Forest development along the former river Aqikesu in the Aibi Hu National Nature Reserve in P.R. China

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Zusammenfassung

Es wurde das Wachstum des Waldes in der Aibi-See-Region in Xinjiang (Sinkiang), Volksrepublik China auf acht 1 ha großen Untersuchungsflächen untersucht. Die wichtigsten Parameter der dominierenden Pappel *Populus euphratica* wurden gemessen und die absoluten Raten des Höhen- und Durchmesser-Wachstums wurden für zwei Jahre berechnet. Außerdem wurden die morphologischen Eigenschaften von *P. euphratica* erfasst, und der menschliche Einfluss auf das Wachstum der Holzpflanzen-Bestände (Tugai-Wälder) wurde beschrieben. Der Gesundheitszustand von *P. euphratica* wurde sowohl in Abhängigkeit von der Grundwasser-Versorgung und von ausgewählten Bodeneigenschaften als auch von anderen Einflussgrößen, wie Klimafaktoren ermittelt.

Das Wachstum von *P.euphratica* während der beiden Jahre 2006 und 2007 war deutlich geringer als in ähnlichen Tugai-Wäldern im Tarim-Gebiet von Xinjiang. Die Bestände am Aqikesu wiesen keine Normalverteilung der Messgrößen in ihren Populationen auf und waren insgesamt in einem schlechten Zustand. Es gab wenig Aufwuchs und der Allgemeinzustand verschlechterte sich im Untersuchungszeitraum.

Ein Vergleich von kurzfristig erfassten Mikroklima-Daten mit langfristig (40 Jahre) an einer nahegelegenen Wetterstation gemessenen Daten ergab, dass die Einflüsse des Klimawandels und von Klima-Schwankungen auf Waldökosysteme in diesem Gebiet nicht die Hauptgründe für den Rückgang des Waldes gewesen sein konnten.

Vierzehntägige Messungen des Grundwasserstandes über zwei Jahre zeigten, dass Grundwasser, obwohl sich die hydrologische Situation der Gegend insgesamt sehr verändert hatte, immer noch für *P. euphratica* verfügbar war. Bodenanalysen ergaben, dass die Salinität des Bodens entscheidender war als mangelnde Wasserversorgung aus dem Grundwasser. Es kann daraus geschlossen werden, dass auch das beobachtete Absterben von *P. euphratica* während der Untersuchung auf einen zu hohen Salzgehalt im Substrat zurückzuführen war.

Informationen über die Landnutzung, den Rückgang der Fläche des Aibi-Sees und weitere Veränderungen der Umwelt machten die negativen anthropogenen Einflüsse auf die Wälder der Region deutlich.

Die zusammenfassende Schlussfolgerung aus den Untersuchungen ist, dass sich die Gesamtsituation der Restwälder in der Nähe des Aibi-Sees verschlechtert. Das Gebiet läuft Gefahr zur Wüste zu werden.

Abstract

The growth situation of the forest in Aibi Hu region in Xinjiang, P.R. China was investigated. Tree parameters of the dominant species Populus euphratica were measured and absolute growth rate of height and diameter were calculated for the eight selected plots. The characteristics of P. euphratica were analyzed. Human impact on the growth of woody plant stands was described. Health states of these trees were registered in dependence of ground water supply and soil properties, as well as other impact factors like climate etc.

The result of this study showed that growth of P. euphratica over two years during 2006 and 2007 was slower compared to the similar Tugai forest in the Tarim region in Xinjiang China. The stands in this region were not normally distributed and they were in a poor growth situation. There was a lack of regrowth and the forest had a tendency to deteriorate.

The comparison of the microclimate data from two set up stations with the data from local weather station indicated that the impacts of climate change and climatic variability on forest ecosystems in this area is not the major reason for the forest deterioration.

The data of every two weeks measurements of the groundwater level showed that although hydrological conditions had changed a lot from the past until today, ground water was still available for P. enphratica trees. Soil analysis showed that the salinity in the soil and groundwater was more decisive than lack of water supply from the groundwater. It can be concluded that the high groundwater salinity was responsible for the dying of the P. euphratica in the study site i.e. hydrological changes caused the salinization of the soil.

Information about the history of land use, the decrease of the surface area of Aibi Lake and other environment changes showed that the human impacts had negative influences on the forests in this region.

The conclusion of this study is that the situation of the forest near Aibi Lake has a tendency to deteriorate. This area is in danger of desertification.

Keywords: *Populus euphratica*, forests , Aibi Hu, growth, tree parameters, wood samples, tree ring, human impact, ground water, soil properties, climate, microclimate, regrowth, hydrological conditions, salinity, land use, influences, deterioration, desertification.

Content

1 Introduction

Since the 1950s, due to the rapid growth of the human population and the development of agriculture and industries, the eco-environment of Aibi Hu region, northwest end of Xinjiang, P.R. China, sharply degraded from the former gradual deterioration (Yang L.P. and Yang C.D., 1990; Jilili A. and Mu G.J., 2002). In consequence, large areas of arable land have been deserted. The settlements are subjected to continuous dust deposition (Ma M.G., Jiao Y.M. and Cheng G.D., 2002).

The consequences of desertification in this region directly weakened the foundation of social and economic development. The final impact and farreaching threats of desertification are the destruction of the environment and the loss of land resources that humans depend on (Xia X. et al., 1993; Wang G.X., 1999; Huang G.L. et al., 2006).

Therefore, a reestablishment of the shelter vegetation in order to restore its protective function is imperative in Aibi Hu region. In addition, a rational forest management has to be developed that takes into account the environmental needs as well as to prevent future destruction through over-exploitation.

Although forests are very important and they have the environmental benefits on landscape preservation, wind break, soil protection and sand fixation in the semi-arid areas (Xie Y., 2002), since 1950s, nearly 60% of the forests in this region have been destroyed by over-exploitation (Li W.H. et al., 2002).

The major species in Aibi Hu region is *Populus euphratica*. It amounts to 97% of the whole forests in this region (Chen S.J. et al., 2006). Until now, only oversimplified studies have been done in this area. There were no systematic researches on this field. The few studies on scientific researches about Aibi Hu region that have been published had not come to details about forests. Chen S.J. (2006) examined the environment of the area; Li W.H. (2002) studied the vegetation types; Qian Y.B. (2004) studied the eco-environment change and its impact factors. There were also publications about Tugai forest in the similar semi-arid area like Tarim region in Xinjiang (Zen F.J. et al., 2002; Xu H.L. et al., 2003, 2004). There were no publications about the forests in Aibi Hu region.

In 2000, the Xinjiang government confirmed it as a nature reserve and in 2006, the Chinese government confirmed it as a national nature reserve. Because it was a new protective region, there was a lack of scientific analysis about the local forest development.

It was very urgent to protect and reintegrate the ecosystems in this area. For doing this, it was very important to do scientific basic research and give scientific background information about the recent forest development in this area.

This dissertation was planed to study the growth in the past by tree ring analysis and by field measurement at present time. It is part of a joint Sino-German project with the aim of forestry development in Aibi Hu National Nature Reserve (PPP, CSC: LJC/2006/3139; DAAD: D/06/00362).

After the information collection and the first visit of the study site, the following hypotheses were derived:

1. As there were many dead trees and the forest distribution and situation was not as

good as described in former publications (Yang L.P. and Yang C.D., 1990; Su Y.J. et al., 2002), the forest situation was also not so good as the *Populus euphratica* forest in other parts in the similar places (Gao R. H. et al., 2005), it was hypothesized that the forests in this region have a tendency to deteriorate.

2. As *P. euphratica* trees can grow well on the field with high salt content (Wang C., 1989; Wang S. et al., 1996), salinization of the soil could have negative influence on its growth but should not be the major reason for the death of the trees.
3. The impacts of climate change and climatic variability should have negative influence on forest ecosystems in this area (Wang S.D. and Wang J., 2003).
4. According to the administration of Aibi Hu National Nature Reserve and the publications (Li W.H., 2002; Qian Y.B. et al., 2004), shortage of water and lower ground water level should be the major reason for the death of *P. euphratica* in this region.
5. Human activities should have some influences on the forests in this region (Li W.H. 2001; Ji F., 2001).

The following objectives were intended to be investigated:

1. Monitoring the health state of tree stands by inquiry on the ground.
2. Description and quantification of the former and actual forest state with regard to water supply.
3. Linking the water supply of trees to ground water supply and soil properties.
4. Elaboration of guidelines to improve tree growth for nature conservation in the future.

In April 2006, eight *P. euphratica* monitoring plots and one plot for the endemic birch (Aibi Hu Birch) were set along the former band of the Aqikesu River.

In order to obtain the objectives, height and DBH of all the 433 *P. euphratica* individuals on the selected plots were measured four times and growth over two years was analyzed during the growing season 2006 and 2007, wood samples were taken (A 101, A 102, A 111, A 131 and A 201) for the analysis of age structure and growth tendency, three trees were harvested in the study site, microclimate data were recorded on two selected plots (A 102, A 201) by the weather stations set up for this study, groundwater level was measured every two weeks in the four selected plots (A 101, A 141, A 102 and A 112).

Tree parameters of a possibly new birch species (Aibi Hu Birch) on plot A 201 were measured and growth over two years was calculated.

Information about the history of land use, the changes of the surface area of Aibi Lake and other environmental changes and their impacts on *P. enphratica* trees growth were collected.

2 Material and methods

2.1 Aibi Hu region

2.1.1 Geography

This study was carried out in Aibi Hu National Nature Reserve that is located in the north-west part of Zhungeer Basin (Junggar Becken), Xinjiang, China (Fig. 1).

