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Project Report on an Oasis-region

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Research Team for the Oasis Project
Research Institute for Humanity and Nature

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Contents

Preface

NAKAWO, Masayoshi
(Research Institute for Humanity and Nature)

In April 2001, Research Institute for Humanity and Nature (RIHN) was founded in Kyoto, Japan as one of the inter-university research institutions. It is dedicated for carrying out integrated research for the innovation of a discipline that would give us the solution to the so-called environmental problems or global issue. In order to found the new discipline, the institute started implementing several projects which make a new integrated approach bringing together different disciplines from the so-called natural sciences, social sciences, humanity studies, and other fields.

The project "Historical evolution of the adaptability in an oasis region to water resource changes", which is shortened as "Oasis Project", is one of the projects of RIHN. It was initiated as a feasibility study in 2001 fiscal year, while cooperative researchers in both Japan and China were organized, in addition to a preliminary field trip to the Heihe Basin in western China, which is the major field of the project. During the last one year, in addition to business meetings for the implementation of the project, several study meetings were convened where mutual understandings between researchers of different disciplines were built up by introducing one's own research method or presenting the contribution of each field to the project. For promoting the mutual understanding and consolidating the research team, we started publishing a kind of periodicals named "Project Report on an Oasis-region", abbreviated as "PRO". So far two volumes have been published in Japanese, including presentations given at the study meetings.

This third volume was planned to publish in English in particular for those who do not read Japanese. It includes an introduction of the project, and the presentations given at the 4th and 5th study meetings, in which the former was conducted as International Workshops for Heihe Basin in January 2002.

I hope that this volume would help the team members as well as general readers to understand this challenging and enthusiastic project, and to promote further the project in a proper way which RIHN wishes to establish.

Historical evolution of the adaptability in an oasis region to water resource changes
— the scheme and the introduction of the project —

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Outline of the project:

(Objective)

The location of oases and people's lifestyles have been greatly changed historically in response to the water resource changes associated with global change in the arid and semi-arid regions of central Eurasia. The present project examines the historic interaction between humans and natural systems, by analyzing historical documents and a variety of proxies, in addition to analyses of the present adaptability of the region to water resource changes essential for people's life.

(Methodology)

Water resources in the region considered are mainly the precipitation in the mountains and the melt water of glaciers, which change in response to global climate change and possibly a change in lifestyle of the people in the region. People have used the limited amount of water resources and developed their own culture by adapting to the changes in water resources. In the present project the historical change of both water resources and water demand/utilization is investigated by analyzing historical documents as well as a variety of proxies such as ice cores, lake sediments, tree ring samples and wind brown deposits. For interpreting the information, current processes of water circulation systems including the social utilization of water, are investigated with field observations: precipitation process, accumulation and ablation process of glaciers, river and ground water discharge processes, irrigation and evaporation/transpiration (evapo-transpiration) process, *etc*. Through these investigations, the adaptability of water resource changes of the region is assessed historically, and a model for evaluating this adaptability is developed to examine the mode of living in the region for future generations. The study, hence, will elucidate the historical process of cultural development and the criteria that decide the lifestyle of the people in the region, which should contribute to finding a desirable mode of living for the future.

(1) A drainage basin is selected in the arid and semiarid regions in central Eurasia, and each process in the water circulation system, such as precipitation process, glacier melt process, discharge process of surface and ground water and evapo-transpiration process in the irrigation system *etc*., are observed, and the causes for changes in the water circulation system are investigated.
(2) The water demand/utilization processes in the region is examined in such activities as irrigated agriculture, nomadic activities, forestry, industry and the other businesses. The conflict and/or the mutual cooperation between these water utilizations are investigated in relation to the social system, religion and cultural situation in the region through such studies as socioeconomic analysis.
(3) Historical documents and various proxies (ice core, tree ring, lake sediment and wind brown deposit *etc*.), obtained in and around the region, are analyzed to reconstruct the historical evolution of water resources and water demands in addition to archaeological investigations. For interpreting these sporadic data, the studies mentioned in (1) and (2) above are essential.
(4) Based on these results, a model is developed for analyzing the historical adaptability to water resource changes, and examine a suitable mode of living in the region for the future.

(Expected Results)

By examining the history of the interactions between humanity and nature in arid and semi-arid regions in central Eurasia, where the social and natural systems are significantly vulnerable to water resources changes, it would be possible to model the interaction and the validation. To develop a historical perspective of this interaction would provide an important clue for human beings at present, who face serious global environment problems, how to live with their environment, and to potentially create a new concept of living for a well-adapted future capability.

(Why arid and semi-arid regions in central Eurasia)

Central Eurasia is a region where people have been most active historically, living mainly in either farming or nomadic activities. The mixture of the both cultures and the people have produced new types of human cultures by becoming acclimated to the nature of the region. Central Eurasia has been considered the region where information and a variety of goods representing the culture of the West and the East have passed through, having helped an exchange between the two. It has been pointed out recently, however, that it is not only a transit region, but the people in the region have assimilated the information successfully, and developed their own outstanding culture, having been the leading people in the human history of our planet. In addition, "advanced" industrial activities have intensified recently, which presumably have caused the "environmental problems" of the region. One of the advantages lies in that a number of documents written in Chinese, Persian, Turkish and other languages describe the history for about 2000 yeas of the region, which is essential for the present study.

Outcome of the feasibility study in 2001 fiscal year:

(Outline)

The research team has been organized and the implementation plan made. Namely, research institutions in China have been investigated to determine their level of cooperation, and a drainage basin was selected for the major field work. The availability of historical documents and various proxies were examined in and around the basin, and a preliminary field investigation was made. The results have been reviewed by the research team to create an implementation plan for the 5-year project.

1. Collaboration with Chinese institutions

The present project requires a very large study area spectrum covering natural sciences, social sciences and human sciences. It was considered difficult, therefore, to collaborate with a single institution in China on the project. The following institutions were hence visited to discuss the potential collaboration: Chinese Academy of Sciences (CAS), China Meteorological Administration (CMA), Institute of Geographical Sciences and Natural Resources Research (IGSNRR), Nanjing Institute of Geography and Limnology (NIGL), Nanjing Institute of Hydrology and Water Resources (NIHWR), Tsinghua University (TU), Institute of Modern History (IMH), Institute of Archaeology (IA), Institute of History (IH), First Historical Archives of China (FHAC), Institute of Nationality Studies (INS), Cold and Arid Regions Environment and Engineering Research Institute (CAREERI), Lanzhou University (LU), Northwest Normal University (NNU), Institute of Geochemistry (IG), China Institute of Water Resources and Hydropower Research (CIWRHR), and Inner Mongolia Autonomous Region Historical Relic Engage in Archaeological Studies Research Institute (IMARHREASRI). Also the potential for the collaboration was discussed with researchers from Hunan Normal University (HNU), Institute of Global Environment (IGE), Central University of Nationalities (CUN) and Nanjing University (NU). All the institutions were very responsive to the collaboration.

As will be described later, the Heihe River Basin was chosen for the main field, and CAREERI and INS were considered core institutions for the collaboration, because they had accumulated much research experiences, and are still active in field research in the basin. In addition, the following institutions were considered appropriate to initiate collaboration: IGSNRR, NIGL, IA, IH, NNU, NU, IG, HNU, CUN, LU, IMARHREASRI, FHAC and NU. Collaboration agreement has been already signed between the Research Institute for Humanity and Nature (RIHN), and CAREERI and INS. Implementation agreement was also signed with NU, NIGL. This type of agreement will also be singed with the other institutions as necessary. Additional institutions may be involved for collaboration as the project evolves. Table 1 shows a list of major researchers and their institutions.

Table 1 Major collaborating researchers in Chinese institutions

氏　名	FAMILY, Given name	Institution	Major research fields
程　国棟	CHENG, Guodong	CAS, Lanzhou	Analysis of water demand
姚　檀棟	YAO, Tandong	CAREERI	Ice core analysis
康　尔泗	KANG, Ersi	CAREERI	Water circulation analysis
丁　永建	DING, Yongjian	CAREERI	Water circulation analysis
張　斉兵	ZHANG, Qibing	CAREERI	Dendro-chronological analysis
夏　軍	XIA, Jun	IGSNRR	Water circulation model
李　世傑	LI, Shijie	NIGL	Lake sediment analysis
万　国江	WAN, Guojiang	IG	Isotope analysis
袁　　靖	YUAN, Jing	IA	Pollen analysis
張　万昌	ZHANG, Wanchang	NU	Remote sensing
時遠	HAO, Shiyuan	INS	Socioeconomic analysis
色　　音	SAIN	INS	Social anthropological analysis
鍾　進文	ZHONG, Jinwen	CUN	Nomad analysis
李　并成	LI, Bingcheng	NNU	Archaeological studies（Gansu)
謝　自楚	XIE, Zichu	HNU	Ground water analysis
魏　　堅	WEI, Jian	IMARHREASRI	Archaeological studies（Inner Mongolia)
呉　元豊	WU, Yuanfeng	FHAC	Document analysis (Qing Dynasty)
陳　高華	CHEN, Gaohua	IH	Historical documents analysis

2. Study basin

Based on information at hand and obtained at the above Chinese institutions, three drainage basins, Qira Basin at the southern end of Taklamakan Desert, Ili Basin in Junggar, and Heihe Basin in both Gansu and Inner Mongolia (Fig. 1), have been examined to identify the most suitable basin for field investigations. The examination was made in terms of the size, social situation, irrigation system, size and extent of nomadic activities, accessibility to the mountain range, and the distribution of meteorological, hydrological and ground water observatories. It was concluded that the Heihe basin is most suitable for the observation in the present project. The Ili Basin, however, is considered to compare with the Heihe Basin. It would be desirable, therefore, to concentrate the observation mainly in Heihe, but complimentary observations are to be conducted in the Ili Basin as well. A preliminary field investigation was carried out in the fall of 2001 to identify the locations of additional instrumentation, and to have an initial draft of the research activities planned for 2002.

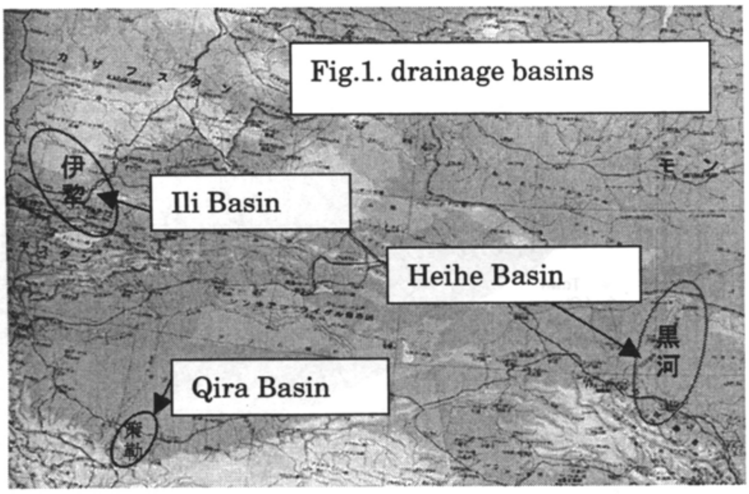
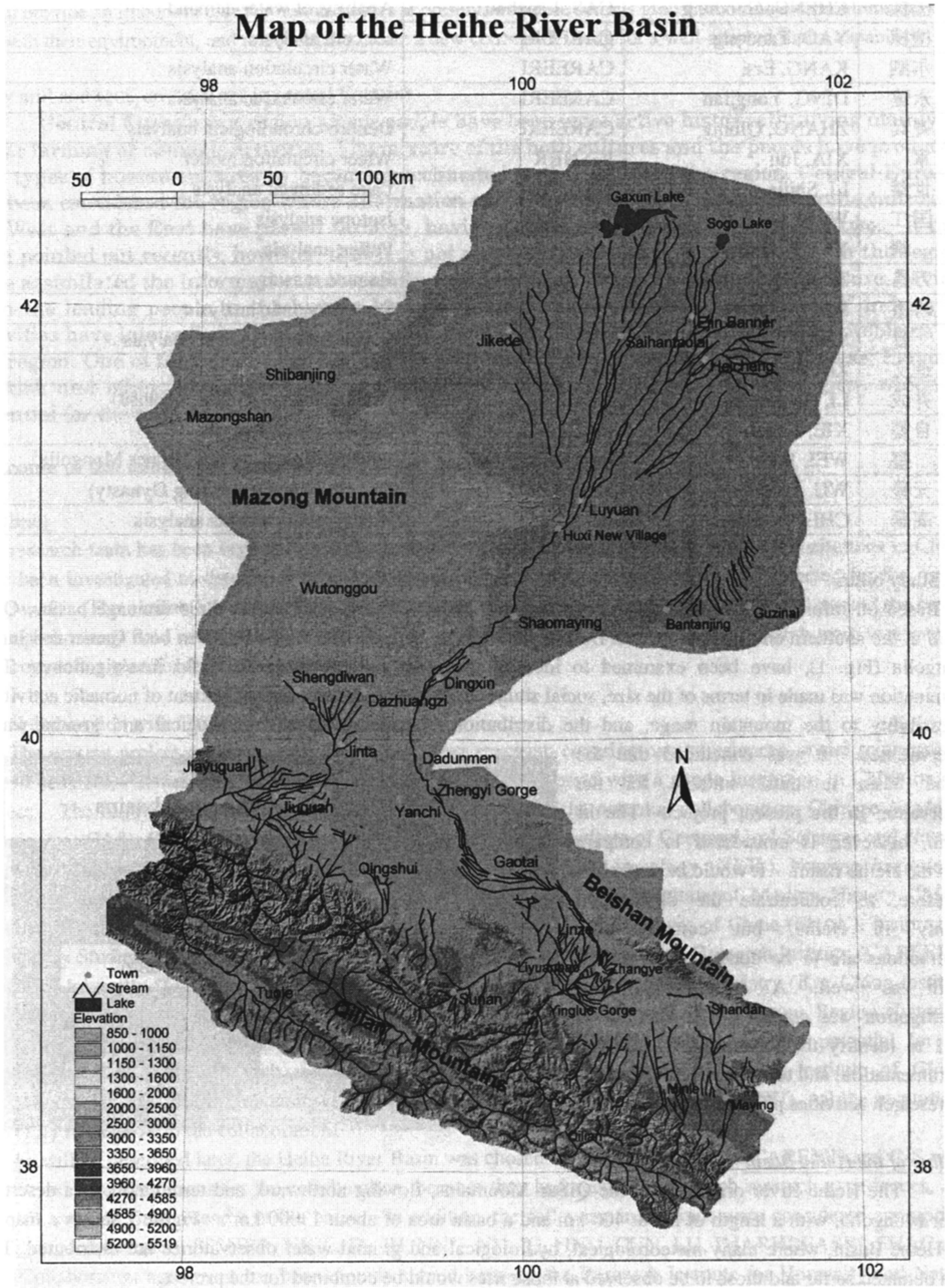


Fig.1. drainage basins

Outline of the Heihe Basin

The Heihe River originates in the Qilian Mountains, flowing northward, and terminating in a desert in Inner Mongolia, with a length of about 400 km and a basin area of about 13000 km^2. Figure 2 shows a map of the Heihe Basin, where many meteorological, hydrological and ground water observatories are distributed. The data obtained so far and those to be observed at those sites would be combined for the project.

Fig. 2


Map of the Heihe River Basin
98
100
102
42
40
38
50
0
50
100 km
Gaxun Lake
Sogo Lake
Ejin Banner
Jikede
Saihantaolai
Haicheng
Shibanjing
Mazongshan
Mazong Mountain
Luyuan
Huxi New Village
Wutonggou
Shaomaying
Bantanjing
Guzinai
Shengdiwan
Dingxin
Dazhuangzi
Jinta
Jiayuguan
Dadunmen
N
Zhengyi Gorge
Jiuquan
Yanchi
Qingshui
Gaotai
Beishan Mountain
Linze
Liyuantang
Zhangye
Tuole
Sunan
Yinglus Gorge
Shandan
Qilian Mountains
Minle
Maying
Qilian
Town
Stream
Lake
Elevation
850 - 1000
1000 - 1150
1150 - 1300
1300 - 1600
1600 - 2000
2000 - 2500
2500 - 3000
3000 - 3350
3350 - 3650
3650 - 3960
3960 - 4270
4270 - 4585
4585 - 4900
4900 - 5200
5200 - 5519

The Research Prevention Research Institute, Kyoto University, in the early 1990s conducted observations on water circulation near Zhangye, one of the largest oases in the basin. This was collaboration with one of the institutes now forming the Cold and Arid Regions Environment and Engineering Research Institute. Their data covers only a couple of years, but their on-aging data are open for public. One example of these data is shown in Fig. 3, where air temperature and precipitation are plotted with solid line and bar, respectively, with gray color for a site in a desert 50 km north of Zhangye and darker color for Zhangye. It is noted that air temperature is 20 to 25 ℃ in summer, and −5 to −10 ℃ in winter. Annual precipitation is about 140 mm in Zhangye, and about 90 mm at the desert station. Precipitation takes place mainly in summer season at both stations.

River discharge is shown in Fig. 4 for both upstream (Yingluo Xia) and downstream of Zhangye (Zhengyi Xia). At the former site, the discharge is about 60 m^3s^{-1}, and the division of the figure by the area of the basin upstream of the observation site resulted in the annual precipitation of about 600 mm. This indicates that the precipitation at high elevations is very significant, since it is only about 100 mm/year near and downstream of Zhangye. This is demonstrated in Fig. 5, where altitudinal distribution of precipitation is shown. As mentioned above, annual precipitation at elevations of about 1500 m, where Zhangye is located, is about 100 mm, while it increases almost linearly as the elevation increases. An extrapolation of the linear trend gives the annual precipitation of about 1000 mm at the elevation of 4000 m, which is roughly the height of the peaks of the Qilian Mountains. It is considered, therefore, that the water available for people comes mainly from the mountains.

Discharge becomes higher in summer at a site upstream of the oasis, and also in winter at a site downstream, as shown in Fig. 4, indicating that significant amount of water is taken out of the river by the people in the oasis in summer. One of the results uncovered by Kyoto University and the

Fig. 3. air temperature and precipitation

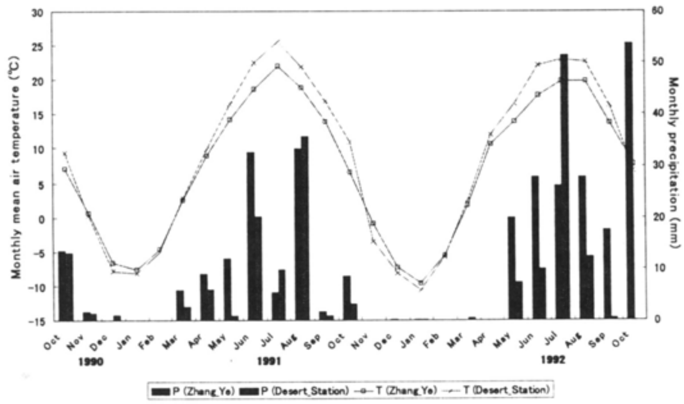


Fig. 4. Discharge of the Heihe River

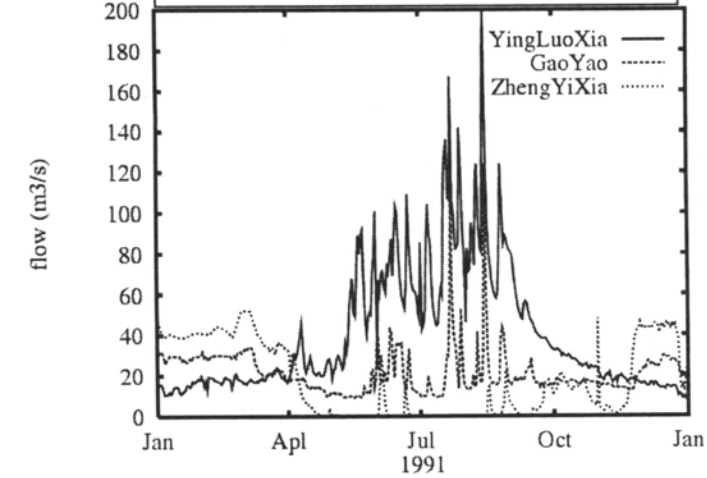
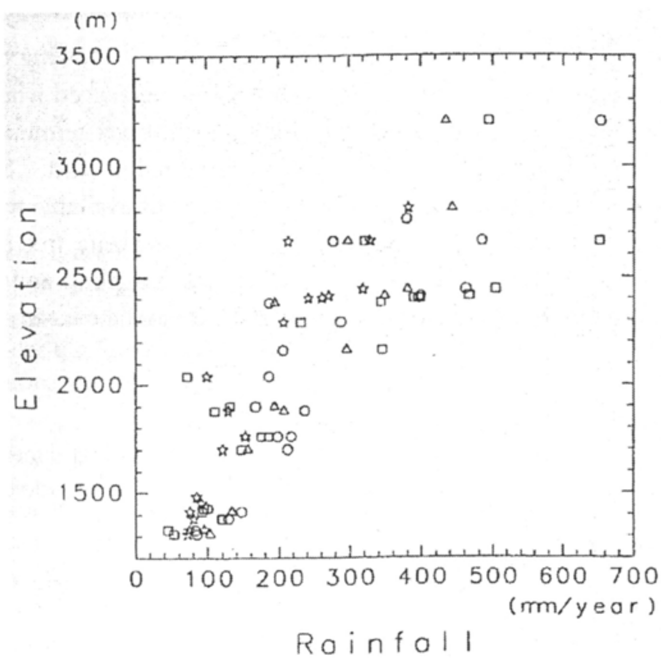


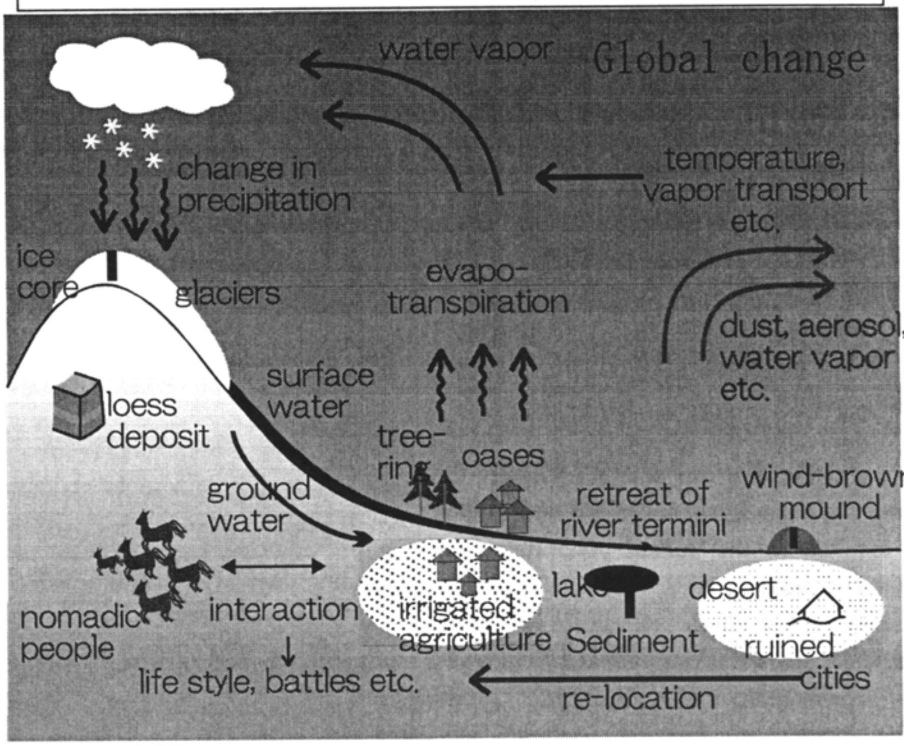
Fig. 5. Precipitation



present CAREERI indicates that annual evapo-transpiration is roughly 500 mm over farmland in the oasis, and about 100 mm even in the desert. Since annual precipitation is about 100 mm near and downstream of Zhangye, the precipitated water is just evaporated toward the atmosphere. The water used for additional evapo-transpiration of about 400 mm in farm land, which is the water used for farming, is compensated by the river flow from the mountains originating in precipitation in the mountains and the melt water of glaciers. The discharge at a site downstream of the oasis increasing in winter seems to indicate that the water stored in soil in summer comes back to the river downstream.

Preliminary investigation of the region, made in the fall of 2001, indicated that the drainage basin can be divided into 5 different zones depending upon altitude. ①mountain zone where glaciers are located and almost no people stay; ② piedmont zone where nomadic activities are intense; ③ oases zone where irrigated farming is predominant with only recent industrial activity; ④desert zone, but where irrigated farming has increased rapidly; and ⑤ terminal zone where both farming and nomadic activities were predominant, but shortage of water became significant recently.

Fig. 6. Schematic representation of the basin



A schematic representation of the basin is shown in Fig. 6. Appreciable precipitation takes place in the mountains mostly in the form of snow, part of which is trapped in glaciers. They are the major water resources of the discharge through rivers and ground water flow. Flowing downward, the water is lost through evaporation and transpiration toward the atmosphere, which is enhanced when an irrigation system is developed. As the result, discharge water decreases downstream, and the river terminates inland where lakes are sometimes formed. There are many ruined cities, some of which are buried in sand. Some of the cities appear to have relocated upstream, probably because of the change in the amount of available water. In the basin, there are many sites where many proxies such as ice core samples, wind brown deposits, tree ring samples, lake sediments are available. These will be described in the following section. The sampling and analyses of the proxies will provide useful data to compare with document records left in and around the basin.

3. Availability of hisorical materials

With data at hand, the availability of historical documents has been examined. The results are shown in Table 2, where the amount of data available is given for various languages and time span.

Archaeological materials:

Found mostly in ruined cities and tombs. In the early stage, bronze works and letters carved on bones and tortoise carapaces are typical. Since AD, varieties of daily tools and equipment have become available. Relic houses are found during any era. After the 16th century, archaeological materials are rarely available partly because of the personal rights of the descendants.

Table 2. Availability of historical materials

	Archaeological materials	Chinese sources	Mongolian sources	Uighur sources	Turkish sources	Tangut sources	Tibetan sources	Manchurian (Jurchen) sources	Persian sources	Arabic sources	Visual materials
Prehistorical age	○										△
B.C.8c-3c	○	△									△
B.C2c-1c	○	○									○
A.D.1c-2c	○	○									○
2c-5c	△	△							:		△
6c-750	○	○			△		△		:		○
750-900	○	◎			△		△		:	△	○
900-1100	○	◎		△		△	:		△	△	◎
1100-1200	○	◎		△		○	:	△	△	:	◎
1200-1400	○	◎	△	△		○	△	△	△	:	◎
1400-1600	○	◎	△				△	△	:	:	◎
1600-1750		∞	△				△	○	:	:	◎
1750-1900		∞	○		△		△	◎	△	:	◎
1900-		∞	○		○		○	◎	△	:	∞

Availability: ∞enormous ◎enough ○significant △some :little

Chinese sources:

Historical documents written with Chinese Characters, including authentic records, which is the history from the viewpoint of Chinese Dynasties. The history of the arid and semiarid regions in central Eurasia is described as well. Since systematic descriptions about the region have not been found, it is essential to examine authentic Chinese history. The other types of edited history become richer as time passes. For certain eras, original documents are available. Inscriptions on pieces of wood and bamboo in the era of Qin to Wei Dynasties, Heicheng Documents in the era of Xixia and Mongol, archives of the Qing Dynasty, and carved documents on stone monuments after the Tang Dynasty are examples. These original documents are crucial for reconstructing the social situation in the respective time periods.

Fig. 7. Cover page of published documents found at Heicheng City

Mongolian to Arabic sources:

Major documents are edited historical texts, which, however, include original data sometimes and reliable hearsay information. Carved documents on stone monuments are also very informative. Languages used in the area under the Qing Dynasty are available in archives of the dynasty after the 18th century.

Visual articles

Portraits and other illustrations carved on brick surfaces are often found for the Han Dynasty. Those found in Gansu and Shanxi Provinces are famous, with which detailed information about food; and clothing and even houses can be obtained for the era. Wall paintings r drawings found in tombs corresponding with various times and places are also very informative. It should be noted that pictures in general are of value not only from the viewpoint of art but also as a historical information source, which show life at the time in question. In the 20th century, the amount of visual articles increases rapidly because of innovation in photograph and film. In the early stage, westerners and Japanese left those pictures to record their exploration in China or to satisfy their curiosity, but in the later stages, local people take pictures for their own records.

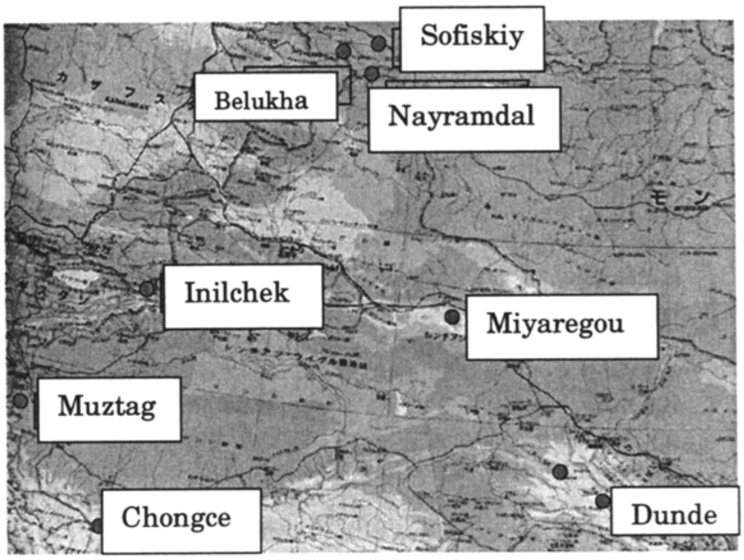
The availability of those documents and articles has been investigated, particularly in China, when the institutions given above were visited. Original documents were found at Juyancheng and Heicheng cities from the Heihe Basin, corresponding with the Han Dynasty and the Xixia-Mongol era, respectively. They have already been compiled in particular those written in Chinese characters, and published. Figure 7 shows a cover picture of the published documents obtained at Heicheng City. Official documents in the Qing Dynasty are kept in the First Historical Archives of China in Beijing, and most of them are found available for looking through, copying or photographing. They include meteorological and glaciological data in and around the Heihe Basin for the period from 1765 (Qianlong 30) to 1908 (Guangxu 34).

4. Availability of proxies

The availability of various proxies such as ice cores, lake sediment cores, wind brown deposits, and tree ring samples, has been examined in and around the Heihe Basin as described in the previous report. It was found that ice cores can be obtained at the Qilian Mountains, and lake sediment cores at Juyanze Lakes. It is considered desirable, however, to take multiple samples in order to get rid of the local effect for any proxy. The other potential sites for ice core retrieval are located in the Altai Mountains and the East Tianshan Mountains, and for lake sediment cores, at Jilantai Lake. The preliminary field investigations revealed that tree ring samples can be obtained from the Qilian Mountains as well as Ejina, near the Juyanze Lakes. This would allow us to carry out the inter-comparison between the records from different proxies.

The potential sites for ice core sampling are shown in Fig. 8. There are two sites in the Qilian Mountains: one at Dunde Ice Cap and the other glacier about 100 km northwest from Dunde. A China-US joint party has taken ice cores at Dunde Ice Cap in 1985. Detailed information is hence available for additional retrieval of ice samples for the present project. The latter site in the mountains, whose name is unknown, was suggested by CAREERI, but preliminary investigation would be required before the actual coring.

Fig. 8 potential sites for ice core retrieval

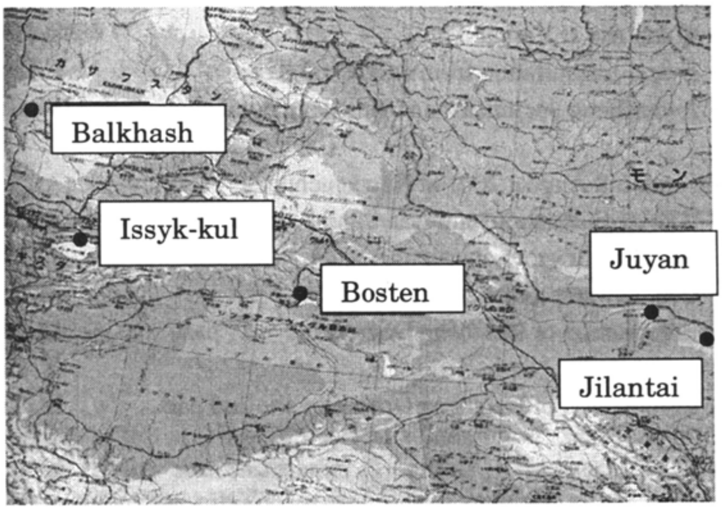


A joint team of Japan, US and Russia was organized and sent to Belukha in the Altai Mountains in the summer of 2001 for preliminary investigations of the site, such as installation of automatic snow depth gauge, ground survey and radio-echo sounding of the glacier. A 18-m long ice core has been retrieved and brought back to Japan. The sample was subjected to an analysis jointly with a team from the National Institute of Polar Research who obtained a 12.3-m long ice core from Sofiyskiy Glacier also in Altai. Glaciers in the Nayramdal Mountains have been investigated from a helicopter for identifying potential glaciers for future ice coring in July, 2001. The helicopter landed at two sites in the Russian Altai, and snow pit observations were made including the measurement of temperature distribution in the surface snow layers. The results, however, indicated no suitable coring site on the Russian side. From a view from the flight observation, there could be an attractive site for coring on a Potanina Glacier, which, however, is located in Mongol. Further examination would be required for an ice sampling in Mongol. Miyaregou Ice Cap in the East Tianshan Mountains is considered a promising site, but a preliminary study is necessary for this site as well. Previous reconnaissance indicated that the support of a helicopter was necessary for coring at the ice cap, and the feasibility of hiring a helicopter from the Chinese Army was investigated. The army's reply was favorable for the use of a helicopter for the transportation of equipments or ice samples, but the feasibility has to be checked prior to the actual operation, which is to be done later.

In the southwestern region, a US party succeeded, in 1998, in obtaining core samples from the Inilchek Glacier in the West Tianshan, and the data would be available shortly. From the Muztag Mountain, a China-French party plans to retrieve samples in a few years. Chongce is an ice cap where Japan has experience in obtaining cores, and the information for retrieval of another core is sufficient.

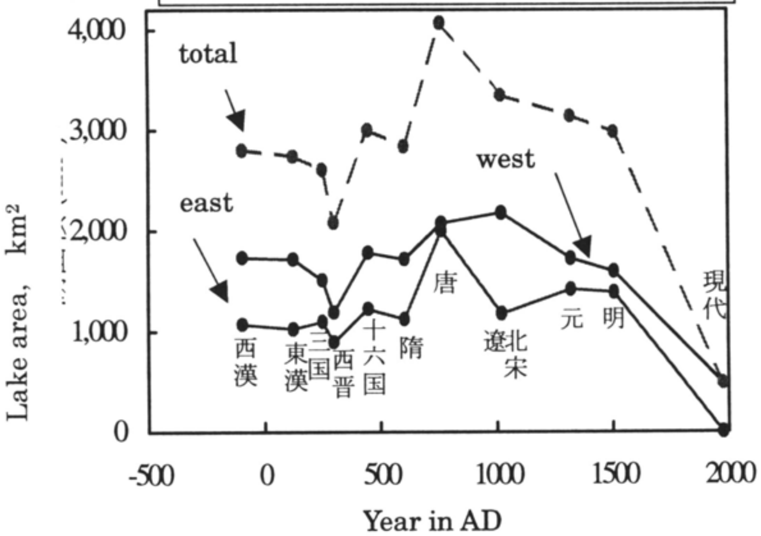
Possible sites for lake sediment sampling are shown in Fig. 9. A sampling from the Jilantai Lake was suggested by NIGL. A reconnaissance party, therefore, was sent in 2001. Preliminary analysis of the sediment core samples taken in 2001, however, showed that the laminar structure was disturbed, presumably because the core site was far from the center of the lake.

Fig. 9 potential sites for lake sediment samples



The Juyanze Lake, located at the terminus of the Heihe River, is considered an excellent site for the sampling for the present project. It used to be a one large lake, but was divided into two lakes, one to the east and one to the west. Referring to the Historical Atlas of China edited in the 1970s to 1980s and published in 1996, the temporal change of the lake area was investigated. The results are shown in Fig. 10. Because two lakes are plotted in the series of maps, the area of respective lakes are shown in Fig. 10 together with the total area. It is difficult to evaluate the reliability of the maps at present, but the lake area seems to have increased toward the 10th century, and become smaller afterwards. The disappearance of the eastern lake was reported to have occurred in 1998. Sampling from the already dried-up lake bottom is very easy. The site has been visited by a reconnaissance party, and it is feasible to obtain samples in 2002.

Fig. 10. evolution of lake area



Looking at the west, a sampling was carried out in early 1990s at the Bosten Lake, and it can be a potential site. For information about Ili Basin, Balkhash Lake in Kazakhstan and Issyk-Kul Lake in Kirgiziya could be the potential sites.

5. Planning for 2002 activities

The specialties of the researchers, listed in the Annex, who are going to promote the present project, are quite different each other. The objectives and mission of the project, however, should be commonly realized and understood by every participant. So far, three meetings by all members were held, and research tools and expertise for individual discipline were discussed, to assist common understanding. In addition to several intra-discipline meetings, the steering committee including members who represent each discipline, has been held six times, and implemented a feasibility study in 2001. Also, a study meeting was initiated where various documents written with various ancient languages are translated into modern Japanese by members able to read them, and the content is discussed by all members including natural scientists who have no other way to receive this information. A study meeting was held three times in 2001, and for the forth, an international workshop was held in January 2002, inviting 6 researchers from China. In the workshop, the knowledge about the project was updated, and further planning for the 2002 activities was discussed. The fifth meeting was held in March 2002. Followings are the list of presentations made in the study meetings so far. The Project Report on Oases-region (PRO) was published for mutual understanding between the participants, as a periodical, which contains mainly the presentations at the study meetings.

