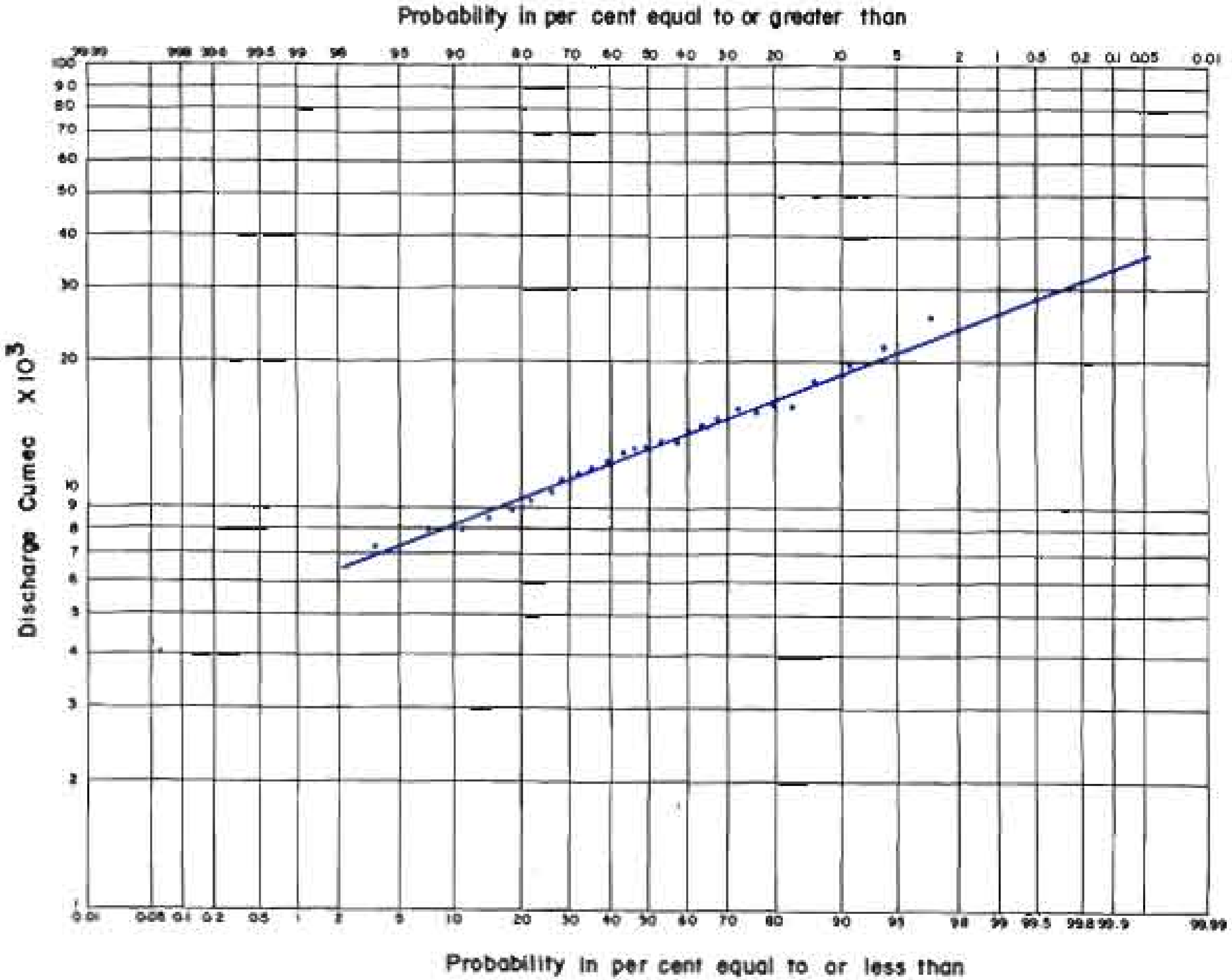


FIGURE 6.6 NARAYANI RIVER AT NARAYANGHAT (Station No. 450)

Source: DHM, Ministry of Water Resources, HMG/Nepal

ANNUAL MAXIMUM DAILY FLOW OF RAPTI RIVER

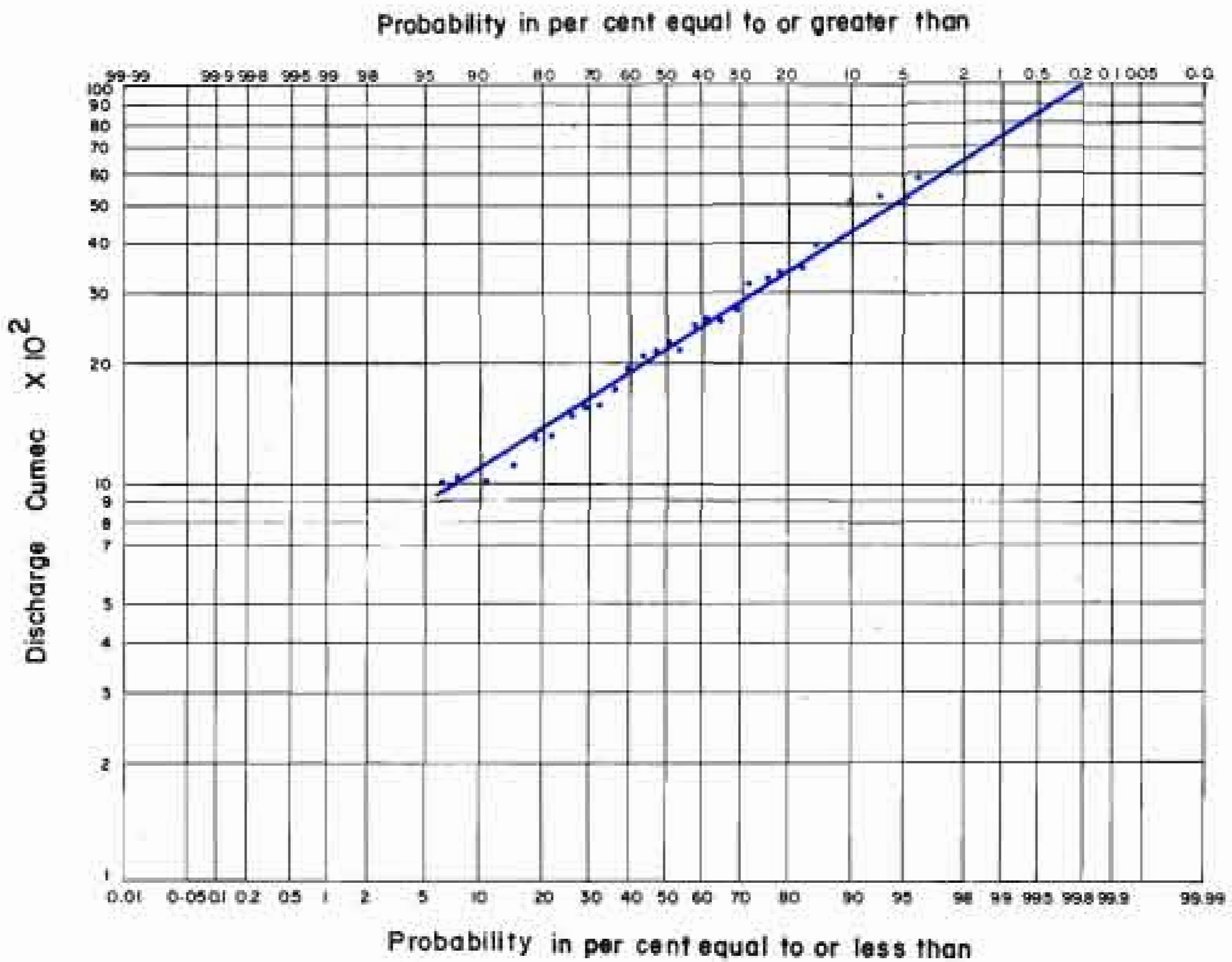


FIGURE - 6.7 RAPTI RIVER AT JALKUNDI (Station No. 360)

