DYNAMIC MONITORING OF EARTH SURFACE ENVIRONMENT

M. Badarch, R. Oyun, M. Enkhbayar

National Remote Sensing Center, Mongolia

ABSTRACT:

In this paper were studied dynamic changes of earth surface condition such as temperature, soil moisture, vegetation and snow cover over territory of Mongolia, using multitemporal, multichannel remotely sensed and ground observation data. The results of the study show that remote sensing application is an effective tool for dynamic investigation and studying of renewable natural resources as heat, water and pasture resources and it plays an important role in optimization of the main economic branches' activities, forecasting of environment changes and its consideration for sustainable development of the country.

KEY WORDS: Multitemporal, Remote sensing, Renewable resource, Developing country

1. INTRODUCTION

To understand global change on short and long time period, we need a system approach to Earth system processes. The approach requires the complete set of observation, analysis, estimation, control and prediction of global changeable processes or, shorter, the Monitoring system.

This system may have different types due to its application purpose. We can divide the system into two major types such as Ecological Monitoring system, the final purpose of that deals with general policy planning of country sustainable development and Environment Monitoring system, with main objectives to provide and serve by necessary information on particular field of activity and planning.

In this case we have concerned problems on developing of Monitoring system for agricultural application.

Mongolia is a country with some geographic and economic specifications. In one hand, it is situated in the Central Asia, through a territory of it are crossed southern boundary of Arctic fermafrost and also northern boundary of Asian Great desert. Therefore the climate of the country is very changeable. There are four completely different seasons, like severe and cold winter, dry and windy spring, warm and short summer, sunny autumn in Mongolia. The country is included into arid and semi-arid area.

In other hand, in the economy of the country predominates an agriculture, basically, cattle breeding and cultivation, growth and productivity of it is directly associated with natural and environmental condition. 78 per cent of total territory of Mongolia is occupied by natural grassland and more than 90 per cent of the required fodder for livestock is derived from this land.

Proceeding from this, there is a significant need to monitor nature and environment condition in seasonal round cycle winter-spring-summer-autumn. In this reason the main purpose our research work is to develop Environment Monitoring system, that will provide agriculture with most required information on earth surface characteristics such as snow coverage, soil moisture, vegetation and temperature.

2. DATA AND METHODOLOGY

In Mongolia since 1970 there have being produced earth surface characteristics maps on the base of data, measured at ground meteorological observation stations. However these maps still not yet fully satisfy all agricultural requirements because of following reasons. The first is that source data for these maps is collected from the stations only once every 10 days and the second, as well as almost all stations are located in populated area, the observed data could not effect real environment condition. Therefore for a such country as Mongolia, where is a much contrast of landscapes (high mountains, widespread steppes, Gobi-desert and so on) and a large territory with its few population, the application of remotely sensed data and methods gives essential effectivity on environment monitoring of interested surface characteristics, dynamically changeable in short and long period of time (daily, 5-10 daily, monthly, seasonally and yearly). In this reason the research work has been carried out on the base of TIROS-N satellite's AVHRR (Advanced Very High Resolution Radiometer) digital data, with help of ground measurement data and various natural resource maps.

During the study except of traditional methods for satellite digital data, including digital image pre- and post-processing method with statistical analysis we have developed numerical and physical models, data processing algorithms and technologies, that had been more suitable for certain cases of study. To develop algorithms and technologies for estimation of studying object's current condition, the first, we have defined their climatological characteristics and they have been taken as background of our study. The technologies and algorithms for Monitoring system were developed in 1988-1991 and are used to estimate and control some surface characteristics in short and long terms of time over the whole territory of Mongolia or part of it. As well as the surface characteristics to monitor, basically, depend on weather condition we also developed a technology for weather analysing and forecasting.

3. APPLICATION ANALYSIS

To estimate and control the surface and climate condition we have chosen the following surface characteristics according to seasonal agricultural requirements for further assessment of its dynamics. These characteristics are in winter-snow cover, in spring and autumn-soil moisture, in summer-vegetation cover and in all seasons-surface temperature.

So in this paper we introduced some results of our research work on dynamic monitoring.

3.1 <u>Snow coverage dynamics</u> (September - April)

The information about snow coverage is very important to really evaluate winter condition for cattle-breeding and pasture current state. Therefore since the remote sensing data has been used in Mongolia there have been done some research works on snow cover assessment based on satellite and ground measurement data. The statistical characteristics of snow cover distribution, stable snow cover formation and its continuation have been determined by Badarch (1987) and the results of the investigation show that in winter about 1.09 mln sq.km or 69 per cent of total territory of the country are covered by snow. In February boundary of stable snow covered area reaches up to latitude 43.4°N and longitude 104°E, taking annual maximum area under snow cover (1.35 mln sq.km).