List of Study meetings during 2001 fiscal year

First, 13 July 2001 at Nagoya University

- Water use at Yarkand — S. Hori
- Evapo-transpiration from desert and oasis — I. Tamagawa
- Juyancheng documents and Heicheng documents — M. Sugiyama and T. Furumatsu

Second, 6-8 August 2001 at Kawaguchiko

- Glacier fluctuation, and water and heat budget — A. Sakai
- Behavior of groundwater — T. Akiyama
- Groundwater analysis — M. Tsujimura
- Introduction of Heicheng Documents 1st part — M. Sugiyama, T. Kinoshita, T. Furumatsu, and Y. Kato, S. Arakawa
- Introduction of Heicheng Documents 2nd part — M. Sugiyama, T. Kinoshita, T. Furumatsu, and Y. Kato, S. Arakawa
- The life and culture of nomads — Y. Konagaya
- Environment change in the last 2000 years revealed by ice core analysis — Y. Fujii

Third, 27 December 2001 at Kyodai Kaikan

- Preservation of farmland at Niger, western Africa — T. Nagano
- Reconstruction of past environment by sediment core analysis — K. Endo
- Water circulation in arid and semi arid region — Y. Ujihashi

Forth (International Workshop on Heihe) 7-9 January 2002 at Kyodai Kaikan

- Historical aspects of arid land in western China (E)
  S. Hori (Konan U.)
- A preliminary study on the history of desert regions in Heihe Basin (C)
  Li, Bingcheng (Northwestern Normal U.)
- Hydrological studies in the Heihe basin, western China (E)
  Kang Ersi (CAREERI)
- Social and human caring for optimizing ecology along Heihe Basin (C)
  Zhong, Jinwen (Central U. Nationalities)
- Agricultural development and the desertification in Inner Mongolia (J)
  Sain (I. Nationality Studies)
- Ancient fauna of China's Northwest (J)
  Yuan, Jing (I. Archeology)
- Reconstruction of climate and environment in western China by sediment core analysis (E)
  Li, Shijie (NIGL)
- The ecohydrological variation and the relocation of ancient oases along the southern edge of Taklimakan Desert (J)
  G. Omar and H. Takamura (Rissho U.)
- Water qualities and stable isotope compositions of river water and groundwater in the Keriya River Basin, Xinjianng, China (E)
  H. Takamura (Rissho U.) and, T. OHTA (U. Tokyo)

Group Discussion for making the implementation plan of 2002 field activities

- Sediment Core Group (Chair: K. Endo)
- Hydrology & History Group (Chair: J. Kubota)
- Ethnology Group (Chair: T. Ozaki)

General Discussion

Fifth, 12 March 2002 at Kyodai Kaikan

- Documents of Qing Dynasty kept in First Historical Archives of China
  Wu, Yuanfeng (FHAC)
- Mongolian nomadism - ethnological survey of Mongols
  -B.-O. Bold (NRC, Iceland)
- Remote sensing data analysis for water circulation in Heihe
  Zhang, Wanchang (NU)

The meetings with all members, and the steering committee also are going to take place to have a final plan for the implementation of the project.

The status of the present project:

Within the program of historical time research axis

The present project is placed within the framework of the program "Historical validation of 'sustainability' and 'development' through the interactions of human activity and changes in the global environment." The program plans to elucidate the evolution of the culture and the criteria for deciding people's lifestyle, which should contribute to examining a desirable mode of living for the future. The program plans to cover a time period of about 2000 years in the past, because written documents are available in that time period in general, without which detailed study is considered difficult. It is planed also to concentrate the study on the arid and semi-arid regions in central Eurasia, because Central Eurasia is the region where people have been most active historically and our present culture is considered to have descended from those developed in the region.

The present project is the first project being implemented within the framework of the program, and hence the project tries to cover the full period, *i.e. ca.* 2000 years. This is because that the first effort should cover the total period, and following projects should concentrate on a certain time periods of importance when so identified as a result of the first project. The main field of the present project is the area where a distinguished culture has been developed from the overlapping two different western and eastern cultures. At the same time, this area is a place where northern and southern cultures have crossed over as well. In other words, the Heihe region was the intersection of different cultures and played an invaluable role for cultures of any region of the world except the New World. It is crucial to start with the most important region first, and then to extend the study area to another region for comparison after appreciable results are obtained.

Relation with other projects underway

For forming an academic foundation to develop measures for solving global environmental problems fundamentally, the Research Institute for Humanity and Nature focuses on research to elucidate the "circle of interactions between humans and natural systems." Five programs have been put in place corresponding with the following five research axes: 1. Environmental change impact assessment axis, 2. Human activity assessment axis, 3. Spatial scale axis, 4. Historical time axis, and 5. Integration axis. The first two are kinds of process studies, missing ring for understanding the interaction. The third examines the relation of global phenomena to those taking place on a local scale, and regarded rather important by local people. The forth looks at, in particular, the time evolution of the interaction, and the fifth tries to integrate the results of the programs placed in earlier four axes. Taking into consideration the research plan of the institute, where different programs complement each other to realize the mission of the institute, the relation of the present project placed in the fourth program with the other projects placed in other programs implemented in 2001 is mentioned below.

Research elements are schematically shown in Fig. 11, where two major components of the project are presented: reconstructing the past history of the interaction, and examination of the process of interaction at present. The latter studies are crucial for the earlier reconstruction because past data obtained by documents and proxies are rather sparse in time and space.

The process studies include an investigation of how water is utilized in irrigated farming in the oasis region in the Heihe Basin and its relation with the recent climate change. This is very similar to the project "Impacts of climate change on agro-ecosystem in arid areas." The present project would hence contribute to this project because it would provide similar data at a different region in culture from the main fields of the agro-ecosystem project, which are Israel, Egypt, Turkey and nearby these countries.

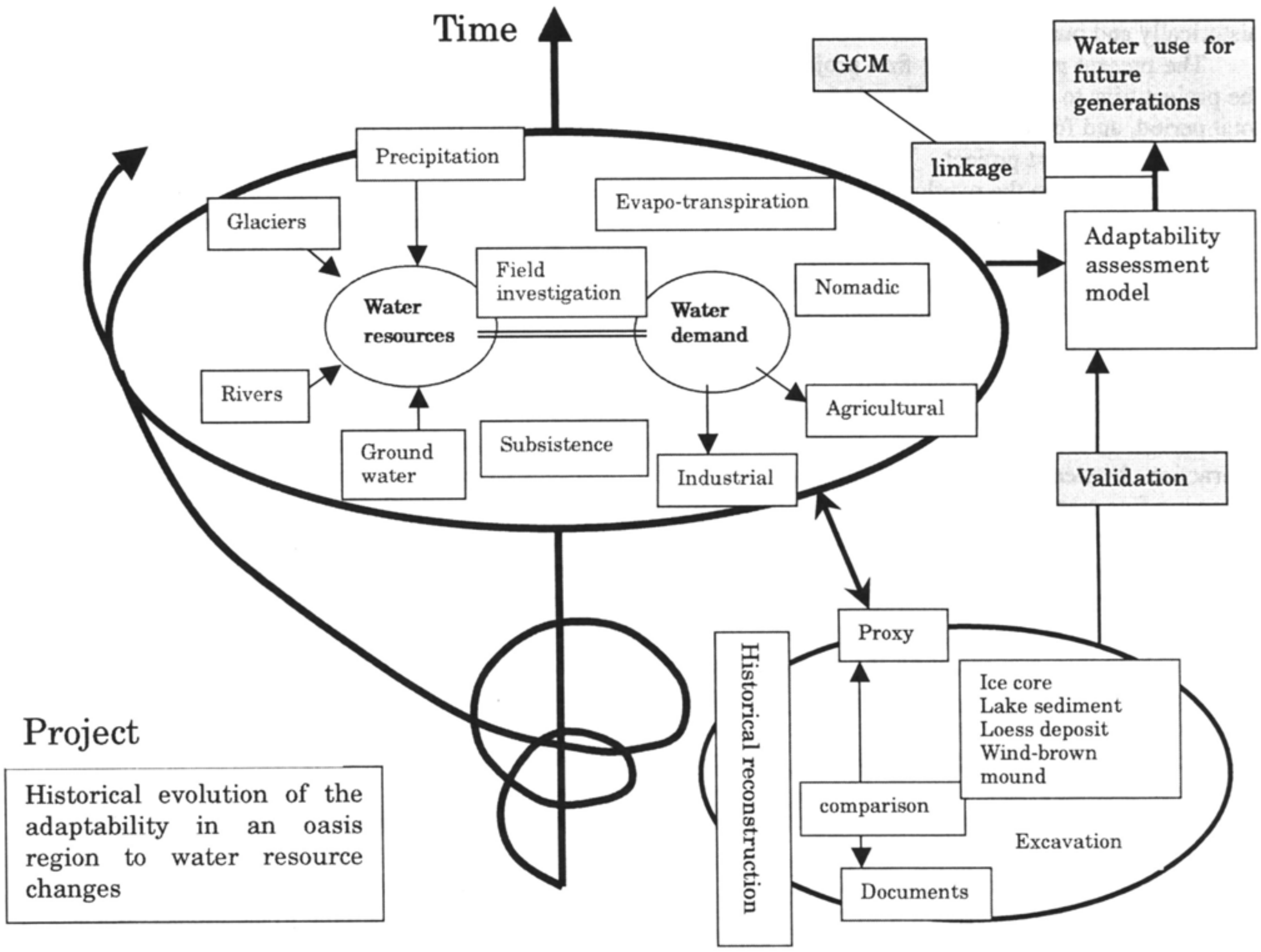
The Heihe Basin is one of the active areas where a significant amount of aerosols and particles are emitted.

The temporal change of the land-use or the desert area, to be examined by the present project, would, therefore, provide a historical point of view to the project "Research on the relationship between human activities and minor constituents in the atmosphere."

The third project, "Multi-disciplinary modeling for understanding interactions between humans and nature in the Lake Biwa-Yodo River watershed" tries to presents possible scenario for the watershed where human impacts are extremely large. This watershed could be the distant future of the Heihe Basin where human impact is not as intense. For examining the future of the basin, the situation in the Lake Biwa-Yodo River watershed is of a good reference, and *vice versa*.

The data to be obtained by the present project should be examined by researchers with many backgrounds. Document data, for example, are to be utilized by say natural scientists, and ice core data, which have been traditionally used by glaciologists only, are to be examined by say historians who have never had access. One of the outcomes of the present project, therefore, is a historical time database with a perspective on water, which is to be used by researchers of any background. The present project would hence contribute to the project, "Integrated water resources management system based on global environmental information library coupled with a world water model."

Fig. 11. Research elements of the project



Annex: List of participants (* steering members)

NAME	Affiliation	Contribution
NARITA, Hideki	Hokkaido University	Ice core analysis
SHIRAIWA, Takayuki	Hokkaido University	Ice core analysis
ENDO, Kunihiko*	Nihon University	Lake sediment analysis
MURATA, Taisuke	Nihon University	Lake sediment analysis
HORI, Kazuaki	National Institute of Advanced Industrial Science and Technology (AIST)	Lake sediment analysis
KOHSHIMA, Shiro	Tokyo Institute of Technology	Biological analysis
NARAMA, Chiyuki	Tokyo Metropolitan University	Geographical analysis
TSUJIMURA, Maki	Tsukuba University	Soil water
FUJII, Yoshiyuki*	National Institute of Polar Research	Ice core analysis
AZUMA, Kumiko	National Institute of Polar Research	Chemistry of ice cores
KOHNO, Mika	National Institute of Polar Research	Particles in ice cores
Huhbator	Showa Women's University	Social system analysis
YANG, Haiying	Shizuoka University	Social system
NAKAMURA, Kenji	Nagoya University	Precipitation
UYEDA, Hiroshi	Nagoya University	Precipitation
OHTA, Keiichi*	Nagoya University	Organic chemistry
FUJITA, Koji*	Nagoya University	Glacier change and ice core
SAKAI, Akiko	Nagoya University	Glacier fluctuation
MIYAKE, Takayuki	Nagoya University	Organic chemistry
NAKAZAWA, Fumio	Nagoya University	Organic ion analysis
AKIYAMA, Tomohiro	Nagoya University	Ground water
TAMAGAWA, Ichiro	Gifu University	Evapo-transpiration
SOHMA, Hidehiro*	Nara Women's University	Historical geography
UJIHASHI, Yasuyuki	Fukui University of Technology	Hydrological model
NAKAWO, Masayoshi*	Research Institute for Humanity and Nature	Data integration
WATANABE, Tsugihiro*	Research Institute for Humanity and Nature	Agro-economic analysis
KUBOTA, Jumpei*	Research Institute for Humanity and Nature	River discharge
YATAGAI, Akiyo	Research Institute for Humanity and Nature	Meteorological Analysis
NAGANO, Takahiro	Research Institute for Humanity and Nature	Irrigation system
KATO, Yuzo*	Research Institute for Humanity and Nature	Chinese documents
TAKEUCHI, Nozomu*	Research Institute for Humanity and Nature	Biological analysis
Mailisha	Research Institute for Humanity and Nature	Nomadic culture
SUGIYAMA, Masaaki*	Kyoto University	Persian documents
YAMAMURO, Shin'ichi	Kyoto University	Politics
YAMANAKA, Ichiro	Kyoto University	Archaeology
FURUMATSU, Takashi	Kyoto University	Chinese documents
ARAKAWA, Shintaro	Kyoto University	Tan gut documents
Kicengge	Kyoto University	Manchurian documents
KONAGAYA, Yuki*	National Museum of Ethnology	Nomadic system
HAMADA, Masami	Kobe University	Uighur documents
HORI, Sunao	Kohnan University	Oasis system
KINOSHITA, Tetsuya	Okayama University	Human philosophy
YOSHIDA, Setsuko	Shikoku-gakuin University	Ecology
KOBAYASHI, Osamu	Ehime University	Dendro-chronology
OZAKI, Takahiro	Kagoshima University	Nomadic system

Historical aspects of arid land in western China

HORI, Sunao
Konan University

Introduction

The purpose of this paper lies in presenting some special aspects of the history in an arid terrain, Central Asia, or Central Eurasia where western parts of China are included, and some problems that seem to be difficult to be solved only by historians, ourselves. (About on the limited problems concerning to water utilization in Yarkand Oasis, References)

In addition to this, I want to show the possibilities of collaborations with natural scientists on the human activities there in the past.

Historical aspects of Xinjiang Area, a part of Central Asia

a. Basic Structure---pastoral nomadism and farming---

The first, Central Asia was different from the place, where people lived in the agrarian society. We can see in Central Asia, people had a society under a peculiar life style, called pastoral nomadism. In the world history, the evaluation of pastoral nomadism is, I think, unfairly low. The reason is that nomadic people did not leave any document and solid heritage because they were disturbances against their moving life. Therefore, we have to rely on records written by agrarian people who had a big prejudice and hostility towards nomadic people. In pre-modern society, the area people only can farm with the rain water was limited in the place with annual precipitation amount over 500mm. The huge area between around Beijing, the east end, to the Danube, the west end, only had less than 500mm. The land with this small amount of rain was called "steppe" in Russian word, reflecting to the natural plants there. People could not plant anything there, and they became nomadic people.

b. Pastoral Nomadism

Pastoral nomadism was a production style that adjusted to the arid land where people could not utilize with pre-modern farming technical skills. Farming was the style people planted edible plants directly on the land. On the other hand, nomadic style was more complex. Firstly, people made their cattle eat natural plants which human beings can not digest. Then after, the milk and meat of these cattle became foods for human beings. This was indirect use of the land and was the consequence of the complex techniques. Therefore, it was naturally considered the pastoral nomadism appeared in between 7th to 8th century B.C., far after the invention of the agriculture in the 80th century B.C.

The main purpose of nomadism was to obtain the milk of herbivorous animals. So the numbers of grown-up female cattle must be bigger than the others. Thus group control and skills to use milk became the basis of the nomadism.

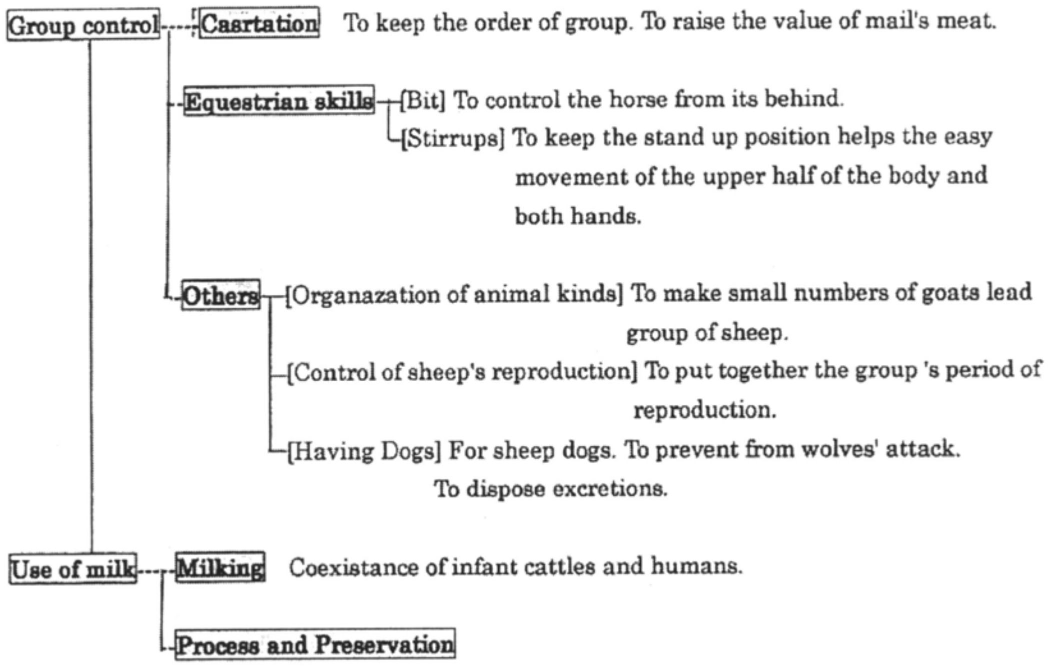
The group control was consisted in the following process and techniques. Selection of cattle is important: it could be sheep, goats, horses, cows or camels. Castration skills needed to control grown-up male cattle's mating and to make them into the group safely. Equestrian skill was used for chasing their cattle that spread over the large steppe.

The use of milk was the complex of the two skills: milking and preservation.

The following Figure 1 shows the diagram of these skills.

Herbivorous animals were not so strong for changes of temperature and small insects. So nomadic peoples must keep seasonal moving to find the suitable place for their cattle, like cool enough in summer and warm enough in winter. This movement was also needed to keep the land in good conditions and clean sanitary conditions. Therefore, to move easily, peoples lived in tents as their houses and made living goods light and compact.

Figure 1 The technical skills for pastoral nomadism



c. Oases Farming

Even in an arid area, people were able to farm some edible plants with irrigation works. Those places became Oases, in Greek word. The oasis farming brought the appearance of many communities in the dessert. Their size was closely related to the size of the water resources they can use. However big they were, they were just like small islands in an ocean.

There were so many oases in the desert of Central Asia in B.C. that they were called "Thousand cities" or "Western 36 countries". At this point, the words, "thousand" and "36" were used to indicate "many" or "a lot". These oases could be considered as village states or city states in historical terminology.

By the 6th or the 7th Century A.D., those oases were gradually united together, and became a big oasis community, that could be called "regional state". This combination was strongly connected with a river system, special products from each oasis and the trading relations. There were 7 or 8 of these states located in the south of current Xinjiang, same region as the southern parts of the Tian Shan Mountains. However, those oasis communities (" regional states ") did not become a big ancient united nations or empires like China, or Japan. Because, nobody walked around in a desert like people do in cities, and the size of the desert was too big to consist only of a big nation. Thus each of these small nations developed their own languages and religions.

Those nations, however, were not isolated. The Central Asia is the place of trading routes, called "Silk Road" that connected to huge civilized societies. And moving nomadic people mediated between these big states to oasis states during a long period in the past.

d. Coexistence of two societies

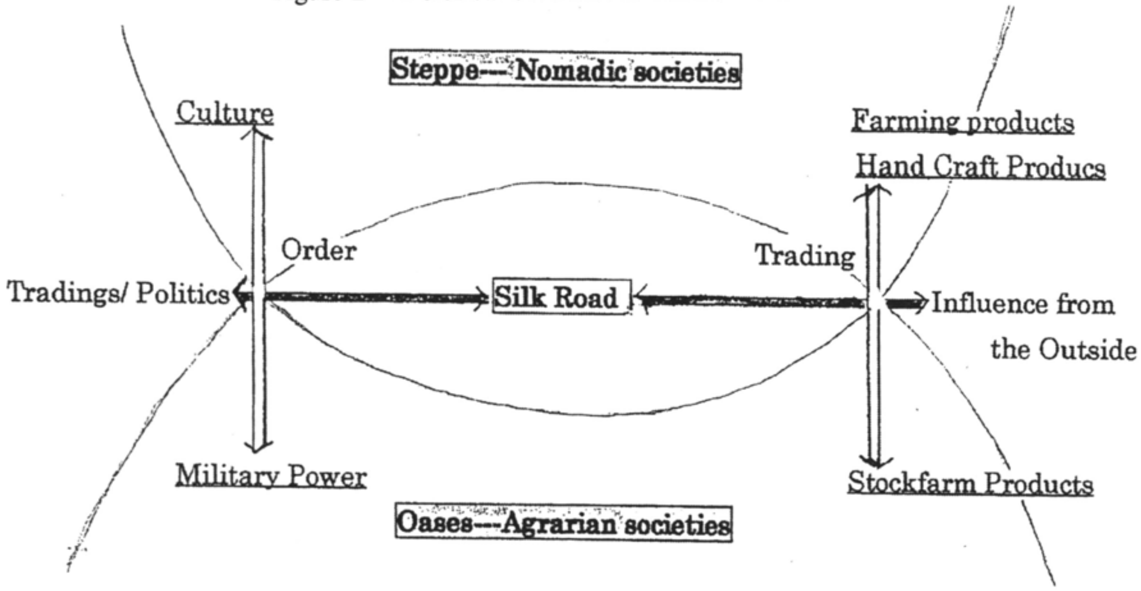
From the beginning of A.D., after the invention of straps, nomadic people pressured agrarian people with their military strength. Their movement and production activity are combined together. Nomadic skilled maneuverable cavalry was always ahead of agrarians' troops. Moreover agrarian people were forced to stay, with a small productivity, in their fields as the place for their production activities. Also, their fighting period was limited, because they must be in their field at the time of the harvest. These facts clearly showed the strength of nomadic people's military force. Only nomadic people side could choose the time and the place for fighting. Battles were hence processed under the leadership of nomadic people.

Therefore, the nomads ruled the agrarians easily. It should not be considered, however, that this was the nomads' one side direction. Because, even if the nomads have the military advantage, they were not able to feed themselves, and more over, there were many nomadic groups that also have good fighting skills. Thus, the real fact of their relationship was "interdependence". It was not definitely the suppressive exploitation.

Such as grains and metals were the products of farmers, who got leathers and castrated male cattle's meat from the nomadic people with these products. This exchange became the basis of their relations. This was very universal in the places of coexistence of several societies, where many different occupations are found. In the case of the Central Asia, as its features, the nomads had good militaries, took in charge of securities in oases and kept public order in the trading routes. Then oases supplied cultural soft-wear such as religions and science technologies needed the accumulation for their consistence. Also, as nomadic people's feature, keep moving with the live-stocks in a huge steppe, they were not good at governing many people in equal. In pastoral nomadic world, not only in whole tribe, but also in one family, many different people existed and dispersed in large farming steppe. So, agrarian people found their advantage in this point. Even they did not have strong militaries, they had very organized communities, as they were placed in the farming land. In other words, people in oases could choose favorite nomadic tribes from various races and languages in the Central Asia.

At the point of oasis communities' view, a reasonable way to prevent from a nomads' attack that would cause communities' destruction was to cooperate with another nomads. It was a waste of properties for agrarians to hold unproductive manpower such as standing armed forces. On the other hand, at the point of nomadic people's view, it was very unfavorable to loose the resources of grains, metals for weapons and luxury goods such as tea and cotton. Therefore, coexistence of these two groups was formed as the Central Asian social relations. This is briefly shown in Figure 2.

Figure 2 Historical Structure in Central Asia



Actual Conditions and Changes in Central Asia

a. Actual conditions of trading to distant places

Many people have mentioned that the Central Asia prospered with the existence of trading routes between the East and the West. The routes were well known in the name of "Silk Road". However this was not the view with enough records, as the commercial records were hardly existed. For this reason, long distance trading in the pre-modern societies was called "Fraud Trading". Their buying and selling were concluded beyond economic factors. For example, in ancient Rome, they said that Chinese silk was exchanged with the same weight of gold. This price was put because having silk brought a high status in the Roman society. So, the value was not made out from the cost price, distribution cost, and profit. It was totally different from the way we do in the modern societies. The information for the merchandise was hidden as much as possible, such as the place of products and the trading routes. Mysterious images held the high price of those products. This was the reason why we could not find the commercial records in the Silk Road. What such documents as "Marco Polo" mentioned was an exception. (This was the mixture of fiction and the non-fiction though.) Also as the tradition, nomadic people did not leave any documents, and Islamic communities had the habit of making verbal contracts. All of these brought the shortage of commercial records.

In pre-modern societies, without the case of Mongolian Empire, as the real fact, the long distance trading barely carried on through the great numbers of networks of local trading.

b. Chinese Empire and Central Asia

The sources written in Chinese brought a big influence into the historical research. The Chinese did a special intervention between the nomadic people and the agrarian people in oases. As Xinjiang was located in the west of China, it was called "Western Region (西域)". There were many articles in Chinese sources about this area. Based on these documents, there was an opinion that especially in the Han (漢) Dynasty and the Tang (唐) Dynasty, the Western Region was put in a part of these territory. Thus the international trading through the Silk Road had prospered more and more.

But, this was the view made out from the Chinese sources only, so that this tended to be in China side. Recently many documents were found and research of nomadic system was performed. Thus the previous opinion needs to be corrected. As one of the reasons, if the fact Chinese power possessed the Central Asia was true, there must be some articles in several sources in local languages. However it was hard to find any. According to the military balance at that period, the Chinese left the records about their temporary military action to intervene in the struggle of nomadic societies, and the diplomatic presence as an alliance, in the traditional style for writing the history in China.

The Chinese dynasties' advance to Xinjiang was started by Emperor Wu of the Han Dynasty (漢武帝) in the end of the 2nd Century B.C. It was a part of military action to the nomadic power, "Hunnu (匈奴)" in the north of China. However, the Han Dynasty's sphere of influence did not reach to the northern steppe in Central Asia. The Han became a leader of oasis communities by taking advantage of Hunnu's internal trouble, and cooperating with other nomadic powers around the Han's territory.

Even the case of the Tang Dynasty, as the real fact, their successful advance was just by taking advantage of the struggle against the Turkic or the Tibet. Moreover, the emperor himself was from nomadic tribes. Also, it was nonsense to find out raise and fall of trading from the fact whether documents were left or not. It was far from the understanding the Fraud trading that mentioned above. It was very literary point of view and totally different from that of economics.

With these Chinese sources, if we talk about the Yuan (元) Dynasty's management, as one of the Chinese Empires, in the Western Region, we must say that the truth of the sources was very opposite. It was like putting the cart before the horse. The fact was that the Mongolian, one of the nomadic tribe in the Central Asia conquered China. So the Yuan Dynasty was just an eastern branch of the Great Mongolian Empire at China.

The reason why the image from Chinese sources is different from the real fact was that the Chinese civilization, as an agrarian society, discriminated the nomadic society. So, they did not want to leave the truth that how strong the nomadic people were. Also, the following was a trick that we may fall into. A phenomenon appeared, that made us think that the pastoral nomadism was behind of the farming. Agrarians conquered the nomads, and the position which can get an advantage was changed from nomads to agrarians.

c. Military Revolution and Ocean Trading--- Cannon and Sailing Boat---

In the 16th Century, the power of the nomads' military force, which supported the tribe's vitality, began to loose, since agrarian people invented cannons in the military revolution that started in Western Europe. The mobility of the horseman was blocked with cannons for its long shooting range. The initiative of the military operation was moved from the nomads to the agrarians. Because agrarians lived in a certain land, they could have the consolidated facilities to make heavy weapons. During this military revolution, sailing boats were also produced. The combination of many sails made a boat be able to move forward regardless of wind direction, and the intensify of the deck prevent from the leak. These features made the ocean transportation became safer than that of previous days. Of course, cannons were, also, set on the sailing boat. The boat can move massive goods with less power. According to these elements, the improvement of sailing techniques changed the trading routes, the connection of the world civilizations, from inland to ocean.

d. Fall of Nomads' Power

Gradually the West-European Ocean force conquered the new continent and brought big changes into the Eurasian agriculture structures with American plants. Potatoes and corns were also introduced at that period. These two became a serious blow for the nomads in the steppe. These two kinds of plants had strength for dry and cold place, and good crop as well. With these plants, agrarians were able to start farming semi-arid and cold zone where they had not farmed and also nomadic people had spread before. In the previous days, the nomads cleaned such inventive enemies from their pasturage with skilled militaries. However, after those invention and improvement, the agrarian empire increased the population rapidly with cannons and new plants. And it became impossible for the nomads to prevent their land from these agrarian conquests. The Qing (清) Dynasty advanced from the east of the Central Asia, and Russia reached from the west. After that, the Great Britain came up to the north via India. Then, the modern borders were set up by these foreign powers without any circumstances of the local people.

In short, the outline of the Central Eurasian history is shown as the Figure 3 and Figure 4.

Some Ploblems remainning unsolved

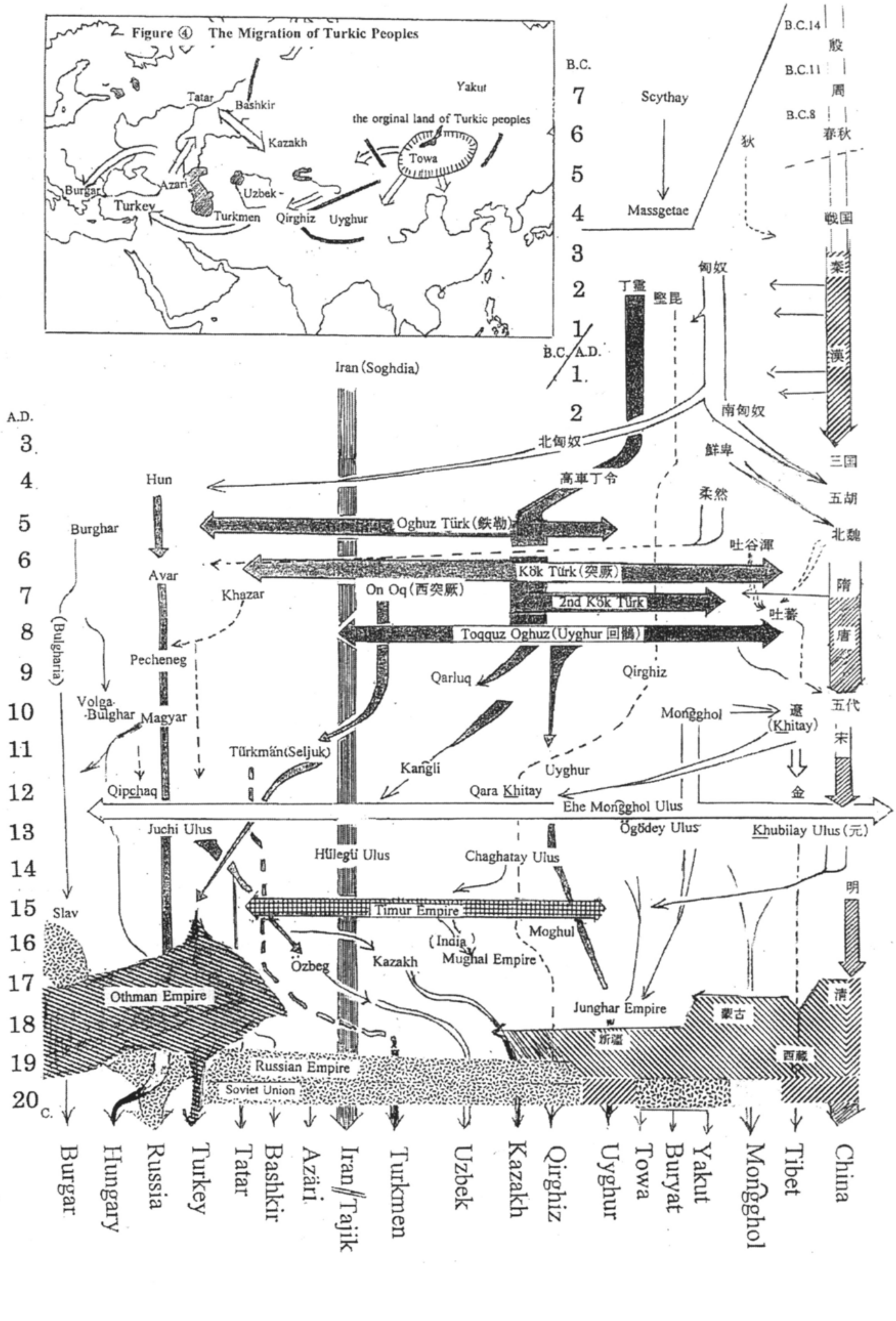
a. The nomads' movement and the climate changes

Figure 3 shows many nomadic powers rose and fell one after another in the Central Eurasia. To present the reasons and the characters of each particular cases is not only beyond my capability but also difficult of explanation in such a limited time as today. Hence, I would like to focus on some points which are too much for us, like historians as human scientists.

The 1st of them is the relation between the rises and falls of nomadic powers and natural phenomena. Some nomadic states are known to be collapsed by natural disasters. For example, the Toqquz Oghuz Empire was overthrown by Qirqiz in 840 after some years' heavy cold-weather damages. But for most of all nomadic powers, these correlations have not been known yet. The fundamental reason of this condition is, as I have stressed at the beginning of this paper, the lack of documents made by nomadic peoples themselves. The reconstruction of past climate changes there in a long time span are expected to be disclosed by natural scientists.

The 2nd point is also concerned with physical environment. Through the Figure 3 or Figure 4, we can understand that the extension or migration of nomadic peoples mostly happened from the east to the west in Eurasian continent. There were a few exceptions, of course. For example, the Temur Empire in the 14th Century and the Junghar Empire in the 17th Century rose in the Central Asia and extended in all directions. The main trend of most cases, nevertheless, moved from the east to the west.

Figure 3 The diagram of Nomadic Powers in Central Eurasia

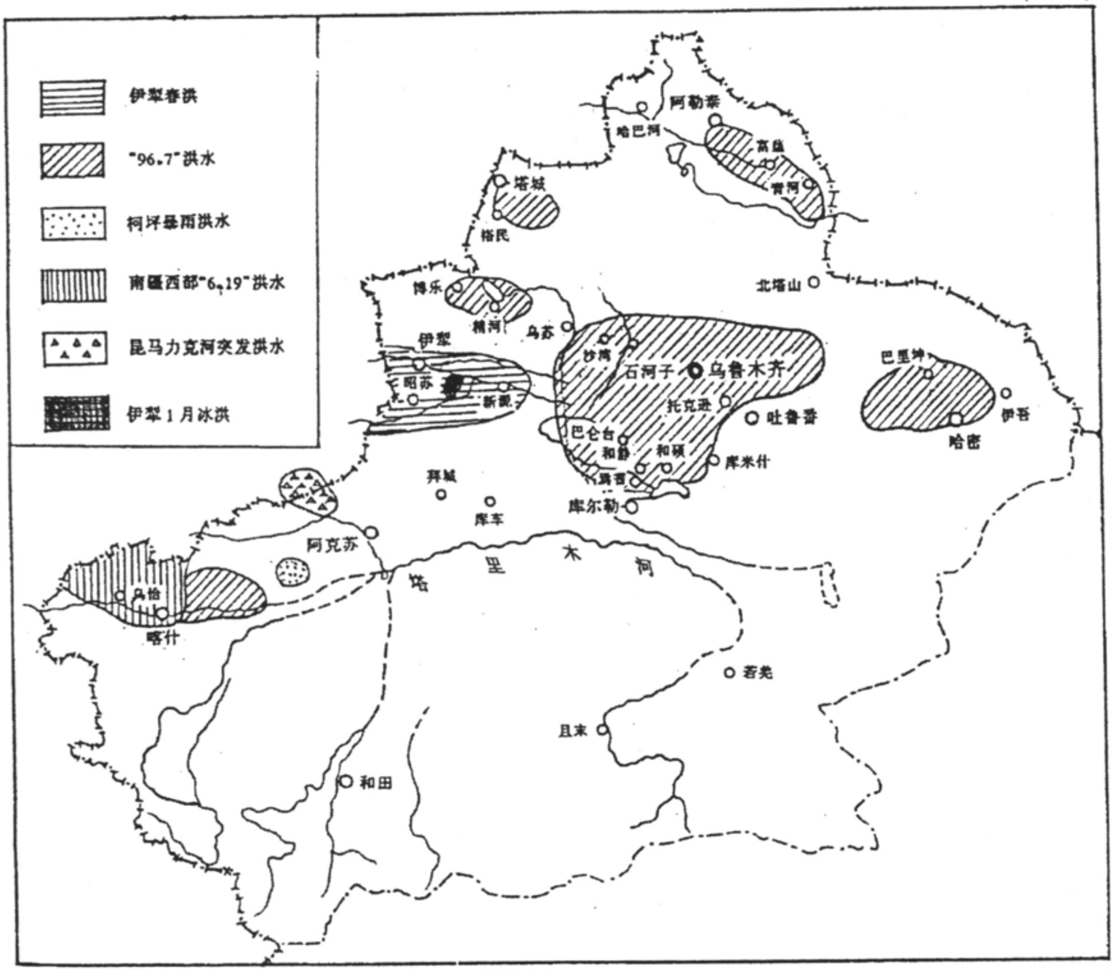


Some historians argued about the migration of the Turkic people. They said, because the Turkics original land was dried up, they were forced to move to another places to live. However, at this moment, it is hard to agree this opinion. We need more detailed ideas from the professional natural scientists.

In addition to a long span climate changes, I would like to know if it is possible to reconstruct climate changes in a limited particular area or not. I pointed out the famine at Aqsu, one of the oases in Xinjiang, recorded in a Persian document (Hori 2001: p.80). Further, Figure 5 shows local flood accidents in only 1996. They were happened at limited districts. The reconstruction of environment in these cases in the past are also expected to natural scientists.

Figure 5 The flood accidents of Xinjiang in 1996

Editorial Committee (2000)



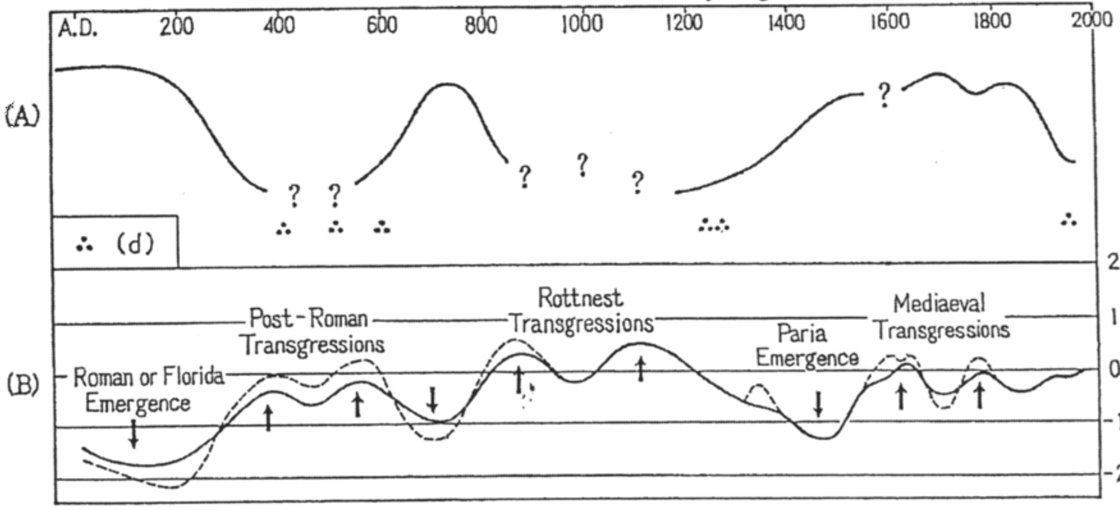
b. The evolution of the arid land---farming zone and oases---

Now I have mentioned many exception or requests to natural scientists. But it is also necessary to speak how human scientists have studied on the climate changes.