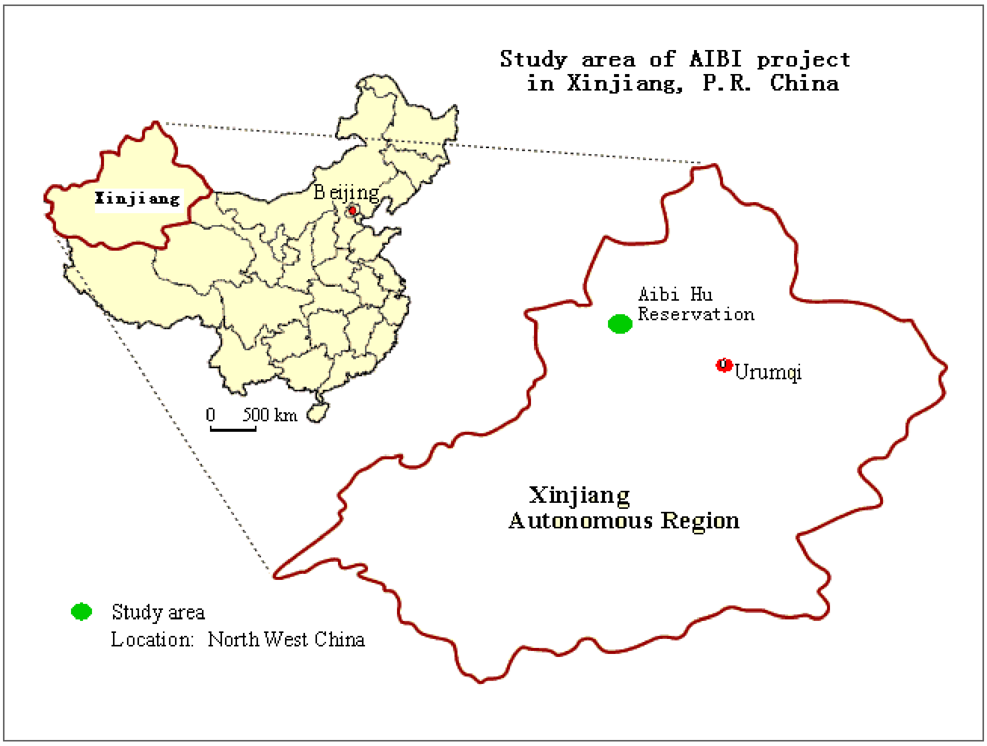


Fig. 1: Location of the study area (modified from a map published by China Cartographic Publishing House, Beijing China, 2001).
Abb.1: Lage des Untersuchungsgebietes in Xinjiang.
图例 1: 研究区域位置图 (资料来源:中国地图出版社).

Xinjiang is located in central Asia between the Tibetan Plateau, Mongolia, and Kazakhstan. The Zhungeer basin is the huge inland basin which is mostly covered by the Gobi desert (Appendix 6 Fig. A-1: Topographical map of Xinjiang, P.R. China). This basin is surrounded by high mountain ranges of the Tianshan Mountains (of which the highest peak reaches 7,450 m a.s.l.) to the South and Altai Mountains to the North and West.
The study area, Aibi Hu region, is the low-lying area located on the western edge of the Zhungeer Basin (Guebantungut Desert is located at the middle of the basin). Aibi Lake is the center of surface and ground water collection in this region, because it is located in the center of the basin with an elevation of 189 m a.s.l. (Appendix 7 Fig.A-2: Relief map of Aibi Hu region).
This area is surrounded by mountains with only opens easterly to the desert. The whole

area is plain and was formed by the flood from the mountains. In 1958, the desert area around the lake covered 1,618.8 km^2. The desertificated area increased very quickly during the last 50 years. Until 1978, it widened to 2,415.6 km^2. At present, it has an area of 3,212 km^2 (Amanu T. and Yarmamat T., 2001).

The study site of Aibi Hu National Nature Reserve is a new national nature reserve with an area of 2,670.9 km^2. It is 102,6 km long from east to west and wide 72,3 km from south to north.

In the middle of the protected area the largest salt lake in Xinjiang, named Aibi Lake (also called Ebinur, 44°34' - 45°08'N; 82°35' - 83°16'E), is located. On Aug. 22nd, 2006, the surface area of the lake amounted to 550.6 km^2 (satellite images data, Xinjiang Institute of Ecology and Geography, CAS, http://www.egi.ac.cn/).

Aibi Hu region was regarded as one of the most important distribution area and species resource for arid and semi-arid species of plants in China. It is the most important place of the ecosystems in the surrounding landscapes and has a big effect on the environmental conditions of whole Xinjiang.

2.1.2 Geology and soil types

The specific geographic situation (2.1.1.1) is causing the soil structure in Aibi Hu region. The thick and loose sediments of the lake provide rich sources of sand and dust for sand storms. Salinization of soils is severe and wide spread in the study area.

Since 1950, because of the quick shrinking of the lake (2.1.1.4), a big amount of the former lake bed has been dried up and opened to air. This contributes not only to formation of various kinds of hydromorphic soils and semi-hydromorphic soils, but also to formation of various types of desert and saline soils (Yuan G.Y., 1990; Wang Z.Q., 1993).

Mother substances of the soil in Aibi Hu region are numerous (Jin H.L. et al., 2005): lacustrine sediment, alluvial-lacustrine sediment, fluvial sediment, accumulations of remnant and aeolian deposits.

All of them contain salt. Due to this common character, it is difficult to find no salt (NaCl) in the soils of that region.

According to the research of Jin H. (2005), soils in this area could be classified to the following types: Hydromorphic soils (水成土), semi- hydromorphic soils (半水成土), saline soils (盐碱土) and desert soils (漠土).

On account of this classification, the following groups were gotten:

Hydromorphic soils: Including bog soils (沼泽土) and peat soils (泥炭土).

Bog soils: This type of soils is mainly distributed along the beaches，lower terraces and the lower reaches of the old river beds. It can also be found near Alashankou area on the lower terrace, where spring water spills over. In our study site, at plot A 201, where Aibi Hu Birch is growing, the soil belongs to this type. Vegetation is relatively rich on this soil type. In this group, the groundwater level is usually within 1 m. In some places, springs can be found. West of the railway line, in the South-East from Bole Railway Station, the irrational utilization of the water-resource have caused water shortage of springs and decline of the ground water level. In consequence, strong wind erosion of upper layers of rooted soil and erosions of inner layers of mineral soil can occur.

Peat soil: This soil type belongs to organic hydromorphic soils. It is mainly distributed in the former lake bed and the lowest reaches of the rivers. Most soils in this area have been destroyed due to the shortage of water supply. It has an average thickness of about 50 cm. In some parts of beaches, which have been destroyed severely by human beings，layer of peat is no longer existing. It changed into dry and naked mineral soil, thus becoming new resources of sand storms.

Semi-hydromorphic soils: This group includes meadow soils (草甸) and shrubby meadow soils (林灌草甸土).

Meadow soils: They are mainly distributed in the lower reaches of Goertu (古尔图古) area. There it can also be found in the lower reaches of Jinghe River. The average ground water level is about 1.3 m in this area.

Shrubby meadow soils: These soils are mainly distributed in the lower reaches of Kuitun River and along some sections of Bole and Jinghe river. Most plots of our study site, where *Populus euphratica* is growing, belong to this group.

In these areas, some parts have been used as farmland and some others have changed to saline land due to the lack of fresh water.

Saline soils: Including bog saline soils (沼泽盐土), shrubby meadow saline soils (草甸盐土) and Orthic Solonetzs (典型盐土).

Bog saline soils: They are mainly distributed in the lower parts of eastern side of Aibi Lake, some are distributed at lower site located in the northeastern part of Aibi Hu region. The groundwater level is about 50 cm, with a high mineral content. On surface of the land, there are salt crusts with a depth of several to more than ten centimeters. Within the layer of soil of 0.3 m, the quantity of salt reaches 20.7% of dry soil.

Shrubby meadow saline soils: They were formed from meadow soils. The area of this group is relatively small. This kind of soil can be found in the northeastern part with a lower elevation.

Orthic Solonetz: This kind of soil is distributed in the northeastern part of the Aibi Hu region. It was formed from shrubby meadow soils. Within the depth of 30 cm, the salt content is above 5%. Only types of halophytic vegetation could be found on the land with this soil type. Within the upper layer of Orthic Solonetz soil of about 20 cm, there are combinations of loose salt and clay that contain large amounts of Na_2SO_4.

Desert soils: Including gray desert soils (灰漠土) and gray-brown desert soils (灰棕漠土).

Gray desert soils: This kind of soils was formed in deep underground of the alluvial soils. They are mainly distributed at the middle and the lower part of Guetugu (古尔图古) area. The groundwater level is below 7 m and soils show clear characteristics of salinization. In this area, some sand dunes of 4.10 m height occur. Very few vegetation can be found in this area.

Gray-brown desert soils: They are mainly distributed at the foot of Mayila mountain in the northern part of Aibi Hu region. Like gray desert soils, very few vegetation can be found in this area.

Apart from the above-mentioned soil types, there are also some non-soil deposits such as salt silt, salt crust and salty loose mineral material on the dried lake bed. Among them, salty loose mineral material is one of the main resources of sand and dust for sand storms.

2.1.3 Climate

General Climate

Situated deep in the interior of Asia and not penetrated by the air currents from the oceans, Xinjiang is an area of rugged mountains and vast desert basins. It has a continental dry climate with little rainfall. Our study area is located in the Northwest of Xinjiang in the warm temperate zone (Fig.2, Appendix 8 Fig. A-3), dominated by a dry continental desert climate. It is typically arid mainland and has a conspicuous continental climate with highly changeable temperatures; sharp difference between summer and winter and day and night; abundant sunshine, intense evaporation and little precipitation (Chen S.J. 2006).