Source: DHM, Ministry of Water Resources, HMG/Nepal

ANNUAL MAXIMUM DAILY FLOW OF BABAI RIVER

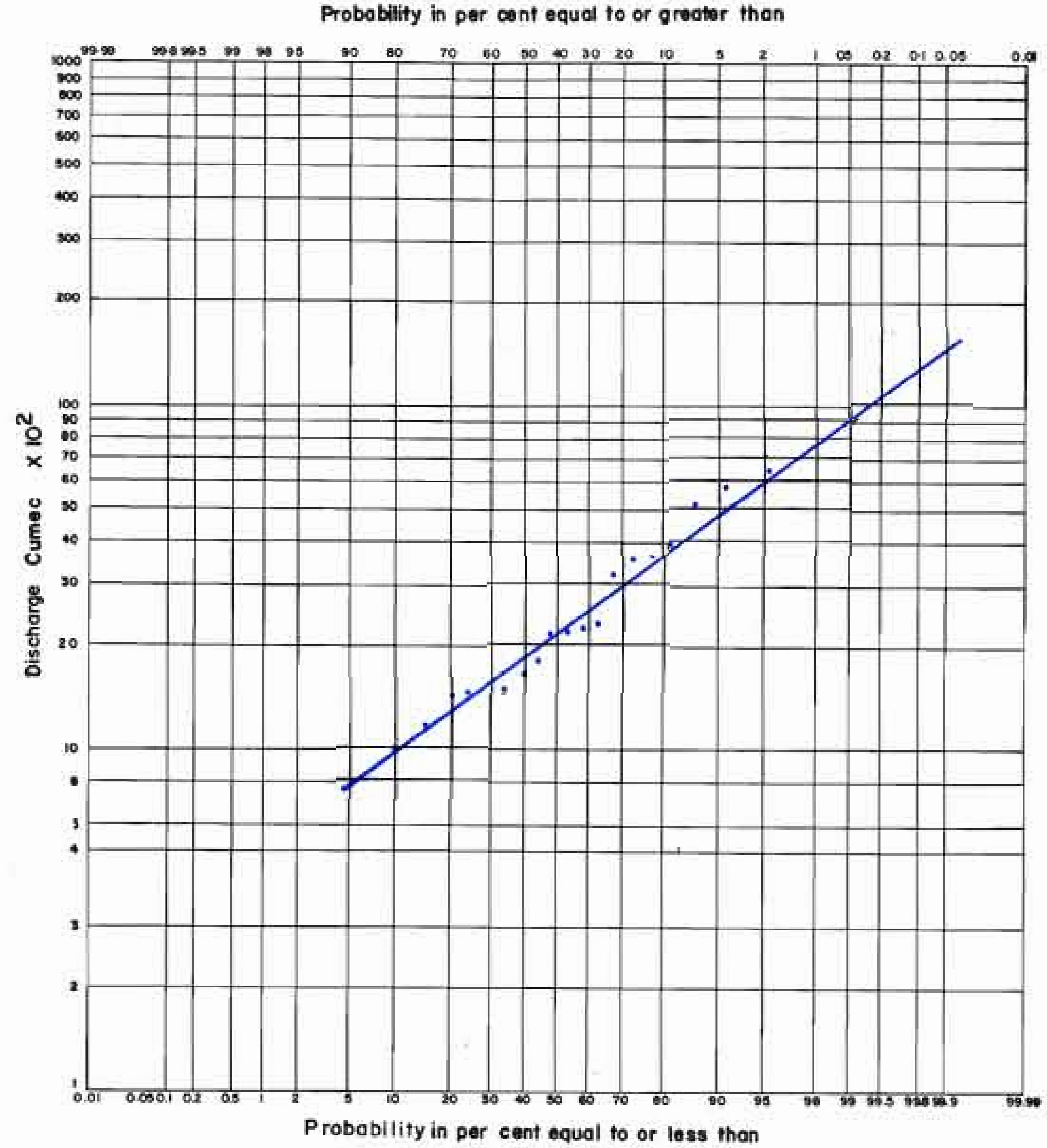


FIGURE - 6.8 BABAI RIVER AT BARGADHA (Station No. 290)

Source: DHM, Ministry of Water Resources, HMG/Nepal

ANNUAL MAXIMUM DAILY FLOW OF KARNALI RIVER

FIGURE 6.9 KARNALI RIVER AT CHISAPANI (Station No 280)