A technology for mapping of snow cover distribution had been developed in 1990 and now every 5-10 days we produce snow cover distribution thematic maps in a scale of 1:5.000.000 and 1:7.000.000 with a plotting of snow depth data, measured at the ground meteorological stations. Thus classifying snow cover by its range of coverage, distinguishing snow covered area from cloudiness and desert by their temperature differences, identifying snow cover among the forested area, mapping whole territory of Mongolia with help of multidate cloud-free satellite data mosaic we have possibility to control snow cover changes, to evaluate its distribution.

Fig.1 shows snow cover maps, derived from AVHRR data on 23 December 1991 and 2 February 1992. Snow cover is classified into 4 different classes as fully snow covered, partly snow covered (2 classes-more and less than 50 per cent of an area covered by snow) and snow-free areas. Also there have been plotted snow depth data and described the percentage of snow coverage classes for local administrative regions.

3.2 <u>Soil moisture dynamics</u> (April-June, September-October)

Almost entire area of Mongolian territory belongs to a region with insufficient and unstable moisture. As well as there predominates non-irrigated cultivation, the information on soil moisture plays significant role to effectively organize agrotechnical policy and increase agricultural productivity. Also in the spring snow cover melts and evaporates within very short time (7-10 days) and so much that in most cases has no effect on soil moisture. Therefore the soil moisture, reserved in the autumn before freezing of soil, remains as main soil moisture resources in the spring, so the information on soil moisture in the autumn is a predictor soil water contents in spring. In this reason this information is more required in the spring and autumn. In the work of Oyun (1990) has been analysed ground observation data for the period of more than 10 years, determined climatological characteristics of soil moisture, produced soil moisture map and developed integral technology for determination of soil moisture characteristics, based on methods of statistics, landscape indication, satellite multichannel digital data processing and heat balance. From those studies it was concluded that the mean statistical value of soil moisture is not reached to the lowest value of field water capacity ranging between hydroscopic water capacity and capillary breaking off. Soil moisture monthly dynamics appears not clearly, but the analysis of water content ground measurements show its high variation within 2-5 days and daily dynamic in the surface layer. Space distribution study shows the maximum value of productive wetness in 1m top layer occurs in Selenge river basin and Khalkhyn-gol river region and it ranges between 99-150 mm, but its minimum value - less than 20mm is observed in the arid-steppe zone and backsides of mountain Altai. In the mountain areas Khangai, Khentii and forest-steppe zone this value counts 46-98mm.

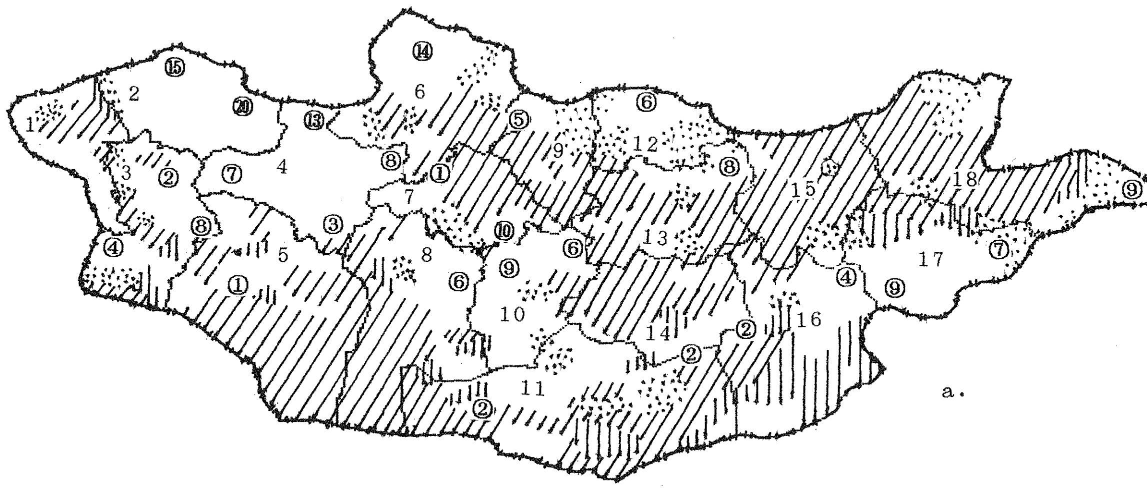
Using thermal inertia, derived from AVHRR radiance temperature of channels 4, and 5, source data of channel 3 and regression model we produce a map of surface soil moisture. Fig.2 is soil moisture map, prepared on the base of AVHRR data in 2 May 1991. In this map the territory of Mongolia is divided into following 5 major categories of soil moisture: water logged area, area with moderately and slightly wet soil, excessively dry soil and snow or ice cover.