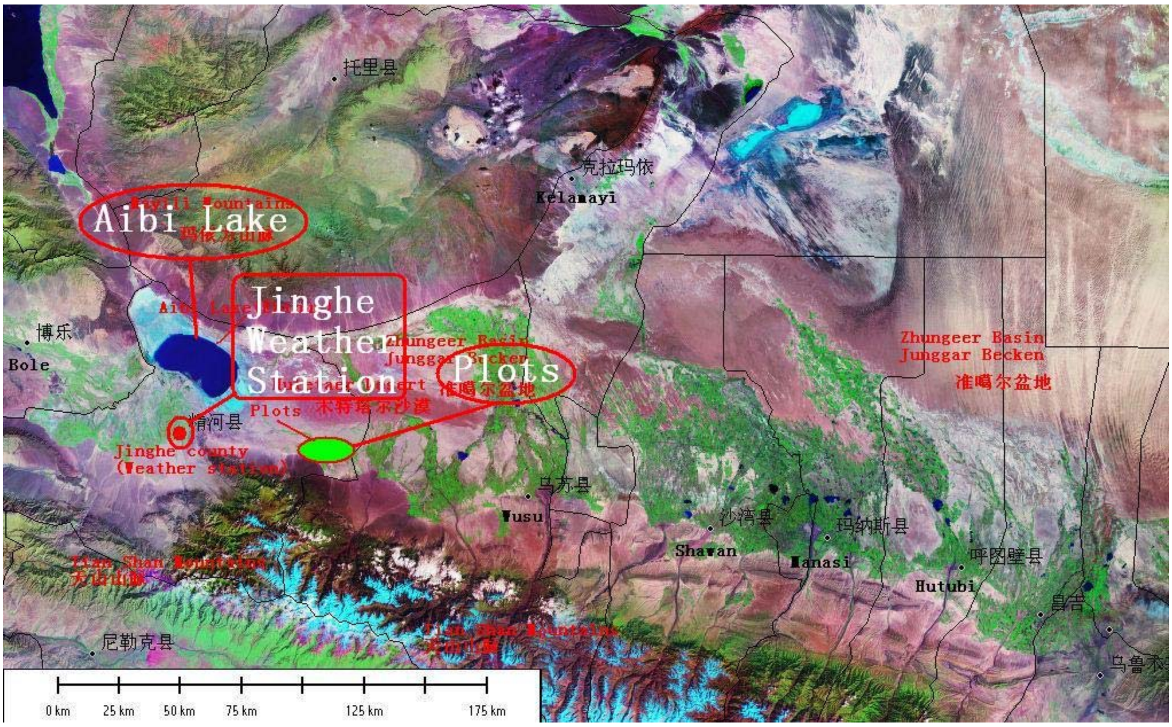


Fig. 2: Location of Jinghe weather station (source: Aibi Hu National Nature Reserver, P.R. China).
Abb. 2: Lage der Wetterstation Jinghe.
图例 2: 精河气象站位置.

In this region, the mean annual temperature is 6.8 ºC, the annual precipitation varies in a range of 90.9 to 163.9 mm and strong winds occur frequently. The frost-free period is about 162 days a year on the average. The total annual solar radiation in this region varies from 5,692 to 6,360 MJ m^{-2}, with 2,780 to 2,980 cumulated sunlight hours. The annual accumulative temperature ≥10 °C ranges from 3,353 to 4,245 °C (Li W.H. et al., 2002).
The wind towards Southeast is very strong and the annual number of days of wind

velocity greater than 17 m s^{-1} is on average 165 days and the recorded biggest wind velocity amounts to 55 m s^{-1}. In the past twenty years, strong winds blew away about 4.8 million tons of salt sand from the dried lakebed every year. It is one of the two main headstreams of sandstorms in Xinjiang (Li W.H. et al., 2002).

Local climate

According to Jinghe weather station (82°54' E, 44° 37' N, 321 m a.s.l., the county town station about 40 km from the plots, Appendix 8 Fig.A-3: Location of Jinghe Weather Station), in January, the mean temperature is –15.4 °C (1961 - 2006), in July, the mean temperature reaches 25.4 °C (Appendix 1 Table A-1: Temperature data of the study area in 45 years, Jinghe station, 1961 - 2006).

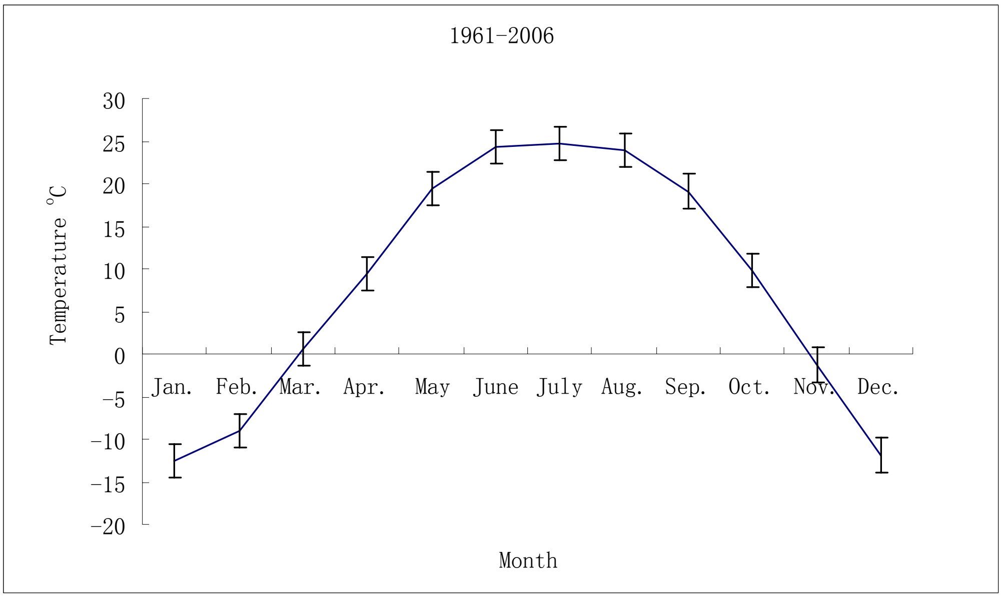


Fig. 3: Monthly mean temperature in Aibi Hu region (Jinghe station, 1961 - 2006).
Abb. 3: Monatsmittelwerte der Lufttemperatur im Aibi See-Gebiet.
图例 3：艾比湖地区月平均气温分部图（1961 - 2006).

Fig. 3 shows that there is a sharp difference in monthly mean temperatures between summer and winter (from –15.4 °C to 25.4 °C), and a very regular increase to the maximum in July and a corresponding decrease to the minimum in January.
From appendix 1 Table A-1: Temperature data of the study area in 45 years (Jinghe station, 1961 - 2006); one can calculate the monthly mean temperature trend in 45 years for the hottest month, which is July (Fig. 4). Fig. 4 shows that the mean temperature in July of the 45 years (1961 - 2006) has a very slight tendency to increase.
One can also find that the monthly mean temperature of the coldest month, January, had a slight tendency to increase (Fig.5).
Fig. 6 shows that the annual mean temperature from 45 years of measurements (1961 - 2006) has a very slight tendency to increase.
By doing linear regression analysis, we can get the annual mean temperature increment rate k = 0.0277 (1961 - 2006).
The annual mean temperature difference between 1961 and 2006 was 0.87 °C.

This formula only gives a rough idea about an increase of the annual mean temperature. As R^2 is low (0.1863), the calculated value is only an estimation by linear regression analysis to indicate the possible annual mean temperature trend.

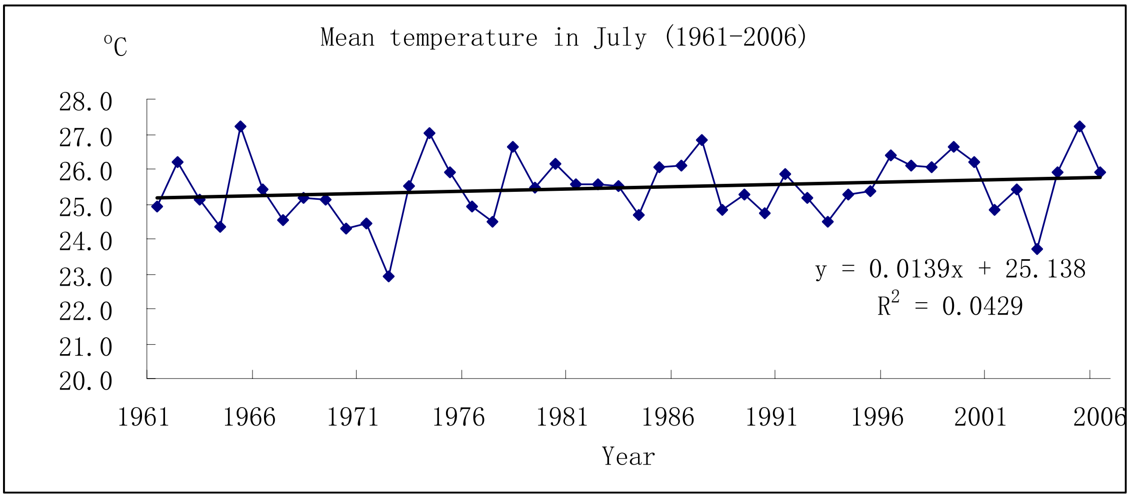


Fig. 4: Monthly mean temperature trend of July at Jinghe station (1961 - 2006).
Abb. 4: Trend der Monatsmittelwerte für Juli, (1961-2006).
图例 4: 精河气象站七月份气温变化趋势图 (1961 - 2006).

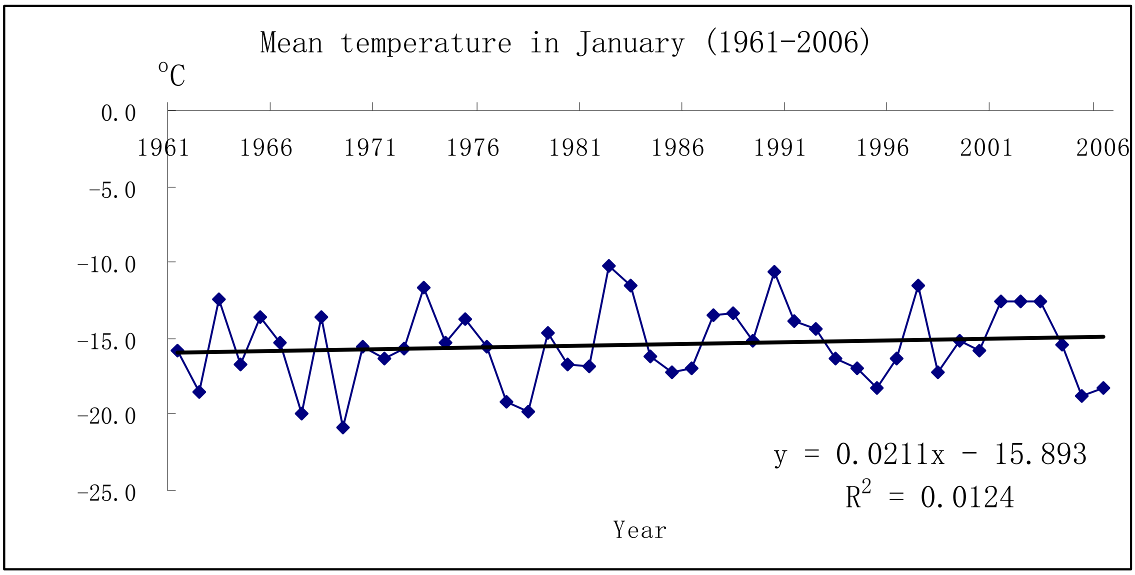


Fig. 5: Monthly mean temperature trend in January at Jinghe station (1961 - 2006).
Abb. 5: Trend der Monatsmittelwerte für Januar.
图例 5: 精河气象站一月份气温变化趋势图 (1961 - 2006).