Source: DHM, Ministry of Water Resources, HMG/Nepal

ANNUAL MAXIMUM DAILY FLOW OF SURNAGAD

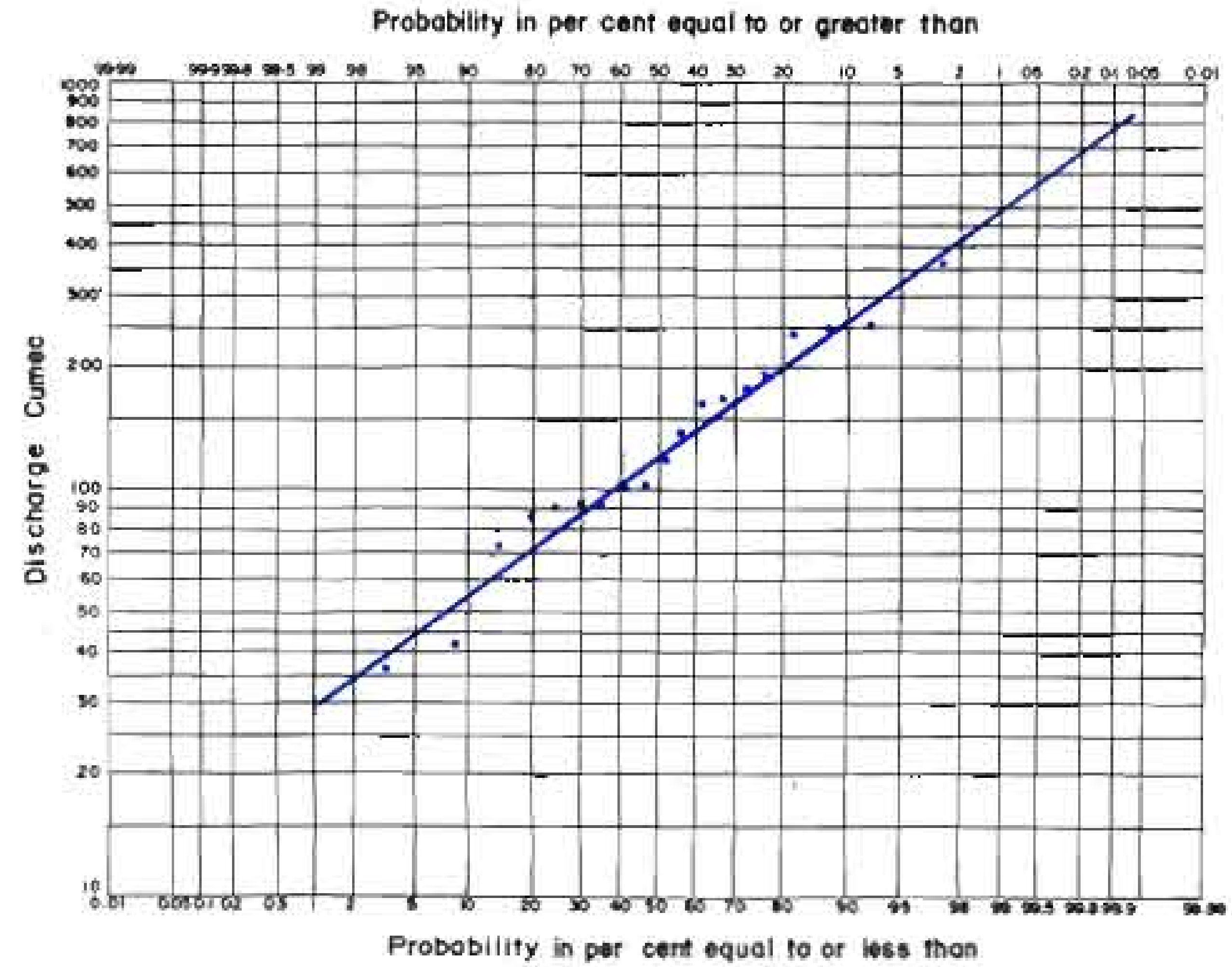


FIGURE -6.10 SURNAGAD AT PATAN NEAR BAITADI (Station No 170)

Source: DHM, Ministry of Water Resources, HMG/Nepal

MONTHLY DISTRIBUTION OF FLOW FOR DIFFERENT TYPES OF RIVER

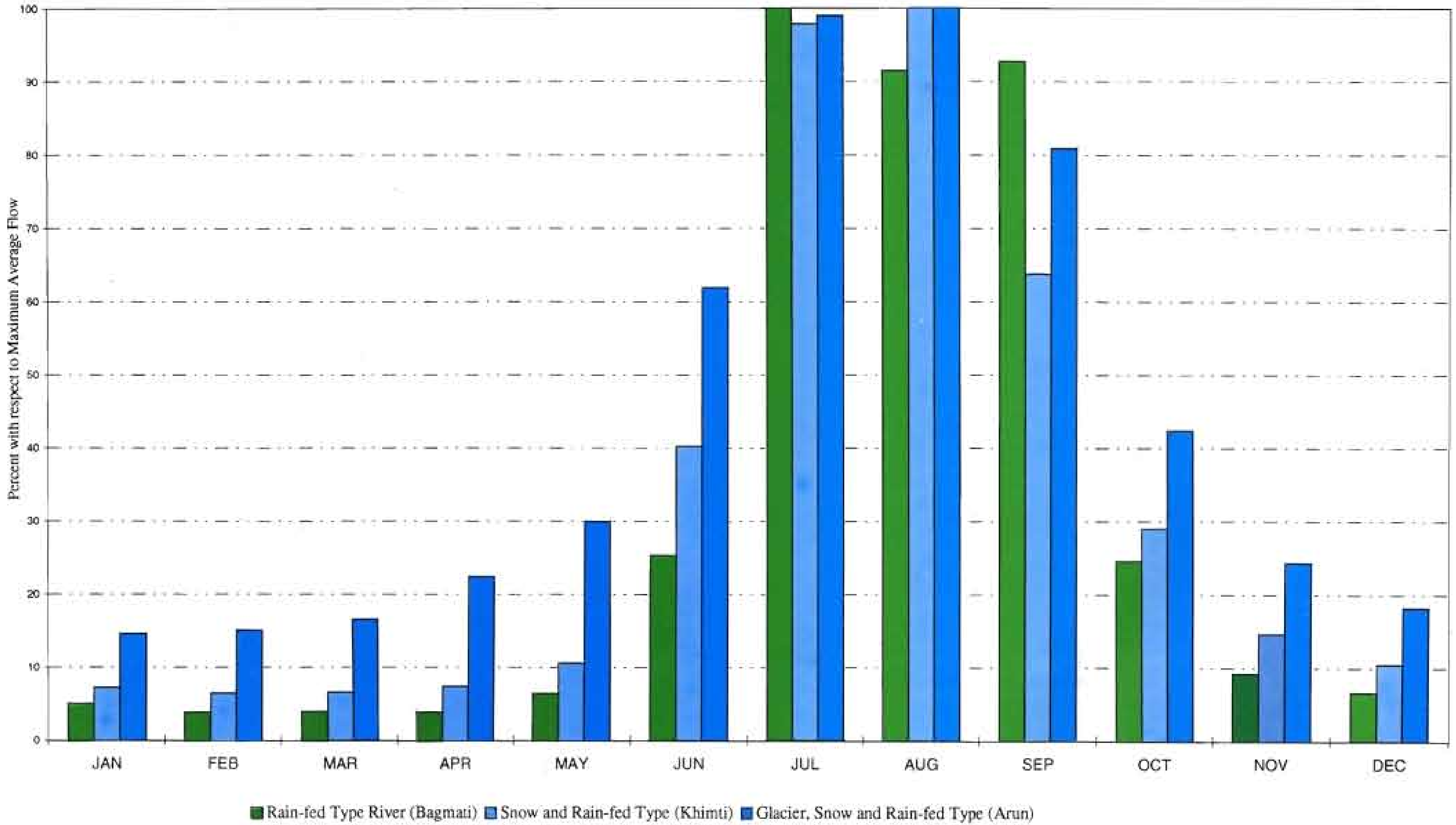


Figure -7

Source: - Department of Hydrology and Meteorology, Ministry of Water Resources, HMG/Nepal.
- Khimti Khola Hydroelectric Project Feasibility Study, Ministry of Water Resources, HMG/Nepal. Table 3.5.1, Vol.1, Apr.1993