A historian, Prof. Shi and Prof. Seo recently pointed out that air temperature in the era of the Han Dynasty and the Tang Dynasty was warmer than that during the other dynasties, based on rich documents written in Chinese.

A similar opinion like them has been presented by Prof. Hoyanagi, who is a geographer, through a reconstruction of the changes of river discharge on the southern side of the Tarim Basin in Xinjiang. Figure 6 is one of Prof. Hoyanagi's conclusions. I do not grudge due praise for his deed as a pioneer. But I am partly hard to understand his opinion, and have some questions on his conclusions.

Figure 6 The change in the amount of river discharge on the southern side of Tarim Basin
Hoyanagi(1976) & Nakawo (2000)



1st of them is the reliabilities of old Chinese sources on the past variation of river discharge on which Prof. Hoyanagi based. Secondly the data of locations of ancient ruins there have gone so old.

Fortunately, many of the native documents have been opened for us at academic organizations all over the world, and the detailed reports on the archaeological survives in Xinjiang have been published during the last two decades.

Moreover, such a geographer like Prof. Souma has disclosed a new horizon of the archaeological studies using visual data from Satellite CORONA. Basing on all kinds of new sources mentioned above, we are able to have a hope to clear some problems about the climate changes and historical evolution of the population and the cultivated land's size, and so on.

c. Further expectations on this project

According to the early draft of this project, such pollen analysis, dendro-chronology, and composition analyses are planed to do. It may be little different from the point of environmental research, I would like to propose to add up the following approaches such as the research physical anthropology and genetics.

Especially the latter, the genetic approaches will bring good evidences to prove hypotheses came through the ethnology or the history.

As an example, in the present at the mountainous district of the Heihe Basin, there live one clan (otoq) in Yu-guo（裕固） tribe, called Yaghlaqar. One hypothesis is, apparently, that this Yghlaqar clan is the descendant of the Uyghur tribe's main clan of the Toqquz Oghuz Empire in the 9th century. From the point of ethnology and history, it is said that there is some relations between the word Yu-gou and Yaghlaqar (夜落葛). To prove above topic, some genetic certify is needed. So now, we, human scientists expect to natural scientists that they can bring a certain proof for this hypothesis.

Concluding remarks

In concluding my presentation, I would like to say that the time given me to prepare this paper was very short. So the content of my argument is preliminary and also plain. I'm afraid that you have miss-understood the research level of Japanese studies on Central Asian history.

References

HORI, S. 2001 The water utilization in Yarkand Oasis---from the standpoint of the historical studies---, Project Report on Oases-region Vol. 1 No. 2, (in Japanese. 堀 直「ヤルカンド=オアシスの水利用」『オアシス地域研究会報』第 1 巻 第 2 号 2001)

Editorial Committee ed. 2000, The studies on the flood accident of Xinjiang in 1996, Urumchi (in Chinese. 『新疆'96 洪水災害研究』烏魯木斉 2000)

Shi N. ed. 1998 The Loess Plateau and Chang'an City in the Han and Tang Dynasties, Xi'an , (in Chinese. 史念海主編『漢唐長安与黄土高原』西安 1998)

HOYANAGI, M., 1976 The evolution of nature in the Silk Road Region, Tokyo (in Japanese. 保柳睦美『シルクロード地帯の自然の変遷』東京 1976)

NAKAWO, M., 2000 Water in Arid Terrain Research. Research Report of IHAS, No. 8, 1-9

SEO, T. 2001 The city planning of Chang'an, Tokyo (in Japanese. 妹尾達彦『長安の都市計画』東京（講談社）2001)

SOHMA, H. 2000 The conditions of ancient ruins' location in Turfan Basin---mainly through the deciphering photoghraphic data from Satellite CORONA---, Studies on Silk Road Vol. 8 (in Japanese. 相馬秀廣「トルファン盆地の遺跡の立地条件---CORONA 衛星写真の判読を中心として---」『シルクロード学研究』Vol.8, 2000)

A preliminary study on the history of desert regions in the Heihe Basin

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The Heihe River Basin was the largest of its kind in the Hexi region. The main river runs 800 km or longer, extending toward the Alagxa League Plateau, now called Ejina Banner. It is a typical region where the desertification has been marked not only in recent years but also historically. It is important to investigate the historical cause of the desertification not only to satisfy academic interest but for the present development and the ecological preservation of the region (Fig. 1).

1. Downstream Region

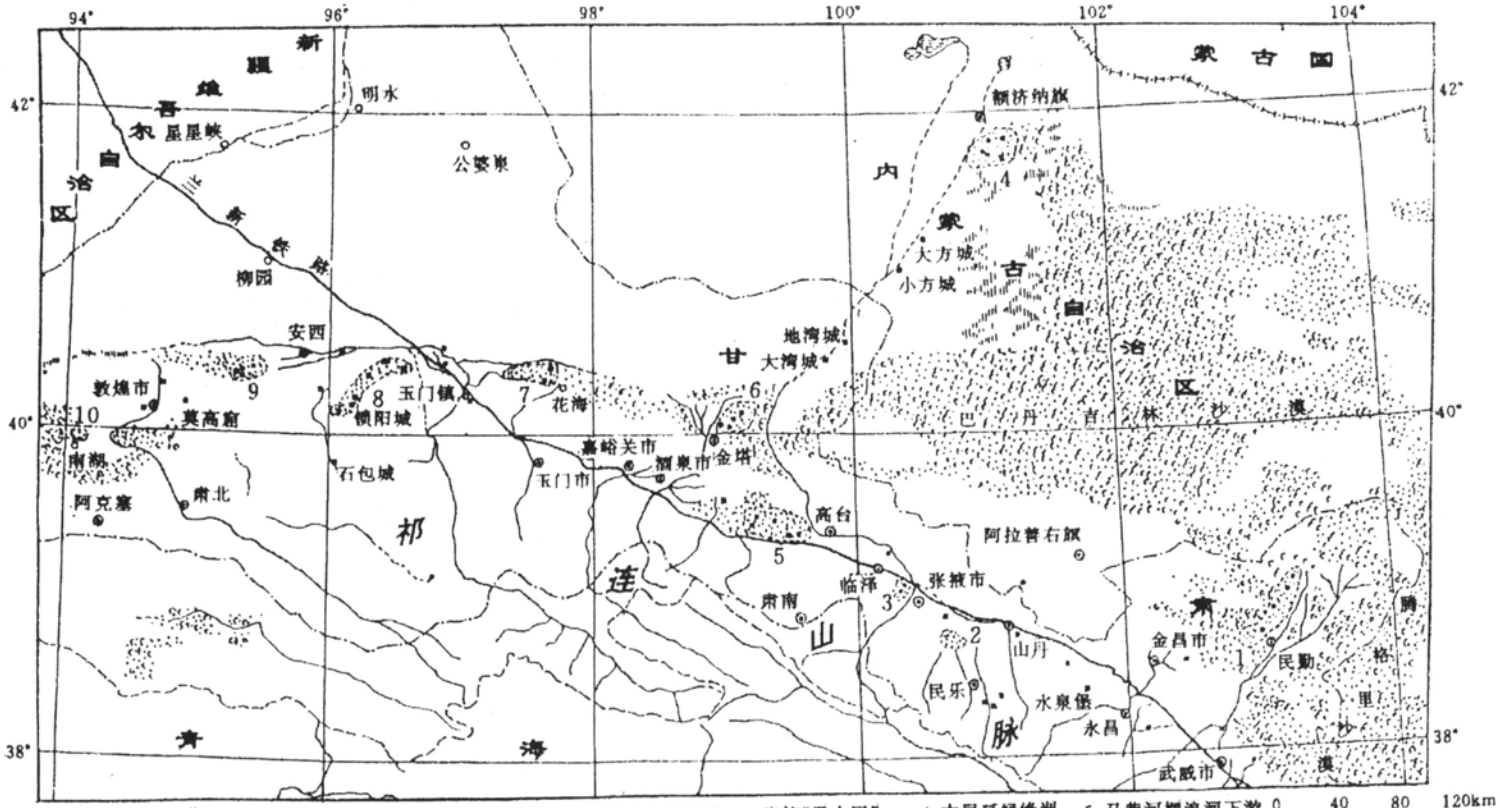
Several investigations have been carried out for understanding desertification in the past in the Juyan and Yangguan regions by HOU Renzhi, and the Juyan and Heicheng regions by ZHU Zhenda, LIU Shu, GAO Qianzhao, HU Zhiy and YANG Youlin are the examples in addition to a study on the Ejina region by JING Ai. The present author investigated the region in 1987, later in 1991, and then carried out a study in September 2001 together with researchers from the Research Institute for Humanity and Nature, Japan, and from the Cold and Arid Regions Environment and Engineering Research Institute, China.

Field investigations and satellite data analysis indicated that there are two deltas: the present one between Gaxun Nur and Sog Nur, and an old one at the western edge of the Old Juyuan Lake, *i.e.*, the northwestern edge of the present Badain Jaran Desert. The Heihe River originating from the Qilian Mountains becomes two distributaries at the northern side of Qingshan and Lanxinshan: the western one flows into the Gaxun Nur, and the eastern one, which also flows northward, has two distributaries also 60 to 70 km downstream of Lanxinshan. One of the distributaries, the present Narin Gol, flows into Sog Nur, and the other flows through, and disappears in, the old Juyuan oases region where the Old Jyuan Lake and Heicheng are distributed.

The old Juyan Oases region, which extends as far as 1,200 km^2, can be divided into several districts depending upon the time of development: in the Han Dynasty, Tang Dynasty, Xixia Dynasty, and the Yuan Dynasty.

(1) District developed during the Han Dynasty

This district is located on an old delta surrounded and protected by three chains of great walls and towers for signal fires: one in the north, another in the west, and the other in the east. Their ruined buildings are now found here and there, and give us clues for estimating the original area of the district.



• 古城址　古绿洲沙漠化区域　1. 民勤西沙窝　2. 民乐李寨菊花地　3. 张掖"黑水国"　4. 古居延绿洲　5. 马营河摆浪河下游　6. 金塔东沙窝　7. 玉门花海毕家滩　8. 昌马河洪积冲积扇西缘　9. 芦草沟下游　10. 古阳关绿洲

图 1　河西地区汉唐古绿洲沙漠化分布图

Fig. 1　Distribution of the deserfication in the ancient Oases of Han and Tang Dynasties in the Hexi area

The district has been investigated intermittently in 1974, 1976, and 1986 -1988. The eastern wall, Sajingsai, extends from Bugtni northeast, terminating at Bor Suj, a total distance of about 60 km. One can see the part of the wall and 32 towers. The western wall, Jiaqusai, is located between the eastern edge of the Narin Gol River and the western edge of Ehen Gol River, starting from the southern side of Budag, and ending at Qagan Suj. Its length is about 40 km, protecting against the west, and most of the wall remains with 26 towers and a small castle, Pochengzi or Jiaquhouguan. The northern wall, which was an arc-shape protection against the north, retains only part of the wall, 4 towers and a work house for solders. A chapter of a book, Xiongnu in Shiji mentions that Emperor Wu of the Han Dynasty ordered XU Ziwei and LU Bode to construct a series of barrier walls and towers with strong Qiangnus, outside of Wuyuansai on the Juyuanze Lake, thus reforming the protection system of the great wall for the oases region.

Old farmland, irrigation channels and ruined houses are distributed in a large area protected by the three chains of walls and castles. Many crescent-shaped sand dunes and mounds with a height of 2 to 3 m have invaded the area. The southern side of the area is of abandoned farmland with hard soil surface, and old irrigation channels are still distinguishable. There are a few mounds with tamarisk trees inside (tamarisk mound).

The following is one of the examples of statements related to the construction of irrigation systems for agriculture, found in old Juyan Hanjian (documents written on pieces of wood and bamboo in the Han Dynasty, which have been found around the terminal area of the Heihe River). "One hundred and five hundred soldiers/farmers have labored for constructing irrigation channels in the age of Shiyuan 2 (B.C. 85)." Specific names of irrigation channels often appear in Juyan Xinjian Shicui (recently found old documents written on pieces of wood and bamboo from the Han Dynasty). Also, the documents suggested the construction of gates in combination with channels, indicating that they worked as complete irrigation systems. Further excavation of wells is described in the documents, showing that they used water pumped up from wells for irrigation, presumably at a relatively high topographic region where the introduction of water through channels was difficult. There were special positions for those who controlled the irrigation systems.

There are several old cities in the region constructed in the Han Dynasty, as shown in (Fig. 2) : K710, K688, Lücheng, Ondog Tereg cheng (K749), Ulan Delbujing cheng (F84), and A8.

The city K710 is rectangular in horizontal projection, and located at 41° 52' 37" N; 101° 17' 05.3" E. Both southern and northern walls are 110 m in length, and the eastern and western walls are 131 m and 133 m, respectively. They have been damaged significantly, especially the northern and southern ones, by wind erosion and natural weathering. The entrance gate, facing south, is 6 m in width. There is an open space of about 6 m in width in the eastern wall, which might be another entrance but could have been made just by wind erosion. The ground level inside the walls appears to have been lowered by wind erosion from its original level by 0.2 to

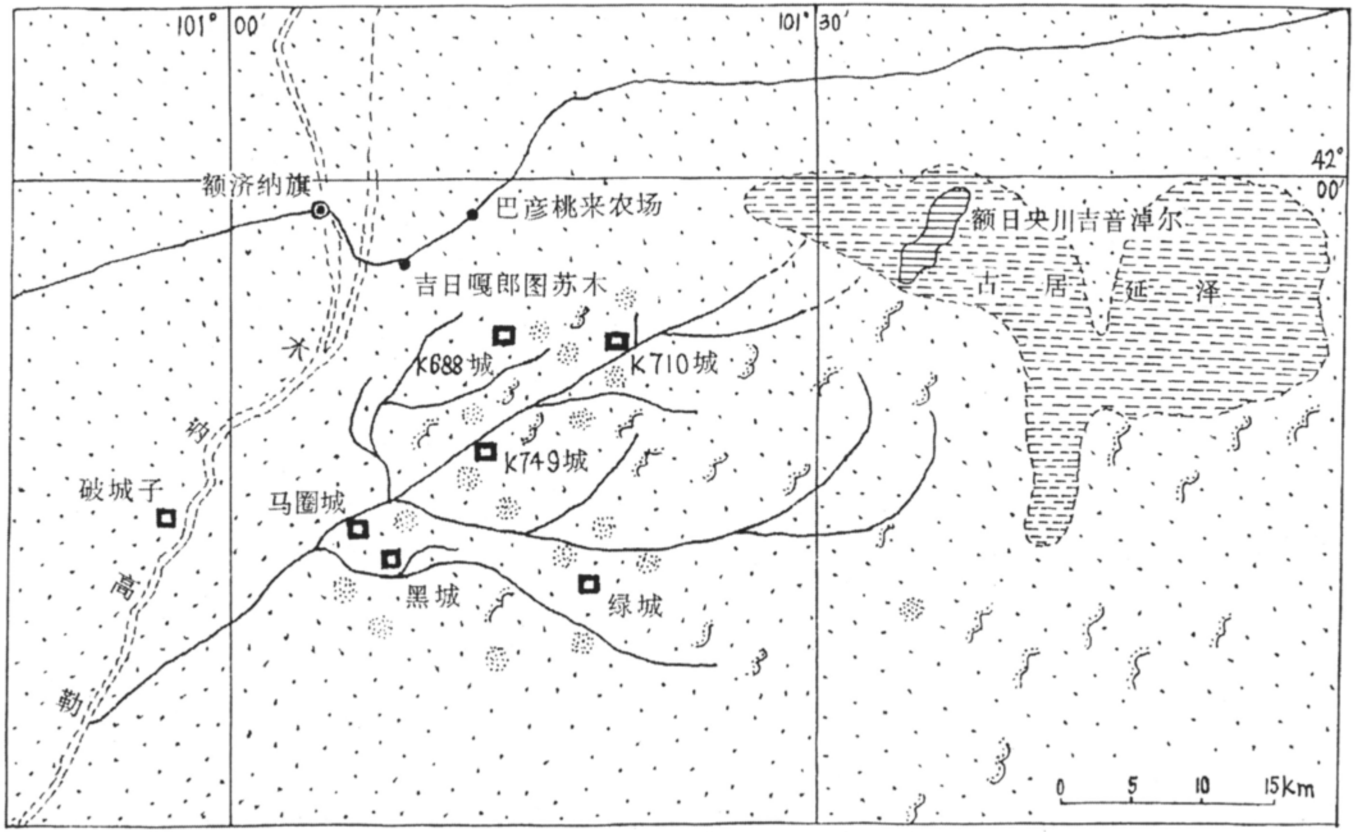


图 2　黑河下游古居延绿洲沙漠化示意图

古河渠　今河道　古城址　今湖泊

Fig.2　Desertification in the ancient Oases of Juyan at the lower reaches of Heihe River

0.4 m. Towers for fire signals are located at the four corners of the city, which is 8 m x 6 m at the its bottom level. There are several tamarisk mounds both inside and outside the city. The relics of houses are found in the city. A brick-made water channel 0.5 m in depth still exists at the surface just outside of the western wall, with a length of 10 m or more at present. This seems to have been brought into the city. Dark and black colored brick pieces, measuring 30 × 18 × 6 cm in their original complete shape in Han Dynasty, are scattered in and around the city, in addition to shards of several kinds of ceramics, a type of coin, and millstones whose diameter was 50 to 65 cm. Abandoned farm lands extends a few kilometers from the city, where one finds pieces of ceramics and bricks scattered about, but at the same time, we also found pieces of green and China blue and white, which are typical ceramics made in the Song Dynasty and the Yuan Dynasty, respectively. This indicates that people were active in the city not only in the Han Dynasty but also in the era of the Song and Yuan Dynasties.

City K688, called Yabrai City or Bandin Bogl in Mongolian, is located at 41° 54' 32.2" N; 101° 11' 46.1" E, about 4 km northwest from K710. The walls are aligned in an almost rectangular shape of 130 m x 127 m, and are severely damaged, in particular, the western wall. The inner part of the city is occupied by many tamarisk mounds, one of which is 3 meters higher than the highest city wall. Significant number of ceramic, brick and iron pieces are scattered in and around the city. A number of tombs from the Han Dynasty are located at a distance of 1,000 m to southeast of the city.

The cities K710 and K688 are located at the site where Ruoshui meets near the guarding line of Tianbeisai, north from the Old Juyuan Oases. They are badly weathered, and the wind erosion caused a height difference of 1 to 1.5 m or more. Pieces of ceramics and iron made in the Xixia and Yuan Dynasties were found, in addition to those in the Han Dynasty, indicating that the cities were used in the Xixia and Yuan Dynasties as well.

City F84 shows a square shape with a side length of 22 m. There is a layer of horse dung deposited there as thick as 47 cm, and ceramic shards are scattered in the city, which is considered one of the most important military buildings in the guard system. City A8 is 24 km southwest of the local government, located almost at the center of the guard system. Double-long walls survive 300 m west of the city, extending north to south. The top of the sand dune deposit approaches the top of the city, which has a rectangular shape of 47.5 m by 45.5 m. There are relics of houses, and facilities for enclosing cattle. In this city, old documents written on 6,865 pieces of wood and bamboo were found in addition to more than 1,600 pieces of ceramics, copper, ironware, arrowhead, bow, coin, farming equipment, fishing equipment, fabrics and other materials. City K749, also called Dongchengquan, is located at 41° 51' 16.7" N; 101° 09' 27.1" E, based on an observation by the Global Positioning System. Its horizontal projection is roughly square with a side length of 55 m, but is slightly concaved at its southeast corner.

Lücheng is located 3 km southeast of Dalai Hob, 14 km eastward from Heicheng (K799), and 17.5 km south of K710. Most of the walls have deteriorated with a horizontal ellipsoid projection. The total length of the delineation is 1,205 m. A gate was made at the eastern part of the north wall. A tower of Lamaism is left in the western part of the city. A water channel goes through the south wall. The sediment in the city, which contains many relics, is divided into two layers. The shallower layer, with a thickness of 8 to 15 cm consists of colorful gravels, containing varieties of colored and white ceramics pieces, some with painted or carved surfaces. The major datings are the Xixia and Yuan Dynasties. The deeper layer is made up of alternating layers of silt and sand, with a thickness of 6 to 20 cm. It contains gray ceramic shards, bricks, cylinder-shaped bottles, trays, large bottles and so on from the Han and Jin dynasties. This city was built probably in the Han Dynasty, and had been in use until the Xixia to Yuan Dynasties.

The old Lücheng City is located in an old cultivated zone, which is the largest cultivated area among the old oases, located roughly at the center of the Old Juyan oasis. The eastern part of the cultivated zone is called, by local nomadic people, Nogon Sum, which means "relics of green buildings", because many pieces of green roofing tiles of the Xixia and Yuan dynasties are found there. Many relics of temples, Buddhist towers, fire signal towers, tombs, and pottery kilns are found in this area in addition to old agriculture lands and water channels. Among them, the fire towers, and several of the kilns and tombs are of the Han Dynasty, but most of them date from the Xixia and Yuan Dynasties. The width of the water channels is 3.5 to 5 m, and the depth of the surviving part is 0.3 to 0.5 m. One of the channels, running northeast from the city is more than 30 km in length. Around the city are several relatively large tamarisk mounds 4 to 6 m high, where old houses are often buried.

Several old relics have been found other than those mentioned above such as towers for fire signals as A12, A13, K778 and A15, which are aligned north to west, and A14, T85, T88, T105 and T106, which are in the western area of the old oasis. Also, A6, A17, A18 and F99 are found on the southeastern side of Heicheng City.

(2) District developed during the Tang Dynasty

The cultivated area developed in the Tang Dynasty is much smaller than that during the Han Dynasty. Only one city was found so far that was built in the Tang Dynasty, Maquancheng City (K789). It is located at 41° 47' 26" N; 101° 05' 16.4" E, 19 km northwest of the local government. Thick layers of horse dung were found in the city, which is the origin of the city name.

The city is a horizontal rectangular shape in projection, and guarded by double walls, most of which, however, have collapsed or been buried in sand. The side length is 155 m in an east-west direction, and 120 m in a north-south direction. The thickness is 8 to 10 m at the wall base, and 2.5 to 4 m at the wall top. In the city, pieces of ceramics and bricks are distributed at the surface, and deposited layers with relics can be divided into three levels with a total thickness of 50 to 80 cm. The uppermost layer with a thickness of 13 to 18 cm, contains ceramics from the Yuan Dynasty, indicating the city was under use in the Xixia and Yuan Dynasties as well. The middle layer consists of sand with ash of grasses and trees, horse dung and grasses. Coins and stone balls of the Tang Dynasty were found in this layer. The bottom layer, with a thickness of 14 to 27 cm, contains pieces of ceramics, bricks and roof tiles.

We can infer, from the piles of horse dung left here, that the city was very active in the old days given the frequent movement and the presence of so many horses in this region.

(3) District developed during the Xixia and Yuan Dynasties

The district developed during the Xixia and Yuan Dynasties is concentrated in the central to southern area of the old oasis, with Heicheng city (K799) as the center. The district is slightly more than 30 km in its east-west dimension, and more than 15 km in its north-south dimension. Its northern and eastern parts are superposed upon the southern and eastern parts of those developed in the Han Dynasty, and the western part on those in the Tang Dynasty. This indicates that the northern part of the Han Dynasty district has been abandoned with the desertification.

The largest city in the Xixia and Yuan Dynasties is Heicheng, located at 41° 45' 40" N; 101° 5' 55" E, 25 km southeast from the present government of Ejina. The city has been excavated by Russian or British explorers in the early 20th Century. After the formation of the present Chinese Government, Chinese researchers excavated an area of 11,000 m^2, roughly one tenth of the total city area, and obtained significant findings.

It was found that two different city walls are superimposed at the city: the larger one is considered the old Ejina City of the Yuan Dynasty, and the smaller one, located at the northeastern corner of the larger one, is the city of the Xixia Dynasty.

The smaller part shows a square shape with a side length of 238 m. Parts of older walls were utilized in the Yuan Dynasty for constructing a Buddhist Temple. The old city appeared to be similar to those of the Liao and Jin Dynasties, having a military function.

The larger city is in the rectangular in shape with the side of 421 m in an east-west direction, and 374 m in a north-south direction. The average height of the walls is over 10 m, and they have breastworks of 4 to 5 m. There is the relic of a yangmacheng, a military construction with relatively lower walls constructed outside of cities against enemies advancing on the city. This type of building was often constructed in the Tang and Song Dynasties, and examples are found in Suoyangcheng at Anxi and Guacheng of the Tang Dynasty, Luotuocheng at Gaotai, and Jian'an , a militaly city of the Tang Dynasty.

At the northwestern corner of the city, a pair of Buddhist towers is found, and five Lama towers are lined up in a north-south direction, the highest of which is rises to 11 m. There appear to be four large streets in an east-west direction, two of which penetrates through the smaller city. There are six large roads running in a north-south direction. The northern most has a width of 18 m at most, and 10 m at its narrowest. The width of many narrow roads is considered to be 2.5 to 5 m.

Relics of houses were found at 287 locations with a total area of 10,759 m^2. One of the largest houses is located near the western gate of the larger city, and the walls surrounding it are 69.1 m and 46.8 m in north-south and east-west lengths, respectively, occupying the area or 3445 m^2.

More than ten temples were found in the city, and many pieces of roof tiles, and bricks, and rotten wooden columns were scattered in the surface layer. Three warehouses were identified in the city, whose entrance is rather wide. Rows of regular houses were also found. Their size is relatively small: one unit consists of two to three rooms only.

There are so many relics found and collected from the city, including construction materials such as bricks, roof tiles, and decorations for roofs; tools for production such as iron plows, iron shovels, iron hoes, stone rollers, and stone mills; arms such as iron arrowheads, and pieces of iron armor; daily goods such as iron pans, iron tongs, chains, smoothing irons, plates for lanterns, iron knives, pots, wooden combs, bamboo sticks, tooth brushes, painting brushes, baskets, shoe horns, small lacquered boxes, copper mirrors, bones chopsticks, and copper cups; stationeries and toys such as ink stones, writing brushes, and wooden Chinese chess boards; dresses and its accessories such as shoes with cloth bottoms, knitted shoes, silk caps, bags for perfume, and skin bags; religious goods such as heads of gods, bones for divination, and wooden statues; moneys such as Kaiyuan Tongbao, Dating Tongbao, Dayuan Tongbao with 'Pags-pa script; copper stamps, and copper weights for a balance. Their variety and quantity is enormous. The most distinguished find in the city is the more than 20,000 written documents, although most of them are now kept outside China. For example, those written in the Xixia letters, found and exported by P. K. Kozlov, are more than 8,000 in number. A. M. Stein also brought more than 3,000 documents to the United Kingdom. Roughly 3,000 documents are kept now in China. They are of extreme importance for a variety of studies on Xixia and Yuan Dynasties.

The district around Lücheng City, located 13 to 18 km east of Heicheng, is another area where many old buildings of the Xixia and Yuan Dynasties have survived. Many pieces of ceramics were found in Lücheng City, indicating that the city was used as one of the central cities during the Xixia and Yuan Dynasties. Many Buddhist towers, temples, and houses are distributed around a wide area. There are three Buddhist towers made with dried-mad bricks. Four temples were found. Between the western and northern temples, more than 30 stages are irregularly distributed whose height is about 2 m. The distances between neighboring stages are 30 to 50 m. In and around Lücheng, a significant amount of construction material such as bricks, roof tiles and others were found in addition to pieces of ceramics.

It can be inferred from the documents found in Heicheng City that large scale irrigation facilities, at lease five irrigation channels, were constructed in the area during the Xixia and Yuan dynasties. Old farming areas are mostly buried with sand at present, near the Heicheng city, but the banks of the channels or relics of stone mills and stone rollers are found here and there. The channels are 2 to 3 m wide and rather shallow in the southern part of the city. The area near Lücheng City was developed during the Han Dynasty, but still in use in the Xixia and Yuan Dynasties. Surface undulation here is rather little, mostly less than 1 m. The remains of old irrigation channels are densely distributed, and they are also rather shallow with the width of 2 to 5 m. Among them, an almost complete channel of more than 200 m in length is found 1 km north of the city (41° 43' 47.5" N; 101° 16' 37.7" E). It runs from southwest to northeast; the banks are higher than the channel bottom by 0.3 to 0.4 m, and the width of the channels is about 5 m.

2. Middle Stream

The middle stream of the Heihe River is in the Zhangye District, Gansu Province, which includes Zhangye City, Shandan Prefecture, Minle Prefecture, Linze Prefecture and Gaotai Prefecture. This area is the richest area not only in the Heihe Basin but also among oases in the whole Hexi.

(1) Black Water City (Heishuiguo)

Located 15 km northwest of Zhangye City almost in the center of the oases in the middle reaches of the Heihe River, Heishuiguo City runs 8 km and 4 km on from east to west, covering area of about 30 km^2. The city consists of two cities: south and north. There are many sand dunes and sand mounds of 5 to 14 m in height in the southern part. In the last 20 to 30 years, corns, Chinese date trees and grasses have been planted, and the surface features have greatly changed.

Remains in the south city are rather numerous. The south city is roughly rectangular in shape measuring 222 m in a north-south direction and 248 m from east to west. The wall is 8 m thick at the base and 2.5 m at the top. It has only one gate facing east, with a width of 7 m. No breastworks are found at the wall top. No buildings are left in the city, and pieces of brick, stone mills, and pottery shard's from the Song, Xixia, and Yuan Dynasties are scattered about. There is an east-west road, which divides the city into its northern and southern portions.

The north city is 2.7 km from the south city. It runs 254 m in an east-west direction and 228 m in the north-south direction. The width of the walls is 5 to 7 m at the base and 1.5 to 2 m at the top. A gate opens toward the south, and its width is 8 m. Breastworks are not found at the wall top in the north city either. The shards found in the city are from the Song, Yuan, and Ming Dynasties. Three kinds of coins were also found here. There is a flat area of 60 x 200 m to the east outside the city, and the Heihe River runs just below the plateau. A type of reed grows along the river.

The remains seen in parts of the city date to the Wei, Jin, Tang, Song and Ming Dynasties, and no materials from the Han Dynasty were evident, indicating that this part was founded during the Wei, Jin Dynasties. In the southern part of the city, however, one comes across relics from the Han Dynasties in addition to those of the Jin, Song, and Yuan Dynasties. There are many old tombs around the north and south cities: more than 30,000 tombs on area measuring 2.5 km x 2 km hail mostly from the Wei and Jin Dynasties.

Heishuiguo City is located in the center of an alluvial plain close to the west bank of the Heihe River, where it is subjected to erosion. It is thought to be an area for hunting and nomadic activities in olden times, and the agriculture started in Han Dynasty days. The city is believed to have relocated to its present position of Zhangye during the Sui and Tang Dynasties. The older site underwent was desertification in the Tang Dynasty, and was completely destroyed during the Ming Dynasty.

(2) Downstream of Mayinghe and Bailanghe Rivers

The Mayinghe and Bailanghe Rivers are the tributaries of the Heihe River, running through Jiuquan City, Qingshui, Tunshengxiang, Hongyazixiang, Xinbaxiang, Sunan Yugur Minghuaqu and Minghaixiang. The annual discharge is 114 million m^3 and 39 m^3 in Mayinghe and Bailanghe Rivers respectively. Six other small rivers course through area: the Shuiguanhe, Dahe, Shihuiguanhe, Heidabanhe, Huangyangbaihe, and Yulinbaihe rivers. Total discharge from these rivers is 196.2 million m^3/year, which accounts for 5.75% of the total discharge of the Heihe River.

The ruined area of the old oases downstream of the Mayinghe and Bailanghe Rivers is 10 to 20 km in a north-south direction, and about 35 km in an east-west direction with a total area of about 450 km^2 (Fig. 3). The soil thickness is now 0.6 to 1.2 m in the area, and channel banks and ridges between each agriculture area are still identifiable. Pottery shards brick pieces and stone mills are found in the area.

Several cities found here included Luotuocheng, Xindunzicheng, Xusanwancheng, and Caogoujingcheng. Luotuocheng is one of the largest cities in the Hexi Corridor, and was divided into two cities: north and south. The north-south distance of both cities is 704 m and the total area is 299,200 m^2. The wall thickness is 6 m at the base, and 1.8 m at the top. Breastworks are associated with the east and west walls. Near the center of the south wall is a dried up well with a depth of more than 20 m. River channel just outside the north city runs east-west with a width of 30 m and about 3 m thick. Another river channel is seen outside the south wall of the south city. Both rivers could be the relics of irrigation channels supplying water to the city of Luotuocheng City long ago. In the city we find three layers with many buried remains. The top layer, with a thickness of about 1 m, is from the Tang Dynasty, the middle layer from the Wei, and Jin Dynasties, and the bottom layer from the Han Dynasty.

Xusanwancheng City is located to the west of Gaotai,7 km west of Luotuocheng (39° 20' 38.9" N; 99° 29' 37.7" E). Its wall is well preserved, with a side length of 84 m in a north-south direction, and 66 m in an east-west direction, and a total area of 5544 m^2. The wall is 8 m wide at its base, and 3.5 m at the top. The entrance gate at the east wall is 8 m wide. Interestingly, outside the inner walls, one encounters an outer wall with a total length of 720 m. Many shards from the Han and Tang Dynasties, and a small number from the Qing Dynasty were found. More than, 1,000 kg of old coins and copper ornaments of the Han to Tang Dynasties were reportedly found in the city. From the information above, it appears that the city dates back to the Han and Tang Dynasties, but saw use at least once during the Qing Dynasty.

Xindunzicheng City is located among sand mounds 15 km north of Tunshengxiang Shashancun, 25 km northwest of Xusanwancheng City. It is roughly square in shape with a

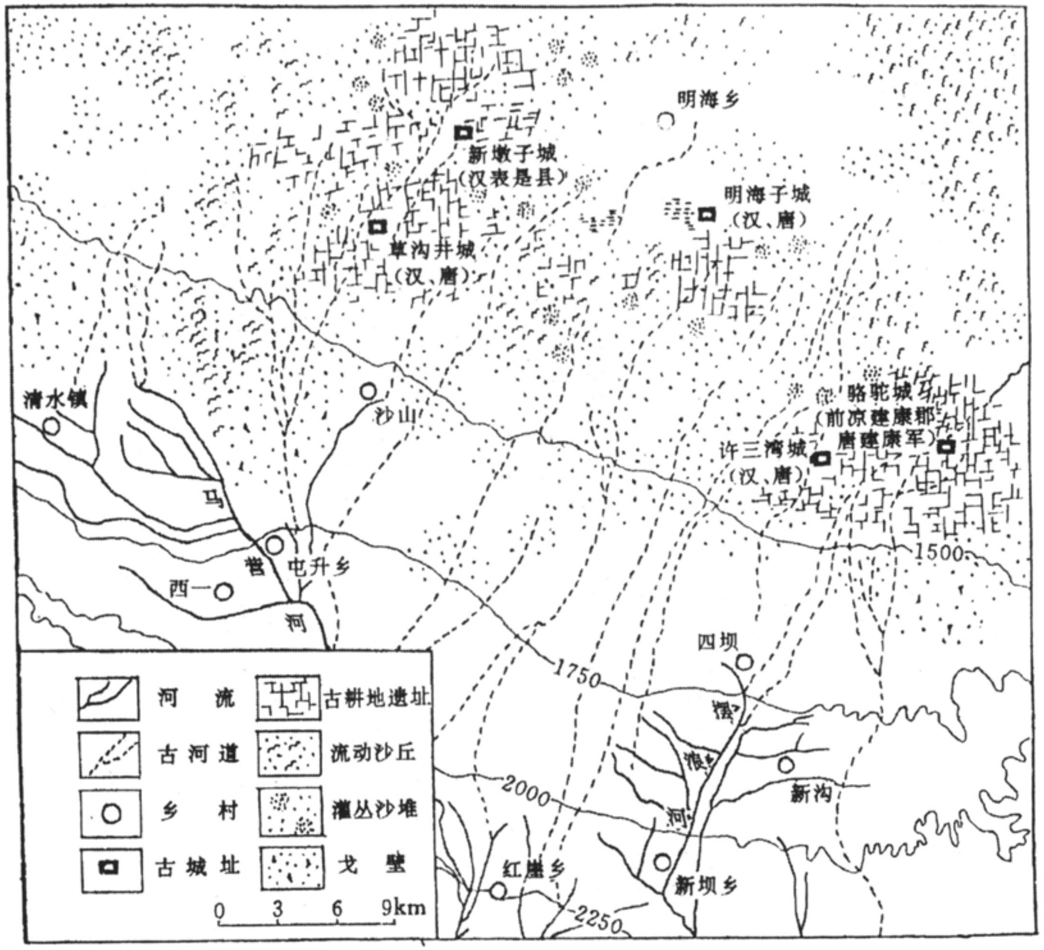


图3 河西走廊马营河、摆浪河下游汉唐古绿洲沙漠化示意图

Fig. 3 Desertification in the ancient Oases of Han and Tang Dynasties at the lower reaches of Maying River and Bailang River in Hexi side length of 200 m. The remains here are from the Han Dynasty. There are also many relics outside the city, but they all date to the Han Dynasty. The city itself originated during that dynasty.

Caogoujingcheng City is just 6 km south of Xindunzicheng City. Its side is 120 m in a north-south direction, and 130 m in an east-west direction. Its gate opens toward the south with a width of 10 m. Several different remains were found in and around the city. An old document mentions that this area was developed by irrigation systems during the Qing Dynasty.

(3) Jinta

The old city of Jinta is located at an eastern side of the present Jinta Oasis, downstream of the Taolaihe River, on the south shores of Tiaohu Lake, which has long since dried up. The old oasis runs 40 km in a north-south direction and 10 to 20 km in an east-west direction, with a total area of 650 km^2 including the former lake area (100 km^2). The groundwater level is rather high there, and types of reed grasses, called Luchang-shawo, grow there.

In the northern part, there was a lake called Baitinghu, where the Beidahe River used to run. Reed grasses are still grown showing the sites of past wetlands. The location of the old lake is considered identical with the site where the Beidahe River now meets the Heihe River.

In and around the region one comes across many old cities, such as Huoshiliang, Ganggangwa, Yushujing, Xisanjiaocheng, Xiaosanjiaocheng, Xigucheng, Yiducheng, Sanjiaocheng, Xiachangcheng, Pocheng, Huangyaduncheng, Yin'erzicheng, Sangeguozhuang, Xiapocheng, Beisanjiaocheng, Huoshitanguchen, and Xiyaopozhuang. There are also many tombs not far from these cities, and a significant number of old pottery kilns (Fig. 4).