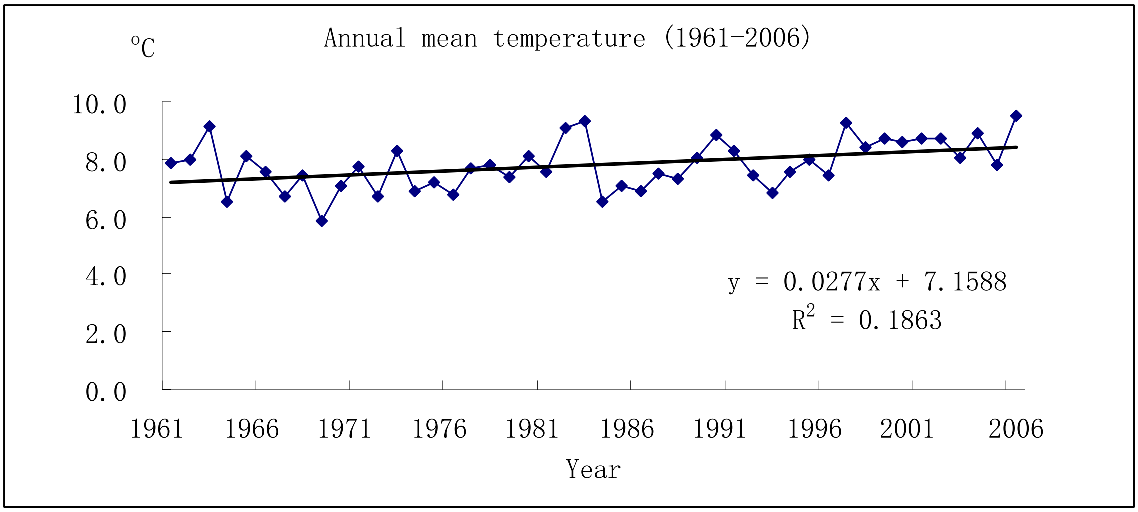


Fig. 6: Annual mean temperature trend in Aibi Hu region (Jinghe station, 1961 - 2006).
Abb. 6: Jahresmittelwerte der Lufttemperatur im Aibi See-Gebiet.
图例 6: 精河气象站年均气温变化趋势图 (1961 - 2006).

Precipitation

There are big differences between years. Fig. 7 shows the mean monthly precipitation of 45 years (1961 - 2006). In this figure, one can find that monthly precipitation is very low in this region.

Fig. 8 shows the annual precipitation of Aibi Hu region in 45 years (1961 - 2006). In this figure, we can find that this area is very dry and the annual precipitation varies in a range of 90.9 to 163.9 mm. In Fig. 8, we can also find the annual precipitation rate of the 45 years (1961 - 2006). Fig. 8 also shows that there is a slight trend of annual precipitation to increase gradually.

With linear regression analysis, one can get the annual precipitation increase rate k = 0.87 ($y = 0.87x+82.22$, $R^2 = 0.16$).

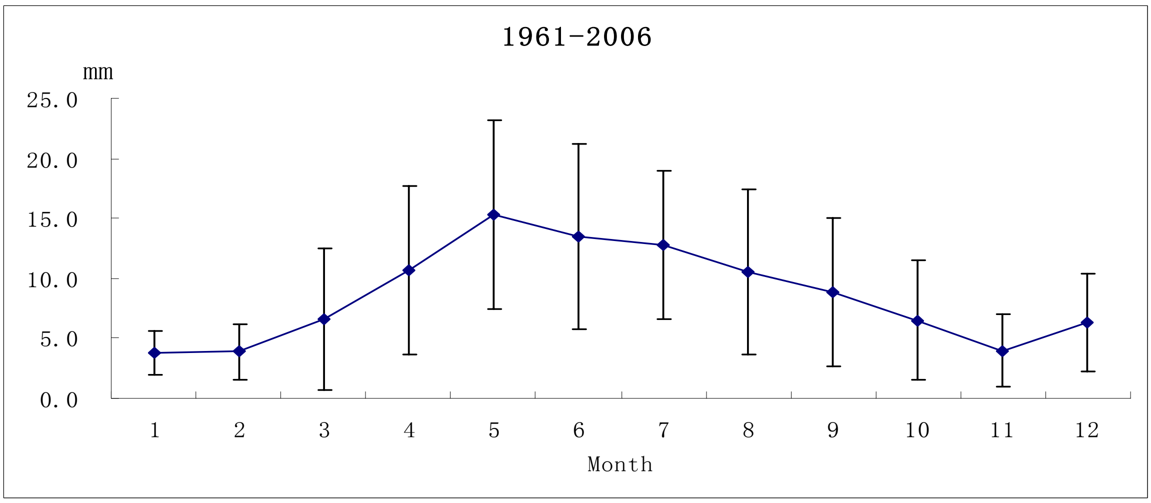


Fig. 7 : Monthly mean precipitation, 1961 - 2006 (Jinghe station).
Abb. 7: Monatsmittelwerte des Niederschlags (Jinghe Station, 1961 - 2006).
图例 7: 精河气象站月平均降水量分布图(1961 - 2006).

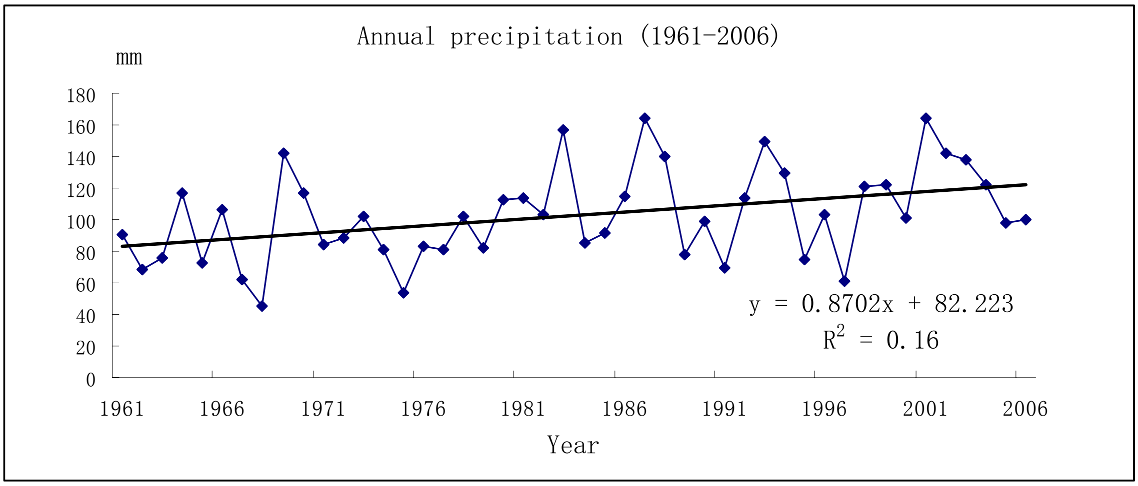


Fig. 8: Annual precipitation of 45 years in Aibi Hu region (Jinghe station, 1961 - 2006).
Abb. 8: Jährliche Niederschläge (Jinghe Station, 1961 - 2006).
图例 8: 艾比湖地区 (精河气象站) 45 年年降水量变化趋势图.

The mean precipitation difference between 1961 and 2006 was 121.38-82.22 = 39.16 mm. As R^2 is very low (0.16), this formula only provides a rough estimation of a possible annual precipitation increment.

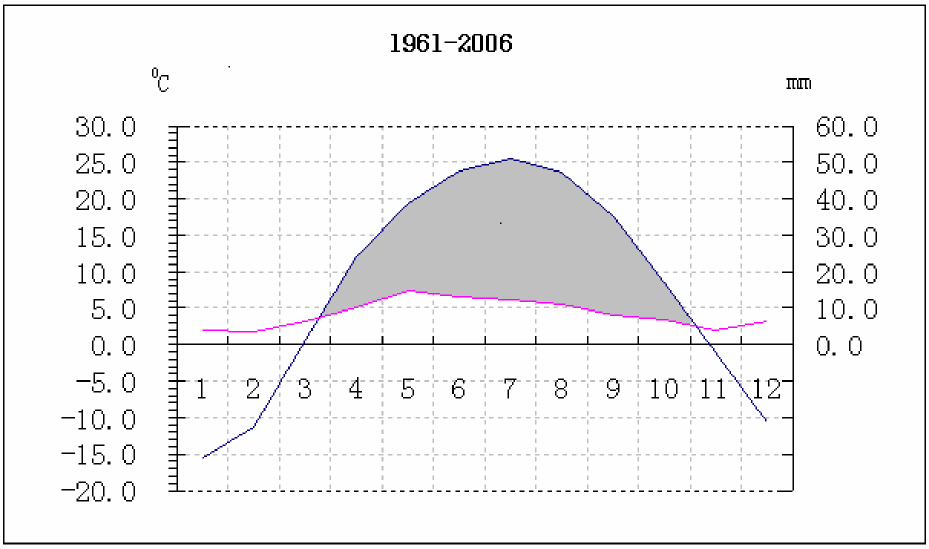


Fig. 9 : Climate diagram of the Aibi Hu region (Jinghe station 82°54' E, 44°37' N, 1961 - 2006).
Abb. 9: Klimadiagramm der Jinghe Station (1961 - 2006).
图例 9: 艾比湖地区(精河气象站)气候图 (1961 - 2006).