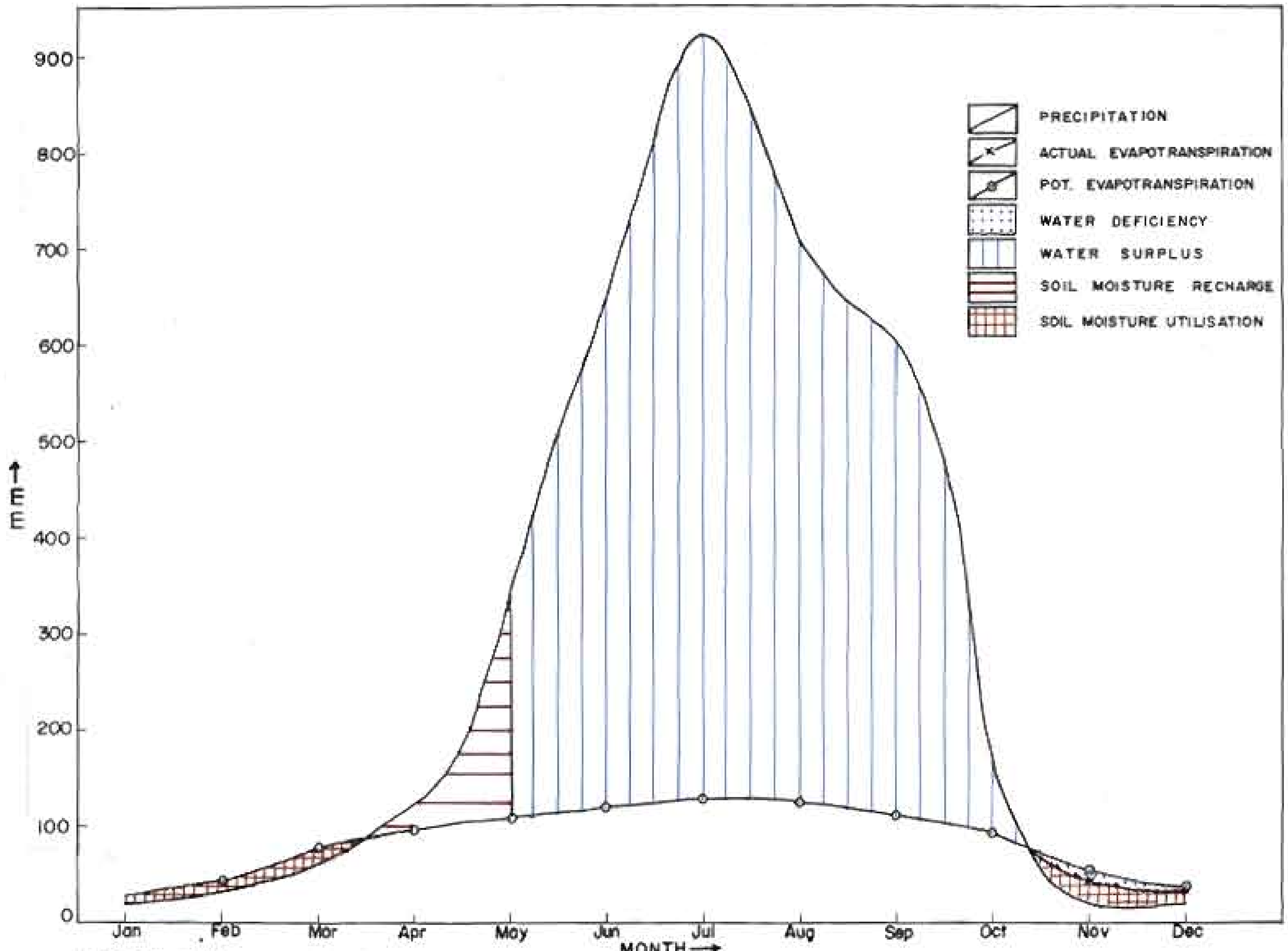


FIGURE 8(a) WATER BALANCE OF POKHARA

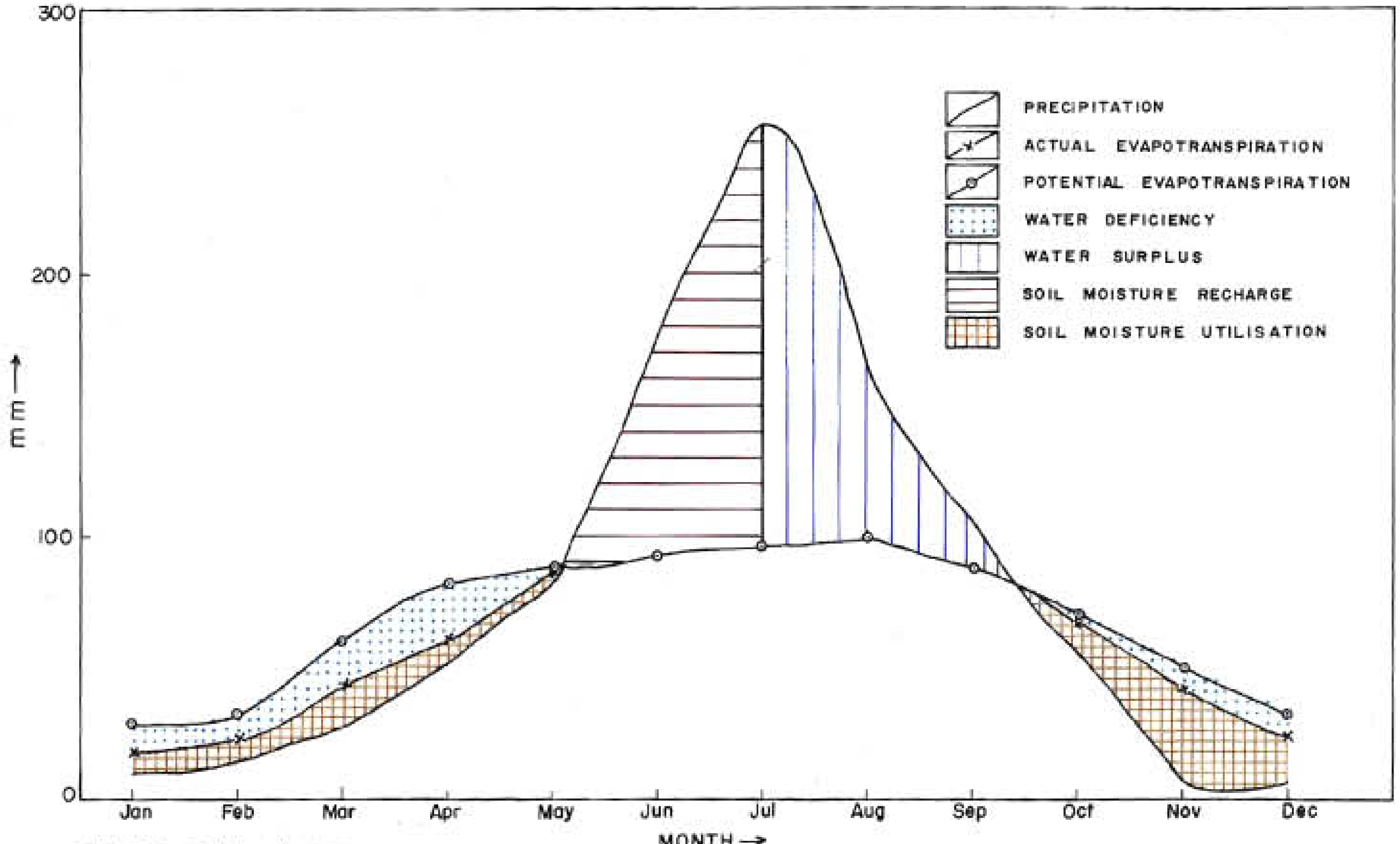


FIGURE 8(b) WATER BALANCE OF DHANKUTA

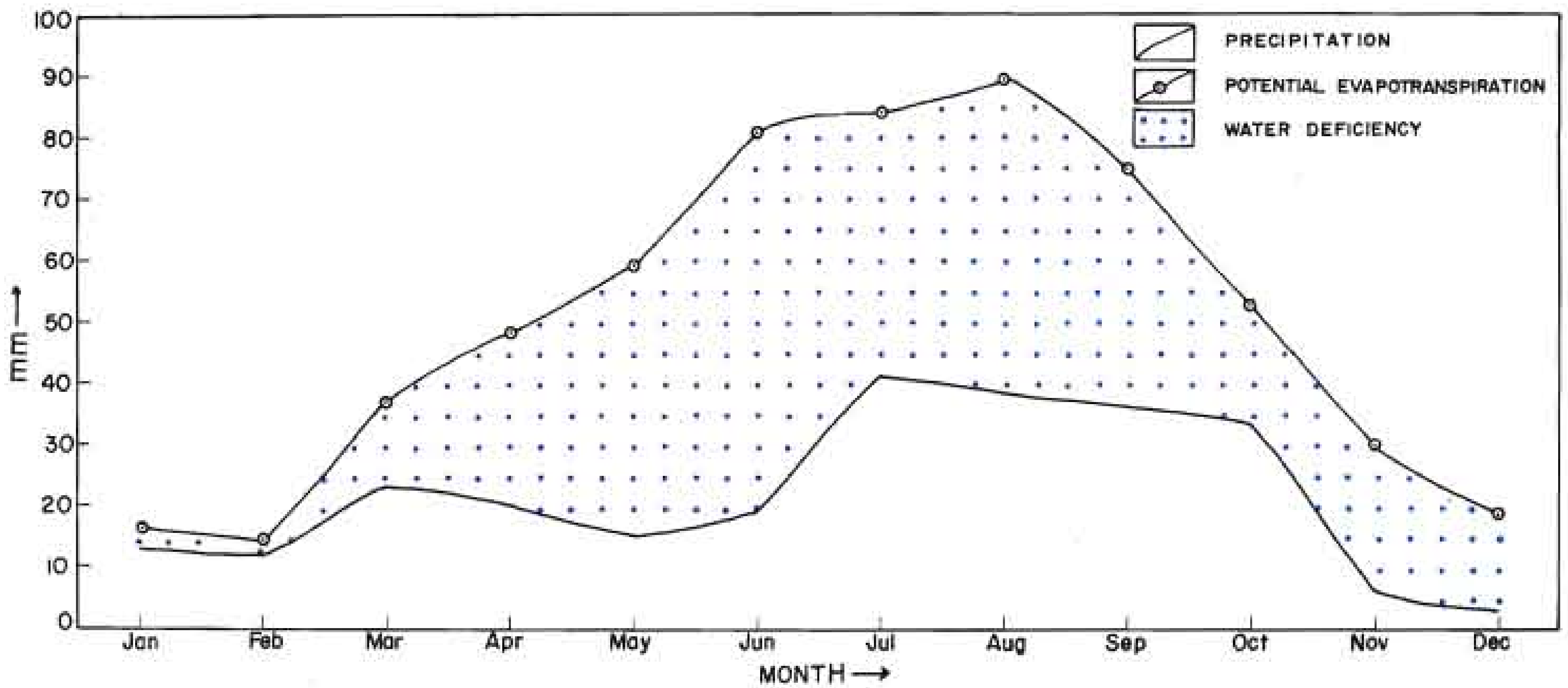


FIGURE 8 (C) WATER BALANCE OF JOMSOM

Section 3
Explanatory Notes

1 Climatic Maps and Diagrammes

1.1 Temperature Maps

Because of the complex terrain, the existing network of temperature stations (80 stations) does not portray a realistic picture of the temperature pattern. To achieve a more realistic picture of the temperature pattern in Nepal, an objective method was developed, as described below.

Temperature correlates closely with elevation, and, at the same time, it also depends upon many other factors such as latitude, longitude, wind, orientation, slope, aspect, and the height of temperature inversion. Inclusion of all these factors in a model makes the problem more complex. Hormann (1994) presented the use of a regression equation model to chart temperatures in a region with complex terrain. Here, only elevation, latitude, and longitude are taken into consideration for the development of the model, as depicted by the following:

$$T = A \times \text{Elevation} + B \times \text{Latitude} + C \times \text{Longitude}$$

where A, B, and C are coefficients and T is the temperature. The elevation is in metres and the latitude and longitude are in degrees.

The coefficients A, B, and C for each month are calculated by using the elevation, latitude, and longitude variables and the mean monthly temperature data from the 80 available stations, using records for more than five years. The coefficients A, B, and C are calculated for mean monthly maximum temperature and mean minimum temperature separately. The elevation data at every minute grid-point coordinate were retrieved manually from the 1:50,000 map produced by the Survey Department of His Majesty's Government of Nepal. The number of grid points extracted totalled 41,800, and, at every point, the coefficients were applied to generate the temperature value. The coefficient of correlation between temperature generated and observed temperature was found to be more than 0.99, demonstrating the usefulness of the model. The mean maximum temperature and mean minimum temperature generated were then used to analyse and prepare the individual monthly maps.

The mean monthly temperatures were computed by averaging the monthly maximum and minimum temperatures generated.

1.2 Precipitation Maps