Among the old cities, Xigucheng is the largest. It is divided into two portions: east and west. The west city is 80 m from north to south, and 90 m from east to west; the east city is 80 m(north-south), and 110 m(east-west) in length. The total area is 16000 m^2. Most of the walls have deteriorated already. No buildings are left, but shards and bricks were found in and around the city.

Pocheng City is 12 km northeast of the present Jinta City. It is surrounded by double walls; the outer walls run 110 m in a north-south direction, and 92 m in an east-west direction. The walls have breastworks, and there is one gate toward the south. There are many pieces of ceramics and bricks in and around the city, in addition to many pieces of iron and stone mills. The lower half of a stone mill discovered here was 45 cm in diameter. In the city, arrowheads, a kind of moneys from the Han and Tang Dynasties, copper rings, and ear cleaners collected were reminiscent of the Han and Tang Dynasties.

Xiachangcheng City is 3.5 km northeast of Pocheng City, and only one side wall is left, 24 m in length, 3 to 4 m in thickness, and 4.5 m in height. Sanjiaocheng City is 2.3 km west of Xiachangcheng City, its horizontal projection (30 x19 m) is triangular in shape, so it has been called the triangle city (Sanjiaocheng). Huoshitanguchen City has also been badly damaged, (size; 34 m x 30 m). Many pottery shards were found in and around the city. It is believed that desertification started in this area after the Tang Dynasty.

The total ruins cover about 2,330 km^2 in the Heihe Basin, and the history of its desertification must be studied in more detail in the future.

- Translated/summarized by NAKAWO, M. (RIHN)

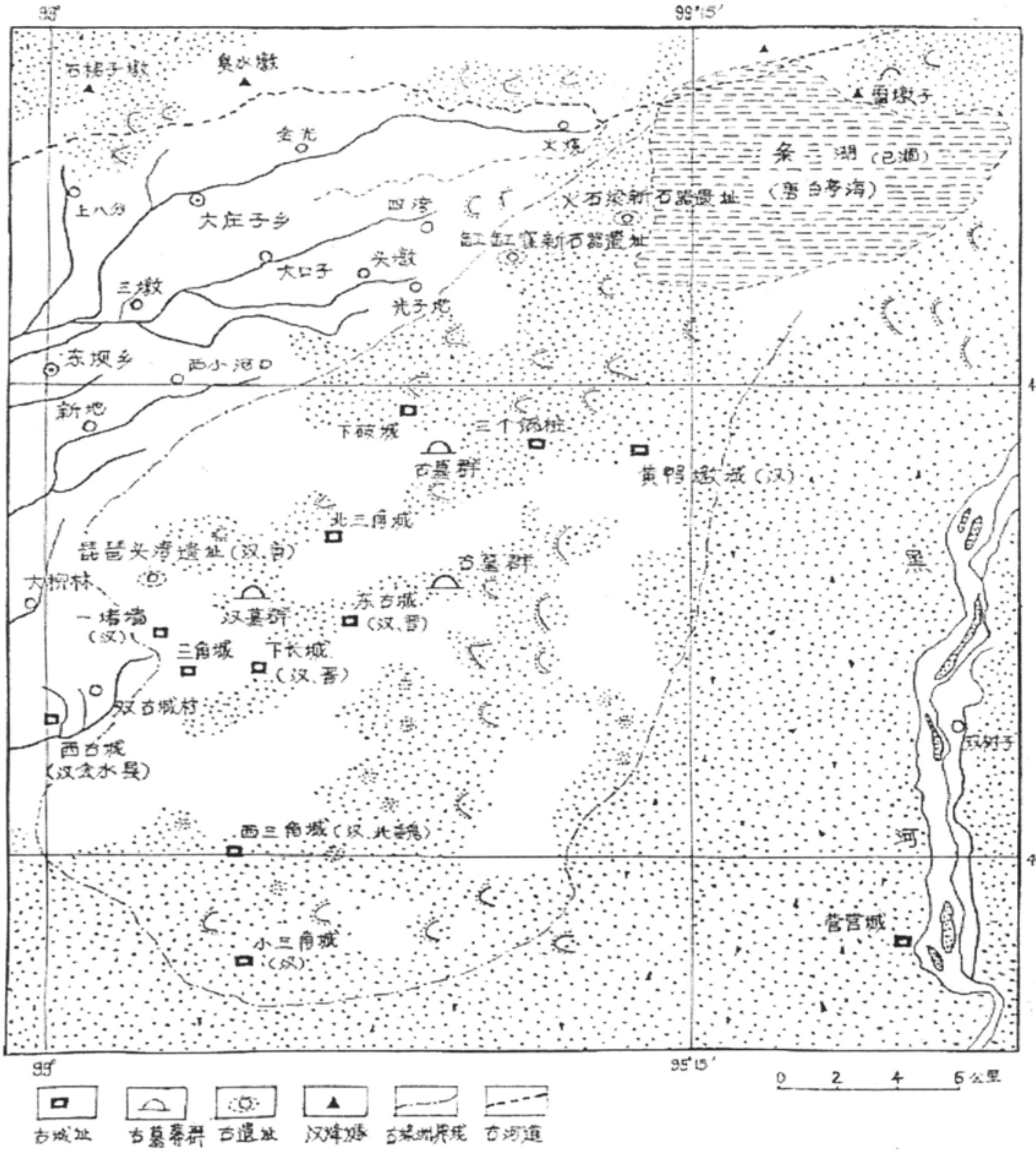


图 4　　金塔县东沙窝古绿洲沙漠化示意图

Fig.4　　Desertification in the ancient Oases of the Eastern Sandy Land of Jinta County

Ancient Fauna of China' s Northwest

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The so-called "northwest" discussed in this article consists primarily of areas in Gansu, Qinghai, Ningxia and Xinjiang Provinces and Administrative Units. The zooarchaeological research in this area of China has been very limited due to a variety of reasons. We can at this point proceed with a systematic summary of this work so that a strong foundation can be established for future intensive research.

1. The excavation situation of various sites

The Fujiamen site in Wushan, Gansu

The specific location of the Fujiamen site is distinctive (3 in Figure 1). The site dates to the Neolithic period and includes cultural levels of both the Shilingxia and the Majiayao phases of the Majiayao Culture so while the specific date of the site is not clear it should predate the Qijia Culture. Minimum Number of Individual (MNI) statistics from the Shilingxia level at the site include 12 pigs which comprise 46% of the complete collection, 5 sheep (19%), 2 dogs (8%), 2 cattle (8%), and one each (4%) of sika deer, rabbit, bamboo rat, pheasant, and hawk. In the Majiayao phase levels they recovered MNI of 11 pig (50%), 4 sheep (18%), 2 dogs (9%), 2 cattle (9%), and one each (5%) of rabbit and bamboo rat (Yuan Jing Forthcoming)

The pigs remains dominate both the collections from the Shilingxia and the Majiayao phases.

The Caiyuancun Site in Haiyuan, Ningxia

The Caiyauncun site is located at 105°36' E, 36°30' N (2 in Figure 1) and dates to the Neolithic period around 2863-1789 BC. The faunal assemblage discovered at this site is somewhat more varied but no precise statistics have been provided. The more common species include *Canis familiaris*, *Sus* sp., *Procapra gutturosa*, *Bos* sp., and *Cervus nippon* while the less common include *Capra ibex*, *Ovis ammon*, *Equus* sp., *Cervus elaphus*, *Moschus moschiferus*, *Lepus* sp., *Marmota sibirica*, and *Gallus* sp. (Han Kangxin 1993).

The Dahezhuang site in Yongjing, Gansu

The Dahezhuang site is located at 103°22' E, 35°54' N (4 in Figure 1) and dates to the Qijia Culture of the Neolithic to Bronze age interface period, approximately 2114-1748 BC. According to the analysis of archaeological specimen, a total so 194 pig remains comprising 73% of the assemblage, 56 sheep (21%), 6 cattle (2%), 4 sika deer (2%), 3 horse (1%), 2 dog (1%), and 1 moose (0.5%) were discovered at this site (Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Gansu Dui, 1974). Again the dominant species at the site was pig followed by sheep and cattle.

The Qinweijia site in Yongjing, Gansu

The site of Qinweijia is close by Dahezhuang (5 in Figure 1) although with slightly different coordinates. This site also dates to the Qijia culture at the transition between the Stone Age and Bronze Age with dates similar to Dahezhuang. The statistical data that can be assessed indicate that 430 pig remains – making up 83% of the assemblage, 50 sheep (10%), and 38 cattle (7%) were discovered at the site (Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Gansu Dui 1974).

The dominant species at this site was once again pig followed by sheep and cattle.

The cemetery at the Chawuhugorge in Hejing, Xinjiang

The cemetery at Chawuhugoukou is located at 86°7' E and 42°26' N (6 in Figure 1). Cemetery number 1 dates to the Western Zhou to Springs and Autumns period approximately 3000-2500 years ago. According to the reports of statistical data, an MNI of 78 horse comprises 78% of the collection. 20 cattle crania make up 20%, and MNI of one each were determined for caprids and cervids. Cemetery number 3 dates from the Eastern Han, about 1900 years ago. The MNI reported for fauna at this site include 14 mountain goats – roughly 67% of the collection, 6 horse (29%), and one cattle cranium (5%) (Yuan Jing 1998).

In terms of chronology, these two cemeteries are separated by about 1000 years. The difference in fauna between these two periods is rather striking. For example, horses make up more than 2/3 of the collection from cemetery number 1 while cattle and caprids are quite rare. On the contrary, mountain goats comprise over 2/3 of the collection from cemetery number 3 but horse and cattle are nearly absent. Additionally, according to the report on the excavations of cemetery 3 released by the Xinjiang Institute of Cultural Relics and Archaeology, in the 20 excavated burials 13 caprid crania were discovered and in three of these tombs horse bones were also buried. This shows that goat bones constitute over 2/3 of the faunal remains (Xinjiang Wenwu Kaogu Yanjiusuo, et al. 1990).

The cemetery of Shidaoluo in Guyuan, Ningxia

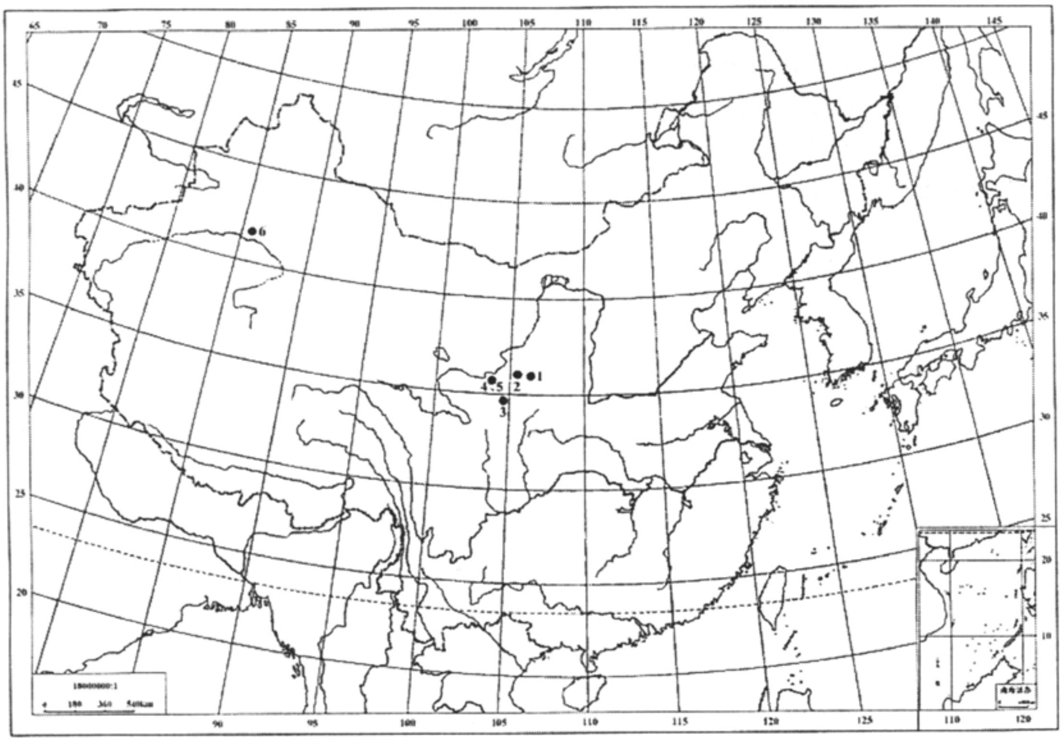
The characteristics of the Shidaoluo cemetery are rather unique since they date to 656 AD (1 in Figure 1). The animal skeletons from these burials were primarily from tunnel used for looting only one dog skeleton was from the tomb chamber. According to MNI estimates, with the exception of 27 bird remains, the excavators discovered a collection of mammals that was 33% goat, 27% dog (MNI 4), 20% cattle (MNI 3), and 7% each of rabbit, deer, and horse (MNI 1 each).

Goats dominate the mammal assemblage from the site although dog and cattle are also present.

2. Discussion

The sites discussed above, with the exception of the extremely western example of Chawuhugoukou, are in a relatively concentrated area. From the species variety and quantity information provided for these various sites, we can see that from about 4000 years ago on the faunal assemblages at the site of Fujiamen, Caiyuancun, Dahezhuang, and Qinweijia all are dominated by pigs and also include some caprid and cattle remains. From the excavated cultural remains we know that these site are characterized by agricultural subsistence. Since we have no data that speak clearly to the question of the nature of the natural environment at that time there is no

Fig. 1



Distribution of Sites

1 Shidaoluo 2 Caiyuancun 3 Fujiamen 4 Dahezhuang 5 Qinweijia 6 Chawuhugoukou

way to discuss this facet of that period but we can say that without question the conditions were suitable for agriculture and domestication. Additionally, from comparative studies using morphological data and craniometric measurements of skulls from the burials at the Caiyuancun Neolithic site, it seems clear that the original inhabitants of this area were closest to the present day East Asia type of Mongolian people and were rather distinct from modern North Asian and Northeast Asian types (Han Tangxin, 1993).

The faunal assemblage excavated at the site of Chawuhugoukou does not include pig and is mostly horse, cattle and goat. Considering the ecology of such animals, they are all well adapted to life in the dry climate of the gentle rolling topography within the desert steppe. Studies of the natural environment and paleo-climatological change during the Holocene epoch in Xinjiang show that during the last 3000 years the weather in this area has become warmer and drier – the sporo-pollen assemblage includes pollen of birches, and a considerable amount of willow, southernwood (artimisia or mugwort family), and *Cyperous rotundus* grass. Again in the last 2000 years the climate turned drier yet. Glaciers shrunk and lakes dried up. The diluvial deposition in front of the mountains and the alluvial deposition in the plains weakened tremendously and the alluvium shrunk in size. Contrastingly, the force of aeolian processes strengthened and the desert areas expanded. In terms of paleobotanical assemblages, pollen of conifers and various deciduous trees diminished while pigweeds increased. Southernwood and hemp persisted (Wen Qizhong 1992). The number 1 and 3 burial grounds at Chawuhu goukou are located on the present day Gobi gravel belt whose surface is covered with small Gobi pebbles or gravel of various sizes. Since the production tools found at cemetery number 1 were all small, portable tools such as bronze knives, grinding stones, loom weights and metal arrowheads used by nomadic groups, and the objects at cemetery number 3 included swords, arrowheads, and knives, neither of these locations have tools that are associated with agricultural production. Based on this the excavators believe that the economy of this area during the period of these sites was based on pastoralism (Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Xinjiang Dui, et al., 1988). According to a variety of evidence including ecological contexts for the fauna discussed above, pollen analysis, investigation of environmental conditions and archaeological finds we know that at least for the past 3000 years, this area comprised the Gobi steppe and was characterized by a warm, dry climate.

Since no wild animals that are particularly sensitive to ecological factors have been identified in the faunal remains recovered from the burials at Shidaoluo, and no other analysis has been conducted, we have no way of directly identifying the environmental situation of the Guyuan area during that period. However, it is the case that the nature of the assemblage of animals that were utilized by ancient man is closely related to the customs of the people of that time and to environmental factors. Based on the fact that cattle and goat dominate the faunal assemblage at Shidaoluo, this site clearly has the characteristics of a faunal in the Northwest or North of China. In terms of the larger picture, the Northwest China area in the last 3000 years has seen the shrinking of the interior lakes, the flora has change from forested grasslands to sparsely wooded grassland, the glaciers retreat, and the climate become drier and colder(Zhou Shangzhe et al., 1991; Wang Fubao, 1992). The Tang Dynasty natural environment of Guyuan area should be an example of climactic patterns of this size. In their discussions of the changes that mark the transition to pastoralism during the historic era, natural scientists have proposed that, starting in the 9th century, the records concerning the customs of the Shaanxi-Gansu-Ningxia-Yellow River plateau in documents from the Northern Song indicate that pastoralism emerged from a mounted –hunting origin. To the west and north of a line from Guyuan in Ningxia to Tianshui in Gansu is the area of pastoralism with this line marking a transition zone between agricultural and pastoral areas (Shi Yafeng ,1996). This corroborates the understanding that we have based on the animal bones.

Since the data that we have about faunal remains from known sites of various periods in the Northwest are limited we cannot predict how long pigs would have lasted after the Neolithic. Because the site of Shidaoluo can be subdivided into periods we can show that at the latest, pigs seem to disappear in this zone around the Tang Dynasty. Also, from the tombstone inscriptions at the Shidaoluo cemetery we know that the Shi lineage came from the west and are therefore certainly different people from those who resided at the Neolithic site of Caiyuancun. As stated above, this area underwent a great deal of environmental change in the last 3000 years. At this point it is impossible to say whether the disappearance of pigs is due to human decisions or environmental change. The American zooarchaeologist Kent Flannery has discussed the present day taboo on pork that presides in Islamic culture but it is clear that both wild and domesticated pigs were present in ancient sites of this area -- although with the passage of time the number of domesticated pigs diminished and eventually completely disappeared from Central Asia. Nomadism is not conducive to the keeping of domesticated pigs since the constant movement about is not suited to the temperament of these swine (Matsui 1991). The emergence and disappearance of pigs in Western Asia is a useful comparison for inspiration concerning our research on Central Asia.

References:

Han Kangxin, 1993, Ningxia Haiyuan Caiyuancun Xinshiqi Shidai Mudi RengudeXingbieNianlingJianding yu Tizhi Leixing (The morphology, and age and sex identification of human remains from the Neolithich burials at Caiyuancun in Haiyuan, Ningxia), in *Zhongguo Kaoguxue Luncong (Collected Discussions of Chinese Archaeology)*. Institute of Archeaology, CASS, , 170-181, Science Press.

Matsui, Aakira 1991, Advanced in Faunal Analysis for Archaeology, Bulletin of the NationalMuseum of Japanese History, Vol. 29, 13-44 (In Japanese).

Shi Yafeng, 1996, *Zhongguo Lishi Qihou Bianhua (Chinese Historical Climate Change)*.Shandong:Shandong Kexue Jixu Chubanshe.

Wang Fubao. 1992, Qingzang Gaoyuan Quanxinshi Qihou ji Huanjing Jiben Tezheng (The characteristics of Holocene climate and environment on the Qinghai and Tibetan plateau), in ed. Shi Yafeng, *Zhongguo Quanxinshi Danuanqi Qihou yu Huanjing(Climate and environment of the warm period of the Holocene in China)*. Shanghai: Hayang chubanshe, 197-207.

Wen Qizhong. 1992, Xinjiang Diqu Quanxinshi Chenji de Guqihou Jilu Jiqi Gaowenqi Fenxi (Analysis of temperature and paleo-climactic records of Holocene precipitation in the Xinjiang area), in ed. Shi Yafeng, *Zhongguo Quanxinshi Danuanqi Qihou yu Huanjing (Climate and environment of the warm period of the Holocene in China)*. Shanghai: Hayang chubanshe, 168-173.

Xinjiang Wenwu Kaogu Yanjiusuo et al. 1990. Hejingxian Chawuhugou Sanhao Mudi Fajue Jianbao (Preliminary excavation report on cemetery number 3 at Chawuhu gou in Hejing County). *Xinjiang Wenwu* 1990(1):15-20.

Yuan Jing et al. 1998. Xinjiang Hejingxian Chawuhugoukou Yi-Sanhao Mudi Dongwu Guge Yanjiu Baogao (Report on research on the animal bones from cemeteries number 1 and 3 from Chaeuhu goukou in Hejing County, Xinjiang). *Kaogu* 1998(6):63-68.

Yuan Jing, et al. 2000. Dongwu Guge (Animal bones), in ed. Yuanzhou Lianhe Kaogudui, *Tang Shidaoluo Mu (The Tang tomb of Shidaoluo)*. Miancheng: Miancheng chubanshe, 296-323.

Yuan Jing. (Forthcoming) Gansu Wushan Fujiamen Yizhi Chutu de Dongwu Guge Yanjiu Baogao (Research report on the animal bones excavated from the site of Fujiamen in Wushan, Gansu).

Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Gansu dui et al., 1974, Gansu Yongjing Dahezhuang Yizhi Fajue Baogao (Excavation report on the Dahezhuang site in Yongjing, Gansu). *Kaogu Xuebao*. 1974(2): 29-61.

Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Gansu dui et al., 1975, Gansu Yongjing Qinweijia Qijiawenhua Mudi (The Qijia Culture cemetery at Qinweijia in Yongjing, Gansu). *Kaogu Xuebao.* 1975(2): 57-96.

Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Xinjiang dui et al., 1988. Xinjiang Hejingxian Chawuhugoukou Yihao Mudi (The number 1 cemetery at Chawuhu goukou in Xinjiang). *Kaogu Xuebao* 1988(3): 75-100.

Zhou Shangzhe 1991, Zhongguo Xibu Quanxinshi Qiannian Chidu Huanjing Bianhua de Chubu Yanjiu (Initial investigation of environmental change throughout the millennia of the Holocene in Western China), in ed. Zhou Kunshu *Huanjing Kaoguxue Yanjiu – 1 (Research on Environmental Archaeology-1)*. Beijing: Kexue chubanshe, 230-236.

Agricultural development and desertification in Inner Mongolia, China

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At the Mongolian highland, nomadic people have little developed agriculture before the Min Dynasty. At the end of the 16th Century, Altan Khaan has introduced Chinese cultures and agriculture into the south part of Mongolia. According to the statistics of 1743, as wide as 80% of the land have been cultivated around the capital town.

The Manchurian Government has forbidden cultivating in Mongolia, but never succeeded to stop agricultural development. Many Chinese peasants came for farming, and many Mongolian nobles allowed them to come for the cultivation, for the money of rent. At the end of the 18th Century, the Manchurian Government has changed their policy to allow the cultivation in Mongolia.

Left banner of Khorchin is one of examples of the fastest and widest developed areas. The good pasture for Mongolian nomads had become a field for Chinese peasants. Mongolian nomads, therefore, had to move to worse pasture, pushed out by the Chinese peasants. At the 20th century, many Mongolians had to give up moving with animals, and started to cultivate themselves.

With the agricultural development, desertification has started in Inner Mongolia. There could be many reasons for desertification, but agricultural development could be one of the most responsible causes. In China especially in Inner Mongolia, desertification is very rapid, and half of the land has become desert in recent years.

Because of desertification, sandstorms have attacked a north part of China many times year after year. Ejina banner in Inner Mongolia is regarded as one of the evil region of the sand storms occurring. Actually the desertification of this region is very serious, which has been influenced by agricultural development outside of this region.

The upper and middle area of the Heihe River has highly developed after the revolution, and many people have started using significant amount of water for agriculture. Many dams and waterways have been constructed for irrigation, and they have acted to decrease the amount of water going downstream. Two big lakes located at the terminus of the river have completely disappeared in the 1990's.

In Ejina banner, the water from the river has become less available, and desertification has become more serious. We must hence quickly examine the water circulation system, and suggest the better decision to take for stopping desertification and sandstorms.

-Translated/summarized by KONAGAYA, Yuki (NME)

Socio-humanistic care for ecological optimization in Heihe river basin

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1. Basic condition of the Yugu

The Yugu, who call themselves Sarag Yugur, is one of the Chinese ethnic groups whose population is very small. According to the national census in 1990, the total population of the Yugu is 12,297, which is the 48^{th} biggest of 55 ethnic groups in China. They live mainly in Sunan Yugu autonomous prefecture of Gansu province, where is located at the upper reaches of Heihe river. They were named Yugu when the autonomous prefecture was founded in 1953, the meaning of which is "rich and hard" in Han language.

The Yugu have two folk languages. Those who live in the western part of the prefecture use western Yugu language that belongs to Turkish languages, whereas those who live in the eastern part use eastern Yugu language that belongs to Mongolian languages. In these days, most of the Yugu people use Han language, in some cases even among the Yugu themselves.

Ancestor of the Yugu is Huangtou (Yellow-head) Uigur, a segment of the ancient Uigur. In the 16^{th} century (Ming dynasty), they moved from Xinjiang to the boarder area of Gansu, Xinjiang, and Qinghai Provinces.

The substance of the Yugu is mainly herding. In the plain area, however, accompanied with the economic reform, pastoral production is changing to agricultural production and in some areas, now the situation is half-agricultural half-pastoral.

2. Some problems in the action for vegetation recovery and anti-desertification

1) Problem of labor skill training in the process of production mode change

The research for estimating total effect of water reservoir forest in Qilian Mountains recognizes that to decrease population pressure in the forest area of Qilian Mountains, people who live in the forest area of Qilian Mountains, especially 378 households 2446 people of eastern core area should emigrate another place needed, and that such a action will decrease the forestay-herding contradiction and create better social environment to protect and develop the forest resources in Qilian Mountains better. Zhangye district once planned to emigrate the Yugu herders who lived in the core area of reservoir forest in Qilian Mountains to the oasis agricultural area and to change them into farmers on the assumption that they were subsidized 15 thousand Yuan per household, but this plan could not be realized. Its main problem was that labor experience and skill of minority people, whose substance had been herding for a long time, was accumulated about herding, so there remained the problem of labor-force change even if socio-economic structure could be regulated. If this problem is not to be taken into consideration, there must be return of emigrants and more severe destruction of ecology.

2) Problem of the change of sense of value

Each ethnic group has their own specific sense of value, which is closely related to its specific cultural tradition and production-life mode. The Yugu people recognize herding as essential. In the early 80's as the price of animal products ---especially cashmere--- rose, pastoral production brought the herders abundant economic profit. Driven by profit inducement, herders increased the number of livestock and developed pastoral production remarkably. This very development, especially rapid increase of goats, caused quick desertification of grassland. Destruction of the bush by goats leaded to destruction and flow of dunes. Today, to protect ecological environment and to recover vegetation, herders whose substance has been herding for generations leave from grassland and stop herding to engage in agricultural production as farmers. In this changing process of production mode, there is not only a problem about maladjusted change of labor power, but also a problem about change of sense of value. As herders has been recognizing that pastoral production is more profitable than agricultural production, to be a farmer from a herder means that his standard of living will be deteriorated, and this fact is relatively big shock to his traditional sense of value. Some Chinese specialists of agriculture recognize that cashmere is natural resource peculiar to China and has very high economic value, and that Chinese western arid area is a natural base of raising goats although there is no condition of it abroad. As of this, Chinese government must combine construction of ecological environment with economic development, taking ecological profit and practical profit of herders in the western area into consideration, and accelerate each development simultaneously.

3) Problem of coordination of inter-ethnic relation

Oases of Hexi corridor are mainly located at Shiyanhe, Heihe and Shulehe river basin. And dwellers of the oases are composed of different ethnic groups. Today, as to population distribution, water reservoir forest area of upper reaches and water concentration lake area of lower reaches are dominated by minority people; Yugu and Tibetan people in upper reaches, and Mongolian people in lower reaches. In oases of the midstream, about 4 million Han people live.

Now the research on ecological mechanism of vegetation recovery and action for anti-desertification recognizes as following; in water reservoir forest area, herding should retreat widely, and remaining herding should be based on improved species of grass, carrying out feeding in livestock barn or in fence, to decrease ecological destruction caused by herding, that is, the forestay-herding contradiction. At the same time, in extremely arid area where desertification is very heavy, villagers and animals should emigrate and stop herding, to carry out blockade protection and let vegetation recover by itself. In the midstream area, it is important to coordinate land-use structure, to utilize land resource reasonably, and to carry out water-saving irrigation and ecologically economic agriculture. These measures are not only effective, but also profitable for sustainable development of Heihe river basin. But such kind of action plan will easily cause another problem; in the process of coordinating population composition of Heihe river basin, most of dwellers that emigrate are minorities. So bad arrangement will affect inter-ethnic relationship.

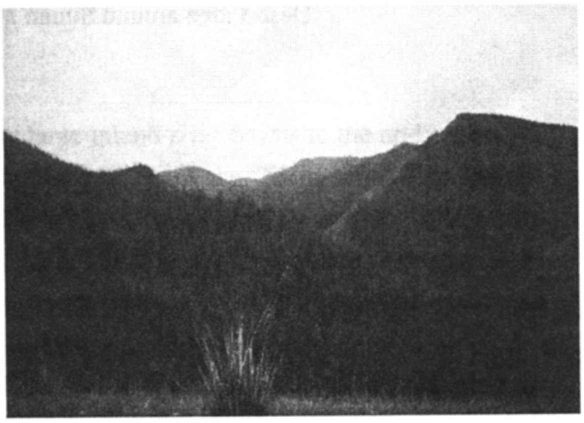
4) Problem of compensation for ecological profit

The main part of anti-desertification project is ecological project, which requires long-term practice and sustainment, but the profit is public. To compensate the expenditure of performers of public ecological protection, to help out the cost of project, to coordinate adequately the profit relation between performers of public ecological protection and its recipients, and to enforce the sense of ecology and responsibility of the society, institution of compensation for ecological profit must be established as fast as possible in the ecological construction area. Here Sunan Yugu autonomous prefecture is illustrated as an example.

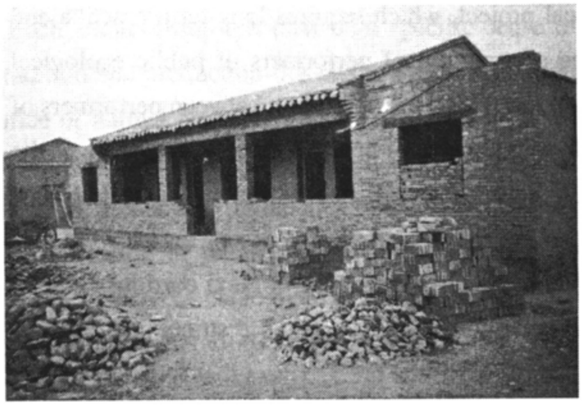
Sunan prefecture is located at northern foot of Qilian Mountains, southern part of Hexi corridor. 70% of Qilian Mountains is in the area of the prefecture; whole prefecture ranges across 5 districts and cities of Hexi, bordering on 15 prefectures and cities of Gansu and Qinghai. There are 33 rivers that form Shiyanghe, Shulehe and Heihe river systems, and the volume of water flowing out of the prefecture is 43 billion cubic meters per year. The water of Qilian Mountains that flows out via Sunan irrigates good field of over 700 thousand hecrares in Hexi corridor, supports over 4 million people, over 5 million animals, nonferrous metal base, and hundreds of mining and manufacturing companies. All of this water comes from water reservoir forest of Qilian Mountains.

As protecting and constructing forest of Qilian Mountains is very difficult only by local capacity, state should establish suitable laws and regulations to take measures for ecological compensation as soon as possible. Specifically, it should contain three aspects; firstly, to establish "fund for protection of water reservoir forest in Qilian Mountains" mainly from national investment, which is only to be used for protection, maintenance, construction, and enlargement of forest area, and also uniformly planned, controlled, and arranged. Construction of water reservoir forest in Qilian Mountains should be one of the national ecological projects and receive long-term investment. Secondly, compensation for ecological profit should be collected from mining and manufacturing companies, sectors, and individuals of recipient area according to their income. Thirdly, those who destruct ecology by haphazard development, felling, or herding should not only pay fine and take the responsibility of recovering ecology, but also pay compensation money that will be incorporated into "fund for protection of water reservoir forest in Qilian Mountains".

White-lipped deer in water reservoir forest of Qilian Mountains



Water reservoir forest of Qilian Mountains



New-built house of the Yugu who sedentarized for agricultural development

Costume of the Yugu

Desert area around Sunan Minghua Development District

-Translated/summarized by OZAKI, Takahiro(Kagoshima University)

Hydrological Studies of the Heihe River Basin in the Northwest Arid Regions of China

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Abstract: Because of the extremely continental dry climate, the Heihe River basin is characterized by less precipitation, rapid evaporation and low runoff ratio. The mountain watersheds of the Heihe River basin receive much more precipitation, and possess lower temperature and lower evaporation rate as compared with the basin area in front of the mountains, therefore are the runoff generation area of the Heihe River basin. A trend analysis indicates that, in the Heihe River basin during the 40 years from 1956 to 1996, air temperature increase is mainly in winter, next in autumn, while summer precipitation increases obviously. As a result, both yearly air temperature and precipitation show some increase trend. The runoff simulation is carried out with a model for simulating the response of monthly runoff from the mountain watersheds in the inland area of northwest China to climate change. Taken the mountain watershed of the Heihe River basin controlled by the Yingluoxia Hydrometric station as an example, the water balance and hydrological processes are simulated. The water balance simulation indicates that from the dry years to the wet years, precipitation, evaporation, runoff and runoff ratio all increase, while the alimentation ratio of glacier and snow melt water to the runoff decrease. The simulation of runoff change under the global warming indicates that, from 1990s to 2000s, as compared with the runoff during 1980s, along with the increase of air temperature, precipitation and glacier melt water increase in some amount. This compensates in some degree the runoff reduction caused by the increase of air temperature and evaporation. As a result, runoff shows slightly increase, and the increment range is within 3%. Then, to 2010s and 2040s, the increase of precipitation and glacial melt water is not enough to compensate the runoff reduction caused by air temperature increase, and the runoff will decrease in the aptitude within 10%.

Key words: Heihe River basin, hydrological characteristics, runoff simulation, water balance, runoff change projection

1. Introduction

The Heihe River basin is one of the relatively large inland river basins in the arid regions of northwest China. It is located at the middle of the north flank of the Qilian Mountains and the Hexi Corridor. The drainage area of the Heihe River basin ranges from 37°45′N to 42°40′N and from 96°42′E to 102°04′E, covering the area of 13×10^4 km^2 (Fig. 1). It originates from the Qilian Mountains in Qinghai province, and flows through the Hexi Corridor of Gansu province and enters the western part of Inner Mongolia Plateau (Gao et al., 1990).

As a representative of the inland river basins, the Heihe River basin can be divided into four altitude zones: high mountain ice, snow and permafrost zone, mountain vegetation zone, oases zone and desert zone. The former two zones constitute the mountain watersheds, which are the runoff generation area, while the latter two zones constitute the low land area where water resources are consumed and runoff is scattering and disappearing. The Heihe River basin is situated at the inland area of Eurasia, far from the oceans. The water vapor current comes mainly from the summer southeast monsoon from the Pacific Ocean and the summer southwest monsoon from the Indian Ocean (Zhou, 1983; Sun, 1977-1978), next from the wester air current (Yang, 1992a). In winter, it is extremely cold and dry because of the dominant control over the area by the Mongolia and Siberia High. Therefore, the Heihe River basin is dry in climate and short of water resources. Based on the data measured at the meteorological stations and hydrometric stations distributed in the Heihe River basin, this paper is intended to discuss the hydrological characteristics, runoff simulation and response of the mountain runoff to climate change in the Heihe River basin.

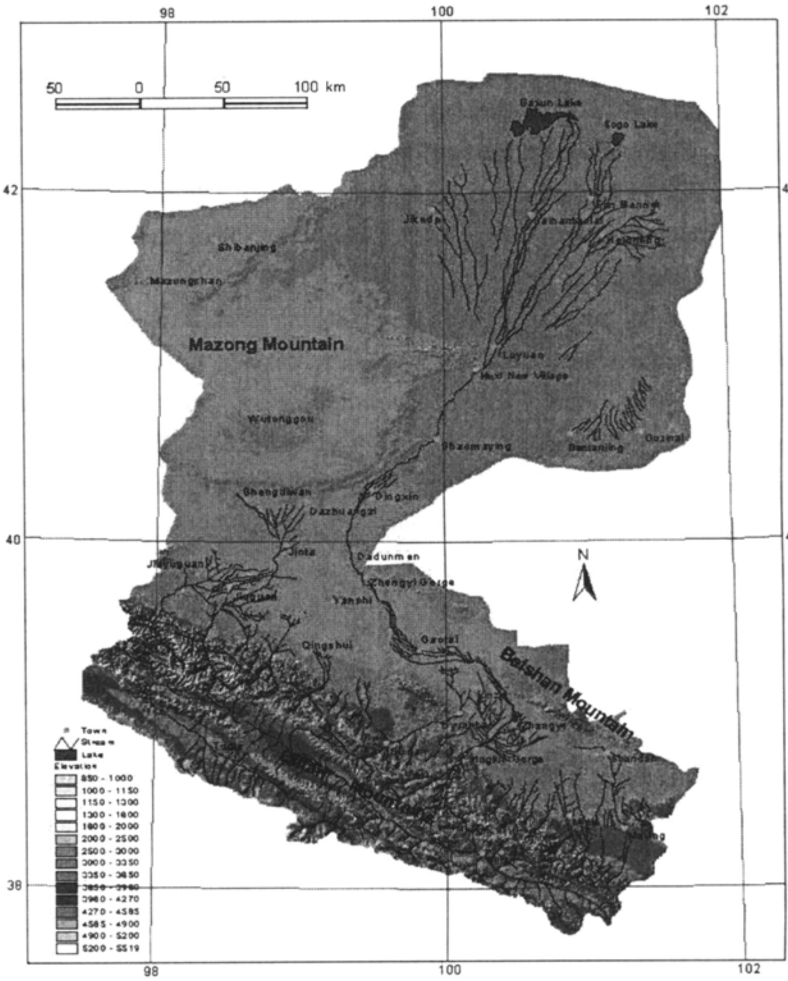

Fig. 1 A sketch map of the Heihe River basin

2 Hydrological characteristics

2.1 Drainage systems

The Heihe River drainage system consists of 35 rivers, which can be divided into three sub-drainage systems: the east sub-drainage system, the middle sub-drainage system and the west sub-drainage system (Fig. 1). Because of the increasing utilization of the water resources, the three sub-drainage systems have been separated from their surface water hydraulic connections, forming three relatively independent drainage systems. However, they may have some under surface hydraulic connections, but it still needs further investigation.

Because of the extremely continental dry climate, the Heihe River basin is characterized by less precipitation, rapid evaporation and low runoff ratio (Table 1).