According to the administration of Aibi Hu National Nature Reserve (Li W.H. et al., 2002), the lowest absolute temperature recorded is –36.4°C (January 3rd, 1955), the highest temperature ever recorded is 41.3°C (July 31st, 1987).
The highest precipitation ever recorded is 163.9 mm (1958), whereas the lowest is 28.5 mm (1957). The annual potential evaporation amounts to 1,662 mm (Li W.H. et al.,

2002).
From the data of Jinghe weather station, the mean annual precipitation was derived. The difference between 1961 and 2006 amounts to 90.9 mm (1961 - 2006, Jinghe station, Appendix 2 Table: Monthly mean precipitation of Aibi Hu region in 45 years).
It can be shown by the climate diagram for Jinghe station (Fig. 9) that the study area has a very long dry season, from late March until early November.
To sum up, one can conclude that the climate in the study area is very arid and continental, with little rainfall, hot in summer and cold in winter. The climate has not changed substantially in the last 45 years.

2.1.4 Hydrology

With an altitude of 196 m, Aibi Lake is the lowest place in Zhungeer Basin. It is the central basin of the surface and underground water in this region. In Aug. 22, 2006, the surface area of Aibi Lake covered about 550.6 km^2 (data from the administration of Aibi Hu National Nature Reserve). The water sources of the lake are surface water from the rivers and underground water (Qian Y.B. et al., 2004).

Surface water

There are 47 rivers in the whole area. Most of them dried up before they reach the lake. At present, only four of them are supplying water to the lake. These four rivers are Kuitun (奎屯河), Jinghe (精河), Boertala (博尔塔拉河) and Daheyanzihe (大河沿子河).
The rivers from the north Mayili Mountains (玛依力山) are Liushugou (柳树沟), Qialegai (恰勒盖河), Suwuer (苏吾尔河), Suyeke (苏也克河), Laba (拉巴河), Qiadansu (恰当苏河) and Kuxiaqigou (库夏奇沟). All of them are dried up before they reach the lake. They supply water to the lake by way of underground water. Only the rivers Laba and Qiadansu supply floodwater to the lake occasionally (information from the administration of Aibi Hu National Nature Reserve).
The rivers from the west Alatao Mountains (阿拉套山) are Jingelesayi (京格勒萨依), Xiaerli (夏尔希里河), Salike (赛里克河), Halatuluke (哈拉吐鲁克河), Wulasitaiwusu (乌拉斯台乌苏), Aerxiati (阿尔夏提), Mierqike (米尔其克), Yihehusitai (伊和呼斯台), Bayansayi (巴彦萨依), Tuergen (图尔根), Huguerte (呼古尔特), Cahuwuerte (查呼乌尔特) and Cagansayi (查干萨依), Doulangte (多浪特), Halulinguole (哈鲁林郭勒), Aketawu (阿克他乌), Zalenmute (扎冷木特), Ailiketuluke (艾里克吐鲁克) and Saerkan (萨尔坎) etc. Only four of them flow together to the river Boertala, supplying surface water to the lake.
The rivers from the south Tianshan Mountains are Kuitun, Sikeshu (四棵树河), Guetuhe (古尔图河), Tuetuehe (托托河), Jinghe, Kusitanwusu (库斯坦乌苏), Wulasitai (乌拉斯台河), Asaleawuzi (阿沙勒阿乌孜), Suletielieke (苏勒铁列克), Tusunnengsu (托逊能苏), Kusunmuqieke (库松木切克), Daheyanzihe (大河沿子河), Haxia (哈夏), Wuertagesaleihe (乌尔塔格萨雷河) and Aqikesu (阿其克苏河) which is the river in our research area, it was almost dried up at present. Apart from Jinghe River which is still

supplying water to the lake, all of the others are dried up or were stopped by dams.
One thing should be mentioned that, Kuitun River, which was the most important water source supplied the biggest amount of water to the lake, was completely dried up in 1970s. Since 2000, it begun to supply water to the lake occasionally.

Table 1: Annual surface water flow volume of the five rivers in the Aibi Hu region [10^8 m^3].
Tab.1: Jährliche Oberflächenabflußrate der fünf wichtigsten Flüsse der Aibi See-Region.
图表 1: 艾比湖流域各入湖河段断面实测年平均流量统计表.
(Data source: Administration of Aibi Hu National Nature Reserve).

Year 年份	Boertala 博尔塔拉河	Jinghe 精河	Wuertagesaleihe 乌尔达克赛河	Daheyanzihe 大河沿子河	Kuitun 奎屯河	Total 总量
1980	16	15.1	4.4			35.5
1981	18.4	17	6.09			41.49
1982	14.2	16.1	4.81			35.11
1983	14.4	15.4	4.32			34.12
1984	14.1	16.3	4.88			35.28
1985	13.2	12.8	3.92			29.92
1986	14.6	13	4.66			32.26
1987	15.3	16.6	5.28			37.18
1988	16.1	19.1	4.91	5.74		45.85
1989	12.8	12.5	4.07	3.57		32.94
1990	14	14.7	5	3.84		37.54
1991	12.8	13.5	4.46	3.33		34.09
1992	14	11.6	3.52	3.1		32.22
1993	15.4	15	3.49	3.98		37.87
1994	16.8	14.2		3.53		34.53
1995	13.3	14.4		3.15		30.85
1996	12.5	14.9		3.84		31.24
1997	12.9	14.3		3.18		30.38
1998	16.8	18.1		5.72		40.62
1999	16.9	16.8		5.35		39.05
2000	15.7	16.2		3.83	0.326	36.056

Table 1 shows the annual surface water flow volume of the biggest five rivers in Aibi Hu region. In this table we can find that the total amount of surface water in the whole region comes to 3.61×10^9 m^3（2000）. Only 5.6×10^8 m^3 flow to the lake. The others, which supply 3.05×10^9 m^3, are evaporated or used by farmland.
In this area, most of the rivers are seasonal rivers. The greatest flow occurs from June to September with ~ 75% of the annual amount.
Because of the intensive exploitation and use of water resources in this area in the past five decades, the stream flow in this area has been cut off for a long time, some of them has became dried up already. This caused the smaller lake surface and a severe draw-down of groundwater levels.

Underground water

Table 2 shows the distribution of underground water in this region. The total amount is about 3.026×10^9 m^3. Among these, 52.5% in Kuitun area, 16.6% in Jinghe area and 28.2% in Boertala area. In Touli area, it is about 3%.

Table 2: Underground water in Aibi Hu region (2000, provided by the administration of Aibi Hu National Nature Reserve) in 10^8 m^3.
Tab. 2: Grundwassermengen in der Aibi See-Region (2000).
图表 2: 艾比湖流域地下水资源.
(Data source: Administration of Aibi Hu National Nature Reserve).

Area 分区	Mountain area 山区	Plain area 平原地区	Iterate amount 重复计算部分	Total 地下水资源
Kuitun Area 奎屯河区	6.59	10.51	1.29	15.81
Jinghe Area 精河区	2.25	3.16	0.4	5.01
Bole Area 博河区	3.63	5.92	1.01	8.54
Touli Area 托里小河区	0.3	0.7	0.1	0.9
Aibi Hu region 艾比湖流域	12.77	20.29	2.8	30.26

Table 3 shows the surface water and underground water distribution in Aibi Hu region. It shows that the annual total amount of surface water and underground water in this region comes to 41.61×10^8 m^3 (2000).

Table 3: Surface and underground water in Aibi Hu region (2000) [10^8 m^3].
Tab.3: Oberflächen- und Grundwassermengen in der Aibi See-Region.
图表 3: 艾比湖流域水资源分布状况.
(Data source: Administration of Aibi Hu National Nature Reserve).

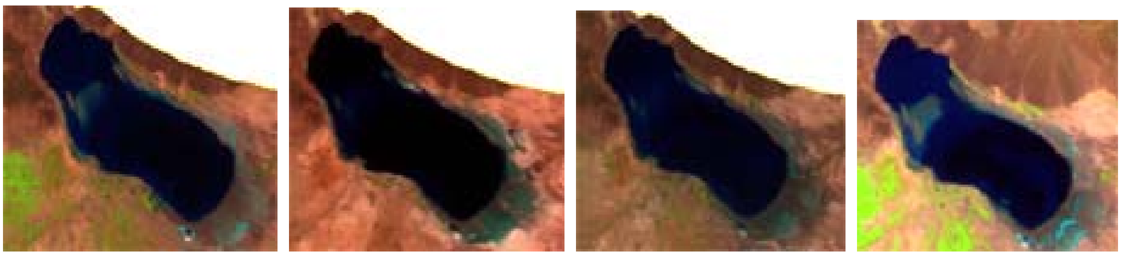
Area 分区	Surface water 地表水资源	Underground water 地下水资源	Iterated amount 重复计算部分	Total amount 水资源总量	%
Kuitun Area 奎屯河区	16.7	15.81	13.86	18.65	44.8
Jinghe Area 精河区	9.36	5.01	3.06	9.97	23.9
Boler Area 博河区	10.7	8.54	7.15	12.09	29.1
Touli Area 托里小河区	0.7	0.9	0.7	0.9	2.2
Aibi Hu region 艾比湖流域	37.46	30.26	26.11	41.61	100

Due to the rapid growth of the human population and the development of agriculture and industries in this region the annual surface water flow to Aibi Lake decreased very quickly (Li W.H. et al., 2002). The surface area of Aibi Lake fluctuated also in the course of one year. Fig. 10 shows the transformation of the surface area in different months

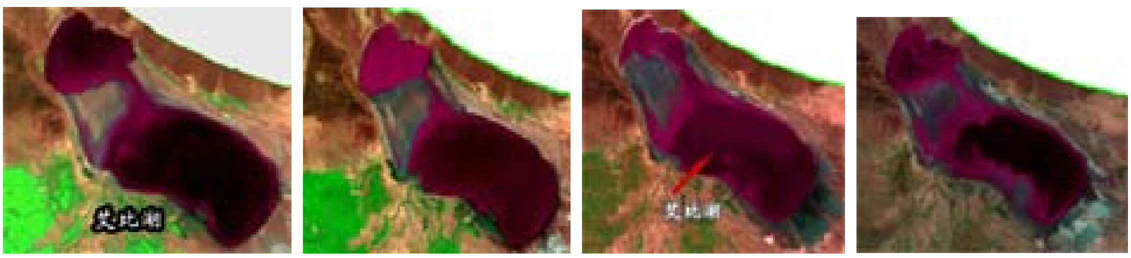
(2004, provided by the administration of Aibi Hu National Nature Reserve). It shows that, the surface area is the largest in winter; in contrast to summer, because of the big amount of water being used for irrigation in the upper reaches of the rivers and the low precipitation rates (2.1.1.3).