Considerable spatial variations in precipitation were observed, due to the exceptionally rugged terrain of Nepal. The minimum density of rain-gauges recommended by the WMO for pluviometric networks is 100 to 250 per sq. km., i.e., about 600 to 1,500 stations will be necessary in Nepal for good representation. But, because of the financial and topographical constraints, as well as the lack of manpower in the remote mountain areas, the recommended norms could not be followed, especially in the northwestern parts of the country. Available data from 264 stations with records going back over five years up to the year 1990 were used for the precipitation analysis. With these data, mean monthly precipitations were computed for all the stations and used in mapping.

The mean annual precipitation was computed by considering the total precipitation of the 12 mean monthly precipitation from all stations used for the analysis. The precipitation during the monsoon season (June-September) contributes about 80 per cent of the annual total, and so the understanding of its characteristics becomes important. Therefore, the total mean monthly precipitation data for the period from June through September are presented.

The frequencies of rainy days (>1.0 mm per day) are presented on a monthly basis, but, for the monsoon months of June through September, additional frequencies of other intensities such as > 10 mm, >20 mm, and >30 mm per day are also presented.

The highest 24-hour precipitations were extracted from the records available from the 264 precipitation stations till the year 1995. These data were analysed to prepare the highest 24-hour precipitation map. This will help to identify the region with a greater tendency for heavy 24-hour precipitation.

1.3 Relative Humidity Maps

In most meteorological stations, dry-bulb and wet-bulb temperature observations are taken at 0300 UTC (0845 NST) and 1200 UTC (1745 NST) and monthly mean relative humidity is computed at these times. The relative humidity average at these two times is taken as the mean relative humidity for that month. In a real sense, this value can deviate from the actual relative humidity, but these are the only data available, and so the computations are performed in this way. It is expected that this will provide some idea of the relative spatial distribution of this parameter.

For analysis and mapping, data from 106 station were used with records going back at least five years.

1.4 Sunshine Duration Maps

Sunshine duration is measured in Nepal by using the Campbell-Stokes' sunshine recorder. The number of stations with this equipment is low for the purposes of having a representative map and, therefore, 41 stations with records going back at least two years were included in the analysis.