3.3 <u>Vegetation dynamics</u> (May - September)

In recent years more and more scientists are interested in monitoring of vegetation progress using NOAA-AVHRR data due to its daily repeat cycle and large territory coverage in contrast to other satellite data.

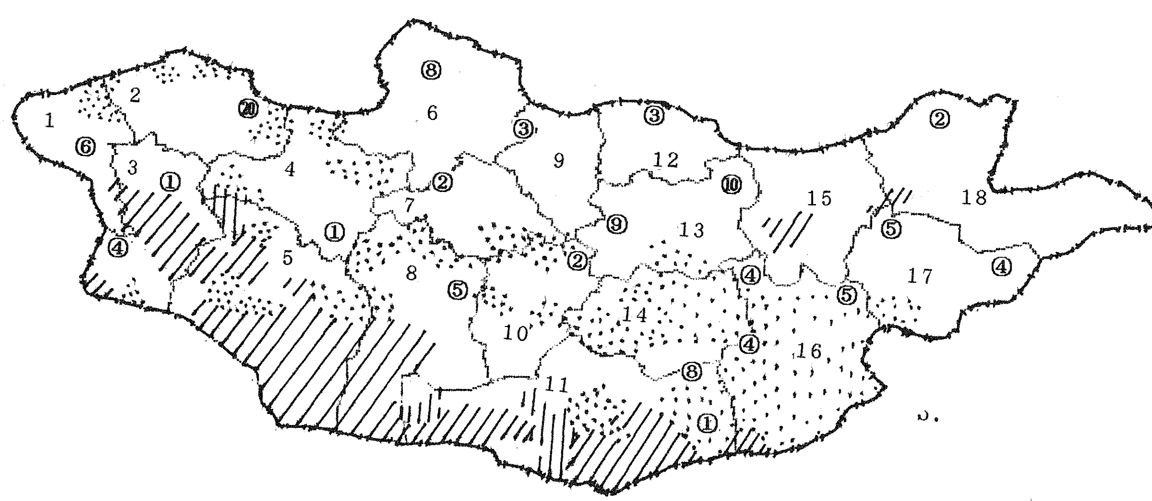
A methodological approach for natural grassland current state estimation and determination of its production in the steppe pasture zone of Mongolia using ground measurement data and Normalized Vegetation Index (NVI), derived from AVHRR multichannel digital data (Adyasuren, 1989) had been developed and based on this method we had possibility to map vegetation condition every 10 days.

It was concluded that the variation of NVI value corresponds to real pasture condition in steppe zone of Mongolia and in the beginning of June these values vary within 0.17-0.37, depending on current



a.

Classes:		Region number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
snow-free area		24	0	14	1	64	29	54	49	56	10	41	17	49	52	85	29	12	55
<50% area with snow		7	0	7	1	3	1	2	3	2	3	13	4	3	8	2	29	8	8
>50% area with snow		5	5	9	1	2	7	5	3	15	7	8	19	12	9	5	9	10	14
fully covered		64	95	70	97	31	63	39	45	27	80	38	60	36	31	8	33	70	23



b.

Classes		Region number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
snow-free area		1	0	21	1	59	0	0	35	0	1	39	0	1	2	6	5	1	1
<50% area with snow		4	0	3	1	4	0	0	3	0	0	5	0	0	0	0	1	0	0
>50% area with snow		10	14	6	16	8	3	10	16	1	19	14	1	10	44	1	69	7	0
fully covered		85	86	70	82	29	97	90	46	99	80	42	99	89	54	93	25	92	99

Fig. 1. Snow cover maps and percentage of snow coverage classes for local administrative regions. a. 23 December 1991. b. 20 February 1992. 2 - local administrative region number, ⑨ - Snow depth data, measured at ground meteorological station.