Table 4: Water use by human activities in Aibi Hu region.
Tab. 4: Wasserverbrauch durch menschliche Aktivitäten in der Aibi See-Region.
图表 4: 艾比湖流域人类活动用水量情况.
(Data source: Administration of Aibi Hu National Nature Reserve).

Year 年份	Total amount 总量（10^8 m^3）	Agriculture 农业（10^8 m^3）	Industry 工业（10^4 m^3）	Animal husbandry 牧业（10^4 m^3）	Subsistence 生活（10^4 m^3）
1950	4.09	4.05	3.77	263.35	127.19
1955	6.56	6.51	21.74	392.73	157.79
1960	22.10	22.00	153.11	490.90	284.62
1965	27.01	26.86	234.39	777.37	492.77
1970	26.35	26.16	473.66	723.14	732.36
1975	23.96	23.73	521.81	799.20	980.54
1980	22.17	21.90	730.94	762.61	1129.60
1985	19.93	19.54	1870.02	824.86	1180.79
1990	21.37	20.77	3684.55	961.52	1296.64



April 16th 2004, 985Km^2 May 16th 2004, 987Km^2 June 18th 2004, 908Km^2 July 12th 2004, 841 Km^2



Aug.14th 2004, 839Km^2 Sept.24th 2004, 803Km^2 Oct.17th 2004, 788Km^2 Dec. 8th 2004, 975 Km^2

Fig. 10: Changes of surface area of Aibi Lake in 2004 (provided by the administration of the Aibi Hu National Nature Reserve).
Abb.10: Veränderungen der Größe der Oberfläche [km^2] des Aibi Hu-Sees im Verlauf des Jahres 2004.
图例 10: 2004 年艾比湖水域面积变化情况.

According to the investigation conducted by the administration of Aibi Hu National Nature Reserve, the amount of water used by human activities increased very quickly during the last 50 years. Table 4 shows the annual volume used in different years. The amount of water used in the last 10 years has still to be quantified.

Fig. 11 : Relatively low water level of Aibi Lake in early spring 2006 (photo by author, April 12th).
Abb. 11: Relativ niedriger Wasserstand des Aibi-Sees im Frühjahr 2006 (12. April).
图例 11: 艾比湖水域面积减少，部分湖床裸露 (2006 年 4 月 12 日作者摄).

2.1.5 Vegetation

The study area of Aibi Hu region belongs to plain desert vegetation landscape (2.1.1.1). The major difference from other desert areas is that a lake is located in the center of the region and that there are several seasonal inland rivers transporting water toward this lake.
It is recorded that before 1950, Aibi Hu region was very rich in vegetation. It was called ‘green labyrinth in arid area’ (Li W.H. et al., 2002).
At the beginning of the 19th century, the whole area was covered by forests and grassland with species like willows, birches, poplars, *Tamarix chinesis, Lycium chinense, Haloxylon ammodendron* and *Nitraria sphaerocarpa* etc. There were many types of arboraceous forests in this region (Environmental problems about Aibi Hu region http://www.tianshannet.com/GB).
Until the beginning of the 1950th, most of the land in Aibi Hu region was still covered with green and the plants were widely distributed. The main plant species in this region still included *Tamarix spec.* (柽柳), *Halimodendron halodendron* (铃铛刺), *Glycyrrhiza spec.* (甘草) and *Lycium ruthenicum* (苏枸杞) etc.
At that time, the *Haloxylon ammodendron* covered a total area of 48,000 ha and the *P.*

euphratica forest about 53,000 ha. In some areas, forests even covered 70% of the ground. Along the shore of Aibi Lake, 60-90% of the ground was occupied by *Phragmites communis* (芦苇) (Li W.H. et al., 2002).

Since 1950, a great deal of the vegetation has degenerated significantly (compare chapter 2.1.1.9). But one can still find plant and animal communities representing many of the world's desert biomes.

An investigation accomplished by Aibi Hu National Nature Reserve shows that there are 385 plant species in this region today (Li W.H. et al., 2002).

Although the region is species rich, the abundance of each species is relatively low. Some of the species are in danger to disappear.

Details about the main vegetation types and their distribution can be seen on the vegetation map made by the Aibi Hu National Nature Reserve (Appendix 9 Fig.A-5.: Vegetation map of Aibi Hu region).

In Appendix 9, one can find the main vegetation types of Aibi Hu region. In the quagmire area near the lake, there are many vegetation types. The main plant species are *Halostachys caspica* (盐穗木), *Halocnemum strobilaceum* (盐节木), *Salicornia europaea* (盐角草) and *Kalidium foliatum* (盐爪爪) etc.

There are some arboraceous species of desert vegetation in this region, especially stands of *P. euphratica*, willows and birches.

Fig. 12: Shrubby vegetation in Aibi Hu region (photo by author, 2006).

Abb. 12: Strauch-Vegetation in der Aibi See-Region.

图例12: 艾比湖地区植被.

According to the investigation (Li W.H. et al., 2002), temperate deciduous forest is strictly represented only by scattered willow species and *Tamarix chinensis* groves and ribbons of riparian trees in gallery forests.

Natural stands of *P. euphratica* are distributed along the river banks of current rivers. It forms the most prosperous forest ecosystem in this region, and it is the main tree species that forms the arboraceous forest type. The biomass productivity of *P. euphratica* ecosystem is much higher than that of other vegetative types. Its total area covers 5,818.34 ha (Amanu T. and Yarmamat T., 2001).

In addition to *P. euphratica*, along the courses of the rivers, *Haloxylon ammodendron* and *Tamarix ramosissima* etc. form small dominant colonies.

The canopy of the plants in this area is normally very fragmentary. Plants are mainly ground-hugging shrubs and short woody trees. Their leaves are 'replete' (fully supported with nutrients) with water-conserving characteristics. They tend to be small, thick and covered with a thick cuticle.

The riparian communities in this region are regarded as a unique habitat type. The vegetation types in washes (arroyos) are regarded as 'dry riparian' habitats. Though they may carry water only in short periods during the year, they share most of their special characteristics with traditional 'wet' riparian habitats. They are chronically disturbed, unstable sites where water and nutrients are harvested and concentrated from larger areas (watersheds). Like wet rivers, washes are corridors for dispersal of plants that need more water than the surrounding habitat.

Grassland in Aibi Hu region belongs to the semi-desert grassland community, it is located between the desert and the lake. The main species are: *Plantago asiatica* (车前草属群系), *Phragmites communis* (芦苇群系), *Aeluropus pungens* (小獐茅群落) and *Salicornia europaea* (盐角草群落) etc.

Special environmental conditions are responsible for the fragility and instability of ecosystems in the region. The landscapes and their vegetation in this region are shaped and changed by many different natural and anthropogenic factors, the most important factors are wind and erosion interacting with vegetation and land use.

Vegetation in this region is protecting against hazardous environmental factors. It provides a natural defense against wind by preventing sand movement. Thus it plays an important role in keeping this region free of wind erosion.

2.1.6 Forests

In Xinjiang Autonomic Region, the forested land occupies 3.5% of the total land area (Zhang X.M., 1996). These forestry resources in Xinjiang consist of natural forest in mountain areas, natural forest in plain areas and planted forest in plain areas (Wang C.W., 1961; Ma M., 2001; Xinjiang Guide, for details see the website: http://www.xjx.cc/html/zhibei.htm).

In mountain areas, forests are distributed mainly in the northern regions of Xinjiang, especially in the Tianshan and Altai Mountains, near the borders of Kazakhstan and Russia. The natural conifer forest is the main forest type in the mountain regions, whose total area amounts to 1.56 million ha. The forest in the mountains is an important base for water conservation and wood production.

In plain areas, most of the forest are scattered along the rivers and in the surrounding basins. The scattered distribution of 'green lands', in the vicinity of deserts, are named oasis. The oasis forestry shows high potential for overall development in Xinjiang and has a long history.

The diversiform-leaved poplar forests (Tugai forests) in the deserts are mainly distributed along the banks of several branches of the Tarim River in Tarim Basin and in the banks of the inland rivers in Zhungeer Basin. It is a valuable and long life forest which can resist salinization, aridity, wind and rottenness. Its total area covers 725,000 ha (Xinjiang Guide, for details see the website: http://www.xjx.cc/ html/zhibei.htm, 2004).

There are also forests in the river valleys in other regions in Xinjiang, whose total area amounts to 53,000 ha (Forest situation in Xinjiang, http://www.west-develop.com/resource/nl/hnl-08-12-11.htm, 2005).

In addition to those forests, there are unique oases of trees that dot the desert. The peculiar geographic location and strong physical and biological functions of these forests play an important role for plants and animals as well as for the regional social and economic development of the region. For this reason, the forests are often called ‘wet islands’ in the desert.

Fig. 13: Forest in Aibi Hu region (plot A 111, photo by author, 2006).

Abb. 13: Wald in der Aibi See-Region.

图例:13: 艾比湖地区林区.