Table 1 Precipitation and runoff in the Heihe River basin

	Drainege area (km^2)	Precipitation		Runoff		Runoff ratio
		10^8m^3	mm	10^8m^3	mm	
East drainage system	105602	122.6	116.1	29.28	27.7	0.24
Middle drainage system	5273	9.8	185.9	2.97	56.3	0.30
West drainage system	19125	33.5	175.2	9.61	50.2	0.29
Whole Heihe River basin	130000	165.9	127.6	41.85	32.2	0.25

According to the Glacier Inventory of China (Wang et al., 1981), there are 1078 glaciers covering 420.55km^2 in the Qilian Mountains of the Heihe River basin. The water storage of the glaciers accounts for $137.7\times10^8m^3$, and the annual glacial melt water accounts for $2.98\times10^8m^3$. The alimentary ratio of the glacial melt water to the total river runoff is averaged at 8% (Yang, 1991).

2.2 Runoff generation

The spatial distribution of annual air temperature and precipitation shows that, in the Heihe River basin, precipitation is more and air temperature is lower at the mountainous area than those at the low land area in front of the mountains (Yang, 1992b). Fig. 2 shows significant altitude dependency of annual air temperature, precipitation and pan evaporation measured at the standard meteorological stations distributed in the Heihe River basin. Along with the increase of altitude, precipitation increases, air temperature and evaporation decrease. As the regional characteristics, precipitation is closely related to altitude (Fig. 2). This indicates that the topographical lifting mechanisms play a very important role in the formation of precipitation in this area. This can be explained by the facts that the Qilian Mountains stretch from southeast to northwest, facing actually northeast. The controlling low pressure system over the Qilian Mountains and the subtropical high moving west during summer make the air current carrying water vapor from southeast move towards west (Yang, 1992a). Therefore, the lifting mechanisms are built up by the interaction between the air current, elevation and slope orientation of the Qilian Mountains. The precipitation is mostly concentrated during the summer season in a year (Yang, 1991), therefore, the annual precipitation shows obvious altitude dependency.

Fig.2 indicates that the mountain watersheds receive much more precipitation, and possess lower temperature and lower evaporation rate, and therefore are the runoff generation area.

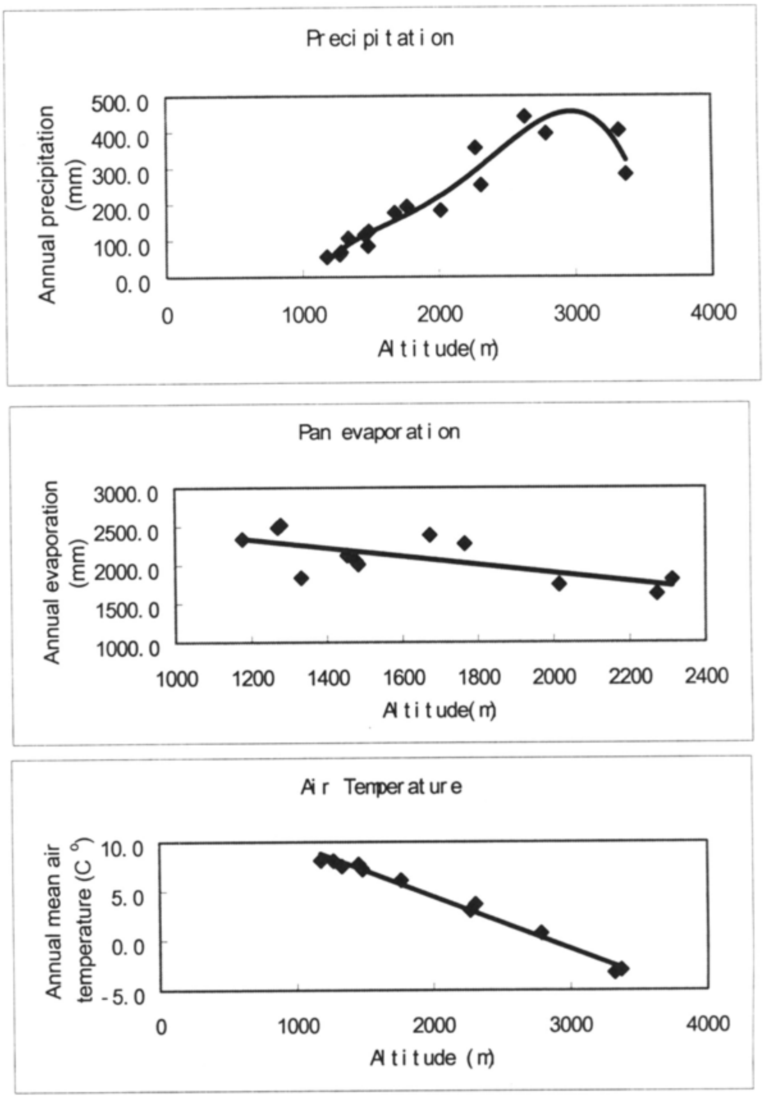

Fig. 2 Altitude dependency of yearly mean air temperature, total precipitation and pan evaporation in the Heihe River basin (averaged values at the standard meteorological stations during 1956 to 1998)

2.3 Monthly runoff distribution

Figure 3 shows the mean monthly runoff depth at the hydrometric stations of four sub basins of the Heihe River basin. The hydrometric stations Yingluoxia, Qilian and Zhamask control the three mountainous watersheds of the north flank of the Qilian Mountains, which represent the runoff generation area of the mountains. The Zhengyixia hydrometric station is located at the north side of the Hexi Corridor, at the north Beishan Mountains, which is much lower than the Qilian Mountains. The catchment area controlled by the Zhengyixia station consists of the mountainous part in the Qilian Mountains and the low land part of the Hexi Corridor. Therefore, runoff at the Zhengyixia station represents the surplus of the mountain runoff after utilization of water resources in the Hexi corridor, and is much smaller than the runoff at the other three hydrometric stations. Figure 3 indicates that runoff is generated from the mountain watershed and consumed at the low land Hexi corridor area. Runoff from the mountains is mostly concentrated during the months from May to September, and the largest runoff occurs during the summer months from June to August. The three mountain watersheds can be divided into the high mountain ice, snow and permafrost zone and mountain vegetation zone by the altitude line 3600m(Gao et al., 1991). The high mountain zone accounts for 55%, 40% and 83% in the hydrometric basins of Yinglouxia, Qilian and Zhamask respectively. The hydrographs of the three mountain watersheds show the similar characteristics. The monthly runoff distribution is the same, and the runoff generation is also close to each other. At the high mountain zone, the runoff coefficient is large because of the more precipitation, less evaporation, and the existence of glaciers and permafrost (Yang, 1991). At the mountain vegetation zone, the water restraining forests have strong ability to conserve water, and therefore to promote the runoff generation (Che et al., 1996). Therefore, both the high mountain zone and the mountain vegetation zone are important to contribute the runoff generation.

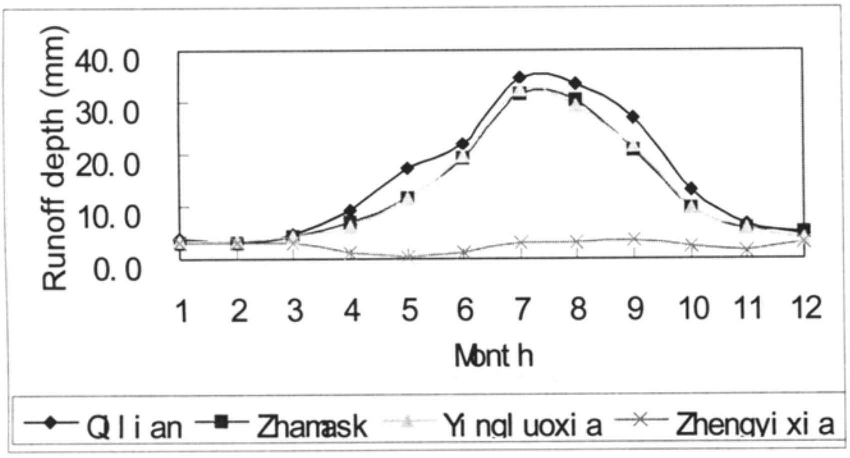

Fig. 3 Mean monthly runoff distribution at the hydrometric stations of Heihe River (Averaged from 1967 to 1995)

Station	Altitude(m)	Catchment area(km^2)
Qilian	2590	2452
Zhamask	2635	4589
Yingluoxia	1674	10009
Zhengyixia	1995	35634

3 Runoff simulation

3.1 Model structure

The basic structure of the model for simulating the response of monthly runoff from the mountainous watersheds in the inland area of northwest China to climate changes is presented in Fig. 4 (Kang et al., 1999).

The basic inputs to the model are precipitation *P* and air temperature *T* at a standard meteorological station, outputs are evapotranspiration *ET* and runoff *R* from the mountainous watersheds (Fig. 4), and the time step is a month. In the model, the mountain watersheds are divided into two basic altitude zones, the high mountain ice, snow and permafrost zone (expressed as high mountain zone in Fig. 4) and the mountain vegetation zone.

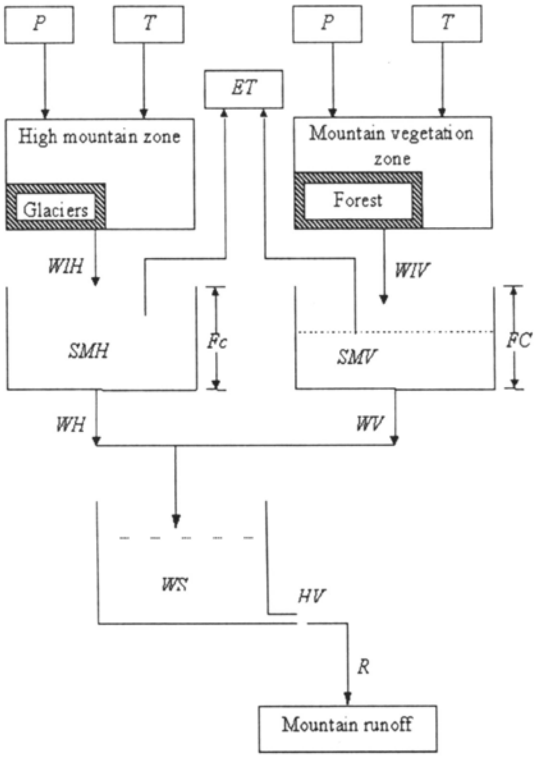

Fig. 4 Diagrammatic sketch of the model for simulating the from the mountainous watersheds in the inland area of northwest China (designed based on HBV runoff model (Bergstrom, 1976), and the symbols are interpreted in the text.) (from Kang Ersi et al., 1999)

The procedure of runoff simulation expressed in Fig. 4 is interpreted as follows.

1) Computation of water inputs

The glacial melt, separation of solid and liquid precipitation, and snow accumulation and melt are computed. The water inputs to the mountainous watersheds are composed of glacier meltwater, snow meltwater and liquid precipitation. The water inputs are symbolized as *WIH* in the high mountain ice, snow and permafrost zone, and as *WIV* in the mountain vegetation zone.

2) Computation of water content in the soil moisture layer

The concept of soil moisture layer of HBV runoff model is used (Bergstrom, 1976). The ground surface and subsurface layer including the active layer of permafrost and the layer above the groundwater level constitute the soil moisture layer. The water storage of soil moisture layer in the high mountain ice, snow and permafrost zone is symbolized as *SMH*, and that in the mountain vegetation zone as *SMV*. The output of the water storage in the soil moisture zone is evapotranspiration *ET*. The critical water content of the soil moisture layer for runoff generation is symbolized as *Fc* in the high mountain ice, snow and permafrost zone, and as *FC* in the mountain vegetation zone.

3) Computation of runoff

Taking the soil moisture layer as a reservoir, then when its water storage reaches to *Fc* or *FC*, there will be runoff generation *WH* or *WV*. *WH* of the high mountain ice, snow and permafrost zone and *WV* of the mountain vegetation zone form together the water storage WS of the mountainous watershed. Then, through a lumped watershed response function with a drainage coefficient *HV*, the runoff *R* out of the outlet of the mountainous watershed is simulated.

4) Model test

Model test is carried out by the model evaluation criteria R^2 (Bergstrom, 1976) and a relative error expressed with the ratio of simulated value minus measured value to the measured value.

3.2 Water balance simulation of the mountain watershed

3.2.1 The mountain watershed

Taken the mountain watershed of the Heihe River basin controlled by Yingluoxia Hydrometric station (38°48'N, 100°11'E) (Table 2) as an example, the water balance and hydrological processes are simulated.

Table 2 The Heihe mountain watershed controlled by Yingluoxia hydrometric station at the Qilian Mountains [1)]

Hydrometric station	Altitude (m)	Drainage area (km^2)	Glacier covered area (km^2)	Glacier water storage (10^8m^3)	Glacier covered ratio (%)	Annual runoff (10^8m^3)	Glacier melt runoff (10^8m^3)	Alimentation ratio of glacier melt (%)
Yingluoxia	1674	10009	59	13.808	0.59	16.05	0.72	4.5

1) The years for statistics are from 1959 to 1993

The underlying surface of the high mountain glacier, snow and permafrost zone consists mainly of glaciers, snow cover, permafrost and alpine meadow, while that of the mountain vegetation zone consists of grass land, shrub and forests. In the mountain watershed controlled by Yingluoxia hydrometric station, the area of the high mountain zone accounts for 59% of the mountain watershed, and its mean altitude is 3993.1m. The mean altitude of the mountain vegetation zone is 3142.3m, and the mean altitude of the mountain watershed is 3737.7m.

3.2.2 Runoff variation

Figure 5 shows the yearly runoff departure time series of the Yingluoxia hydrometric station.

Suppose the yearly runoff departure is Q_d (%), according to the variation range of Figure 5, the yearly runoff is divided into the following groups.

Dry years:	$Q_d \leq -15.0\%$
Partial dry years:	$-15.0 < Q_d < -5.0\%$
Normal years:	$-5.0\% \leq Q_d \leq +5.0\%$
Partial wet years:	$5.0\% < Q_d < 15.0\%$
Wet years:	$Q_d \geq 15.0\%$

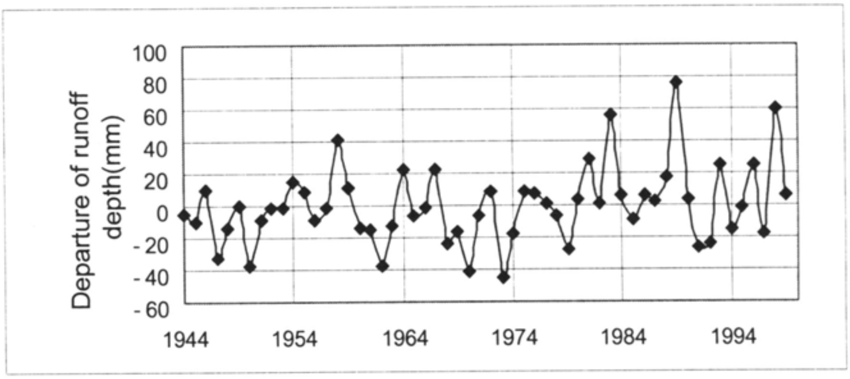

Fig. 5 Departure of the yearly runoff depth at the Yingluoxia hydrometric station
(the years from 1944 to 1999)

Then the runoff simulation is carried our for the different yearly runoff groups. Each group has tow parts, one for model calibration and another for model test. The simulation processes is as mentioned by Kang (Kang et al., 1999)

Table 5 Water balance composition of the different degree of wet and dry years in the Heihe mountain watershed controlled by the Yingluoxia hydrometric station

Sample years	Precipitation (mm)	Evaporation (mm)	Glacier melt water (%)	Snow melt water (%)	Runoff (mm)	Runoff ratio (%)
Dry	364.8	250.8	10.7	35.8	114.0	31.3
Partial dry	405.8	265.2	8.1	35.7	140.6	34.6
Normal	412.7	259.9	7.7	34.2	152.8	37.0
Partial wet	483.0	311.4	6.7	34.3	171.6	35.5
wet	534.4	328.8	5.6	30.6	205.6	38.5

3.2.3 Water balance simulation

With the runoff simulation, the water balance of the mountainous watershed is then simulated. Table 3 indicates that from the dry years to the wet years, precipitation, evaporation, runoff and runoff ratio all increase, while the alimentation ratio of glacier and snow melt water to the runoff decrease. This shows the regulation role of the glacier and snow melt water to the runoff. Because in the dry years, the more glacier and snow melt water compensates the runoff reduction, while in the wet years, less melt water makes the glaciers increase their ice storage. The water balance composition of Table 3 indicates that, the runoff ratio of the mountain watershed, that is the ratio of annual runoff to annual precipitation, is larger than the average value 16.5% of the inland dry regions of northwest China, but it is less than the average value 42.0% of the whole country. Therefore, although the mountain area of the inland river basins is the runoff generation area, because of the dry climate background, the water resources are still limited.

4 Response of the mountain runoff to climate change

The runoff model shown in Figure 4 is employed to simulate the response of mountain runoff to climate change (Kang et al., 1999).

4.1 Scenarios of climate change

According to the trend analyses of air temperature and precipitation at the hydrological and meteorological stations distributed in the Heihe River basin, which have the altitude ranges from 1178.6m to 3368.0m, the trend aptitudes are obtained from 1956 to 1996 (Table 6). During the years from 1956 to 1996, the glacier covered area of the Heihe River basin was reduced by 7% (Liu et al.,1999), while the annual runoff of the mountain watershed controlled by the Yingluoxia hydrometric station increased by 11%.

Table 6 Change of air temperature and precipitation in the Heihe River basin during the years from 1956 to 1996

Time interval	Air temperature (°C)	Precipitation (mm)
Spring (March to May)	-0.1	-9.8
Summer (June to Aug.)	-0.2	+25.1
Autumn (Sep. to Nov.)	+0.8	+0.9
Winter (Dec. to Jan.)	+2.1	-0.5
Yearly	+0.7	+15.6

Table 6 indicates that, in the Heihe River basin during the 40 years from 1956 to 1996, in terms of the change trend, air temperature increase is mainly in winter, next in autumn, while summer precipitation increases obviously. As a result, both yearly air temperature and precipitation show some increase trend.

In order to get the climate change scenarios in a decade time interval in future 50 years, the simulation results of HadCM2Gsa climate model (Viner, 1996) is used. The climate model made a climate prediction by the yearly increase of 1% both for CO_2 and for sulphate aerosol. After a comparison between HadCM2Gsa results and the measured results at the Hexi Corridor area during the years from 1956 to 1996, it is found that in the area, HadCM2Gsa results over estimate the air temperature increase and underestimate the precipitation increase. Thus a regional correction factor is added to the HadCM2Gsa results, for air temperature, it is –0.3°C, and for precipitation, it is +25%, to get then the climate scenarios for the mountain watershed during the future 50 years (Table 7).

Table 7 Estimation of climate change scenarios of decade mean in the mountainous watersheds of the Heihe River (a regional correction is carried out on the prediction by the HadCM2 climate model (Viner, 1996)) 1)

Watersaed	1990s versus 1980s		2000s versus 1980s		2010s versus 1980s		2020s versus 1980s		2030s versus 1980s		2040s versus 1980s	
	t (oC)	p (%)	t (oC)	p (%)	t (oC)	p (%)	t (oC)	p (%)	t (oC)	p (%)	t (oC)	p (%)
Heihe mountain watersheds	+0.09	+14.8	+0.28	+16.6	+0.63	+23.2	+0.87	+18.3	+1.37	+20.4	+1.20	+23.4

1) In the table, t and p represents the yearly mean air temperature and precipitation separately.

4.2 Runoff change projection

Based on the climate scenarios and the model shown in Figure 4, the runoff change of the Heihe mountain watershed controlled by the Yingluoxia hydrometric station is simulated and compared with the measured yearly mean runoff value during 1980s for the future decades (Table 8). During the simulation, the glacier- covered area is reduced by the ratio of –0.2%/year (Liu et al., 1999). The simulation indicates that, from 1990s to 2000s, along with the increase of air temperature, precipitation and glacier melt water increase in some amount. This compensates in some degree the runoff reduction caused by the increase of air temperature and evaporation. As a result, runoff shows slightly increase, and the increment range is within 3%. Then, to 2010s and 2040s, the increase of precipitation is not enough to compensate the runoff reduction caused by air temperature increase, and the runoff will decrease in the aptitude within 10%. Along with the air temperature increase, evaporation will increase, but precipitation also has some increase, and glacier melt water will also increase its alimentation to the rivers. On the other hand, the alimentation of snow melt water to the rivers would decrease in some degree because of the reduction of the solid precipitation caused by the air temperature increase.

Table 8 Simulation of the decade mean runoff composition and change of the mountainous watershed of the Heihe river controlled by the Yingluoxia hydrometric station in the future 50 years[1)]

Decades	Runoff (mm)	Runoff change versus 1980s %)	P (mm)	E (mm)	Glacier melt alimentation(%)	Snow melt alimentation(%)
1980s measured	173.3	100.0	463.2	287.6	5.7	34.8
1990s simulated	178.3	+2.9	526.7	309.0	5.4	35.6
2000s simulated	176.1	+1.6	531.0	320.8	5.7	35.5
2010s simulated	167.6	-3.3	560.9	337.8	6.8	30.3
2020s simulated	170.2	-1.8	540.1	334.0	6.6	29.3
2030s simulated	155.5	-10.3	545.4	343.6	7.7	27.7
2040s simulated	158.4	-8.6	555.9	344.7	7.2	30.5

1) In the table, P and E represent yearly mean precipitation and evaporation separately.

5 Conclusion

Because of the less precipitation, rapid evaporation and low runoff ratio of the Heihe River basin, it is extremely lack of water resources. The human activities are concentrated in the oases area in front of the mountains and the ecological environment is extremely vulnerable. Although the mountainous watersheds receive more precipitation and have less evaporation rate, forming the runoff generation area, the runoff is still limited because of the dry continental climate background. The water balance composition is different from the dry years to the wet years. The glacier covered area is relatively small in the Heihe River basin, therefore the glacier melt water contribution to the river runoff is limited, but the glaciers still play some regulation role to the mountain runoff.

Under the global worming conditions, the change trend of air temperature shows increase mainly in winter, next in autumn, and the precipitation change trend shows increase in summer. As a result, the yearly air temperature and precipitation both show some increase trend, and the mountain runoff shows slight increase trend.

The response of monthly runoff from the mountain watershed of the Heihe River basin is simulated. It is projected that, under the climatic warming, precipitation and evaporation would increase in some degree, and the alimentation of glacial meltwater runoff to the Heihe river would be increasing in some amount. The mountain snow melt runoff would have a reducing trend. In the future decades to 2040s, as compared to the mean yearly runoff during 1980s, the decade mean runoff from the mountain watershed would increase by the amount within 3% first to 2000s, then along with the continuous climatic warming, the runoff could be reduced by the amount within 10%.

Therefore, during the future 50 years, the global worming impact to the mountain water resources of the Heihe River basin is not very serious. If we can achieve a rational utilization and exploitation of water resources, then we can get the sustainable ecological and social development of the Heihe River basin.

References

BERGSTROM,S. Development and application of a conceptual runoff model for scandinavian catchments1976, (M). Bulletin Series A, No 52, Lund: Lund University, 12 - 83.

CHE,Kejin, Fu Huien and Wang Jinye, 1996, Experimental studies on the ecosystem of water restrainting forests in the Qilian mountains of Zhangye. Science and Technology of Gansu Forestry, No.4. 1

GAO,Qianzhao and Li Fuxing, 1990, Case study of rational development and utilization of water resources in the Heihe River basin. Gansu Press of Science and Technology, Lanzhou. 3 - 15.

KANG, Ersi, Cheng Guodong, Lan Yongchao. 1999 A model for simulating the response of runoff from the mountainous watersheds of inland river basins in the arid area of northwest China to climate changes[J]. Science in China (Series D), 42(Suppl.): 52~63.

LIU,Chaohai, Kang Ersi, Liu Shiyin et al.. 1999 Study on the glacier variation and its runoff responses in the arid region of northwest China[J]. Science in China (Series D), 42(Suppl.): 64~71.

SUN,Guowu, 1977 - 1978. Researches on the seasonal variation of atmospheric environment of Qinghai-Xizang plateau and its surrounding area and the Gansu drought. Proceedings of meteorology in Qinghai-Xizang plateau. Science Press, Beijing. 129 - 141.

VINER,D. 1996 The climate impacts LINK projects: data sets available for climate change research,http://www.nerc.ac.uk

WANG, Zongtai, Liu Chaohai, You Gengxiang et al., 1981, Glacier Inventory of China I, Qilian Mountains, Lanzhou Institute of Glaciology and Geocryology, Academia Sinica, 59 – 119.

YANG, Zenniang, 1991, Glacier water resources in China. Science Press, Beijing. 119 - 136.

YANG, Zenniang, 1992a, Glacier water resources and effect of glacier water in stream runoff in Qilian Mountain. Memoirs of Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences, No.7. Science Press, Beijing. 10 - 20.

YANG, Zenniang, 1992b, Water balance and water resources of Heihe basin in Qilian Mountain. Memoirs of Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences, No.7. Science Press, Beijing. 133 - 147

ZHOU, Qinnan, 1983, A study on the source of water vapor for precipitation of Xinjiang. Weather in North China, No.4, Beijing University Press, Beijing. 179 - 181.

Simulation Experiment of TOPMODEL to the Binggou Catchment, Heihe River Basin, Northwest China

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Abstract

This paper describes a distributed modeling approach applied to stimulate the stream flow on a 30.06 km^2 Binggou watershed on the North Slope of the Tuolai Mountains in Heihe Basin, Northwest China. The simulation process has assembled a modeling system centered on TOPMODEL, simulation of saturated excess runoff was mainly based upon topography, the other components deemed relevant to the hydrologic processes in the basin, however, were simulated not only upon the topography but also the Geographic Information System (GIS) data . Precipitation was spatially interpolated from five rain gauges using linear interpolation on Delauney triangles and scaling by an annual rainfall surface to represent orographic effects. The model included the following components: 1) reference evapotranspiration estimation by following Maident D.R. (1993); 2) interception and throughfall, an unsaturated zone soil layer that delayed water inputs to the saturated zone and provided infiltration excess runoff generation capability, and a kinematic wave channel routing component. Procedures were developed to generate model input files from digital elevation model and land resource inventory GIS data. Model elements are subwatersheds automatically extracted based upon the channel network generated from the Digital Elevation Model (DEM) and a specified stream order threshold. Model element parameters are linked to GIS information averaged over each subwatershed. Totally 9 subwatersheds were subdivided, and the model was calibrated using an interactive calibratioing package with the Gauss-Marquardt method. The calibration uses scale multipliers to retain GIS landcover derived relative differences between parameters across subwatersheds. Model parameters were first calibrated for one year then independently tested there for the following years. The calibration used precipitation measured at this small watershed while the validation exercised the precipitation interpolation methodology. The results indicate that streamflow estimates are sensitive to uncertainty in the precipitation due to variability and orographic effects, and this precipitation uncertainty takes prodominate role among all the sources.

Introduction

Orginally developed at the Leeds University, UK in the mid-1970s, topography based hydrological model (TOPMODEL) has been widely used in predicting or estimating catchment water discharge, spatial soil water saturation pattern, temporal-spatio distribution of soil moisture, geochemical flux, evaporation, erosion and deposition … etc. (Beven, 1986; Quinn and Beven, 1993) in its recent development based upon precipitation and evapotranspiration time series with topographic information. The objective of TOPMODEL was to establish a physically based rainfall runoff model that only requires simple parameters as input to predict various hydrological responses (Ambroise et al., 1996; Beven and Kirkby, 1979; Beven, 1997). A minimum of four effective catchment parameters need to be estimated to characterize the discharge dynamics of the catchment. The parameters are fitted from the discharge predictions. Neither horizontal or vertical soil parameters need to be supplied. However, to estimate water table or soil moisture content from the saturation deficit requires soil information. A correct estimation of evaporation is critical for model performance. Evaporation is most frequently estimated by using the Penman-Monteith methods, However, Shuttleworth method (Maident D.R. 1993) was found much practical since it need less input parameters. Indeed, TOPMODEL is not a hydrological modeling package. It is rather a set of conceptual tools that can be used to reproduce the hydrological behaviour of catchments in a distributed or semi-distributed way, in particular the dynamics of surface or subsurface contributing areas (Beven et al., 1995). The simplicity of TOPMODEL comes from the simplification of physical mechanism of hydrological processes. The detailed model describation can be found elsewhere (Zhang et al., in submitting), the oral presentation on the detail of the model will be give in the conference.This summay was given in two part. First of all, the basic geographical, meteorologic conditions and the ecologic informaion was described with GIS or remote sensing data analyses with the brief description of the model. Then the calculation of hydrological parameters using digital elevation model (DEM) of the Bingguo Basin, as well as the simulation results and discussions was followed with the end of simple conclusion.

The Target Area

Located in the middle part of the Hexi Corridor in Gansu Province, northwestern China, the Heihe River Basin takes the rank of the second largest inland river basin in the arid regions of China. Its geographic location lies from 96°42'-102°00'E and 37°41'-42°42'N encompassing a catchment area of about 128,700km^2. Administratively, it trans 11 counties / cities including Qilian County in Qinghai Province, some northwestly cities / counties in Gansu Province, and part of Ejin Banner in Inner Mongolia Autonomous Region. Some quite noticeable and characteristic landscapes in the whole catchment of the Heihe region can be viewed evidently, which exhibates three major geomorphologic units from south to north. These geomorphologic units are entitled as the Southern_Qilian_Mountains type, the Middle_Hexi_Corridor type and the Northern_Alxa_plateau type. Each geomorphologic unit has its own unique geologic, geomorphologic, hydrologic, meteorologic, soil and vegetation characteristics. Owing to its relatively rich land resources, abundant sunshine and longer cultivation history, the Heihe River Basin has become an important commodity grain base of northwest China and an inland region with more rapidly socioeconomic development and denser population. However, on the other hand, the shortage of water resource seriously hinders the further development of the region's secioeconomy and leads to severe deterioration of the eco-environment in the downstream sections of the basin. Furthermore, since the river system flows through two administrative areas of Gansu Province and Inner Mongolia Autonomous Region, the water shortage also stirs up serious troubles among people with different nations. The water resource distribution in the region has dramatically constrained to the sustainable development and caused serious social problems in the surrounding area (Cheng, 1996; Feng and Cheng, 1998; Feng et.al., 1999). Accordingly, in such an area with diversty geomorphologic units, complex water resource conversion relations, fragile eco-environment, and acute water shortage, classifying the relations of water resource conversion among different geomorphologic units to rationally utilize and effectively allocate water resources in the basin so as to coordinate the contradictions between socioeconomic development and environmental protection are all crucial and urgent problems that require the policy-makers to handling. Under such a cirsumstance, several pronounced scientific projects has been carried out in recent decade under the leadership of the Cold and Arid Regions Environment and Engineering Research Institute, Chinese Academy of Sciences. Some in-depth studies of hydrology and water resources have been undertaken on arid regions of northwestern China. In these projects, many water circulation and sustainability-oriented studies have been conducted, and some significant results have been obtained. In the present study, a distributed modeling in hydrology using digital data and GIS systems to a 30.06 km^2 Binggou watershed on the north slope of the Tuolai Mountains in Heihe Basin, Northwest China is attempted. The Binggou Basin is a small watershed located in 100°11'-100°18'E and 38°00'-38°04'N at the altitude with elevation span ranging from 3433 to 4406 m. Figure 1 schamatically shows the drainage system of the Heihe River Basin with the target modelling catchment of Binggou sub-basin exhibated. As an ideal place for the studies of water balance and runoff formation mechanism in the alpine frozen soil region, the Lanzhou Institute of Glaciology and Geocryology, Chinese Academy of Sciences has conducted hydrological experiments since the 1980s in the basin (Yang et al., 1992).

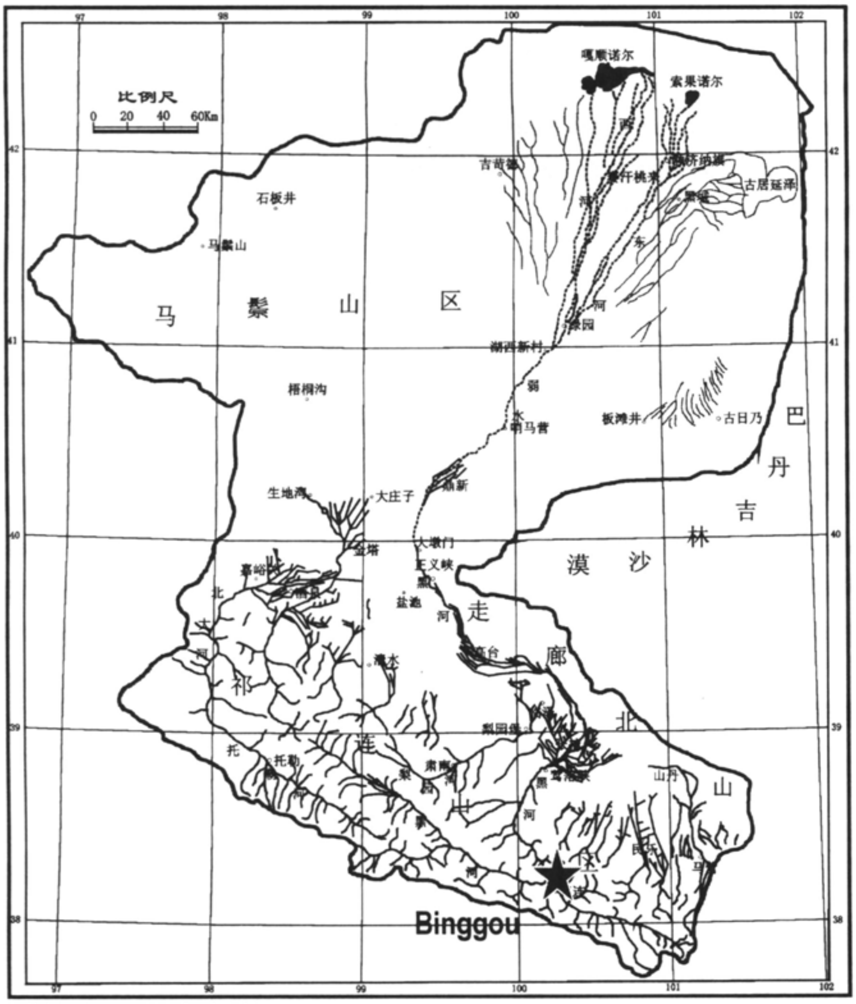


Figure1. Schematic map of geographic location of the Heihe River Basin showing the basic channel sysyem with the Binggou watershed location exhibated

Principles of the TOPMODEL model

The basic hypotheses (Beven, 1997) of the TOPMODEL can be sumarized as followings:

(1). The dynamical changes of water table can be approximated by uniform subsurface runoff production per unit area.

(2). The hydraulic gradient of the saturated zone can be approximated by the topographic slope.

Based on the above hypotheses, the topographic index is used as basic input in TOPMODEL (Kirkby and Weyman, 1974) and is defined as:

$$k = \ln(\alpha / \tan\beta) \qquad (1)$$

Where α is the area draining through a point from upslope and β is the slope angle. The topographic index is used as an index of hydrological similarity. All points with the same value of the index are assumed to respond in a hydrologically similar way (Beven, 1997). The spatial component requires a high quality DEM (digital elevation model) without sinks. Surface runoff is computed based on variable saturated areas, subsurface flow using a simple exponential function of water content in the saturated zone. Channel routing and infiltration excess overland flow are considered in the model. The structure of the model with regard to interception and root zone storage compartments is variable, allowing much flexibility to simulated different systems. Time steps should be in the range of day to represent surface runoff peaks. The length of the simulation period depends on the availability of precipitation and evapotranspiration input data. The spatial component requires a high quality DEM (digital elevation model) without sinks. Parameters scaled by GIS average properties is assigned to each subwatershed. Kinematic wave routing of streamflow was treated through channel network.

Many methods have been developed to calculate the topographic index (Quinn et al., 1997). It is worth to notice that its accuracy depends upon the DEM resolution. Generally, the DEM resolution should be at least larger than the length of the mountain slope, the higher the DEM resolution, the more reliable the calculated result of topographic index. We also developed a program for calculating topographic index using the hydrological analysis programs in the hydro.avx, which is an extension run in the ArcView Spatial Analyst (ESRI, 1996).

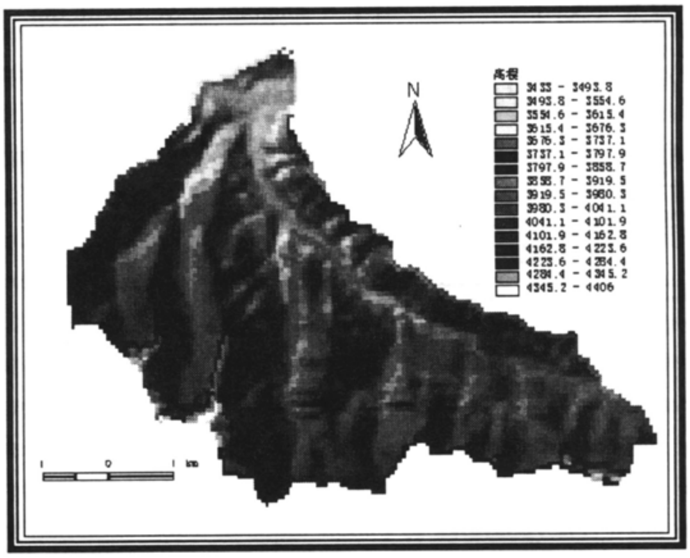


Figure 2. Digital Elevation Model (DEM) of the Binggou watershed with spatial resolution of 60 meter.

DEM was also used to calculate the hydrological parameters such as flow direction, flow accumulation, and flow length. Furthermore, it can be used to extract channel network, drainage divides and sub catchment (Jenson and Domingue, 1988; Tarboton et al., 1991; Band, 1986; Marks et al., 1984; O'Calllaghan and Mark, 1984; Lu et al., 1988a; Lu et al., 1988b). These basic hydrological parameters are essential to any distributed hydrological models. For example, above parameters is the basic input of the distributed hydrological model TOPMEDEL.

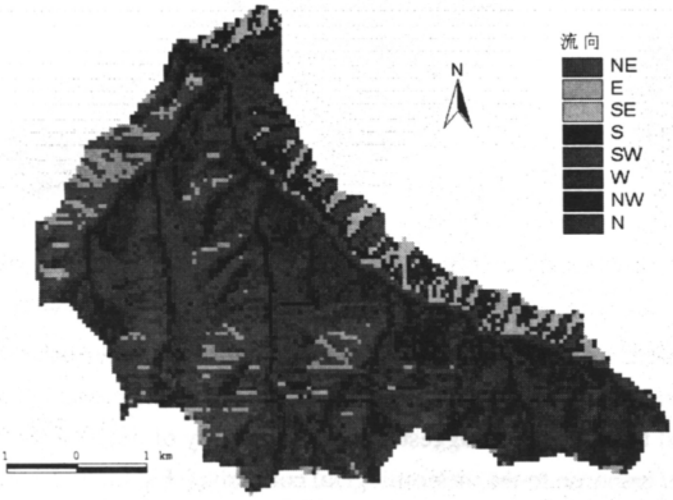


Figure 3. Simulated flow direction of the Biggou watershed.