1.5 Fog Frequency Figures

Fog is a meteorological phenomenon which is observed and recorded regularly at synoptic stations. In this Atlas, the daily frequencies in fog occurrence were calculated from the observations taken at 0000, 0300, 0600, 0900 and 1200 UTC at twelve synoptic stations, namely, Taplejung, Biratnagar, Dhankuta, Okhaldhunga, Kathmandu, Simara, Pokhara, Bhairahawa, Birendranagar, Jumla, Dipayal, and Dadeldhura. The data used were from the period from 1981 - 1990.

A brief explanation of the type of fog observed is presented here. Fog, in any place, usually occurs when ambient temperature tends to be equal to dew-point temperature. In valleys, radiation fog dominates in the winter season, with less or no occurrence of fog during other times of the year. The stations over the ridges and slopes show a greater frequency of fog during the summer (rainy) season. In fact, these stations are within the cloud deck, which is mostly formed due to the mechanical and thermal lifting processes of air masses.

1.6 Monthly Variation of Temperature and Precipitation for Selected Stations

In the previous maps of temperature and precipitation, spatial features for each month were depicted. In this case, the temporal features are presented on a monthly basis of maximum temperature, minimum temperature, and precipitation for a period of one year at 12 stations. The average, maximum temperature, minimum temperature, and precipitation values used here were derived from the long-term data available from those stations and can be taken as the representative values for those stations.

2 Hydrologic Maps/Figures

2.1 Drainage System of Nepal

The scale of the map (Map 1) is 1:2,000,000. The map depicts the drainage network and the delineation of major sub-catchments. Forty regularly operating stations, along with seven stations that had been operating regularly for at least for ten years, are indicated in the map with reference numbers. Details incorporating the location, elevation, drainage area, instrumentation, and date of establishment for each station are presented in Section 2.1. The map is useful for general hydrological studies. The main constraints to the establishment of a minimum/optimum hydrological network are remoteness, poor accessibility, and lack of resources. Frequently, stations are destroyed by floods, landslides, and intense sediment/debris flows. Insufficient and unskilled manpower hamper routine hydrometric work and hydrological data analysis.

The map has been prepared with information gathered from the various sources (Dept of Hydrology and Meterology 1983; Survey Dept, HMG Nepal 1985; Water Induced Disaster Prevention Technical Centre, HMG/N 1994)

2.2 Hydrographic Scheme for the Karnali, Sapta Gandaki, and Sapta Koshi with Tributaries Equal to or Greater than 10 kilometres (Figures 1.1 to 1.3)

Sometimes it is essential to measure the length of tributaries and the main stream for various planning purposes. Therefore, tributaries longer than 10 kilometres for the three major river systems, namely, the Karnali, Sapta Gandaki, and Sapta Koshi, have been straightened out linearly and are depicted in Figures 1.1 to 1.3.

The length of various rivers can be measured efficiently and accurately, and such a scheme is very useful in morphometric and hydrologic studies. A base topographical map on a scale of 1:506,880, published by the Department of Survey, Ministry of Defence, United Kingdom (1967), has been used for the preparation of the hydrographic scheme. Preparation of a more elaborate hydrographic scheme using a larger scale map to incorporate tributaries less than 10 kilometres in length would be useful for a more detailed understanding of hydrographic and morphological characteristics.

2.3 Water Availability Histograms for Major Rivers in Nepal (Figure 2)

Water is the most important natural resource in Nepal. The annual mean streamflow in Nepal is estimated to be about $200\times10^9 m^3$. The major glacier-fed rivers, namely, the Sapta Koshi, Karnali, and Narayani, contribute about 72 per cent of this amount. About 75 to 80 per cent of the total surface water flows out of Nepal in the monsoon season only. Water availability histograms for major rivers, namely, the Narayani, Sapta Koshi, Karnali, Mahakali, Bagmati, West Rapti, Kankai, and Babai, have been prepared with long-term mean monthly discharges acquired from the Department of Hydrology and Meteorology (DHM), HMG/N. For each hydrometric station, the volume of discharge during the monsoon season (June 15 to September 15), non-monsoon season, and during the entire year have been calculated and depicted in the form of histograms in Figure 2. These statistics are useful for water resource planning and management. Discharge data have been made available by the DHM/N. At least twelve years of data for each station have been used for this purpose.

2.4 Probable Maximum Floods and Unusual Flood Discharge in the Nepalese Context with Respect to Floods in Some Regions of the World (Figure 3)

Floods resulting from high intensity rainfall occurring in mountainous regions occasionally overflows the river banks and inundates the surrounding low-lying regions after reaching the plains, destroying property and lives. Floodplains are densely inhabited, because rivers satisfy man's domestic, municipal, irrigation, and other demands. Therefore, it is important to safeguard such areas from floods. Reservoirs and river training works are among the flood control measures used. Floods have to be estimated with reasonable accuracy to design such infrastructure.

The purpose of Figure 3 is to compare the estimated and unusual floods measured in Nepal (WIDPTC 1994 and Ministry of Water Resources 1985, 1989, and 1990) with those from other regions of the world. These floods have been plotted on a curve (Raudhivi 1977 and Mutreja 1986) from Creager's equation given by:

$$Q = 46CA^{(0.894A^{-0.048}-1)}$$

where Q is the extreme specific flood discharge in ft^3/s per sq. mile, A is the catchment area in sq. miles, and C is the coefficient dependent on flood characteristics. The curves presented in Figure 3 are in SI units. These envelope curves are used extensively to gain an indicative idea of extreme floods for planning water resources' projects.

2.5 Flow Duration Curve for a Typical Himalayan River, Karnali at Chisapani (Figure 4)

In hydrology, one important aspect is the study of runoff variability. One way of doing this is by plotting flow duration curves. A flow duration curve is plotted with the rate of runoff on the ordinate against the percentage of time such flow is equalled or exceeded on the abscissa. Such curves can be drawn using daily, weekly, and monthly values. Flows are arranged in descending order of magnitude with each flow value being assigned a rank. The percentage of probability, P, for each flow which is equalled or exceeded, is calculated as

$$P = \frac{m}{n} \times 100$$

where m is the rank assigned to the flow and n is the total number of data in array. An example of the flow duration curves for a typical Himalayan river, the Karnali at Chisapani (Ministry of Water Resources 1989), is shown in Figure 4. Discharge of about $3.5 \times 10^2 m^3/s$ with 0.80 probability excedence occurs during the lowest flow months, December to March. On the other hand, discharge of about $34 \times 10^2 m^3/s$ in the highest flow month of August occurs with 0.80 probability of excedence. The flow duration curves allow evaluation of flows occurring at different levels of probability. This is very useful for determining the potentials for firm and/or average power generation. Such curves can also be used in design of drainage systems and other structures. These curves have been developed with 25 years of data from 1962 to 1986.