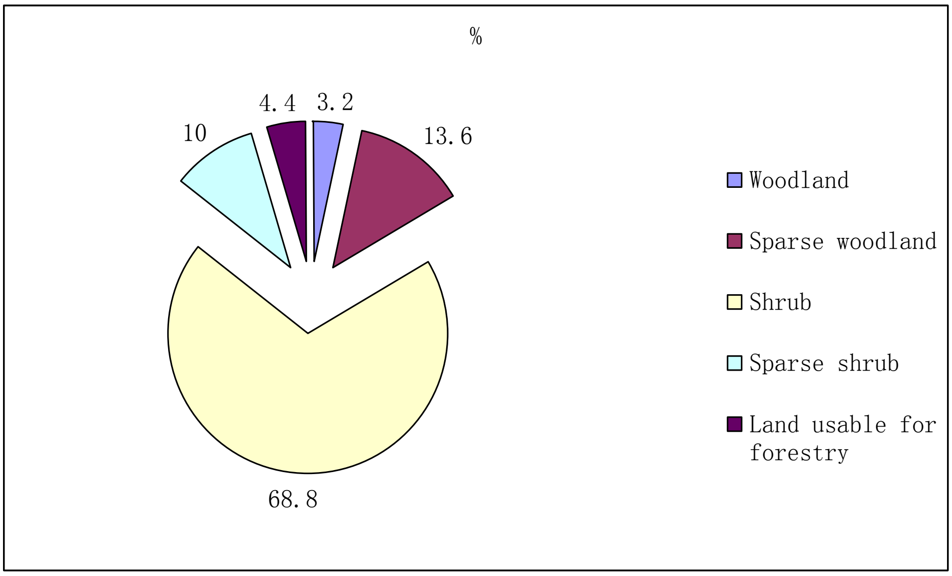
Until about 50 years ago, the study area, which is situated at the lower reaches of the rivers from the mountain area, created luxurious forests for many species that formed a green area, which effectively controlled the sand drift coming from the deserts area near Aibi Lake.

These forested areas, however, have been seriously degraded by the rapid development occurring in this region and the surrounding areas. The most serious problems have come from the agricultural reclamation that has occurred over the last 50 years. This reclamation has involved turning a great amount of desert into fertile farmland. This has come at a great cost to the forests and the grasslands in this area, which are now seriously degraded. According to the report from Aibi Nature National Reserve, 60% of forest in this region had already been destroyed.

The investigation accomplished by Aibi Hu National Nature Reserve shows that, at this moment, the forests in Aibi Hu region cover 182,625.29 ha. It includes woodland: 5,849.2 ha, sparse woodland: 24,902.37 ha, shrubland: 125,667.92 ha, sparse shrubland (coverage less than 30%): 18,260.21 ha and land usable for forestry: 7,945.50 ha (Table 5).

Table 5: Forest land in Aibi Hu region (data from Aibi Hu National Nature Reserve).
Tab. 5: Waldfläche in der Aibi See-Region.
图表:5: 艾比湖地区林区分布.

Forest land	Woodland	Sparse woodland	Shrub	Sparse shrub	Land usable for forestry	Total area of forest land
Area (ha)	5849.2	24902.37	125667.92	18260.21	7945.5	182625.2
%	3.2	13.6	68.8	10.0	4.4	100



There are only 3 types of woodland in Aibi Hu region. The main tree species are *P. euphratica* and different willows. There are also a few birch species in this region. The total area of *P. euphratica* in Aibi Hu region covers 5,818.34 ha, whereas willows cover 29.45 ha and birch 1.5 ha.

In the sparse woodland, the total area of *P. euphratica* amounts to 24,373.06 ha and the area of willows to 529.31 ha.

The distribution of forest in the study area can be seen in the vegetation map made by the Aibi Hu National Nature Reserve (Appendix 10 Fig. A-5: Vegetation map of Aibi Hu region).

All of the forest land in this region has been protected by the Aibi Hu National Nature Reserve since 2000.

2.1.7 *Populus euphratica*

Populus euphratica Oliv. (*P. euphratica*) is the oldest tree species in genus *Populus*. It is growing in arid and semi-arid regions of Central Asia where its distribution remains restricted to riverbanks or on sites where underground water is available. It is estimated that this species has existed for about 300 to 600 million years (Qin R., 1959).

Distribution

In regards of its altitudinal distribution, *P. euphratica* covers a wide range. In China, its stands are now present mainly in alluvial plains crossing the desert, between elevation of 300 -1000 m, with the top limit at 2400 m a.s.l. According to the information presented by Pakistan to the International Poplar Commission, the *P. euphratica* stands there can reach an altitude of 4000 m a.s.l. (Wang S. et al., 1996).

The distribution range of *P. euphratica* stretches across the three continents of Europe, Asia and Africa and is present in twenty countries surrounding the Mediterranean Sea. It is also located in the arid and semi-arid desert area in Northwestern China and Mongolia.

At present, *P. euphratica* is mainly distributed in the economically poor areas. However, during the long ancient historical period, *P. euphratica* was more widely distributed.

Table 6: Distribution and area of *P. euphratica* in China (Data source: Wang S. et al.,1996).
Tab. 6: Verbreitung von *P. euphratica* in China.
图表 6: 胡杨在中国的地理分布.

Location	Xinjiang(1) Tarim Basin	Xinjiang(2) Zhungeer Basin	Inner Mongolia	Gansu	Qinghai Ningxia	Total
Area(×10^3ha)	352.2	8.0	20.0	5.0	Sparse	395.2
%	89.1	2.0	5.1	3.8	-	100

Table 7: Distribution of *Populus euphratica* in different countries of the world (Data source: Wang S. et al.,1996).
Tab. 7: Weltweite Verbreitung von *Populus euphratica*.
图表 7: 胡杨在世界的地理分布.

Countries	Area (×10^3ha)	%		Countries	Area(×10^3ha)	%
China	395.2	61.0		Turkey	4.9	0.8
Central Asia country	200	30.8		Pakistan	2.8	0.4
Iraq	20	3.1		Spain	Sparse	
Iran	20	3.1		Others	Sparse	
Syria	5.82	0.9		Total	648.72	100

In China, *P. euphratica* is present with natural stands in the Northwestern region. Nearly 91% of the stands are concentrated in Xinjiang Autonomous Region (Table 6).

In Xinjiang Autonomous Region, its vertical distribution range is: upper limit of south slope of Tianshan Mountains, 1300 m a.s.l.; upper limit of Kunlun Mountains 2300-2400

m; below Luobupu Lake on the Kuluptake Mountain Valley, the upper limit is 2100 m a.s.l.. The most suitable place for the natural stand is the river alluvial plain between altitude 300 -1000 m a.s.l. (Wang S. et al., 1996).
In the study area, the *P. euphratica* forests are growing at the altitude of 360 m a.s.l..
Table 6 and Table 7 listed the distribution location and the area of *P. euphratica* both in China and in the world.
In the Aibi Hu region, *P. euphratica's* growing sites are mainly along the bank of Aikeqisu River in the Eastern part of the region. There are also some sparse *P. euphratica* forests distributed along Kuitun River, Boertala River and Jinghe River. The whole area of *P. euphratica* species in Aibi Hu region amounts to 5,818.34 ha (Li W.H. et al., 2002).

Characteristics
In the arid desert area, *P. euphratica* is always the only arboreous species. It can be seen from its morphological characteristics that the significant difference between *P. euphratica* and other poplars is the obvious difference between the leaf shape of the young tree and the adult tree. That is why it is called diversified poplar.
Another characteristic of *P. euphratica* is the bending trunk when it is planted on poor sites. Though it is reported that its total height can reach 30- 38 m, which is very rare. Generally, not many trees exceed the height of 20 m and their trunk height exceeds no more than 1-2 m.
The main ecological characteristics of *P. euphratica* consist in the fact that it is fond of light, saline-tolerant, tolerant to atmospheric drought, adapts to height temperature but is also tolerant to cold (Wang S. et al., 1996).
Based on these traits, in special conditions, it is the only naturally distributed arboreous tree species at the limit of barren desert or semi-barren desert region, like the study area in the Aibi Hu region.
According to the records, a number of remarkably old *P. euphratica* trees were found. Among these, the following examples are selected: ***A*** One tree was found along the banks of Tarim River with a height of 19 m and a diameter of 170 cm. Its determined age was over 200 years (Chen B.H., 1986); ***B*** An old tree of *P. euphratica* was found along the river banks in Yie County, Hami Prefecture, East Xinjiang, in open desert. It is about 750 years old, having a height of 15 m and a circumference of over 400 cm, equal to a diameter of 127 cm. Its volume is 12.25 m^3 (Chen B.H., 1986); **C** An old tree of *P. euphratica* was found at Dalaikubu, Alashaneqina, Inner Mongolia. It is about 880 years old, having a height of 27.5 m and a circumference of 6.5 m, equal to a diameter of 2.07 m. It is the longest living *P. euphratica* tree ever found (Renming Wang, 2005.11.14, http://scitech.people.com.cn/GB).
P. euphratica forests are the most important habitat for plant and animal life in the desert regions. They are very important for human settlements. Their environmental benefits are landscape preservation, wind break, soil protection, sand fixation and riverbank protection. *P. euphratica* forests are also important for water conservation to oases, wildlife habitat and as a natural protective screen for protection of husbandry and agricultural fields (Huyang http://202.127.158.9/cbiswh1/qdbh).
Though *P. euphratica* usually is not a tree species with a deep root system, its main roots

penetrate one meter vertically into the soil. There are also a lot of lateral and feeder roots growing on the lower end of the main root. This kind of special structure of the root system is favourable for resisting to the mechanical impact to strong winds in the barren desert. Besides, having a short and thick trunk, a sparse tree crown, and short branches, *P. euphratica* opposes strong winds. As a result, there is no overthrowing of forest by wind. This quality is very important for *P. euphratica* to grow in Aibi Hu region because the annual average number of days with strong wind in Aibi Hu region is 165 days per year (Chapter 2.1.1 Climate).

Fig. 14 : *Populus euphratica* forest in Aibi Hu region (photo by author, 2006)
Abb. 14: *Populus euphratica* - Wald in der Aibi See-Region.
图例:14: 艾比湖地区胡杨林.

In forward positions of desert area, like Aibi Hu region, where the shifting of sand occurs vigorously, the dunes often encroach upon the *P. euphratica* trunks at the forest edge and often bury the stems in sand, leaving only the crowns free. In this situation, progression of dunes are stopped. This proves that *P. euphratica* can live under the most disbennifit conditions. When the dunes are removed it becomes evident that the trunk of the tree has developed abundantly new adventitious roots and underground shoots, which permit its existence in the dry and hot dune.
To sum up, *P. eupratica* forests play an important role in maintaining the ecological balance in desert areas because of its tolerance to severe drought and high salinity and alkalinity in soils. They are very important for human settlements in arid and semi-arid areas.