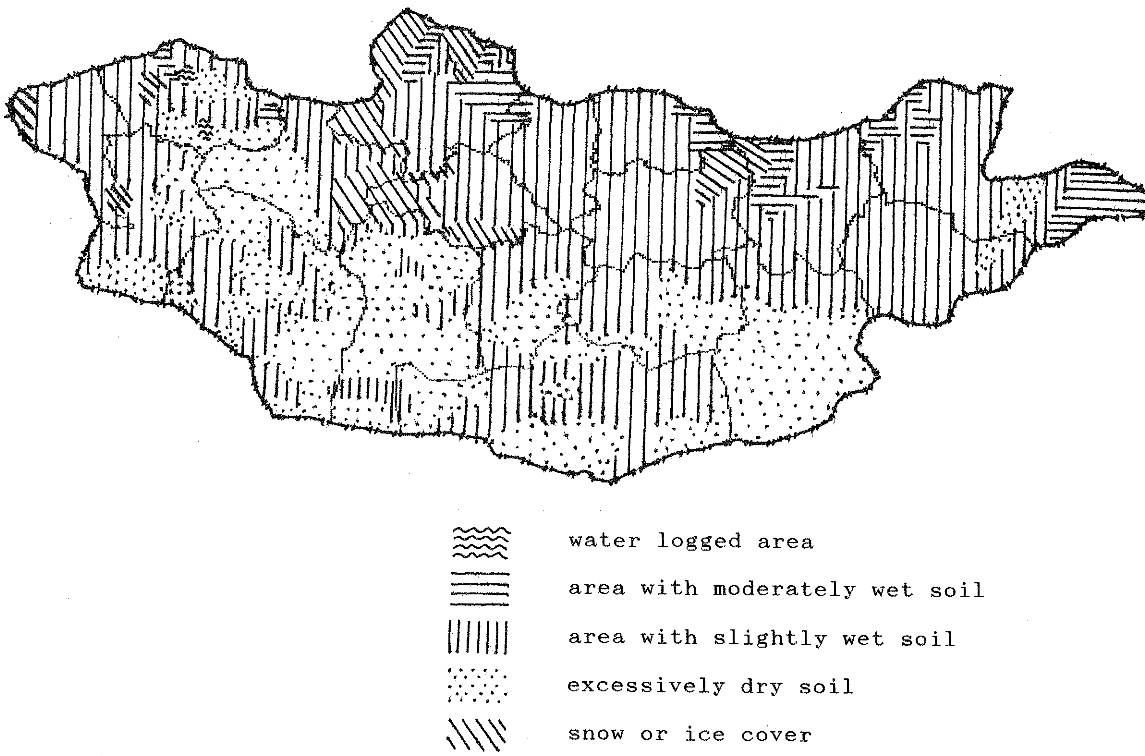


Fig. 2. Soil moisture map in 2 May 1991

condition of vegetation cover. Also there has been analysed statistical characteristics of NVI. The northern dense forested area and dry-steppe zone the value of NVI is increased by 0.45 than the value observed in desert area.

The Fig.3 shows vegetation maps in 17 June 1991 and 7-12 September respectively. Here are identified 4 different classes of vegetation condition according to NVI values as barren area (NVI=0.-0.04), sparse vegetated (NVI=0.05-0.1), moderately vegetated (NVI=0.11-0.2), highly vegetated (NVI=0.21-0.4) and excessively dense vegetated or forest (NVI>0.41) areas.

3.4 Temperature dynamics (January - December)

There is a requirement to monitor surface temperature in all seasons. For example determining surface temperature in the winter and summer we find out an area under cold and warm temperature anomalies, which is the main reason of complication for livestock climate condition. In spring the surface temperature differences give to identify and control steppe or forest fire, to distinguish snow covered and sandy areas.

Though we do not produce surface temperature map every day but using AVHRR data we control and analyze surface temperature over whole territory of Mongolia and a technology for mapping of surface temperature determination, considering an emmisivity of various natural and artificial objects. The accuracy of derived surface temperature is $\pm 3^{o}C$ (Oyun, Altankhuyag, Tuya, 1991).

However, there still not yet exist environmental ground observation stations in those parts of Mongolia, where impossible or difficult to reac.. and carry out any observation, for example high mountains, dry and hot desert, big lakes and density forest, the use of NOAA-AVHRR data is desirable for observing Global daily surface temperature and its dynamics. Also the daily temperature estimation of various landscapes gives possibilities to detect the appearance of surface temperature anomalies, to extend ground measurement data range in terms of times and spaces. In case of surface temperature determination we have used radiance temperature, derived from channels 3, 4, 5 of AVHRR data, corrected by ground measurement data.