2.6 Drainage Density Map of Nepal (Map 2)

Drainage density can be interpreted as a measure of the closeness of the spacing of stream channels. Low drainage density reflects poor drainage conditions in a basin. Such basins are generally resistant to erosion or are very permeable with fewer slopes and scanty vegetation cover. Drainage density, D, is the ratio of the total length of streams of all orders in the basin, ΣL, to the basin area, A, and is given by

$$D = \frac{\Sigma L}{A}$$

The drainage density shown as Map 2 includes only the wet course of rivers/rivulets with lengths greater than two kilometres up to the outlet gorges in the Siwalik Range for major rivers (Dept of Survey, UK 1967). Kankai river basin has the highest value of 0.37 km/sq.km. The other drainage basins have values ranging from 0.35 to 0.29 km/sq.km. The average drainage density of Nepal is about 0.31 km/sq.km. Drainage density is important in hydrology as it affects the speed of runoff following a period of precipitation. Water generally moves faster through a well-developed system of river channels. In other words, with greater drainage density the lag time for runoff decreases, resulting in higher peak.

2.7 Monthly Average Flow of Major Rivers (Figure 5)

Streamflow records constitute the most important data for engineers and hydrologists, because these data are used in the design of water resources' projects. The discharge data can be graphically presented in many ways. One convenient way to present them is with a bar diagramme on a monthly basis. Long-term monthly average histograms and the average annual flow of major rivers, namely, the Mahakali, Karnali, Babai, West Rapti, Narayani, Bagmati, Sapta Koshi, and Kankai, are depicted as insets in the map. Amongst the main glacier-fed rivers, the Narayani River has more mean monthly discharge during the monsoon and post-monsoon seasons than the other rivers. On the other hand, the Karnali has more mean monthly flow during the pre-monsoon season than the others. All rivers obviously show high flows during the monsoon and low flows during the pre-monsoon months.

The histograms shown in the map include only major and medium rivers. The data period used for this purpose differs from station to station, depending upon the availability of records. Discharge data have been obtained from the DHM/N. At least ten years' data have been used for each station. The monthly flow variations give a quick comparison of flow for different major rivers across the country. Dry and wet months can be delineated for studies relating to water resources' planning and management.

2.8 Flood Frequency Curves for Major Rivers (Figures 6.1 to 6.10)

Design of culverts, roads, drainage works, irrigation diversion works, etc requires reliable estimates of floods for the site concerned during a specific period of time in future. Runoff, being essentially a random process, can be estimated only with specific probability. A design flood with certain probability is adopted for the design of structures after useful consideration of economic and hydrologic factors. As the magnitude of the design flood increases, the capital cost of the structure increases, but the probability of risk will decrease. The most economical design flood can be found after studying various alternatives.

The prediction of future floods based on historical records is an important aspect in hydrology. The frequency analysis makes use of the observed data to predict the future flood magnitudes along with their probability of return periods. By definition, the return period or recurrence interval, T, is calculated as

$$T = \frac{1}{P}$$

where P represents the probability of flood occurrence. Log normal distribution, which reasonably fits most Nepalese flood discharges, has been used to draw the frequency curves for various rivers. The 100-year floods for major rivers, such as the Narayani, Sapta Koshi, Karnali, and Bagmati, are estimated to be about 25.5×10^3 m^3/s, 22.5×10^3 m^3/s, 19.5×10^3 m^3/s, and 12.5×10^3 m^3/s respectively. For the Bagmati River, discharge data from Karmaiya station from 1965 to 1979 have been incorporated with those from Pandherodobhan station from 1980 to 1990, since these stations are within a distance of 1.5 km of each other,and the former station has been abandoned. It is to be noted that prediction of floods is probabilistic rather than deterministic. Data for maximum floods have been obtained from the DHM/N. At least eleven years' data have been used. Most stations have data going back 19 to 28 years.

2.9 Monthly Distribution of Flow for Different Types of Rivers (Figure 7)

Most of the rivers originating from the Himalayan and the Mahabharat ranges are perennial in nature, whereas those originating in the Siwaliks generally dry up in the summer season. Three categories of river are found in Nepal, considering their sources.

These are:

a) rain-fed rivers
b) rain-fed and snow-fed rivers, and
c) rain-fed, snow-fed, and glacier-fed rivers.

The Bagmati is typically categorised as a rain-fed river, whereas the Khimti is a rain-fed and snow-fed river. The Arun is a rain-fed, snow-fed, and glacier-fed river, considering the main sources. Base flow contribution persists for all of these rivers throughout the year. Monthly flows, obtained from the DMH/N and the Ministry of Water Resources (1993), have been used to represent the flow distribution histograms. These flows have been converted into percentages of maximum monthly flows for better comparison. The Arun has about 14 per cent of the maximum average monthly flow in its driest month. The Khimti and Bagmati have about 6 per cent and 4 per cent of the maximum average monthly flow in the driest months. This bar diagramme is very useful for comparison of rivers originating from different zones. Glacier-fed rivers have substantial flows in the dry season. The other two classes of river originating below the permanent snowline are fed significantly by groundwater, including springs, in the dry season. Rivers originating in the Siwalik Range generally dry up in the summer and have not been included in the figure due to inconsistent data.

2.10 Water Balance for Some Typical Stations (Figures 8[a] to 8[c])

The distribution of water balance elements in time and space can reflect the water potential for agriculture. Using monthly average temperature and precipitation data up to 1990, Thornthwaite's water balance technique has been used for three typical stations. Thornthwaite's method has been used to calculate the potential evapotranspiration (Thornthwaite and Mather 1955). If rainfall and soil moisture together do not equal potential evapotranspiration, then water deficiency occurs. Subsequent rainfall may check the water deficiency. On the other hand, when rainfall exceeds the water need, soil moisture gradually increases and saturates the soil to give surface runoff. Soil plays a unique role in the water balance of a region, since it can store water during the rainy season and release it later on through evapotranspiration. For the computational procedure, field capacity was assumed according to the soil type conditions in Nepal in order to establish the depth of stored water in the root zone.

In the water balance accounting procedure, the precipitation, P, is compared with potential evapotranspiration, PE, and, if PE is greater than P, then the difference indicates the amount by which the precipitation has failed to meet water needs. On the other hand, if P is greater than PE, then the difference is the amount of water in excess of water needs.

Accumulated potential water loss, APWL, is obtained by progressively adding all the values of (P-PE). If the soil has never reached field capacity, the first value of APWL is obtained by a successive approximation method using the field capacity table. The amount of soil moisture held in the soil is derived from the APWL and field capacity table (Thornthwaite and Mather 1955). When measured values of field capacity are not available, they can be assessed by considering the soil type and vegetation cover. When P is equal to or greater than PE, the actual evapotranspiration, AE, will be equal to PE. However, if P is less than PE, AE is obtained by adding P to the change in soil storage ΔS. The water deficiency, W_D, is given by (PE - AE). Water surplus, W_S, occurs only after the soil has been recharged to its field capacity.

Water balance has been estimated for three typical stations, namely, Pokhara, Dhankuta, and Jomsom, which are located in relatively wet, moderately wet, and dry regions respectively. The monthly water balance and the different climatic elements of these stations are given in Figures 8(a) to 8(c). Pokhara's precipitation significantly exceeds the water needs for most of the year (Figure 8[a]). Climatically, an annual amount of 2,653 mm of water surplus is accumulated from April to October. For Dhankuta (Figure 8[b]), precipitation is greater than the potential evapotranspiration from June to September. Precipitation above the water need is stored in the soil and brings the upper layer to field capacity in July. After the soil moisture reaches field capacity, any further precipitation, which is not required for potential evapotranspiration, is considered as surplus ultimately lost as runoff. Dhankuta has an annual water surplus of 215mm accumulated from July to September. In October, precipitation fails to supply the water needs by 14mm, and 12mm are supplied by the water stored in the upper layer of the soil. There is only a 2mm water deficit during October. However, in November, water needs of 46mm are not supplied by precipitation. As the soil dries up, water is not readily available from the upper soil layer and only 31mm can be obtained from the soil. Deficit persists until May, when potential evapotranspiration falls below precipitation.