To calculate the topographic index as well as topography-dependent hydrological parameters of the basin, we firstly digitized 1:50000 topographical map of the Binggou Basin and the DEM of the basin with a resolution of 60m was generated (Figure 2). Then, by using the hydrological extension in ArcView, we mapped a series of hydrological parameters such as flow direction (Figure 3), flow accumulation (Figure 4), channel network (Figure5) and sub-catchment polygons (the threshold for extracting sub-catchment is 500 grids) (Figure 6). Finally, we obtained the topographical index based on the above results (Figure 7). The calculation of topographic index lays a basis for the further use of TOPMODEL and for the development of a distributed hydrological model of the Heihe River Basin.

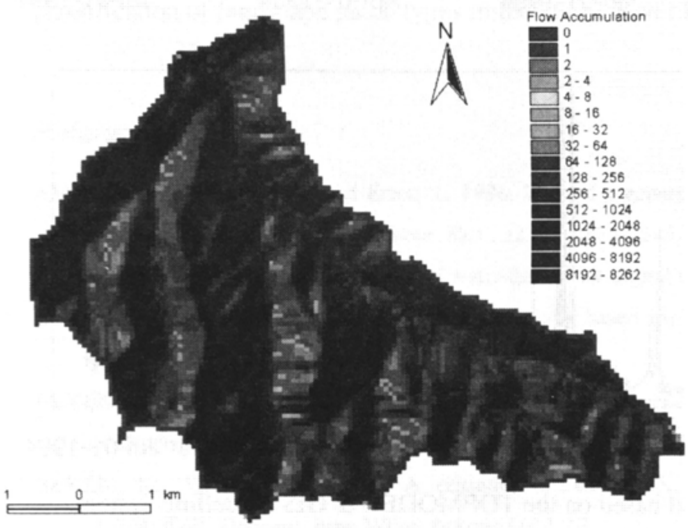
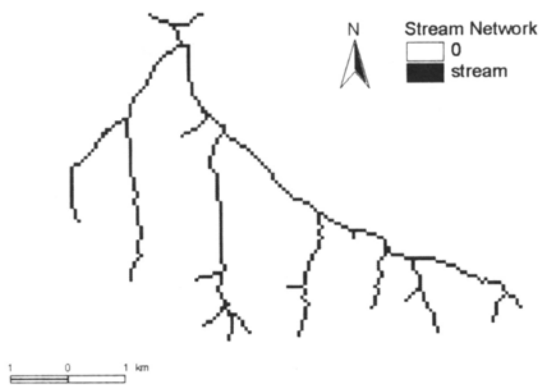


Figure 4. Simulated flow accumulation for Binggou watershed

Figure 5. Simulated stream net work based on 8D methodology.



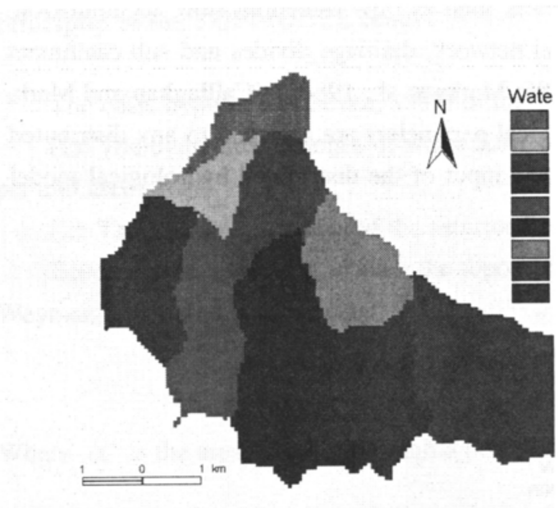


Figure 6. Subwatershed delination by order 5 for the studied basin.

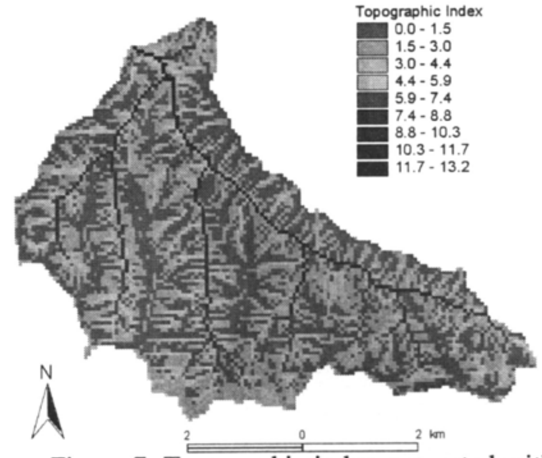


Figure 7. Topographic index generated with 60 m resolution DEM of Binggou watershed.

Results and Discussions

Modeling system centered on TOPMODEL for representation of spatially distributed water balance based upon topography and GIS data (vegetation and soils) has been successfully developed in the present study. The preliminary results are very encouraging, and the simulation suggested the applicability of the TOPMODEL in predicting the water balance and hydrological response to the meteorological conditions. Figure 8 shows the the performance of the modelling system in Binggou watershed hydrological simulations. The simulation process involved several parameter verifications, however, at present physical interpretation of calibrated parameters is still problematic. Moreover, large scale water balance problem due to difficulty in relating precipitation to topography have to be resolved using rather empirical adjustment method.

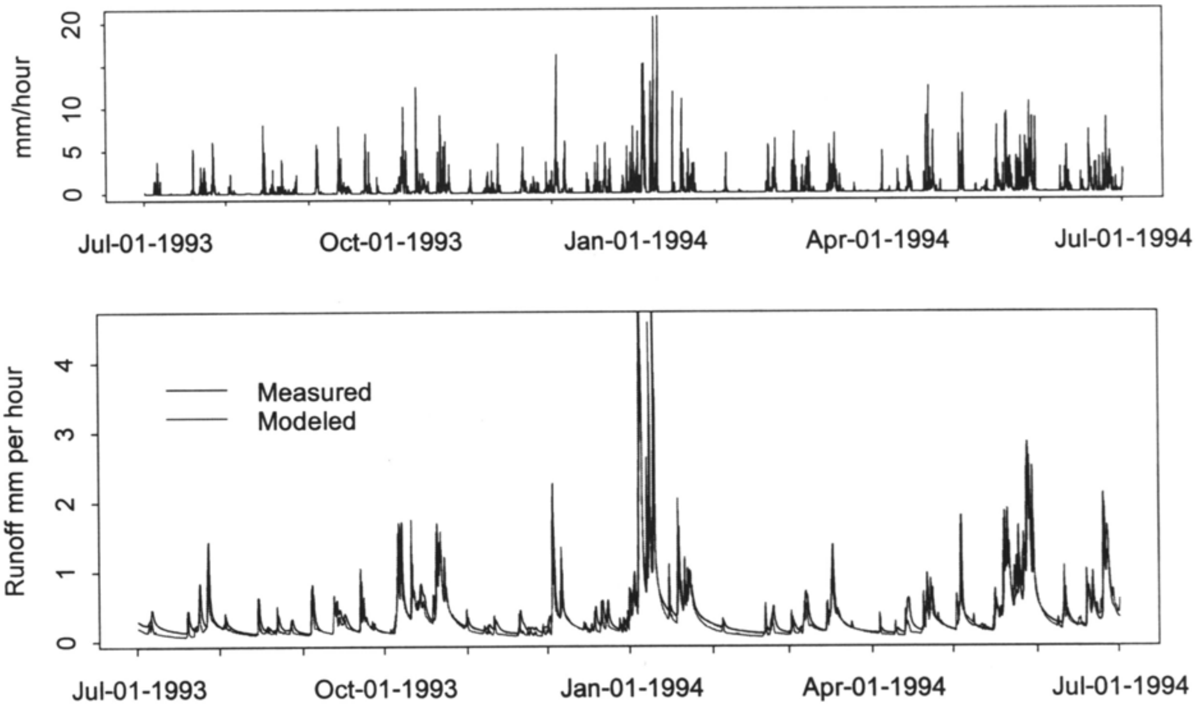


Figure 8. Simulation result of Binggou watershed based on the TOPMODEL & GIS modelling system.

Despite a wealth of data already stored in the water resource information system of the Heihe River Basin, our application study is still in the initial stage. The planned application emphases include: (1) to develop distributed hydrological model suited to arid inland river basin of northwest China, because of sparse meteorological and hydrological stations and limited observation and experiment data in the Heihe River Basin, such model should be a simplification of the existing distributed models, in the meanwhile, combined with existing one-dimension model, it is characterized by definite physical mechanism and clear model structure (Kang Ersi, 1999). It can simulate and calculate the spatial distribution of the hydrological processed such as precipitation, runoff, groundwater and evapotranspiration etc. It is also fully visual and hence the data and results have better direct-vision display ability. (2) to calculate surface water volume, evapotransipiration, ground surface temperature, reflectance and radiation etc, using remote sening data. With the help of new EOS-AMI-borne sensors such as ASTER and MODIS etc, many parameters associated with hydrological processes can be directly obtained (Running et al., 1998). Although the reversion methods of these parameters have been successfully developed, they still require further examination so as to be used in the actual distributed hydrological models. In addition, for those parameters that cannot be determined by remote sensing or limited by remote sensing spatial-temporal resolution, such as the spatial distribution of air temperature and precipitation, spatial analytical method and DEM might be the possible mean to calculate them.

Acknowledgement

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References

AMBROISE, B., Beven, K., and Freer, J., 1996, Toward a generalization of the TOPMODEL concepts: topographic indices of hydrological similarity. Wat. Resour. Res., 32 (7): 2135-2145.

BAND , L., 1986 Topographic partition of watersheds with digital elevation models. Wat. Resour. Res 22 (1): 15-24.

BEVEN, K. J., and Kirkby, M. J., 1979, A physically based variable contributing area model of basin hydrology. Hydrol. Sci. Bull., 24 (1): 43-69.

BEVEN, K. J., 1986, Runoff production and flood frequency in catchments of order n: an alternative approach’ in Gupta, V. K. and Rodriguez-Iturbe. I. (eds), Scale Problems in Hydrology, Reidel, Dordrecht, 107-131.

BEVEN, K., TOPMODEL: 1997, A critique. In: Beven, K., Distributed Hydrological Modelling, Applications of the TOPMODEL Concept. John Wiley & Sons Ltd 1-17.

EASTMAN, J. R., and Fulk, M., 1993, Long sequence time series evaluation using standardized principal components.

Photogrammetric Engineering and Remote Sensing, 59 (8): 1307-1312.

EIDENSHINK, J. C., and Faundeen, J. L., 1998, The 1-km AVHRR global land data set: first stages in implementation. http://edcwww.cr.usgs.gov/landdaac/1KM/paper.html#proc2.

EIDENSHINK, J. C.,1992, the 1990 conterminous U. S. AVHRR data set. Photogramm. Eng. Remote Sens., 58: 809-813.

Environmental Protection Agency(EPA),1994, Landscape monitoring and assessment research plan.EPA620/R-94/009, Office of Research and Development,Washington,D.C.

ESRI,1996, ArcView Spatial Analyst. ESRI.

FUNG, T., and LeDrew, E. 1987, Application of principle components analysis to change detection. Photogrammetric Engineering and Remote Sensing, 53 (12): 1649-1658.

HIROSAWA, Y., Marsh, S. E., and Kliman, D. H.,1996, Application of standardized principal component analysis to land-cover characterization using multitemporal AVHRR data. Remote Sensing of Environment, 58 (3): 267-281.

JENSON, S. K., and Domingue, J. O.,1988, Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis. Photogrammetric Engineering and Remote Sensing, November , 54 (11): 1593-1600.

KANG, Ersi, Cheng Guodong, Lan, Yongchao and Jin, Huijun,1999, A model for simulating the response of runoff from the mountainous watersheds of inland river basins in the arid area of northwest China to climatic changes. Science in China, Series D, 42 (supplement): 52-63.

KIRKBY, M. J., and Weyman, D. R.,1974, Measurement of contributing area in very small drainage basins. Seminar Series B. No. 3. Department of Geography, University of Bristol, Bristol.

MARK, D. M., Dozier, J. and Frew, J.,1984, Automated basin delineation from digital elevation data. Geo-Processing, 2: 299-311.

MCGARIGAL, K., and Marks, B., Fragstats:1994, Spatial pattern analysis program for quantifying landscape structure. Reference manual. Forest Science Department, Oregon State University, Corvallis Oregon, March 62pp.+Append.

O'CALLAGHAN, J. F., and Mark D. M.,1984, The extraction of drainage networks from digital elevation data. Compute Vision, Graphics and Image Processing, 28:323-344.

闾国年，钱亚东，陈钟明．流域地形自动分割研究．遥感学报，1998，2（4）：298-304．

Lu Guonian, Qian Yadong, and Chen Zhongming,1998, Study of automated topography partition of watersheds. Journal of remote sensing, 2 (4): 298-304.

闾国年，钱亚东，陈钟明．黄土丘陵沟壑区沟谷网络自动制图技术研究．测绘学报，1988，27（2）：131-137．

Lu Guonian, Qian Yadong, and Chen Zhongming,1998, Study on automated mapping of channel network in hilly loess region. ACTA Geodaetica et Cartographica Sinica, 27 (2): 131-137. (in Chinese)

QUINN, P. F., and Beven, K. J.,1993, Spatial and temporal prediction of soil moisture dynamics, runoff, variable source areas and evapotranspiration for Plynlimon, Mid-Wales. Hydrol. Process., 7: 425-448.

QUINN, P. F., Beven, K. J., and Lamb, R., The Ln(α/tanβ) index: 1997, how to calculate it and how to use it within the TOPMODEL framework. In: Beven, K., Distributed Hydrological Modelling, Applications of the TOPMODEL Concept. John Wiley & Sons Ltd, 31-52.

RIITTERS, K. H., O'Neill, R. V., Hunsaker, C. T., et al., 1995, A factor analysis of landscape pattern and structure metrics. Landscape Ecology 10: 23-39.

RUNNING, S. W., Collatz, G. J., Washburne, J., and et al.,1998, Land ecosystems and hydrology. In: King, M. D. (Ed), EOS Science Plan. http://eos.nasa.gov

STEINWAND, D. R., 1994, Mapping raster imagery to the interrupted Goode Homolosine Projection. Int. J. Remote Sens., 15: 3463-3472.

TARBOTON, D. G., Bras, R. L., and Rodriguez-Iturbe, I.,1991, On the Extraction of Channel Networks from Digital Elevation Data. Hydrological Processes, 5: 81-100.

杨针娘，杨志怀，张学成．1992, 祁连山冰沟寒区径流及产流模式．中国科学院兰州冰川冻土研究所集刊，第七号．

北京，科学出版社， 91-100.

Yang Zhenniang, Yang Zhihuai and Zhang Xuecheng, 1992, Runoff and its generation model of cold region in the Binggou Basin of the Qilian Mountains. Memoirs of Lanzhou Institute of glaciology and Geocryology, Chinese Academy of Sciences, No. 7. Science Press, Beijing, 91-100.

TUCKER, C., Townshend, J., and Goff, T.,1985, African land-cover classification using satellite data. Science, 227 (4685): 369-375.

TOWNSHEND, J., Justice, C., and Kalb, B.,1987, Characterization and classification of South American land cover types using satellite data. Int. J. Remote Sens., 8 (8): 1189-1207.

肖洪浪, 1999, 编绘黑河流域沙漠化和绿洲土地分布图．中国科学院兰州沙漠所.

中国科学院兰州冰川冻土研究所．1999, 黑河流域水资源合理利用与社会经济和生态环境协调发展研究．中国科学院兰州冰川冻土研究所.

Ecological and socio-geographical conditions of pastoral migration in Mongolia

Bat-Ochir BOLD

The traditional nomadic pastoral economy is the main branch of industry in Mongolia. 1,311,000 km² (98% of the agricultural-effective land) of Mongolia's 1,566,500 km² area is pastoral land. In the pasture areas nearly 50 million tons of forage plants are grown annually. There are 30,2 million traditional five types of animal: camel, horse, cow/yak, sheep and goat. 2000 there were 421,392 livestock keepers. An estimated 45% of the population of the country are directly engaged in nomadic livestock keeping(see: appendix).

Generally accepted as a nomadism widely distributed area of the north hemisphere is the area from the tropical and subtropical regions of North Africa, Near Eastern to the continental moderate dry region of the Central Asia/Eastern Mongolian steppes, which is designated in the Geography as the 'Old-World dry belt'. Due to dominant arid and semi-arid conditions of this region the plant production is concentrated solely in restricted favourable areas. However, the wide-range arid and semi-arid areas provide an enormous potential as a pasture for a livestock production. The natural barrenness of the land, its topography and expansive distances demand an optimally adapted and lasting means of use of this pasture potential. Mobile livestock keeping[1] on which the nomadic society is based was emerged as an only possible economic form and is ecologically and economically adapted form that can make use of these special natural conditions. Nomads own herd animals of regional species, for example, sheep, goats, camels, cattle/yak and horses as means of production, and the natural pasture and water as their production condition. In search of food and water for their herds they have to lead depending on different geographic locations a more or lesser migratory way of life.

The migration of nomads is not a chaotic movement at all. Various ecological factors like climatic conditions, availability of forage plants, distribution of salty soils, supply of water, and socio-political framework, have all played a part in seasonal migrations. The effects of all these factors on migrations are connected with seasonal altitudinal conditions. From this fact it follows that seasonal migrations are in principle directed altitudinally (vertically) between the highlands and the lowlands correspondingly combined with planar (horizontal) migrations which livestock keeper often within a season in order to extend the area of pasturage and to increase feed supply.

There are a number of significant factors of influence giving rise to nomadic migration: politics, economics, social anthropology and ethnography. These viewpoints will be considered but the main determinants will be treated from the ecological and socio-geographic point of view. Nomad's seasonal migration within a region which is ecologically optimal for the yearly rotation of pasture land use is broadly characterised from an ecological and socio-geographical aspect by the below dealing with factors. By means of a description of these significant factors and their close correlation it is possible to explain not only the reason for migrations but also the nature of the nomadic lifestyle at all. In this way the particularities and the generalities of Mongolian livestock keeping and of other forms of mobile livestock keeping in the 'Old-World dry belt' can also be understood. Mongolia is one of the few nomadic areas in which true nomadic livestock keeping is of great significance in contrast to other countries in the region.

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1 The term mobile livestock keeping is used to refer to all regionally specific transitional and mixed forms ranging from true (pure) nomadic economy, semi-nomadic and semi-sedentary pastoralism to sedentary pastoralism.

1. Climatic conditions as a determining factor of seasonal, altitudinally directed migration

The general basis of nomadic livestock keeping in Mongolia, in the high mountains, the forest highlands, the steppes or the Gobi region, is a change of pasture to ecological areas which are climatically favourable in the respective seasons. This means that livestock keepers with their stock must avoid extreme climatic conditions caused by, for example, temperature, storms and precipitation. The effects of temperature (fig. 1), storms (fig. 2) and precipitation on the choice of pasture land are different for each of the four seasons. It is useful to describe the climatically determined choice of pasture for each of the seasons separately.

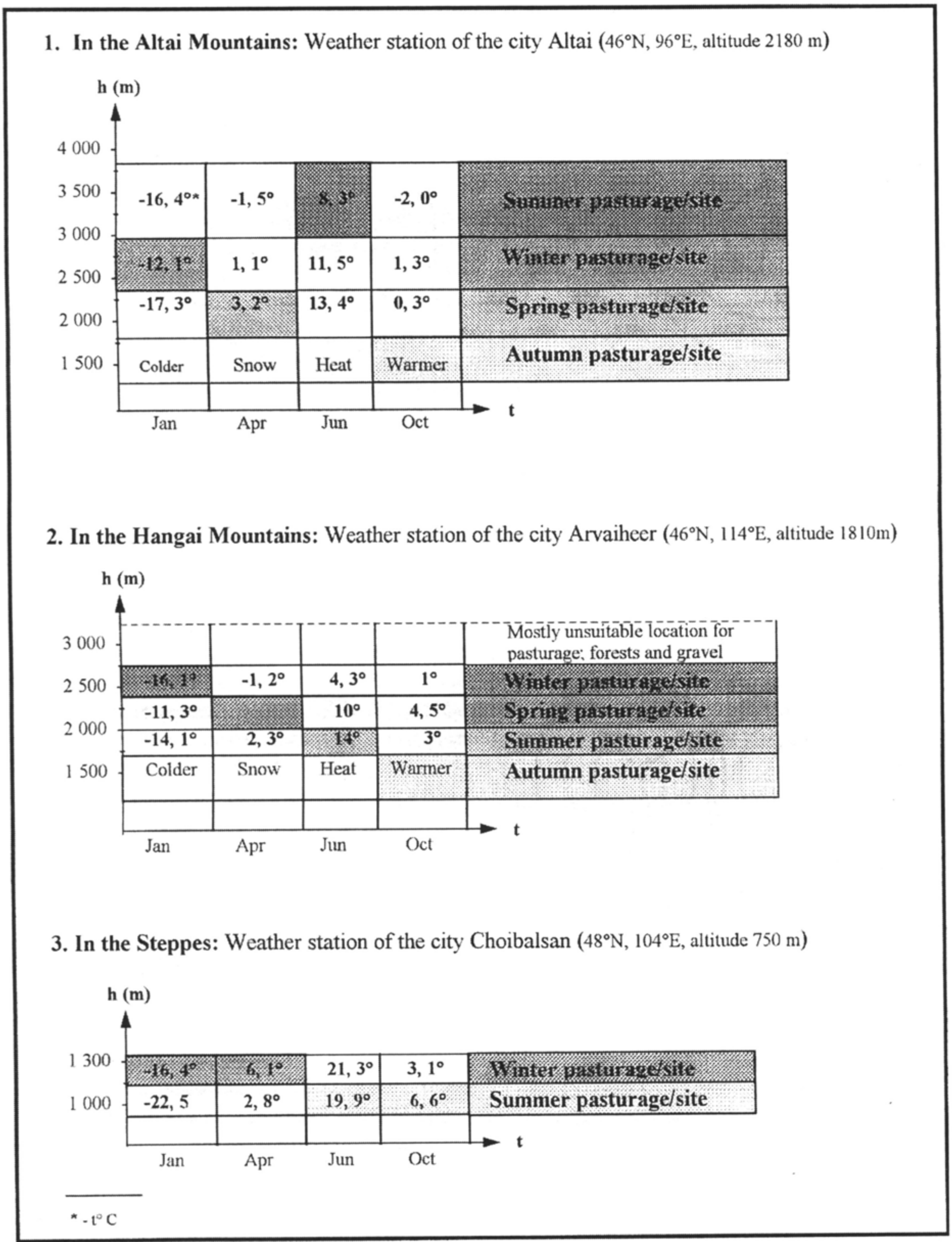
Winter Livestock keeping in Mongolia is still completely dependent upon climatic conditions, particularly in the hard winter. Migration at the start of winter into a region where temperature, wind and precipitation are relatively favourable for livestock keeping in the cold is inevitable. It is obvious that the average temperatures in the natural zones of Mongolia, in the high mountains, the forest highlands, the steppes and the Gobi region, differ. But even within these zones there are general differences in temperature depending upon orographic factors, i.e. altitude, slope, exposure, and moisture, light and warmth conditions.

One of the most important reasons for migration to the winter pasturage is the search for the warmest mountain belt. The winter site is thus located at a point in this belt which is most favourable for humans and livestock. Many years of experience of Mongolian nomadic livestock keeping as well as the results of geographic and meteorological research show that the most favourable locations in winter as far as temperature is concerned - relatively independently of the nature zones of Mongolia - lie between the mountain crest and the middle altitudes of the respective regions. These favourable locations in the differing nature zones stand in close connection with the wind conditions, i.e. the wind direction and the wind strength. The most frequent wind directions in Mongolia are westerly and northwesterly. The annual average wind strength is 4-8m/sec. This means that the south side or the south slopes of the mountains are always suitable for the winter as well as the spring pasturage. Livestock keepers as well take into account in which location less snow, as a result of the wind direction, is blown into the winter pasturage. Moreover, the wind strength must be considered in the choice of location, whether it is sufficient to blow away a possible snow covering. According to experience, livestock keepers choose their winter pasturage at a comparatively windy location if snowfall is high, or at a location most sheltered from wind otherwise. This shows that the evaluation of the wind in the choice of the winter pasturage depends a good deal on precipitation. The average annual precipitation for the entire country amounts to 200-250mm. As well the yearly precipitation decreases from north to south from 400mm to 100mm.

The winter pasturage should in no case be carried out in low-lying regions, where snowfalls are higher or snowdrifts can mount. The best pasture sites in winter are therefore those regions which provide a favourable combination of temperature, wind and precipitation for the livestock. Such sites lie in principle in all three nature zones in the belt between the higher and middle mountain ranges. The winter site is therefore located on a higher south slope of a mountain or in a mountain cleft away from the wind direction (figs 1 and 2).

Mongolian livestock keepers not only seek regions protected from the wind according to natural principles but also make use of long-standing wind shelters (Mong. *halha*, *horoo*). These shelters are constructed mostly from local building materials, from wood and stone in the highlands and forest lands, from compacted manure and straw in the steppes, and from stone in the Gobi region.

Winter shelters have been used in Mongolian livestock keeping for a long time to a greater or lesser degree. Autochthonous sources report that there were frequently in the 13th/14th centuries temporary additional shelters. The remains or traces of winter shelters from the 18th/19th centuries can even today be seen in rural areas. Since the end of the fifties, as a consequence of the policy of forced settlement, permanent shelters for winter and spring were intensively built. In 1993 there were in Mongolia about 76,100 shelters in all. Approximately half of these were winter shelters (Mongolian economy … 1993: 40). Logically, this should have had a positive effect upon the keeping and breeding of the livestock. However, the results were not as expected. It is worthy of mention that before this building of shelters on a massive scale the winter and spring sites were much simpler. Many livestock



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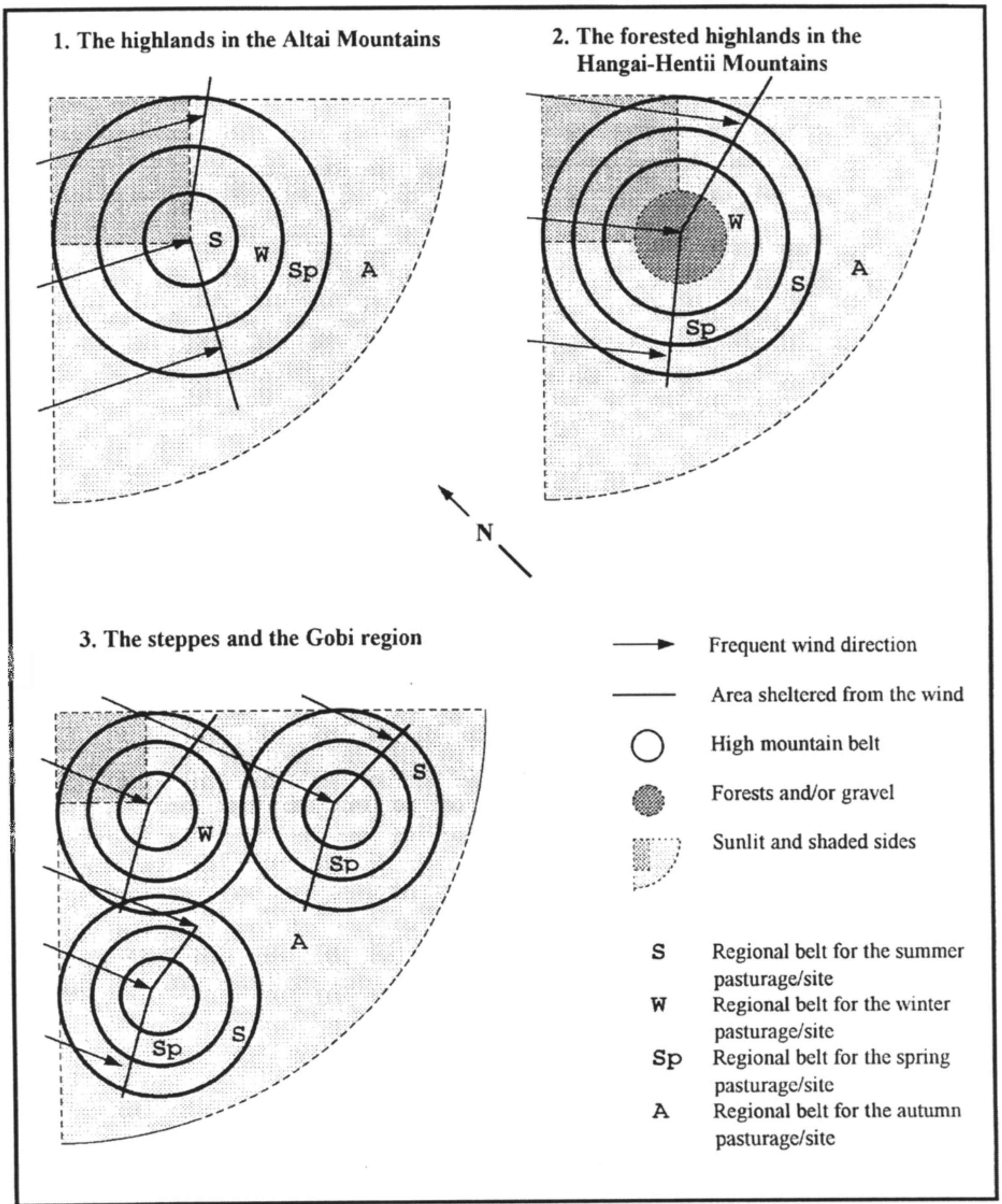
Source: From the statistics of the Research Institute for Climatology and Hydrology, Ulaanbaatar (1985)

Fig. 1. The relation of seasonal migration to altitudinal differences in the air temperature during the seasons



Source: Atlas of Climatology und Hydrology of the MPR (mong.), Ulaanbaatar 1985 Design: B. Bold

Fig. 2. Suitable locations for seasonal pastural areas and sites according to wind direction and sunlight

keepers do not consider from their experience the stabling of stock as a correct method. In traditional livestock keeping the opinion prevails that with stabling the stock should not be sheltered from the cold but rather from the wind, that is the stables should serve only as a wind shelter. Warm stabling makes the animals perspire, and the effect of a sudden change of temperature on a perspiring animal emerging from a stable accelerates the winter process of emaciation and enervation. In this respect the design of the shelters is of great significance (Shagdarsüren 1984: 68). It would make an interesting comparison to represent loss of stock in connection with the construction of permanent winter shelters.

Spring Approximately from the end of February until the start of May the day temperatures increase in the Central Asian highlands. With the collision of the northerly and northwesterly cold air and the southwesterly dry and warm air, air currents are activated and the wind direction is therefore relatively changeable. This has an effect upon the type of precipitation which frequently changes between snow and rain. The conditions which should be considered for the spring pasturage or site can be described in the following manner:

- a wind sheltered, relatively warm location. This is more important in spring than in the other seasons. From time immemorial Mongolian livestock keepers constructed only temporary wind shelters, provisional stables or mere fencing. In the last three decades however, as mentioned above, many permanent spring stables were built. At the end of the eighties there were in all more than 30,000 spring stables in the country. For the spring pasturage mainly those regions are used which lie in the belts of the lower mountain ranges. The spring pasturage therefore is located somewhat below the winter pasturage on the south face of a mountain between a middle altitude and the mountain foot. Although in general the lower the location the warmer it is (fig. 1), snow often remains at the mountain foot and in the lowlands until May, and nights can be cold and damp.
- places situated away from lakes, morasses, gorges etc.: in the windy spring the animals move frequently along the wind direction. Therefore the pasture must be chosen far away from the above sources of danger into which the animals could be driven by wind. This is another reason why livestock keepers in principle never conduct the spring pasturage in low-lying places, or at least not in the first half of the season.
- at a sunlit mountain foot, where the first fresh grass grows and the pasture is as soon as possible free of snow.

Spring is the period in which calves are raised. This makes the pasture, which is located hard by the spring shelter, an important resource for both mothers and calves. A nearby mountain foot with fresh grass is from the middle of April advantageous for both. In order to preserve such a pasture for mothers and calves and to make use of distant pastures, livestock keepers travel often far away with the rest of the stock (Mong. *otor*: see more in Bold 2001: 63; 66).

Summer As far as livestock keeping is concerned, the summer months comprise the second half of May, June, July and the first half of August, during which the livestock put on weight. Average temperatures and the length of the summer period differ in the mountains, the forest highlands and the steppes. There is however a general climatic reason for the migration to the summer pasturage: to avoid the heat. While in winter and particularly in spring the livestock is protected from the cold wind, a windy and cool region is suitable for the summer pasturage. The climate of Mongolia is especially dry; 80%-90% of the annual precipitation falls in the short period of the humid months from May to September. For these reasons the suitable regions for the summer pasturage are in principle higher locations than the winter pastures, for example on mountain crests, where the winds blow more strongly. There are of course differences in connection with the differing nature zones. Since the inversion line of the Hangai and Hentii forest highlands lies lower, for example, the mountain crest on this inversion line should be avoided for the choice of summer pasture and accordingly the summer pasturage is chosen in the foothills below the winter and spring pasturages. In this case livestock keepers move with their stock often to a region with a plentiful water supply, where the inadequate coolth of the wind can be compensated with water, i.e. to a site which lies not directly at a water source but amongst hills nearby to water and which is ecologically appropriate. If mountain crests and declivities are useable for pasturage and there is a water supply to satisfy the large need of the animals, then the most favourable conditions for a summer pasturage are met. Although in the Altai Mountains there are no plentiful water sources, this is all the same characteristic for a summer pasturage in this region.

Autumn From the second half of August the variation in temperatures increases, nights are cooler and days often comparatively warm and free of wind. In this period the animals become restless on account of the increasing fluctuations of temperature. In order to ensure that the livestock remains well nourished from summer into autumn, migrations are carried out to a warmer location where the animals can feed more peacefully and can be fattened in autumn in a regular way. Such sites, which remain even until late autumn warm and free of snow, are located characteristically in low lying regions, in the rule in all nature zones. The migration from the highlands of the summer pasture, or from the hills in forest highlands lying near to water, or from the steppes, into lowlands is carried out often very slowly in order that the summer weight increase of the animals not be lost in the course of long migration treks. This migration from the heights into the lowlands is in principle in all regions the longest of all the seasonal migrations. In the zones where the migration treks from the summer to the autumn pasture are quite long - not infrequently more than 300km - the migrations often last several weeks. As far as wind and precipitation are concerned, they play a comparatively lesser role in the pasturage of autumn than of the other seasons, since mild winds and low precipitation are characteristic for autumn, particularly in the lowlands.

Thus the seasonal climatic differences, in particular the fluctuations in temperature, are important determinants in the frequency and distances of migration in traditional Mongolian livestock keeping, as we have attempted to describe.

2. The state of vegetation as a determining factor of seasonal migration

All forms of pastoral agriculture develop predominantly where, on account of mountain ranges, highlands and valleys, the annual cycle of forage plants exhibits large differentiations over small regions: for thus is the yearly balance of food attainable by means of relatively short migration treks. This means that migration occurs not only for climatic reasons but also for reasons connected with the seasonal food balance of the animals. Therefore one of the most important factors of seasonal migration is the state of the vegetation: the seasonal division of forage plant resources and the distribution of forage plants. The four seasonal migration routes in traditional Mongolian nomadic livestock keeping have always been influenced by these two aspects of the vegetation.

We shall briefly consider their effects upon migration:

1. In the pastoral areas about fifty million tonnes of forage plant material for livestock grow annually. The forage plant resources are certainly differently distributed throughout the seasons. Thus, for example, in the case of the food requirements in summer and autumn there are 2,3 million tonnes of feed in excess. On the other hand there is a deficit in winter and in spring of about 5,5 million tonnes. This means that the food supply in summer and autumn is about 28,9 million tonnes and in winter and spring about 21,1 million tonnes (Chadraabal 1982: 24).

The capacity of pasture land is, in the investigations which form the basis of economic policy and projects, in the rule evaluated by the annual average yield of forage plant material. Since the periods of vegetation in winter/spring and summer/autumn differ due to seasonal length (200 days in the former and 165 days in the latter) and to reserves of forage plants, it would be more accurate to evaluate the actual capacity of the pasture land taking into account the periods of vegetation when the reserves of forage plants are lowest. Thus Mongolia has a reserve of pasture in winter/spring for about forty-eight to fifty million sheep. Moreover it is a fact that in spring compared to high summer the protein content of forage plants is 3,5 times less, the juiciness is 2,5 times less and the time available to pasturing on account of the lesser daylight hours and of the cold is twice as short (Moibuu et al. 1996).

The state of vegetation in Mongolia is especially characterised by the fact that climatic conditions allow only a single short period of growth. In the middle of September the grasses and plants begin to die off. This is a sign of the coming dangerous phase of the year for the herds. The new vegetation does not appear before the end of March or the start of April of the following year and even then it is so sparse that it plays no great role in the upkeeping of the animals for yet another month.

Thus the animals must live for six or seven months on the dead plants which have remained after the period of growth. The decisive factor is the quantity of vegetation at the end of summer, which must be sufficient to supply the stock until the beginning of the next growth period. As a result of this the need arises to exploit the yearly resources of forage plants by means of seasonal migrations with an optimal dividing of the pastoral regions.

From the middle of winter to the first half of spring is the period of the smallest supply of forage plants, during which the capacity of the pasture land reduces by 60% to 75%. In order to maintain a warm pasturage in this especially difficult period, the regions above the mountain slopes are made use of, in principle in all nature zones. By means of this the remains of forage plants, which have been preserved through the entire winter, are available in late spring.

In the second half of spring the period of vegetation begins. At this time too begins the active feeding period of the animals on the natural pasture. This season is characterised by the fact that the animals become especially debilitated. Therefore they must be driven into a region where forage plants that are richer in calories grow. Such sorts of forage plants are plentiful amongst the vegetation lying beneath the middle altitude of a mountain.

In order to make use of pasture areas distant from the winter site, livestock keepers normally leave this site with the entire stock excluding the mothers and the calves. Such treks are frequently quite a distance. The point of the migration is to reach a pasture in which fresh grass can grow. Such pastures are in the rule located at sunlit mountain feet which are watered by the snow.

Regarded biologically, the livestock must put on weight in summer in order that a fat layer might form in autumn to act as protection against frost. Therefore those types of plants are taken into consideration by livestock keepers so that weight increase and fattening can occur in the appropriate order. As far as vegetation is concerned, this is the actual reason for the summer pasturage. A negative consequence of a summer pasturage on a wrong pasture or amongst the wrong vegetation could be that fattening occurs too early, before the livestock has put on sufficient weight. In this case the livestock can not survive the hard winter and the feed deficient spring.

In autumn the ripeness of the various plants gradually deteriorates. Although all forage plants in Mongolia complete their ripening in general during the summer, the period of ripening of individual forage plants is quite different. The period of ripening of vegetation is connected with altitude: from the mountain crest to the mountain foot. Later ripening occurs in the lowlands and in the valleys. Moreover, as a result of the ripening process and of low precipitation the plant concentrate is comparatively high and the water content always low. There is nonetheless a climatically determined difference in the preservation of water in the plants in connection with the altitude. The point of the autumn pasturage is therefore to seek still juicy green grass and a vegetation appropriate for the fattening of the livestock. Such sites are located in the lowlands.