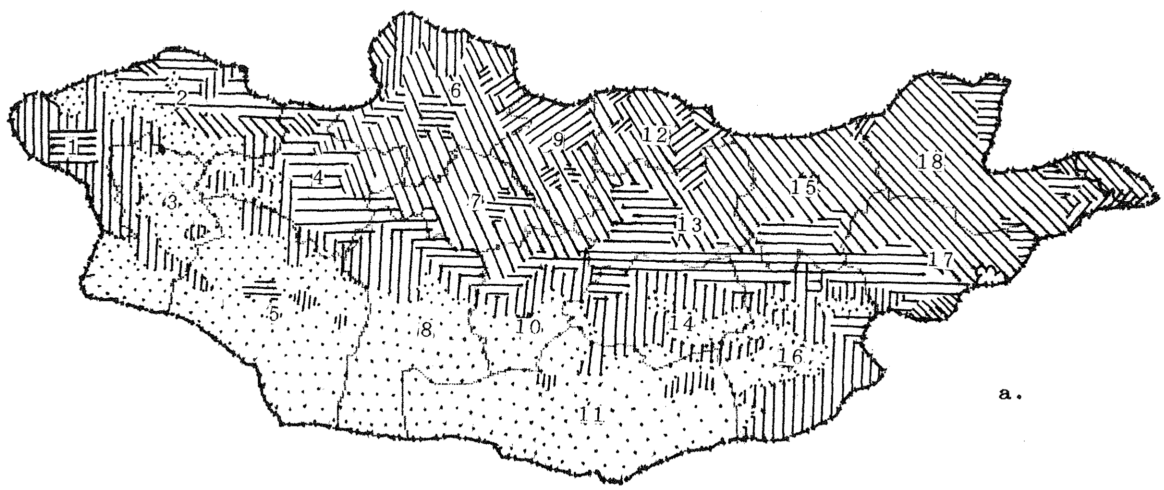
The analysis, carried out in mountain area show there is a daily temperature dynamics at the top of mountains but its amplitude is decreased with increasing of elevation. In July daily temperature dynamics at highest picks in Mongolia (Munkhkhairkhan 4204m and Tavan-Bogd 4374m) ranges 10-12^{o}C and in October 9-10^{o}C, respectively.

Integral temperature map in 7 January 1991 is shown in Fig 4. According to temperature range value we identified 6 different classes.

4. CONCLUSION

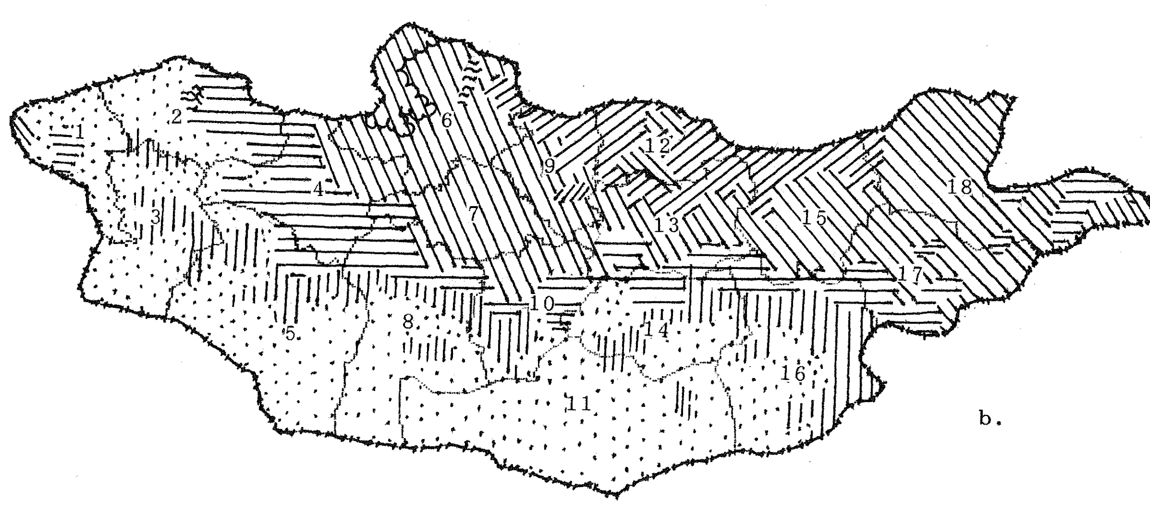
Significant progress has been achieved for observation of dynamic characteristics in various natural phenomena using traditional methods and remote sensing techniques and prepared information allows to effectively monitor and forecast environment changes, to generate database for natural resource, to manage agriculture and other economic branches.