Jomsom (Figure 8[c]) does not experience water surplus as precipitation does not exceed potential evapotranspiration throughout the year. The June to October period is comparatively wet.

SECTION 3: Data Processing

3.1 Software Used

The software programmes used for the analysis and preparation of climatic maps were:

a. Surfer for Windows version 5 and
b. ARC/INFO version 6.1 on an IBM RS/6000 platform.

3.2 Preparing Precipitation, Relative Humidity, Sunshine Duration, and Rainfall Frequency Maps

Generation of Contours (Isolines)

Surfer for Windows was used to generate the isolines of Precipitation, Relative Humidity, Sunshine Duration and Rainfall Frequency.

Step 1. *Creating a Grid from the Data File*

A grid file was created from the given data for a given month. After a number of trials with various grid sizes, an optimum grid size of 60 rows by 100 columns, each cell being 0.08333 x 0.0847 degrees, was adopted. The extent of the grid was from 25.5 degrees latitude and 80 degrees longitude to 30.5 degrees latitude and 88.25 degrees longitude, so that it covered the whole country.

Step 2. *Generating Contours from the Grid File*

There are various options available for generating contours from SURFER software. The method adopted was that of KRIGGING with medium smoothing of lines. A copy of this contour with gray shading and contour labels was printed out so that the different regions could be clearly identified.

Converting the Contour Maps to ARC/INFO Coverage

Step 3. *Exporting the Contour File to DXF Format*

The surfer file was exported to the AutoCAD DXF format. Default parameters were adopted during conversion.

Step 4. *Importing the DXF File to Arc/Info*

The DXF files were then converted to Arc/Info coverages. After creating the labels, a polygon coverage of a corresponding file was built.

Step 5. *Assigning User Ids to Different Polygons*

The coverage was then clipped with the country boundary of Nepal in Arc/Info software. User ids were assigned to the different polygons with the help of the contour map with shade and contour labels. This method, though more mechanical, proved to be simple and less time consuming than various other alternatives such as using CAD and TIN.

3.3 Preparing the Temperature Maps

A different procedure was followed in preparing the temperature maps. First, a point coverage was generated from the source data. The monthly temperatures were assigned as the attribute data for those points.

A *Triangular Irregular Network (TIN)* was generated from the point coverage with the temperature of a certain month as its spot item. This *TIN* was then converted into a grid. A polygon coverage was created from the grid using **gridpoly**. The polygon coverage was then clipped with the country boundary of Nepal and final maps were prepared.

3.4 Map Preparation and Printing

Once the Arc/Info coverages were ready, the map-making process was automated with the use of simple AML (Advanced Arc Macro Language) programmes of Arc/Info. Those maps were then printed in A3 sizes on a Tektronix Phaser III colour printer for high quality reproduction.

References

Department of Hydrology and Meteorology, 1983. *Surface Water Records of Nepal.* Supplement No 10. Kathmandu: Ministry of Water Resources, HMG/Nepal.

Department of Survey, 1967. *UM62.* United Kingdom: Ministry of Defence.

DHM, 1971. *Climatological Records of Nepal, 1968.* Kathmandu: DHM

DHM, 1972. *Climatological Records of Nepal, 1969.* Kathmandu: DHM

DHM, 1973. *Climatological Records of Nepal, 1970.* Kathmandu: DHM

DHM, 1977. *Climatological Records of Nepal, 1971-75.* Kathmandu: DHM

DHM, 1982. *Climatological Records of Nepal, 1976-80.* Kathmandu: DHM

DHM, 1984. *Climatological Records of Nepal, 1981-82.* Kathmandu: DHM

DHM, 1986. *Climatological Records of Nepal, 1983-84.* Kathmandu: DHM

DHM, 1988. *Climatological Records of Nepal, 1985-86.* Kathmandu: DHM

DHM, 1995. *Climatological Records of Nepal, 1987-90.* Kathmandu: DHM

DHM, 1992. *Precipitation Records of Nepal, 1987-90".* Kathmandu: DHM

Environmental Systems' Research Institute (ESRI), 1990. *Understanding GIS: The Arc/Info Method.* Redlands, USA: ESRI.

Environmental Systems' Research Institute (ESRI), 1990. *TIN- Arc/Info Surface Modeling and Display, Users Guide.* Redlands, USA: ESRI

Golden Software Inc., 1994. *Surfer for Windows: Users Guide V5.0.* Colorado USA: GSI

Hormann, K., 1994. *Computer-based Climatological Maps for High Mountain Areas.* MEM Series No. 12. Kathmandu: ICIMOD.

Map published in the Surface Water Records of Nepal, Supplement No. 10, 1983, DHM, Ministry of Water Resources, HMG/Nepal.

Map published by the Survey Department, Topographical Survey Branch, 1985, HMG/Nepal.

Map published by the Survey Department, Topographical Survey Branch for Water Induced Disaster Prevention Technical Centre, Ministry of Water Resources, 1994, HMG/Nepal.

Ministry of Water Resources, 1985. *Pancheshore Multipurpose Project.* Kathmandu: HMG/Nepal

Ministry of Water Resources, 1989. *Karnali (Chisapani) Multipurpose Project.* Kathmandu: HMG/Nepal

Ministry of Water Resources, 1990. *Kali Gandaki "A" Hydro-electric Project.* Kathmandu: HMG/Nepal

Ministry of Water Resources, 1993. *Khimti Khola Hydroelectric Project Feasibility Study.* Vol 1. Kathmandu: HMG/Nepal

Mutreja, K N, 1986. *Applied Hydrology,* pp 746. New Delhi: Tata McGraw Hill

Raudhivi, A. J. 1977. *Hydrology,* pp 288. UK: Pergamon Press

Survey Department, 1985. Topographical Survey Branch. Kathmandu: His Majesty's Government of Nepal

Survey Department, 1994. Topographical Survey Branch for Water Induced Disaster Prevention Technical Centre. Kathmandu: Ministry of Water Resources, HMG/Nepal

Thornthwaite, C.W. and Mather J.R., 1955. *The Water Balance Publication of Climatology.* Laboratory of Climatology, Vol 8 No 1.

Water Induced Disaster Prevention Technical Centre, 1993. *Annual Disaster Review.* Kathmandu: Ministry of Water Resources, HMG/Nepal

Participating Countries of the Hindu Kush-Himalayan Region

- Afghanistan
- Bhutan
- India
- Nepal
- Bangladesh
- China
- Myanmar
- Pakistan

International Centre for Integrated Mountain Development (ICIMOD)
4/80 Jawalakhel, G.P.O. Box 3226, Kathmandu, Nepal

Telex : 2439 ICIMOD, NP
Telephone : (977-1-525313)
e-mail : dits@icimod.org.np

Cable : ICIMOD, NEPAL
Fax : (977-1) 524509
(977-1) 536747