2. Also the distribution of forage plants plays a large role in the direction of seasonal migration. Regarded generally, the vegetation density in Mongolia continually decreases in the direction from highlands and forest highlands to southerly or southwesterly steppes and lowlands. Moreover there are in the highlands in both the Altai Mountains and the Hangai-Hentii Mountains separate vegetation zones which are dependent on the moistness, the amount of sunlight etc. of the respective microecology. However in all nature zones it is possible to establish altitudinal belts of distribution of definite sorts of forage plants, corresponding to the respective altitudes, climatic conditions and soil types (table 2). In the steppes and the Gobi region there are few altitudinal vegetation and nature belts since the difference between highlands and hollows as far as pasture is concerned is too small.

On the 131.1 million hectares of pasture area of Mongolia about 2,300 types of herbage grasses and other plants grow, which belong to about 580 different plant families. Of these about 600 types of plants are usable for the food requirements of the five most important sorts of animals (Cerendulam 1994: 3).

Of the above mentioned 2,300 plant types about 550 widespread types of forage plants have been quite well researched. Pasture scientists claim that 47% of these are frequently or willingly eaten by livestock and nutritious plants, 4% are of very good food quality, 44% are rarely or unwillingly eaten plants and 5% are poisonous plants for animals (Mongol orny ... 1966: 4). Of course the forage plants have different significance for the various animal types. From available research material concerning

Table 1. Forage plant types in the nature zones according to the seasonal need of the animal types

	In summer and autumn	In winter and spring
Sheep/Goat	In mountain highlands: Festuca lenensis, Poa attenuata, Koeleria macrantha, Oxytropis nitens, Oxytropis filiformis, Phojodicarpus sibiricus, Stellera chamaejasme, Festuca sibirica, Polygonum angustifolium, Coluria geoides, Cotoneaster melanocarpa, Grossularia acicularis, Pentaphylloides fruticosa, Helictotrichon altaicum, Carex pediformus, Koeleria cristata, Aster alpinus, Allium senescens, Allium odorum and Artemisia frigida; In steppes: Stipa klemenzii, Stipa gobica, Cleistogenes squarrossa, Artemisia frigida, Stipa glareosa, Anabasis brevifolia, Allium polyrrhizum, Thymus gobicus, Dracocephalum foetidum, Artemisia rutifolia, Ajania fruticulosa. Lagochilus ilicifoius, Scorzonera capito, Agropyron repens, Koeleria pers. und Zygophyllum pterocarpum; In Gobi and desert region: Stipa gobica, Stipa glareosa, Anabasis brevifolia, Ajania fruticulosa. Lagochilus ilicifoius, Scorzonera capito, Zygophyllum pterocarpum, Artemisia xanthochroa, Artemisia xerophytica and Salsola laricifolia	In mountain highlands: Stipa krylovii, Arenaria capillaris, Arctogeron gramineum, Artemisia ruthifolia, Agropyron cristatum, Filipendula adens. and Caryopteris; In steppes: Cleistogenes squarrossa, Koeleria cristata, Sibbaldianthe adpressa, Haplophyllum dauricum, Astragalus galactites, Caragana microphylla, Caragana stenophylla, Stipa grandis, Stipa baicalensis, Stipa krylovii, Arinaria capillaris, Arctogeron gramineum, Artemisia ruthifolia, Caryopteris mongolica, Koeleria macrantha, Artemisia scoparia, Agropyron cristatum, Ephedra sinica, Caragana bungei and Leymus chinensis; In Gobi and desert region: Stipa klemenzii, Stipa krylovii, Stipa glareosa, Stipa gobica, Cleistogenes squarrossa, Salsola passerina, Artemisia dracanulus and Artemisia commutata
Cow	In mountain highlands and grassland steppes in mountains: Larix sibirica, Betula platiphylla, Carex lanceolata, Vicia venosa, Vicia unijuga, Iris luthenica, Fragaria orientalis, Filifolium sibiricum, Polygonum divaricatum, Iris dichotoma, Hemerocallis minor, Clematis hexapetala, Stipa baicalensis, Helictotrichon schellianum, Helictotrichon desertorum, Coluria geoides, Onosma arenarie, Scabiosa ochroleuca, Spiraea hypericifolia, Koeleria mukdenensis, Cleistogenes kitagawae, Lespedeza dahurica, Saposhnikovia divaricata and Stellera chamaejasme; In steppes and lowlands: Larix sibirica, Salix kochiana, Salix viminalis, Pentaphyloides fruticosa, Carex dichroa, Carix orbicularis, Salix rhamnifolia, Cyperceae J.St., Stipa krylovii, Stipa baicalensis, Dasiphora raf. and Salix ledebouriana	In mountain highlands: Lasiagrostis link., Agropyron cristatum and Agropyron repens; In steppes in middle mountains: Stipa baicalensis, Stipa sibirica, Thalictrum petaloideum, Filifolium sibiricum, Cerastium arvensa, Clausia aprica, Stipa krylovii, Arenaria capillaris, Arctogeron gramineum, Artemisia ruthifolia and Caryopteris mongolica
Yak	In high mountains: Cerastium lithospermifolium, Dryadanthe tetrandra, Waldheimia tridactylites, Parrya exscapa, Valerianapetrophylla, Kobresia bellardi, Kobresia humilis, Carex rutestris, Hylokomium splendens, Aulacomnium turgidum, Kobresia billardii and Festuca altaica	

Table 1. (continued)

Horse	<u>**In mountain highlands:**</u> Helictotrichon desertorum, Coluria geoides, Onosma arenaria, Scabiosa ochroleuca, Filifolium sibiricum, Poligonum devaricatum, Iris dichotoma, Hemrokallis minor, Clematis hexapetala, Stipa baicalensis, Helictotrichon schellianum, Stipa krylovii, Arenaria capillaris, Arctogeron gramineum, Artemisia ruthifolia, Caryopteris, Koeleria mukdenensis, Cleistogenes kitagawae, Lespedeze dahurica, Saposhnicovia divaricata, Stellera chamaejasme, Stipa krylovii, Leymus chinensis, Bupleurum scorzonerifolium, Galium verum and Astragalus melilotoides; <u>**In steppes:**</u> Agropyron repens (L.) P.B., Stipa (L.), Agropyron cristatum (L.) Geartn, Cleistogenes Keng., Koeleria Pers, Artemisia frigida and Allium senescens; <u>**In Gobi and desert region:**</u> Artemisia commutata	<u>**In mountain highlands:**</u> Stipa krylovii, Arenaria capillaris, Arctogeron gramineum, Artemisia ruthifolia and Caryopteris mongolica; <u>**In steppes:**</u> Stipa baicalensis, Stipa sibirica, Thalictrum petoloideum, Filifolium sibiricum, Cerastium arvense, Clausia aprica, Stipa krylovii, Arenaria capillaris, Arctogeron gramineum, Artemisia ruthifolia, Cariopteris mongolica, Cleistogenes squarrossa, Koeleria cristata, Sibbaldianthe adpressa, Haplophyllum dauricum, Astragalus galactites, Caragana microphylla, Artemisia frigida, Artemisia scoparia, Agropyron cristatum, Ephedra sinica and Caragana bungei; <u>**In Gobi and desert region:**</u> Stipa klemenzii, Stipa krylovii und Cleistogenes squarrossa
Camel	<u>**In steppes:**</u> Stipa klemenzii, Stipa gobica, Cleistogenes squarrossa, Artemisia fregida, Stipa glareosa, Anabasis brevivolia and Allium polyrrhizum; <u>**In Gobi and desert region:**</u> Sympegma regelii, Haloxylon ammodendron, Ephedra przewalskii, Kalidium, Salsola passerina, Reaumuria songalica, Haloxylon ammodendron, Vicia costata, Hedysarum fruticosum, Iris tenuifolia, Allium mongolikum, Artemisia klemenzii, Caragana bungei, Psammochloa villosa, Leymus racemosus, Artemisia xerophytica, Artemisia sphaerocephala, Colligonum mongolicum, Arnebia guttata and Eurotia ceratoides	<u>**In steppes:**</u> Stipa glareosa, Stipa gobica, Salsola passerina, Lasiogrostis link., Cleistogenes squarrossa, Chenopoiaseas less., Eragrostis host. and Urtucaceae endl.; <u>**In Gobi and desert region:**</u> Haloxylon ammodendron, Stipa gobica, Stipa glareosa, Ajania fruticulosa, Lagochilus ilicifolius, Scorzonera capito and Caragana pygmaea

Source: Gonchigjav, Ds,... (ed.), Livestock breeding (mong.), Ulaanbaatar 1980; National Atlas of the MPR (mong. und rus.), Moskau 1990

Table 2. The altitudinal distribution of forage plant species in the environs of the Hangai Mountains

h (m)	
higher than 3500	1. Gravel and forests
3000	2. The pastural region in the grassland mountain tundra with Betula rotundifolia, Dryas oxyodontha and in the forest high mountains with Hylocomium splendens, Aulacomnium turgidum, Kobresia bellardii and Festuca altaica
2500	3. The pasture land in the mountain taiga with Poa sibirica, Viola biflora, Hylocomium splendens, Rhytidium rugosum, Festuca altaica, Carex amgunensis, Pedicularis verticillata, Delphinium crassifolium, Rhydidium rugosum, Carex lanceolata, Iris ruthenica, Vicia venosa and Fragoria orientalis
2000	4. (Northwest to south) The pasture land in the semi-desert steppes with Cleistogenes squarrosa, Stipa glareosa, Caragana bungei, Caragana leucophloea, Stipa sibirica, Agropyron nevskii, Artemisia rutifolia, Allium eduardii, Lophanthus chinensis, Amygdalus pedunculata and Berberis sibirica; The pasture land in the dry steppes with Cleistogenes squarrosa, Agropyron cristatum, Stipa krylovii, Ephedra sinica, Iris tenuifolia, Vincetoxicum sibiricum, Artemisia campestra, Leymus racemosus, Caragana bungei, Artemisia dolosa, Saussurea pricei, Allium eduardii and Berberis sibirica; The pasture land in the dry steppes of the lower mountains with Stipa krylovii, Cleistogenes squarrossa, Koereria kristata, Sibbaldianthe adpressa, Haplophyllum dauricum, Astragalus galactites, Caragana microphyla, Caragana stenophylla Stipa grandis, Stipa baicalensis, Koeleria macrantha, Artemisia frigida, Artemisia scoparia, Arenaria capillaris, Arctogeron gramineum, Artemisia ruthifolia and Caryopteris mongolica
1000	5. (Northwest to south) The pasture land in the desert with Amygdalus pedunculata, Artemisia xerophytica, Artemisia xanthochroa, Eurotia ceratoides, Ephedra przewalskii, Calligonum mongolicum, Psammochloa villosa, Iris tenuifolia, Arnebia gutatta, Artemisia globosa, Artemisia sphaerocephala, Eurotia ceratoides, Anabasis brevifolia and Stipa glareosa; The pasture land in the desert steppes with Caragana bungei, Stipa glareosa, Artemisia xanthochroa, Artemisia xerophytica, Psammochloa villosa, Leymus racemosus, Hedysarum fruticosum, Artemisia sphaerocephala, Stipa gobica and Salsola passerina; The pasture land in the semi-desert steppes with Stipa klemenzii, Stipa krylovii, Cleistogenes squarrosa, Stipa gobica, Artemisia frigida, Thymus gobicus, Dracocephalum foethdum and Artemisia rutifolia; The pasture land in the desert steppes of the lower mountains with Stipa gobica, Stipa glareosa, Anabasis brevifolia, Allium polyrrhazum, Ajania fruticulosa, Lagochilus ilicifolius, Scorconera capito and Zygophyllum ptercarpum

Source: Yunatov, A. A., Fundamental features of the vegetation cover of the Mongolian People's Republic (Rus.), Leningrad 1950
Ölziihutag, N., Overview of the distribution of vegetation in Mongolia (Mong.), Ulaanbaatar 1989
National Atlas of the MPR (mong. und rus), Moskau 1990

forage plants it can be determined which plant types are preferred by which animal types (table 1). This then makes it possible to ascertain, according to the distribution of the forage plants, in which direction the animals should migrate in the course of the seasons.

In general the seasonal food balance for all types of animals can be divided into two main periods: firstly, the active feeding in the period of vegetation, and secondly, the period of maintenance of weight gain and fattening in the inactive months of the vegetation. The time of vegetation is so short that it must be exploited to the full for an effective pasturage. Therefore the attaining of a well-nourished condition of the livestock in the active vegetation period is divided into the following feeding periods:

1. the return of strength (Mong. *usan badailga*) from April until May, the second half of spring,
2. the putting on of weight (Mong. *mahan targa*) from June until the middle of August,
3. the fattening (Mong. *ööhön targa*) from the second half of August until the start of November.

Thus the distribution of the forage plants is one of the most important factors for pastoral migration, upon which the direction and distance of the migration depends.

In order to understand this better, it is useful to consider an example in closer detail. The seasonally eaten forage plant types found predominately in the region of the Hangai Mountains have been schematised in table 1, classified according to animal types. In table 2 which represents the altitudinal distribution of forage plants in this region we see that levels of vegetation containing the basic forage plant types are formed following one upon the other according to altitude.

If we compare the two tables, namely the seasonal division of the supply of plants and the distribution of the forage plant types, it becomes clear that the seasonal pasture regions in the environs of the Hangai Mountains, as far as the distribution of forage plants is concerned, are unequivocally connected with the differences in altitude. This in principle corresponds to the climatically determined altitudinal ordering of seasonal migrations.

3. Salty soils as a determining factor of altitudinally directed migration

The significance of salty soils for livestock and for seasonal migration has been neglected in investigations concerning nomadic livestock keeping in Mongolia. The reason for this is that the original seasonal migration to salty soils has become impossible or is overlooked, in particular in the last decades, as a result of newly established territorial-administrative borders. I consider it important that salty soils be considered as a basic motive for seasonal migration.

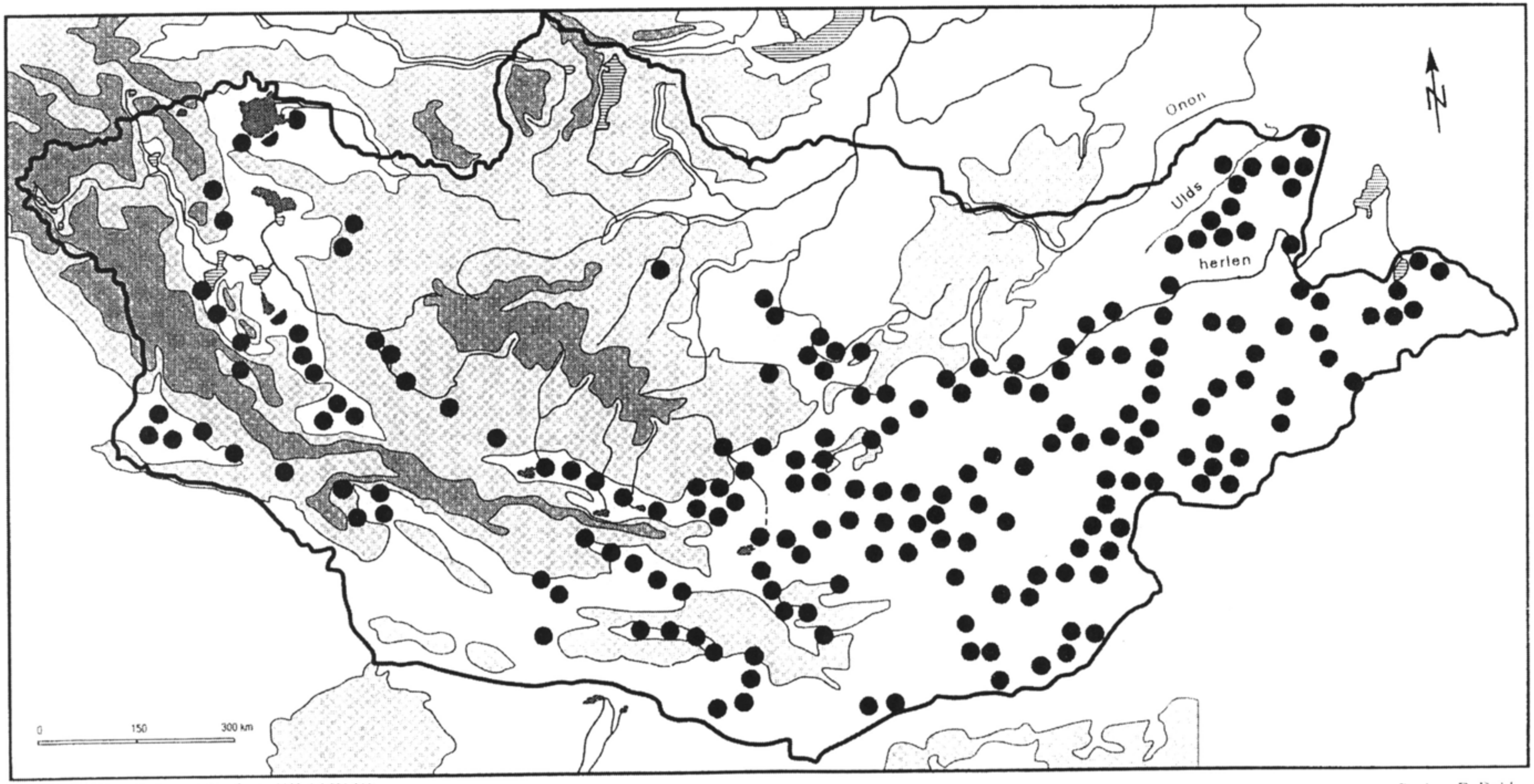
The salty soils of the pasture land of Mongolia are very rich in sodium (Na) and potassium (K) which are the most important elements for the growth and the strengthening of the bone tissue of the animals as well as the most important chemical constituents of bone marrow, magnesium (Mg) which is one of the most important elements of the muscle tissue, and copper (Cu) which is necessary for blood formation and for the functioning of the respiratory organs.

Thus salts play a very important role in the putting on of weight and in particular in the fattening as well as the maintenance of a well nourished condition of the livestock in autumn. Since the livestock do not obtain an adequate amount of the above mentioned elements from plants, salty soils are the only supplementary source of minerals. Salty soils are in no way used occasionally or seasonally but quite regularly. For example sheep must pasture on salty soils in average once every five to seven days in winter, every three to four days in spring, every four to seven days in summer and autumn (Gonchigjav et al. 1980: 141). The regularity of course depends upon the mineral content of the soil. If the summer and autumn pasturage takes place on soils low in salt, horses, for example, must once every seven to ten days pasture on salty soils.

Thus there arises the need to allow livestock to graze in regions rich in salts. Livestock keepers take into consideration when choosing a pasture not only favourable climatic conditions and the state of the vegetation but also the salt content of the soils. In the rule every seasonal pasturage must have salty soils available.

A physical-geographic investigation of the pattern of the distribution of salty soils in connection with the pasture land in Mongolia has only to a limited extent been carried out. As we see in the

Map 1. Distribution of Salty soils in Mongolia



Source: Map of Mongolia (mong.), Ulaanbaatar 1993, 1:1 000 000

Design: B. Bold

distribution of salty soils in(map 1), an increase in salt deposits is noticeable from about the northwest tothe southeast of Mongolia. In the forest highlands the proportion of salty soils is the smallest, while in the steppes and the Gobi and desert regions very high. This tendency is valid not only generally on a large scale but also locally: in the mountains almost nothing, at the mountain foot and in the valleys more frequent.

That the density of vegetation, as mentioned above, decreases gradually from the highlands and forest highlands to the steppes and the Gobi and the nutritional value of a food unit thereby increases, stands in close connection with the distribution of salty soils. Salty soils are divided in livestock economic practice according to the concentration of minerals into sparse and rich soils. In the lowlands the mineral content of salty soils is in the rule higher than in the highlands. According to experience as well as to the results of research the following regions in the steppe zones have been identified as having salty soils of good quality: Bor Ovoo (in the Övörhangai-Aimag/Bayanöndör-Sum), Olon Nuuryn Gol (in the Bayanhongor-Aimag/Bayanbürd-Sum), Erdene Uul, Gutlyn Ulaan Uul, Rashaant (in the east steppe region) etc. (Mongol orny ... 1966: 52).

Mongolian historical sources report that livestock keepers migrated in autumn with their stock often far into the south or the southeast, to the Gobi, to regions with soil rich in salts. This is still more or less the case today. But in this there are considerable difficulties in connection with the current close-meshedness of the rural territorial-administrative borders. In the period of collectivisation (*Negdel*), 1959-1991, it became habitual to satisfy the needs of the animals by transporting salt. However there is still today amongst the herdsmen in those Sums, within the borders of which there exists a region of salty soils, an attempt particularly in autumn to move with their stock into low-lying areas. Here the direction of migration to salty soils corresponds with the other goals of autumn migration, namely the attainment of favourable climatic conditions and of a suitable vegetation.

4. Access to drinking water as a determining factor of migration

Water plays differing roles in mobile livestock keeping. Above all water is one of the most important constituents of nourishment. For example a sheep requires three to four litres of water in order to digest one kilogram of dry food. The required amount of water of course depends upon the respective climatic conditions as well as the juice content of the plants. Sheep drink each time about two to two and a half litres of water. In summer sheep must receive water two to three times daily under the most favourable climatic and vegetative conditions, in spring and autumn once or twice daily and in a winter with heavy snowfalls once every second day. This is valid also for the other types of animals (Gonchigjav et al. 1980: 144).

On hot summer days the need for water is even higher since the livestock are cooled down by means of water, i.e. by perspiring. Therefore livestock keepers in summer as well as in autumn migrate to the river valleys and lakes. Since on summer days there are at the water sites in the lowlands many mosquitoes, midges and horseflies, the summer pasturage is carried out on windy hills lying near to water. When the insect pests disappear in autumn on account of the decrease in temperature, it is possible to move downwards direct to the water source.

In winter the livestock require relatively little water on account of the sparse vegetation and of their physiological adaptation. The need for water in winter is mostly satisfied by the disintegration of acquired fat and by snow. A superfluous amount of water through drinking would decrease the resistance of the livestock to cold. Therefore a pasture distant from a water source is most favourable in winter. The fact that regions lying nearby to water are cold in winter is another reason to seek out a pasture away from water sources and rivers. Moreover the source of water is of great significance in the division and the divided use of the pastoral regions. Watersheds delimit climatic-geographic belts and the gradings of vegetation both altitudinally and planarly, and thereby form comparatively isolated pasture strips or areas.

In historical sources and on ancient maps of Mongolia the locations of the ancient tribes were always represented in the vicinity of sources of drinking water - larger rivers or permanent fresh water lakes or abundant springs. Also in the later establishment of territorial-administrative borders the entirety of a pastoral area and the availability of water were especially considered. For example larger rivers, lower river valleys or fresh water lakes in the lowlands were used as border lines of pastoral areas. However in the Negdel period this was of lesser significance. Owing to the organisation of livestock keeping, the territorial-administrative divisions were made smaller and the number of such regions was massively increased. In 1990 there were in all 310 Sums in Mongolia (see more in: Bold 1997).

The supply of drinking water is often ensured by the building of wells. In 1991 there were about 37,600 treadwheel wells (in the Gobi and steppe regions the wells must be dug deeper) and 3,600 built up springs (Mongolian economy ... 1993: 40). This brought both advantages and disadvantages. If in the case of a scant network of natural water sites the pasture lands about these sites do not overlap, then the pastures remain unused for the greater part of the year or even over the years. They offer in the alternative planning of the nomads a natural food reserve, which is opened up only in those years when natural water sites are formed owing to a greater degree of moisture, since then sufficient water is available. These mostly unusable pasture zones are now opened up to the nomadic economy by means of the construction of the treadwheel wells. The nomads now make use of these wells even during periods of low rainfall, and as a consequence the natural food reserve is used up. The damage is even greater since the water potential of the wells is in most cases higher than the grazing potential in their vicinity. The mobility of the nomads, which was once forced by the exhaustion of the water sites, is being limited. A certain devastation of the vegetation of the pasture about the wells is also a consequence. The wells therefore are more or less depriving the nomads of their natural pasture reserves.

5. Geographic borders as an influencing factor of the direction of migration

Not only climatic conditions, the state of the vegetation and the distribution of salty soils and water sources are of significance for the distance and frequency of migration, but also geographic borders. In general they are divided into ecologically and economically determined borders. The ecologically determined borders include mountain crests, larger rivers, cliff regions, deserts, valleys, etc. Besides these, which are determined by altitude and natural markings, there are also economic margins of the pasture land. Obvious borders are formed by settlements and industrial areas, by paths, roads and railways.

From the above the wrong impression might be gained that the borders of the pasture land are once and for all fixed. This is however in no way the case. The ecologically determined borders are relatively stabile, but the economic margins are certainly not. They are formed in flexible adaptation as a consequence of technological and social-economic development. Thus there is, for example, in the lower river valleys of Orhon, Selenge and other rivers, which have their sources in the Hangai and Hentii Mountains and which today are located in the Selenge-Aimag, hardly any pastoral area. The reason for this is that the pasture land has been superseded as a result of the development of farming and industry in this region. The rate of industrialisation in the Selenge-Aimag is in average three times higher than in the other Aimags.

On the basis of what has been said about the ecological factors of seasonal migration, the ordering of the seasonal pasture areas in Mongolia, i.e. how and in what relation to the ecological factors the four seasonal pasture regions lie, can be described. There are however two variations: first, the locations of the actual or the original pasture areas, in which case the economic or socially determined borders have no part, and second, the locations of the present pasture areas, in which case all economic and ecologically determined borders are considered.

On the basis of the above discussed ecological determinants we can distinguish basic forms of seasonal migration.

In winter the best pasture regions lie, on account of the favourable combination of temperature, wind and precipitation, in principle in all three nature zones in the belt between the higher and middle mountain ranges. The winter site is therefore located on a higher south slope of a mountain or in a mountain cleft away from the wind direction.

The spring pasturage on the other hand takes place somewhat below the winter pasturage, on the south face of a mountain between a middle altitude and the mountain foot. Although in general the lower the location the warmer it is, snow often remains at the mountain foot and in the lowlands until May, and nights can be cold and damp.

The suitable regions for the summer pasturage are for climatic reasons located on the higher parts of a mountain, higher than the winter pastures, for example on mountain crests, where the winds blow more strongly. There are of course differences in connection with the differing nature zones. Since the inversion line of the Hangai and Hentii forest highlands lies lower, for example, the mountain crest on this inversion line should be avoided for the choice of summer pasture and accordingly the summer pasturage is chosen in the foothills.

In order to ensure that the livestock remains well nourished from summer into autumn, migrations are carried out to a warmer location where the animals can feed more peacefully and can be fattened in autumn in a regular way. Such sites, which in comparison to other areas remain even until late autumn warm and free of snow, are located characteristically in low lying regions, in the rule in all nature zones.

If we compare the forage plant types according to seasonal divisions and the altitudinal distribution of forage plants it becomes clear that the seasonal pasture regions, as far as the distribution of forage plants is concerned, stand in a belt-like relation with the differences in altitude.

Moreover salty soils play a very important role in the putting on of weight in summer and in the fattening as well as the maintenance of a well nourished condition of the livestock in autumn. Since in the distribution of salty soils there exists the phenomenon that the mineral content is lowest in the highlands and highest in the lowlands, the seasonal migration should in the main be determined altitudinally.

Since on summer days there are at the water sites in the lowlands many mosquitoes, midges and horseflies, the summer pasturage is carried out on windy hills lying near to water. When the insect pests disappear in autumn on account of the decrease in temperature, it is possible to move downwards direct to the water source. The fact that regions lying nearby to water are cold in winter is a reason why it is necessary to seek out a pasture away from water sources and rivers during this season. Moreover the source of water is of great significance in the division and the divided use of the pastoral regions.

Geographic borders influence migration routes, i.e. they determine in which direction and where the migrations should be carried out.

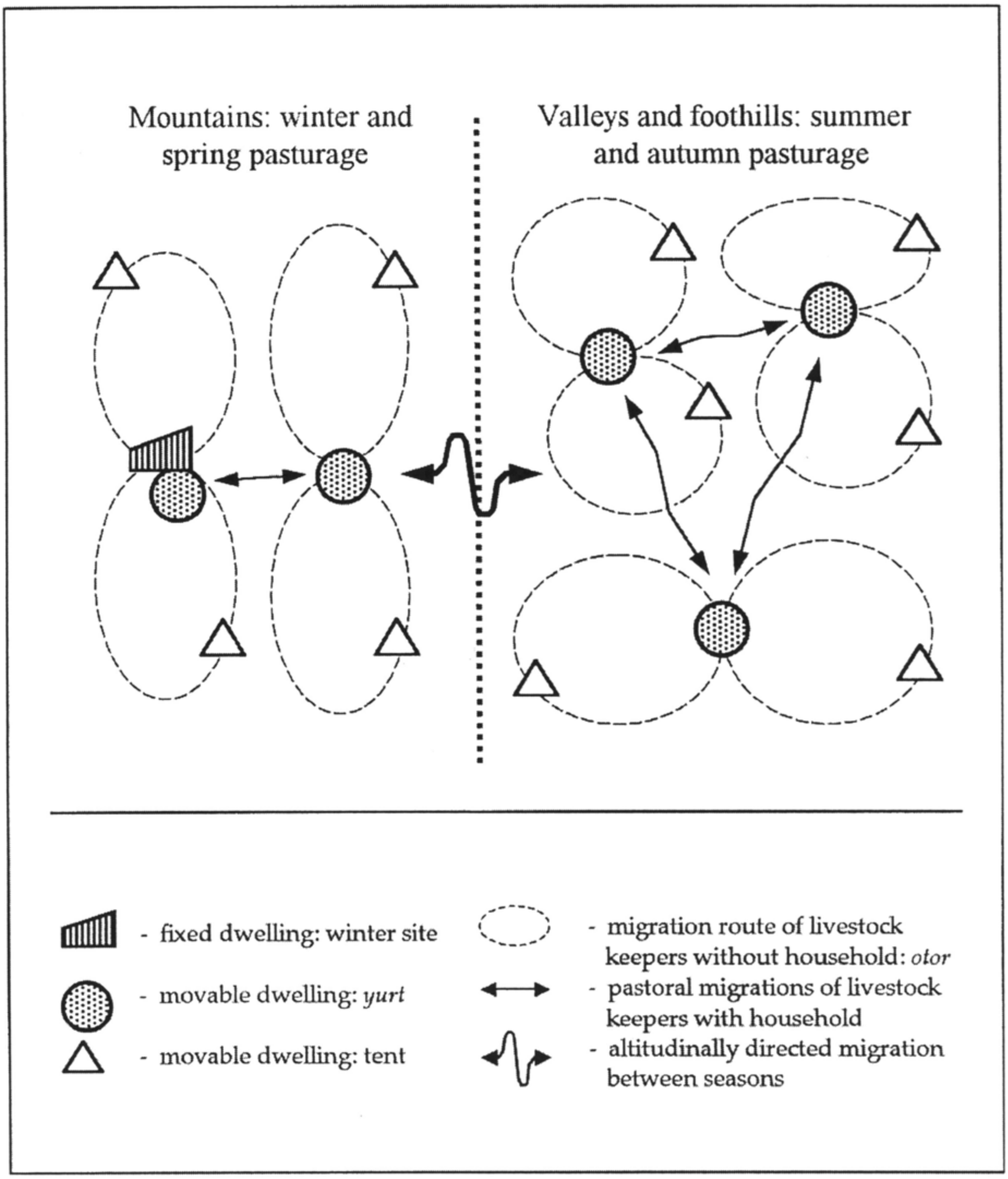
The effects of all these factors on the seasonal migrations are connected with differences in altitude. From this it follows that the seasonal migrations in principle in all nature zones are determined altitudinally. However this view should not serve as an argument that in Mongolia there are absolutely no planar migrations. On the contrary livestock keepers undertake quite frequently planar (horizontal) migrations in the course of a season in order to extend the pasturage and to satisfy food requirements (fig. 3).

There are in respect to pasture and ecologically speaking two main regions of Mongolia: mountainous land and the steppes/Gobi, whereby mountainous land is divided according to the respective ecosystems into two sub-regions, the highlands in the Altai Mountains and in the Hangai-Hentii Mountains (Bazargür et al. 1989: 104–44). As far as pastoral migration is concerned, there are thus three different types of migration corresponding to the defined nature zones: migrations in the Altai Mountains, in the Hangai-Hentii Mountains and in the steppes/Gobi region. In addition livestock keepers conduct their seasonal migrations in the steppes in Central and East Mongolia and in the southeast Gobi region in quite different manners.

This has probably been caused by the too closely drawn administrative borders, in which the actual pastoral region has not been considered. In the first two forms the seasonal migrations quite evidently correspond to differences in relief and are altitudinally directed. There is however a clear difference in connection with the order of the change of pasture, depending upon orographic conditions.

Seasonal migration in the Altai Mountains This mountain chain, which stretches from the northwest of Mongolia to the southern Gobi, is almost devoid of forests. The mountain system is surrounded by valleys and hollows. It borders onto the Altai valley of the northern Gobi which is covered with numerous saltpans and sand plains and which extends from the basin and over the broad valley of the Gobi lakes, as well as onto the Altai valley of the southern Gobi where there are

Figure 3 General pattern of holizontal migration of Mongolian nomads



substantially less lakes and sand plains but more gravel plains. This valley is comprised of three parts: in the west the Achit valley, in the south the Alashan Gobi and between the two the Trans-Altai Gobi. These orographic conditions enable livestock keepers to exploit to the full by means of migration the natural pasture from the mountain crests to the valleys and foothills. This permits a seasonal migration from the peaks to the lowlands in the order summer, winter, spring, autumn. There are however in some regions other variations of the order, eg. winter, spring, summer, autumn (fig. 4A).

Seasonal migration in the Hangai-Hentii Mountains The massive Hangai-Hentii Mountain system also borders on the great lake basin in the west and on the southern Gobi in the south, and is bordered in the east and southeast by the undulating eroded plains of the steppes and Steppe-Gobi which are covered with numerous saltpans. Between these two mountainous lands, the broad river valleys of the Orhon, the Selenge and the Tuul are situated. It is here characteristic that the south faces of the slopes and partly of the mountain crests (eg. in Hangai) are cliffy and steep rising. The northern slopes and in part also the northern crests are on the other hand forested and levelled out. Mongolian forests, which cover in all only 9.6% of the country, are comprised almost entirely of the forest regions of the Hangai-Hentii Mountain system and the Khövsgöl Mountains.

As a consequence the herdsmen are not able to make use of the mountain crests for pasturage, and in particular for the pasturing of sheep and goats, and therefore allow their stock in the rule to graze only as far as the inversion line. Thus it happens that the altitudinally directed seasonal migration from the peaks to the lowlands are ordered winter, spring, summer, autumn (fig. 4B). However in a region where either there are crests devoid of forest or gravel and accessible to the livestock or the inversion line is higher than about 2,300m, the first variation of migration as in the Altai Mountains is also possible.

Seasonal migration in the steppes The high steppes of eastern Mongolia, which in the west are bordered by the Hangai-Hentii Mountains, are above all in the north covered with undulating eroded plains rich in salts. They are divided approximately through their centre by the voluminous Herlen River which flows into the Dalai Nuur. The east lying Lake Buir is situated on a huge plate-like high steppe. Here there is a relatively small difference in altitude between the highlands and the lowlands. For this reason seasonal migrations from the heights into the lowlands are ordered winter/spring, summer/autumn, whereby the pasturages for winter and spring are conducted at about the same altitude, as are those for summer and autumn (fig. 4C). One sees here that this form is not only a planar migration determined by thermal and humidity conditions but also clearly altitudinally directed.
The extremely extensive and flat eastern and southeastern Gobi valley is a steppe sparse in vegetation. Stretching valleys and flat hollows, partly covered with salt lakes and sand marshes, characterise the landscape. Desert steppe and desert alternate. Ponds and small flat lakes are formed temporarily after heavy rainfalls. Although some scholars conjecture that migrations specially suitable for the region are here carried out, results from research show no particular form of migration comparable to that in the steppes. I am of the view that seasonal migration within the steppes is incomplete on account of a delimitation of the original pastoral strips by territorial-administrative borders. Through this the traditional, ecologically adapted migration routes and directions have in essence been simplified.

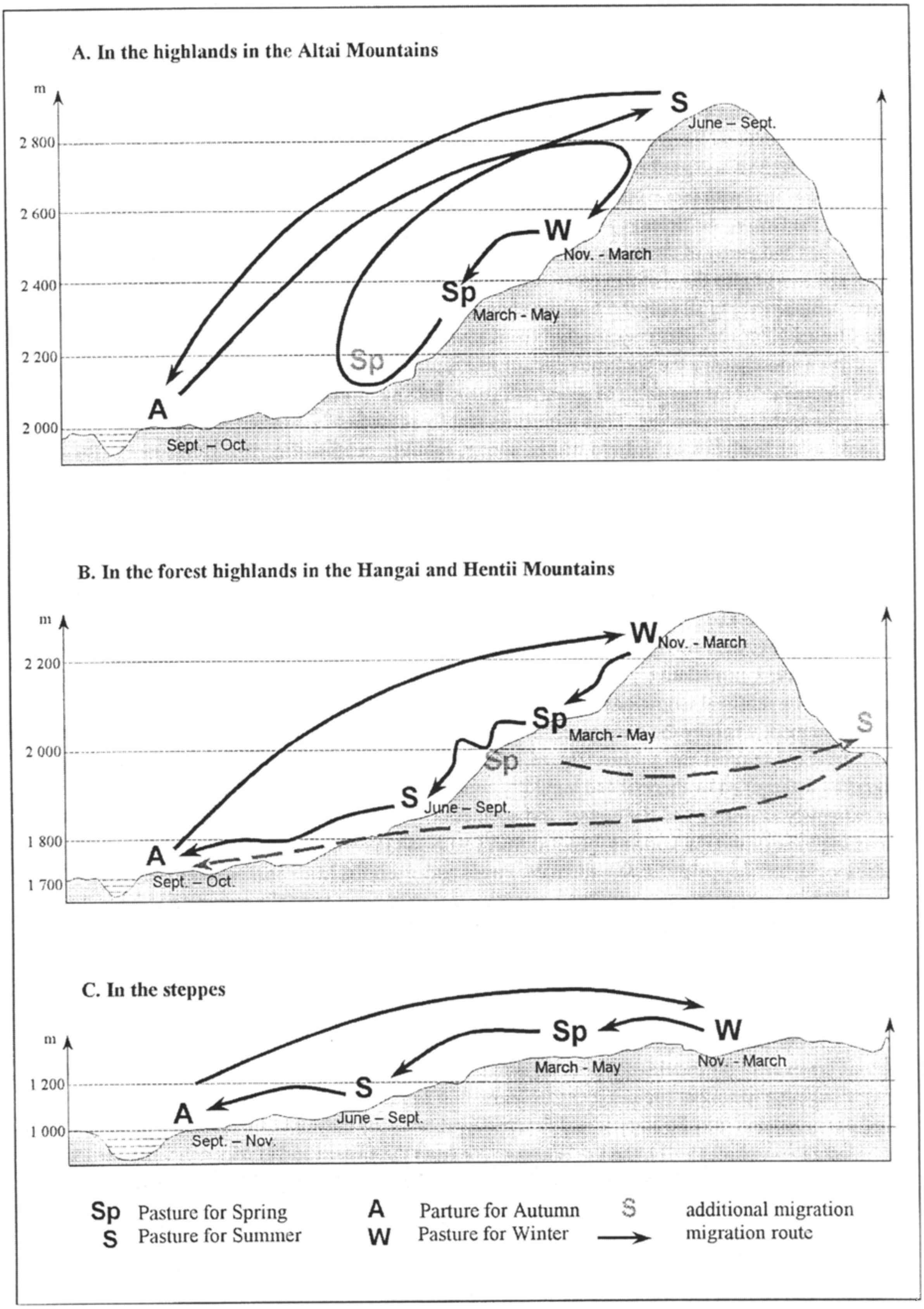
The climatic and vegetative conditions and the numerous saltpans and water reserves in these regions are exactly the requirements for an autumn pasturage, and in part too for a summer pasturage. From Mongolian historical sources it can be learnt that nomadic herdsmen for just this reason moved in particular in autumn into the steppes and desert steppe, whereby they covered distances of up to 750km. Regarded geomorphologically, the lowland corridor from the eastern end of Mongolia, the Menen Steppes, to the southern end, the Galbiin Gobi, is a geographic borderline of the flatlands of the northwestern and southwestern highlands and of the pastoral regions of both sides.