The above mentioned surface characteristics had been studied independent-



a.

Classes	Region number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0.00-0.04	29	23	59	18	72	11	2	60	3	36	73	0	4	35	4	37	4	3
0.05-0.10	29	21	20	26	17	14	8	22	5	26	16	1	10	48	8	49	15	9
0.11-0.20	29	30	15	27	6	24	24	12	17	18	4	13	33	16	24	13	36	18
0.21-0.40	13	20	6	26	3	39	54	6	45	17	4	50	45	1	54	1	45	60
0.41<	0	6	0	3	2	12	12	0	30	3	3	36	8	0	10	0	0	10



b.

Classes	Region number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0.00-0.04	68	43	59	26	60	16	23	54	5	40	86	0	2	44	0	44	0	4
0.05-0.10	14	21	24	19	22	8	13	20	6	28	10	0	5	34	2	40	2	6
0.11-0.20	14	24	13	33	13	18	21	18	12	16	4	2	25	20	9	14	36	14
0.21-0.40	4	12	4	22	5	48	39	8	43	15	0	29	51	2	73	2	62	75
0.41<	0	0	0	0	0	10	4	0	34	1	0	69	17	0	16	0	0	1

Fig. 3. Vegetation cover maps and percentage of vegetation cover classes in every administrative regions. a. 17 June 1991. b. 7-12 September 1992.

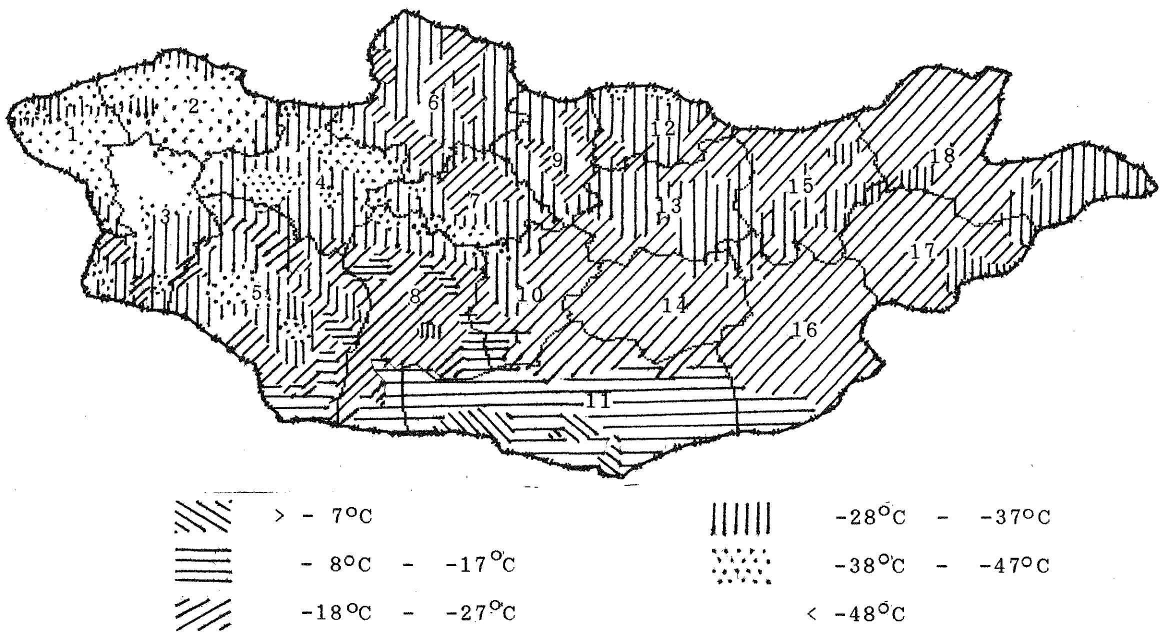


Fig. 4. Surface integral temperature map in 7 January 1991(15.00 h).

ly, though actually, they are closely related and changed depending on each to other. Therefore, continueing our study we will connect and integrate meteorological, geographic information and remotely sensed databases and develop estimation models for water and heat resources and livestock fodder.

These models will be background of the Monitoring system and their main potential benefits is in improving thematic mapping and monitoring accuracy, predicting future resource availability and condition, saving founds and providing by important resource information for decision making, effective organization of economic policy and nature resource management.

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