As already mentioned, these are only the basic forms of migration. There are in addition numerous variations of and experiments in seasonal migrations connected with the respective conditions and geographic borders of the pasture land.

7. Rural territorial-administrative divisions as an influencing factor on migration pattern

Thetirection, distance and frequency of nomadic migration is determined not only by ecological

Figure 4 General pattern of seasonal migration in different zones



indicators. The migration pattern has been affected by socio-political dimensions during different historical periods (see more: Bold 1997).

Research into a concrete regionalisation of the seasonal pastoral regions in Mongolia has hitherto been carried out only to a limited extent. For this reason the division of pastoral areas, which should make available a sufficient area of the pasture land as well as defined ecological areas required for the four seasons, has received no consideration in the territorial-administrative policies of the last seven decades in particular.

The traditional migration paths, directions and distances, which have been established by many years of empirical experience, are actually the significant factor for a conception of the location of the pastoral areas. These migration paths have been in the course of history more or less strongly influenced, i.e. livestock keepers now migrate with their stock no longer according to the traditional migration paths. Livestock keepers of today confine themselves to the pasture land within a defined territorial-administrative region. This means that with present seasonal migration paths the actual pastoral area, which in principle is ecologically fitted to a seasonally divided use, is hardly recognisable.

Therefore it is also important to briefly compare the influence of territorial-administrative borders and their relationship to pastoral areas in a historical context.

In the ancient Chinese chronicles frequent reports about the northern nomadic neighbours appear only after the 2nd century B.C.E. There are many reports in the chronicles about how the nomads appropriate for themselves a certain area. This is established by the fact that the nomads had a certain pastoral region and conducted the four seasonal migrations within these borders.

These reports convey to us notions about the past territories of the nomadic tribes. With the help of the ample reports to be found in the chronicles of the 2nd B.C. to the 1st A.D. and of the 6th to the 8th centuries, one can approximately see that the territories of the nomadic peoples ranged over highland and lowland regions (Bichurin 1950: vol. 1; Kyuner 1961; Taskin 1984). However to what extent the pastoral areas and the tribal locations corresponded with one another cannot be detemined from the details on account of the deficiency of the documentation of the chronicles.

From reports in the chronicles such as 'Collection of Chronicles' by Rashid ad-Din, 'Secret History of the Mongols' and 'Altan Tovch' etc. one can clearly see the constellation between the pastoral areas and geographical relief. There were no homogeneous but heterogeneous ecological conditions in the geographical background of the locations of the then larger nomadic tribes: each tribal group possessed its own region of pasturage which extended from the mountains into the lowlands.

If we compare the location of the pasture regions, which are to be altitudinally ordered between highlands and lowlands/valleys - as depicted in fig. 1 - with the locations of the tribal groups, we see that they on the whole harmoniously correspond.

'Altan Tovc' reports that even the Mongolian subtribes, which carried out livestock keeping in the spacious pasture land of the eastern Hentii Mountains lying between the voluminous Herlen and Onon Rivers, often moved in fall far northeast to the Ulz River. The reason for this was the salty soils. From the details of the source one can see that the summer pasturage was conducted in the somewhat higher region of the upper surrounding area of the Onon River (Luvsandanzan, 18, 23, 26, 30, 31, 38).

The development of the territorial-administrative border setting of the Mongolian Hoshuu[2] system in the period under the Manchurian rule strongly influenced the gradual breakdown of the above described correspondence between the locations of tribes and of the pasture regions.

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[2] Hoshuu: It is conjectured that the term 'Hoshuu' was used about the 14th/15th century in connection with military regions. Gradually Hoshuu became a term to describe the largest administrative-territorial units until that time when the Aimag became the largest units. In the 16th century after the death of the prince Geresendz (1513-1549), the youngest of eleven children of Batumungke Dayan Khan (ruled 1470-1544), the last emperor of the Mongolian Empire, his territory was divided between his sons into seven Hoshuu. From the seven Hoshuu in the first half of the 17th century there arose the first three Aimag (see footnote 3) in Halha (Outer) Mongolia: Tusheet Khan Aimag, Secen Khan Aimag, to each of which one Hoshuu belonged, and Zasagt Khan Aimag, to which four Hoshuu belonged. From this there followed a small loss of significance of the original Hoshuu division. After the conquest of Halha Mongolia by Manchuria, these administrative Aimag and Hoshuu divisions were taken over, however in a strongly

Since we do not have a detailed documentation and cartography[3] of the locations of the Hoshuu in the period from the end of the 16th to the end of the 17th century, it is difficult to determine the degree of correspondence between the location of the pasture area and the then territorial-administrative divisions. However, it seems that the correspondence of these two factors has been still harmonic. The number of Hoshuus in this period were comparatively small. And the number of complaint charges in this period, regarding the lack of pasture land, were relatively small in comparison to the later developments in the Hoshuu structure.

From the middle of the 18th century until 1911 the number of territorial-administrative units increased further.

On the Aimag[4] and Hoshuu maps from the period of the end of the 18th to the start of the 19th century one can in a general way recognise the geographical location of the four Aimag and Hoshuu which one could compare with an ecologically appropriate regions for pastoral utilisation.

From the sizeable and now improved manuscript maps of the Hoshuu, which had been produced since the middle of the 19th century, it is clearly recognisable that the majority of the Hoshuu were situated in a natural region, which extended altitudinally from the highlands to the lowlands/valleys in a linear way (Albun 1987).

In the course of the time many Hoshuu were formed by imperial command as appanage or favour or reward for service to the Manchurian emperor. According to descriptions from the official files and laws the Hoshuu territories were officially differentiated into:

- traditionally formed Hoshuu (Mong. *hev olson*),
- Hoshuu formed by command (Mong. *danst* or *togtoolt*).

Many Hoshuus had been formed not only in the Manchurian period but also after the victory of the national independence movement in 1911, as appanage or favour or reward for service to the great dignitary rJe-btsun dam-pa Hutagt – the religious head of Halha Mongolia.

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administered form. With the appointment of thirty-four representatives of the nobility descended from Genghis Khan as the first ruling princes at the conference at Dolon-Nuur (42°N, 116°E: with which began the official and legal subjection of the Halha Mongolian princes) in the year 1691, the new division of the Aimag into Hoshuu was completed. The Manchurians however meant by the term Hoshuu the Manchurian military-administrative unit 'Banner' (Manch. gusa) in Mongolia. Afterwards the number of Hoshuu increased. In the year 1725 there were already seventy-five and in the year 1755 eighty-four Hoshuu were registered. As well, in 1725 a new fourth Aimag, Sain Noion Khan, was founded.

3 The oldest Mongolian maps known to us today are two maps referred to as Renat maps which the Swedish prisoner of war Johan Gustav Renat brought back to Sweden after serving with the prince of the Jungar (the West Mongolian kingdom 1636-1755), Galdan Cerin (ruled 1727-1745) (Poppe, 157-59). These maps were drawn in 1739 in order to settle region disputes of the prince of the West Mongolian Ordos League. The bulk of historical Mongolian maps come, however, from the 19th century. There are 335 maps of the Hoshuu pasture regions of Mongolia, which were produced from about 1850 until the 1920's, in the State Library as well as in the State Central Archive for History in Ulan Bator. In the second half of the 19th century there were around a hundred Hoshuus. All Hoshuu are numerously mapped because almost all Hoshuu territories were remapped with or without changes after each new appointment of the governing Hoshuu princes. The State Library of Marburg possesses by the way 182 maps collected by H. Consten and W. Heissig (Heissig 1944; Haltod 1966), which represent a large portion of the settled regions of Mongolia in the 19th century. The Library of the Tenri University of Japan keeps a further 44 maps of predominately Inner Mongolian regions which correspond with the respective maps of the Marburg collection. All maps represent a bird's-eye view of the respective regions, in particular of the pasture regions. Despite a certain standardising of the map drawing a real image of the countryside prevails on most of the maps. As borderlines of definite region mountains, rivers and stone heaps are frequently used on the maps. The rivers are depicted by blue or brown-yellow wavy lines, the dried out beds are drawn white, mountains are brown-red or covered with vegetation, clearly elaborated trees and bushes.

4 Aimag: This word underwent many changes of meaning in the course of history. In ancient times the Aimag was essentially a tribal and familial grouping and afterwards, until the 19th century in West Mongolia, until 1691 in East Mongolia, a territorial unit bound by a tribal federation. After the Manchurian conquest the Aimag became with the establishment of the Banner policy a territorial administration unit. Today there are 18 Aimags and 3 Aimag-level cities.

The vast majority of the newly founded units was formed by the pasture, livestock and subject property of the high clergy, Otog (property of rJe-btsun dam-pa Hutagt) and Shav' (property of the second most senior high clergy Hutagt with Seal), which administratively resembled the Hoshuu. There were besides other forms of Otog and Bag ownership which existed within a Hoshuu. They enjoyed a status of autonomy within the Hoshuu government, which manifested itself especially in the facts that the pasture region, Otog, could only be used by Shav' subjects of the clergy and that these subjects needed not perform administrative service in the Hoshuu government. According to statistics from 1918, the rJe-btsun dam-pa Hutagt (the religious and state head of Mongolia 1911-1924) had altogether 198 Otog and Bag. Most of these were not independent territorial-administrative units, rather ownership of pasture land, livestock and subjects within the Hoshuu.

With the territorial-administrative changes after the release of Mongolia from Manchurian rule in 1911 127 Hoshuu and similar administrative divisions were determined: namely all together 115 Hoshuu and 12 independent Otog and Shav' (Shirendiv et al. 1968: 445–46).

All this resulted in the livestock keepers quarreling with one another on account of the deficit of necessary natural area for the seasonal pasture ways.

The State Central Archive for History and the State Library in Ulan Bator preserve a vast number of complaint charges of normal livestock keepers against members of the nobility and of members of the nobility against one another, not only within a single Hoshuu but also amongst Hoshuu, concerning the illegal confiscation of pasture region acquired by generations of tradition. They prove that the disputes about pasture land had intensified in particular from the second half of the 19th century. Most of the disputes arose, in those Hoshuu whose borders did not correspond with the natural strips which normally contain ecologically optimal regions sufficient for the four seasonal pasture ways. The majority of these Hoshuu had been formed by imperial command.

After the People's Revolution of 1921 territorial-adminstrative reorganisation measures were carried out on a large scale in the twenties, the start of the thirties and the sixties.

adminis At the start of the twenties several old Hoshuu were dissolved as a result of the trative renewal policy of the recently founded People's Government. Through this the number of Hoshuu was reduced to ninety-three (Mongolische Landeskarte 1926). For example the above mentioned Shav' and Otog were thereby dissolved: some were returned to the respective Hoshuu from which they had derived, others were converted into independent Hoshuu (Istoriya Mongolskoi ... 1983: 354). This structure thus resembled the situation of the Hoshuu existed in the middle of the 18th century, that is when there were still eighty-four Hoshuu. One sees here that the geographical locations of the Hoshuu are closely connected with the altitude conditions (map 2). This means that the degree of correspondence between the possibility of pasture land use according to seasonal needs and the territorial-administrative divisions was still rational.

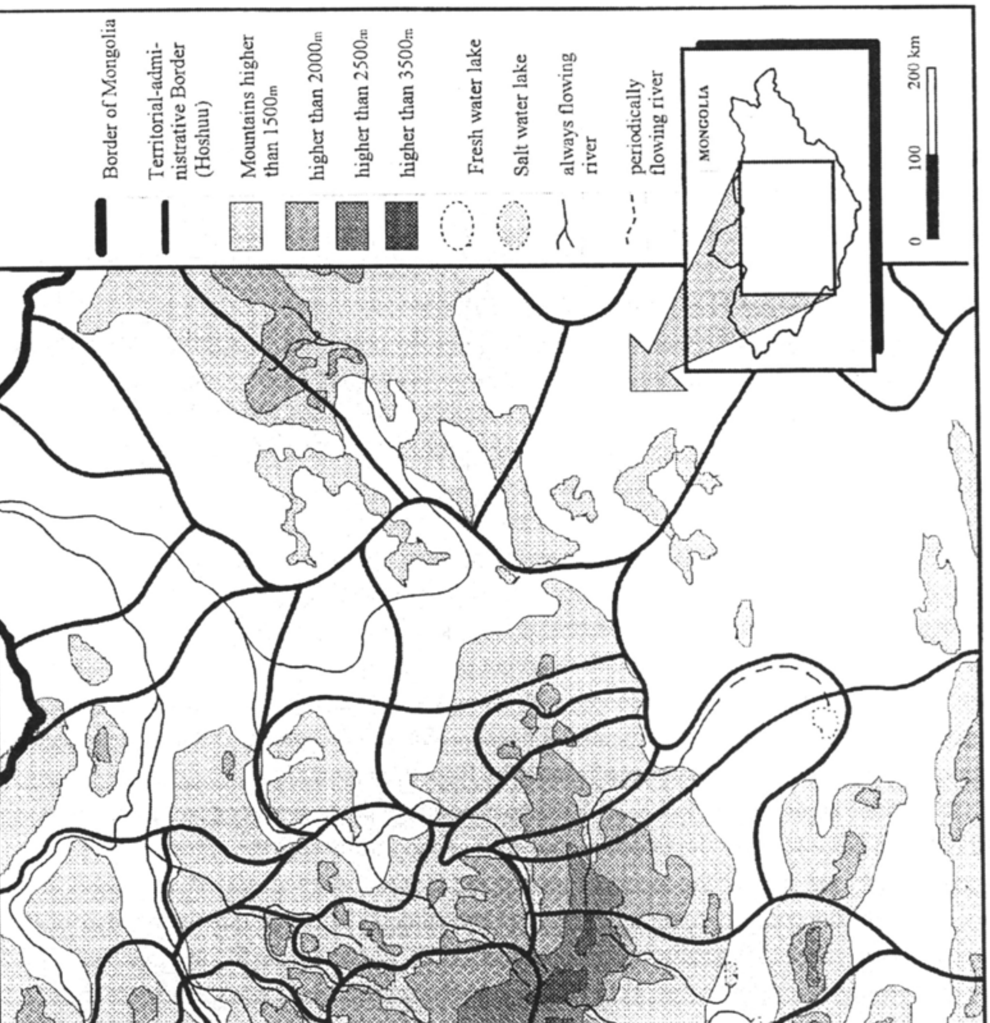
The further territorial-administrative reorganisation policy of the thirties was oriented so as to dissolve as quickly as possible the old system and to build up a controlled revolutionary dictatorship over the expanded population of the country.

To this end a new administration structure was established. The old term Hoshuu was replaced by the term Sum, which originally had been used for the administrative sub-unit within the Hoshuu.

But the number of territorial-administrative units became again more and more. 1925 there were 6 Aimag including 96 Hoshuus. 1931 – 13 Aimag including more than hundred Sums, and after the reogranisation in the sixtieth they became 18 Aimag covering 360 Sums. They had a direct connection with the cooperative movement of the fifties. As the result of the forced politics of livestock breeding families into economic cooperatives, Negdel, in the fifties were established 675 cooperatives, which comprised 99.3% of all households. On account of the improvement in economic potential the cooperatives were then brought together or enlarged, and their number thereby decreased in 1959 to 389, and at the end of sixtieth to 255. There were established 55 state agricultural and fodder enterprises. In order to optimise the economic and administrative organisation of rural regions these 310 economic units have been organised territorial-administratively as a Sums (255 Sum-Negdel, 51 Sum as property of the state and 4 Sum as production of fodder enterprises).

Same times the disputes amongst livestock keepers concerning the natural area for the required seasonal pasturage were thereby intensified on account of the borders which had been drawn up without

Map 2. The relief conditions of the *Hoshuu* Territories (1926) in the vicinity of the *Hangai* Mountains



consideration for the wholeness of the ecologically appropriate pasture regions. These complaints were controlled by administrative means. It was much worse as cooperatives were reorganised into 870 Bag (or Brigad) and about 33,629 Suur' (Onuki 1990: 65) as a sub-units within cooperatives and were in practice shared pastures in very close-meshed form. This enabled the state to more easily economically and administratively manage the country and the nomadic population expanding over its huge territory. The error in this policy was rooted in the fact that one did not consider the indivisibility of the pasture strips necessary for the seasonal pasturage, which are located according to geographical relief conditions and exposure related climatic, vegetative etc. differences. For this reason the correspondence of the heterogeneous ecological backgrounds of the seasonal pasture regions and the territorial-administrative units adapted to them was lost due to the existence of too many Sum (map 3). I would like to cite here an example which makes clear the consequence of this contradiction. The present location of the Ugii-Nuur Sum of the Arhangai-Aimag was before and after the People's

Revolution a point of intersection of the then three to five Hoshuu borders (map 3*). At this location livestock keepers from the respective Hoshuu earlier carried out in principle only the summer and fall pasturage, since the region is ecologically appropriate for these seasons. Thus the newly created Sum had no pasture region for the winter and spring. The Ugii-Nuur Sum therefore experienced since its establishment in 1961 often high animal and in particular calf losses on account of the lack of fodder in winter and spring. In 1983 it was the Sum which had lost the most calves. Since then in the Ugii-Nuur Sum seven Sum-Negdel directors have been dismissed from office due to so called irresponsibility.

Nevertheless, there have been many instances of seasonal grazing migrations. Livestock keeper often crossed the territorial border lines of their residential Aimag and Sum into other areas seeking essential pasture land (eg. Müller et al. 1996: 45).

If the seasonal pasture regions lie linearly from mountains into lowlands, the territories of the Sum in most cases are not situated on the lines. For example of the above 255 Sum-Negdel about 60 are situated in the high mountain regions, about 40 in the mountain forest regions, about 60 in the steppes, about 40 in the basins of the large lakes and about 60 in the Gobi region (Batnasan 1978: 57). Over and above this it is not unusual for the entire territory of an Aimag to be an ecologically homogeneous zone. That demonstrate that on account of the last re-division of the pasture land, which had been introduced from the government, the equilibrium between the necessity of ecologically differing pasture regions for seasonal migrations and the possibility of pasture land use within the allocated Sum territories according to the methods of seasonal migration has been critically disturbed (map 4).

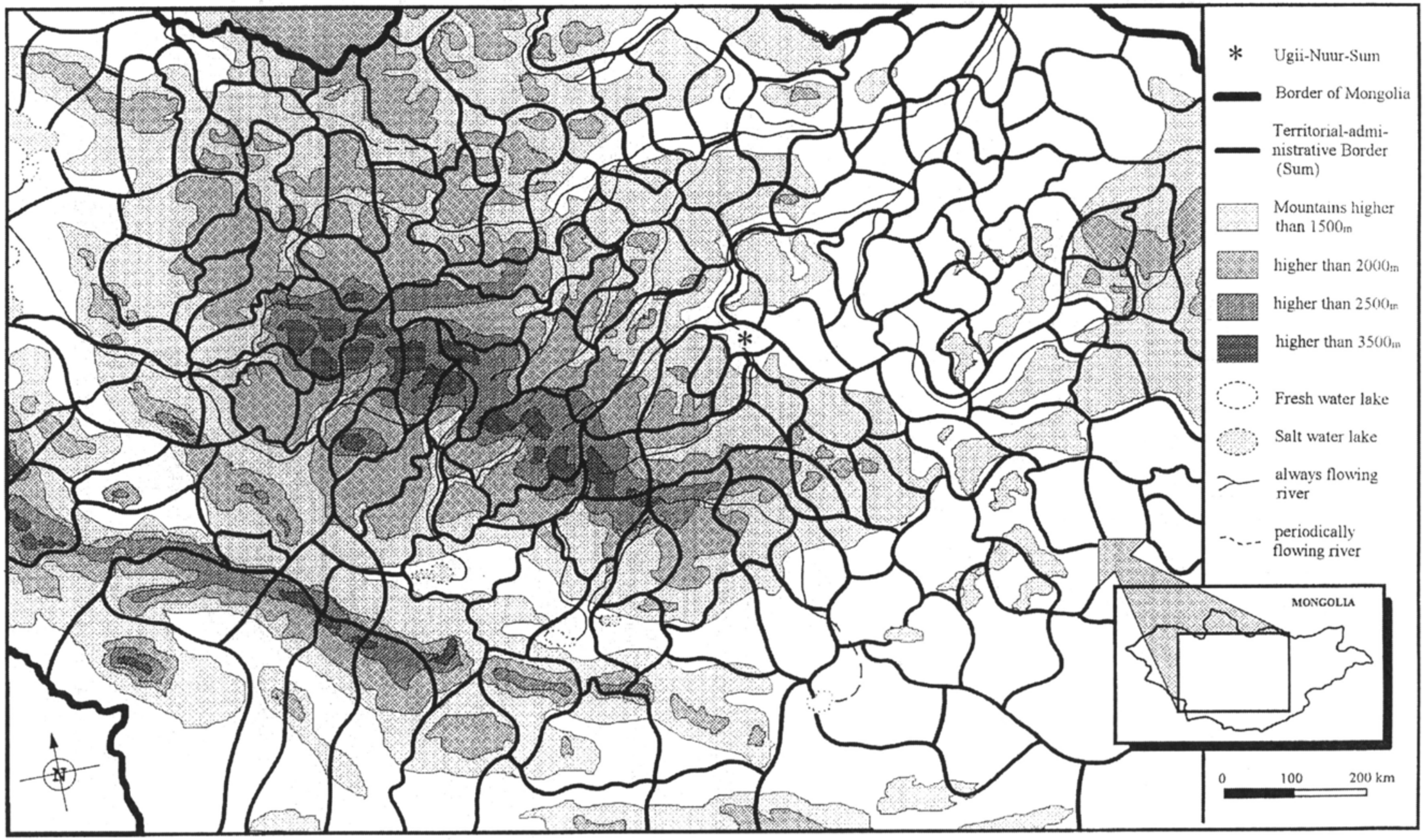
In the collective system the loss of the seasonal pastures had been compensated for partly by additional hay. With the abolishment of the collective-economic system and the privatisation of animals owned by the collectives in the early 1990s the problem of regulating the use of pasture land remained unresolved. Subsequently the situation deteriorated. Thus, mainly for this reason, today uncontrolled grazing can be observed everywhere.

Mongolian specialists estimate that around 30% of the pastoral lands are so badly over-grazed that the meagre humus layer is now exposed to a very great amount of wind and water erosion. According to the evaluation, 41.3% of total pastoral land is damaged and/or sand-silted and of that, 4% strongly so, 20% moderately, and approximately 70% lightly so (Ölziibat 1997). Ecological damage to pastures under the cold, arid conditions of the Mongolian steppes and deserts takes a long time to repair - if it can be done at all.

Nevertheless, since private stocks are quickly increasing, irregular utilisation has already started leading to serious problems of exceeding the carrying capacity and to the spoiling of the pastures, especially around urban areas where more livestock-breeders concentrate due to favourable sales prospects for animals and animal products. The negative impacts of high concentration of livestock combined with reduced spatial mobility which can arise for the natural environment as well as for the quality and the state of health of the animals are well known.

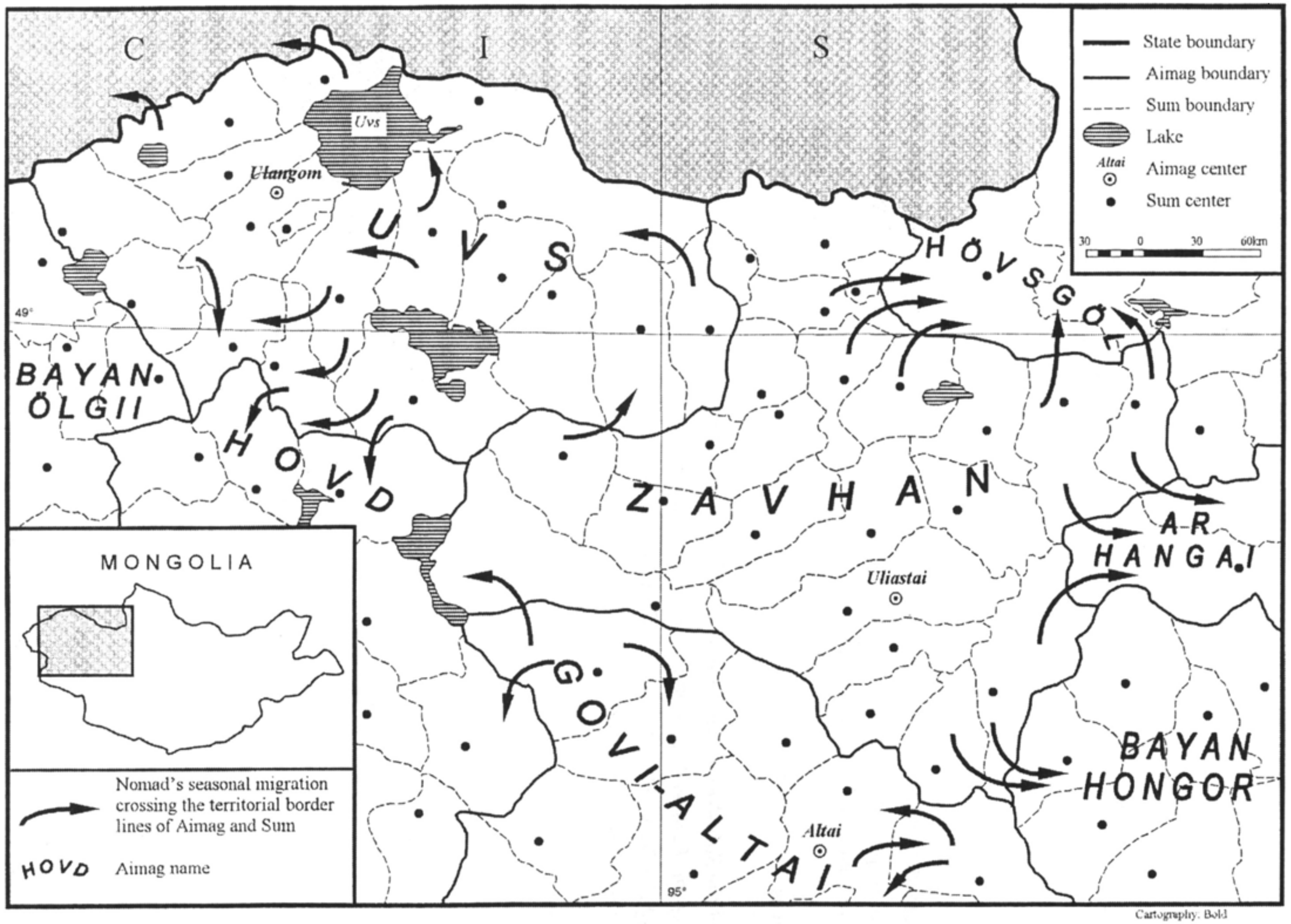
As mentioned above, in the pastoral land of Mongolia (84% of the total land and 98% of the agricultural-effective land) nearly 50 million tons of fodder is grown annually. When converted into 'sheep units' (1 horse, or cattle or yak equals 7 sheep; 1 camel equals 10,5 sheep; 1 goat equals 0,7

Map 3. The relief conditions of the *Sum* Territories (1989) in the vicinity of the *Hangai* Mountains



Design and cartography: B. Bold

Map 4. Pastoral migration crossing the territorial border lines of Aimag and Sum in the 70s and 80s



Source: Govi-Altai aimgiin hörsnii sudalgaany tailbar bichig, 1991, Gazryn bodlogyn hüreelen, Ulaanbaatar, p. 57ff.
Graivoronskii, V. V., 1979, Ot kochevogo obraza jizni k osedlosti, Moscow, p. 115ff.

sheep) this is equal to the annual fodder needs of approximately 60 million 'sheep'. If one considers the average numerical ratios of the traditional five types of animal (camel, horse, cow/yak, sheep, goat) this means 22 million mixed species. But today we have, in sheep units, about 67 million sheep namely 30,2[5] million mixed species in the country (Bold et al. 1999). All this clearly shows that the limits of the carrying capacity of pastoral land have already been exceeded – by having too many animals.

The vast majority of the present territorial-administrative divisions, which have more or less interfered with the availability of pasture regions for the migrations necessary for a four seasonal pasturage, must be reorganised. For example, many territorial-administrative Sum divisions should be brought together into larger regions taking the pasture regions into special consideration. Here both historical-practical experience as well as the results of ecological-economic studies concerning regionalisation of the pasture regions are worthy of consideration. This will be not only the most important prerequisites for the effective use of the pasture land and for an increase in the productivity of the nomadic livestock economy which is fully dependent upon the natural pasture, but only through this it will be possible to combat the latent process of desertification and conserve and rehabilitate vegetative cover, soils and water resources.

References

Album of the Sain-Noion-Han-Aimag, 1 987, Ulaanbaatar.

Album of the Tusheet-Han-Aimag, 1987, Ulaanbaatar.

Album of the Secen-Han-Aimag, 1987, Ulaanbaatar.

Album of the Zasagt-Han-Aimag, 1987, Ulaanbaatar.

BATNASAN, G., 1978, *BNMAU dakh' negdelchdiin aj akhuigaa khötlökh arga ajillagaany tukhaj* [Modus operandi of the livestock economy in the Mongolian People's Republic], Ulaanbaatar.

BAZARGÜR, D., Chinbat, B., Shiirev-Ad'ya, S. 1989, *Bügd Nairamdakh Mongol Ard Ulsyn malchdyn nüüdel* [Migration of livestock keepers in the Mongolian People's Republic], Ulaanbaatar.

BICHURIN, N. Y., 1950, *Sobranie svedenii o narodakh srednei azii v drevnie vremena* [Collection of information about the peoples of Central Asia in ancient times], Vol. 1, Moscow.

BOLD, B.-O., 1997, "The coordination of territorial-administrative divisions with pastoral areas - an important prerequisite for the effective use of pasture land", in: *Mongolian Studies*, Vol. 20, 1997, Indiana University, Bloomington.

BOLD, B.-O., 1998 (a), "The quantity of livestock owned by the Mongols in the 13th century", In: *Journal of Royal Asiatic Society*, Vol. 8, Part 2. 1998, London.

BOLD, B.-O., Batbuyan, B., 1999, "The pastoral land use: One of the Most Important Problems in Mongolia". in: *NIAS nytt, Nordic Newsletter of Asian Studies*, 4, no. 4, 1999, Copenhagen

BOLD, B.-O., 2001, *Mongolian Nomadic Society. A Reconstruction of the 'Medieval' History of Mongolia*, London.

Bügd Nairamdah Mongol Ard Ulsyn Ündesnii Atlas [National atlas of the Mongolian People's Republic], 1990, Moscow.

Bügd Nairamdah Mongol Ard Ulsyn uur am'sgal, gadragyn usny nööciin Atlas [Atlas of the climatology and hygrology of the Mongolian People's Republic], 1985, Ulaanbaatar.

CERENDULAM, R., 1994, "Bilcheer ashgilakh arga" [Ways of pasture land utilisation], in: *Gov' khangain sonin bichig* (newspaper), No. 2.

CHADRAABAL, G. (ed.), 1982, *BNMAU-yn mal aj akhujg khötlökh sistem* [The management of the livestock economy of the Mongolian People's Republic], Ulaanbaatar.

GONCHIGJAV, Ds., Zavdsmaa, R., Unenbüren, C. (eds.), 1980, *Mal aj akhui* [Livestock keeping], Ulaanbaatar.

HALTOD, M., 1966, *Mongolische Ortsnamen*, Teil 1, Wiesbaden.

HEISSIG, W., 1944, *Über mongolische Landkarten*, Teil 1, *Monumenta Serica*, Vol. 9, Wiesbaden.

[5] At the end of the 1998 the total livestock figure was 32,897,500 per head. The reason for the difference between the end of 1998 and end of 2000 livestock number is the drop in stocks, more than 3 million, due to the last two winters and the subsequent springs which were particularly hard (see Appendix).

Istoriya Mongol'skoi Narodnoi Respubliki [History of Mongolian People's Republic], 1983, Moscow.
KYUNER, N. V., 1961, *Kitaiskie izvestiya o narodakh Yuzhnoi Sibiri, Centralnoi Azii i Dal'nevo Vostoka* [Chinese reports about the peoples of South Siberia, Central Asia and the Far East], Moscow.
LUVSANDANZAN., 1990, *Altan tovch* (ed. Z. Shagdar), Ulaanbaatar.
MAISKII, I. M., 1921, *Sovremennaya Mongoliya* [Contemporary Mongolia], Irkutsk.
Map of Mongolia, Ulan Bator 1993, 1:1,000,000.
MOIBUU, D.; Bakei, A., 1996, "Mal aj akhuig khögjüülekh bodlogyn zarim asuudal" [Aspects of the development policy for the livestock economy], in: *Zasgiin gazryn Medee*, 17/1/1996, No. 12 (452), p. 2.
Mongolische Landeskarten, Leipzig, 1926
Mongol orny bilcheeriin mal mallagaany arga turshlaga [Practical experience in the pastoral livestock economy of Mongolia], 1966, Ulaanbaatar.
Mongolian economy and society in 1993, Statistical Office of Mongolia.
MÜLLER, F.-V.; Bold, B.-O., 1996, "On the Necessity of New Regulation for Pastoral Land Use in Mongolia", in: *Applied Geography and Development*, 1996, Vol. 48, Tübingen.
National Statistical Office of Mongolia. Mongolian Statistical Yearbook, 1998, Ulaanbaatar, 1999.
National Statistical Office of Mongolia. Mongolian Statistical Yearbook, 2000, Ulaanbaatar, 2001.
ONUKI, M., 1990, *Nüüdliin mal aj akhuin niigmiin orchin üe* [Contemporary nomadic society], Osaka.
ÖLZIIBAT, N., 1997, "Cöljilt Mongolyn nutgiin 70 huv'd sul, dörvön huv'd hüchtei ilersen". in: *Zasgiin Gazryn Medee*, 24.06.1997.
ÖLZIIKHUTAG, N., 1989, *Mongol orny urgamalyn aimgiin toim* [Overview of the distribution of vegetation in Mongolia], Ulaanbaatar.
POPPE, N., Renats Kalmuck Maps, Imago Mundi XII; 1955.
RASHID ad-Din., 1952, *Sbornik letopisei* [Collection of Chronicles], Vol. 1, book 1, Moscow.
SCHOLZ, F., 1995, Nomadismus. Theorie und Wandel einer sozio-ökologischen Kulturweise, Stuttgart.
SHAGDARSÜREN, O., 1984, "Mongolchuudyn bilcheeryn mal mallagaany tüükhen arga ajillagaanuud" [The traditional livestock breeding method of Mongols], in: *Shinjlekh Ukhaan Am'dral*, No. 3.
SHIREENDIV, B., Nacagdorj, Sh, et al., 1968, *Bügd Nairamdah Mongol Ard Ulsyn Tüüh* [History of MPR], Ulaanbaatar.
TASKIN, V. S., 1984, *Materialy po istorii drevnykh kocevykh narodov gruppy dunhu* [Materials for a history of ancient nomadic peoples of the Dunhu-Group], Moscow.
YUNATOV, A. A., 1950, *Osnovnie cherty rastitel'nogo pokrova mongol'skoi narodnoi respubliki* [Fundamental features of the vegetation cover of the Mongolian People's Republic], Leningrad.

APPENDIX

'Old World Dry Belt' (OWDB) Zone: Mongolia – Asia – Africa: land and number of livestock

	Total territory in *ha*	Potential pasture land in *ha*	Number of livestock in thousands (1992)				
			Camels	Horses	Cattles	Sheep	Goats
Mongolia	156.650	155.254	415	2.200	2.819	14.657	5.602
Asian countries of OWDB	1.995.739	1.762.711	2.830	13.807	143.479	335.491	184.971
African countries of OWDB	1.658.401	1.553.975	11.717	408.1	108.963	148.151	118.086

Source:

Mongolian economy and society in 1993, Statistical Office of Mongolia.

Scholz, F., 1995, Nomadismus. Theorie und Wandel einer sozio-ökologischen Kulturweise, Stuttgart.

(FAO (1993): Production Yearbook 1992, Vol. 46)

Mongolia: population and livestock owner

	Total population in thousands	Rural population in thousands	Herdsmen's households	Herdsmen
1989	2095.6	902.0	68.963	135.420
2000	2407.5	1030.5	191.526	421.392

Source:

National Statistical Office of Mongolia. Mongolian Statistical Yearbook, 2000, Ulaanbaatar 2001.

Mongolia: number of livestock in thousands

	Total	Camels	Horses	Cattles	Sheep	Goats
ca. 1220	±15 200.0 (1)	400.0	1400.0	1400.0	9000.0	3000.0
1918	9 645.6 (2)	228.7	1150.5	1078.4	5700.1	1487.9
1940	26 204.8 (3)	643.4	2358.1	2722.8	15 384.2	5096.3
1941–1993	± 22–25million	-	-	-	-	-
1998	32 897.5 (4)	356.5	3059.1	3725.8	14 694.2	11 061.9
2000	30 227.5 (4)	322.9	2660.7	3097.6	13 876.4	10 269.8

Sources:

1 Bold, B.-O., 1998a

2 The first official quantity of stock can be determined only after the count of 1918. There are reports in official files and in historical chronicles that animal counts were carried out in the eighteenth century and especially in the nineteenth century, but the results of these have only in part been preserved (Maiskii: 122–23).

3 This is the record number of stock of animals of Mongolia until 1994 (Source: 4).

4 National Statistical Office of Mongolia. Mongolian Statistical Yearbook, 2000, Ulaanbaatar 2001, pp. 118.

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