Water use

According to the investigations of Xinjiang Forest Bureau, there is a close relation between the ground water level and the prosperity or decline of the individuals and stands of *P. euphratica*. When the underground water is at the depth of 3 m to 4 m, its growth is still satisfactory but when the water level is below 8 m, or it was lowered down sharply, as in the case of a shifting river course, the *P. euphratica* forests would decline or even die over a large area (Gries D. et al., 2005).

In addition to the dependance from underground water for living, *P. euphratica* can thrive under flooded situation, on the condition that the water is flowing, not stagnant. In such a case, it will grow normally (Wang Q. et al., 2007). This character of flood tolerance makes it possible for *P. euphratica* to be used as a tree species for the protecting belt around agricultural fields. In areas with high level of underground water it can also be used to help lowering the level of underground water (Wang S. et al., 1996).

Fig. 15: An old *Populus euphratica* in Xinjiang P.R. China (photo: Aini Y., 2004).
Abb. 15: *Populus euphratica* in Xinjiang P.R. China.
图例:15: 生长在新疆地区的胡杨古树.

Because desert lands or sand dunes are the main sites of *P. euphratica* forests, where the soil is intensively salinized, it is very hard for other plants to grow (Wang S. et al., 1996; Li W.H. et al., 2002).

The vegetation types are quite similar among various *P. euphratica* forest areas, with a few species and simple ecological structure.

In general, although the number of plants species composing the *P. euphratica* forest vegetation is relatively low, the xeric shrub species represent a variety of geographical origins and show a certain complexity, with wide distributions and mixing in the *P. euphratica* communities (Zhao F.X. and Yin L.K., 2007).

The shrub species in the *P. euphratica* forest vegetation are common to desert regions, it includes the following genera: *Haloxylon, Lycium, Zygophllum* and *Atraphaxis* etc. (Li W.H. et al., 2002; Zhao F.X. and Yin L.K., 2007).

2.1.8 The endemic birch (Aibi Hu Birch)

In 2002, a possibly new species was found in Aibi Hu National Nature Reserve (Aibi Hu Birch). This species occurs in the Eastern part of Aibi Hu region (Aqikesu area) in a solitary population. According to Yang Changyu (Xinjiang Agriculture University, personal communication), it is a species which was not yet described. As there is no record about this species, he suggested the name Aibi Hu Birch for this species.
There are 6 species for the genus *Betula* in Xinjiang. Aibi Hu Birch does not belong to any of them as was found by morphological and anatomical comparisions.

Fig. 16: Aibi Hu birch (photo by author, 2005).
Abb.16: Aibi Hu-Birke.
图例 16: 艾比湖桦.

The number of individuals was recently counted 328. The elevation of their growing area is at about 345 m a.s.l.
In 2004, the area in which Aibi Hu Birch is growing has been surrounded by a fence and this species is now protected by the administration of Aibi Hu National Nature Reserve.
A special research plot (A 201) was adjusted to the complete area on which Aibi Hu Birch is growing. Tree parameters were measured.

2.1.9 History of land use until today

The whole area of Aibi Hu region was in a good ecological condition 50 years ago. It was recorded that the lake surface area was stable and a surface area of about 1200 km^2 was maintained for a long time. All of the surrounding landscapes were covered with vegetation (Li X.L., 1997).

Since 1950s, the human population increased very quickly. In 1950, there were 37,825 people living in this region. In 1959, it increased to 77,800. Until 2000, the population in this region counted to 413,713 (Fig. 17, Table 8).

Table 8: Human population increase in Aibi Hu region (Tayir and Tawakul, 2001).
Tab. 8: Bevölkerungszunahme in der Aibi See-Region.
图表 8:艾比湖地区人口增长情况.

Year	1950	1959	1972	1985	2000
Human population	27,825	77,800	184,493	293,058	413,713

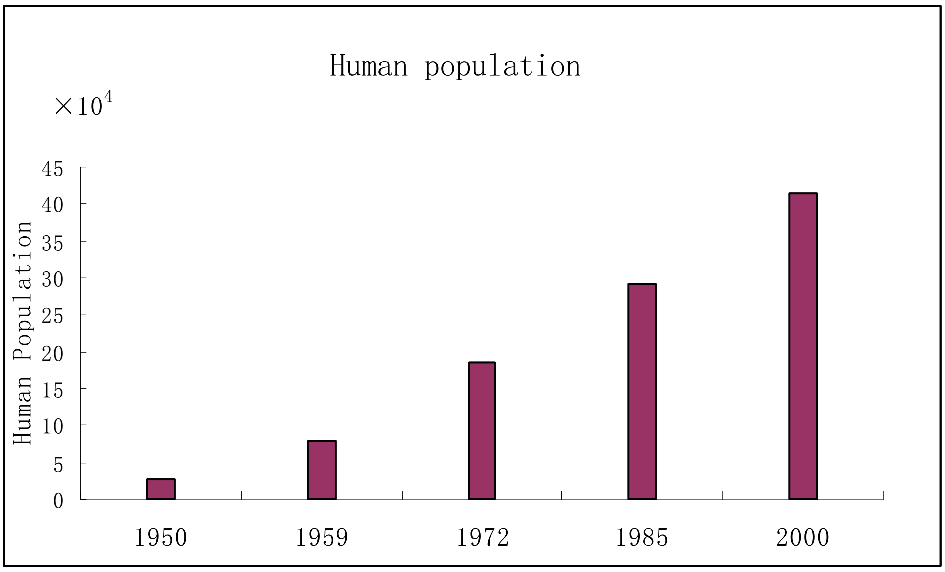


Fig. 17: Human population increase in Aibi Hu region (Jin H.L. et al., 2005).
Abb. 17: Bevölkerungszunahme in der Aibi See-Region.
图例 17:艾比湖地区人口增长情况.

In the same period, from 1950 to 1959, the farmland area increased very quickly, about 10,000 ha yearly. From 1959 to 1985, it also increased but not so rapidly. Since 1985, the area remained almost the same at about 200,000 ha (Fig.18, Table 9).

As the farmland increased, the total water used for irrigation increased very quickly from 1950 to 1959, about 1.35×10^8 m^3 yearly, it increased from 4.09×10^8 m^3 to 17.54×10^8 m^3. From 1959 to 1972, the water used by farmland still increased but not so quickly as before (about 0.25×10^8 m^3 yearly). From 1972 until now, while farmland was not increased a lot, the amount of water used for irrigation remained almost unchanged (about 20×10^8 m^3, Fig. 19, Table 10).

During 1950 to 1972, the construction of large-scale water storage projects caused another serious problem. There are now several large reservoirs and some small ones which were built in the up and low courses of the rivers. These reservoirs have all been created since 1950. They were apparently built with short-term economic growth in mind, and too little attention was paid to the impact of the projects on the ecological balance of the region.

Table 9: Farmland increase in Aibi Hu region (Tayir and Tawakul, 2001).
Tab. 9: Feldflächenzunahme der Aibi See-Region.
图表 9:艾比湖地区农田面积增长情况.

Year	1950	1959	1972	1985	2000
Farmland ($\times 10^4$ha)	2.2	12.	17.2	20	20

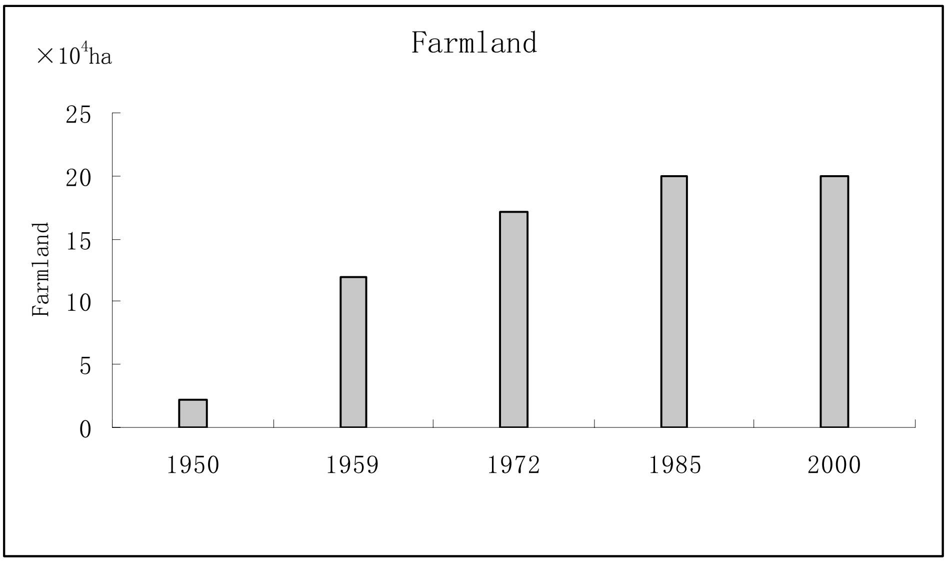


Fig. 18: Farmland increase in Aibi Hu region (Tayir and Tawakul, 2001).
Abb. 18: Feldflächenzunahme in der Aibi See-Region.
图例 18:艾比湖地区农田面积增长情况.

Because of this, the annual surface water flow volume in Aibi Lake, which is located at the lower reaches of the rivers, decreased by 5.6×10^8 m^3 in the mid-1990s from the former 25.9×10^8 m^3 (1950). To meet the need of irrigation, large-scale exploitation of water was initiated in the early 1970s and the annual volume of water is as high as 20×10^8 m^3, and it is estimated that the annual volume of pumping underground water is about 2.0×10^8 to 2.5×10^8 m^3. At present, only two of the seven rivers are still supplying this lake with water. Consequently, such unwise irrational utilization of water resources resulted in directly further accelerating the modern desertification process in this region, particularly at the fringe of oasis areas (Wang Q.J. et al., 2003).

Table 10: Water use in Aibi Hu region (Tayir and Tawakul, 2001).
Tab. 10: Wassermenge für die Feldbewässerung der Aibi See-Region.
图例 10: 艾比湖地区农田灌溉用水量.

Year	1950	1959	1972	1985	2000
Water used for irrigation ($10^8 m^3$)	4.09	17.54	19.50	19.93	21.37

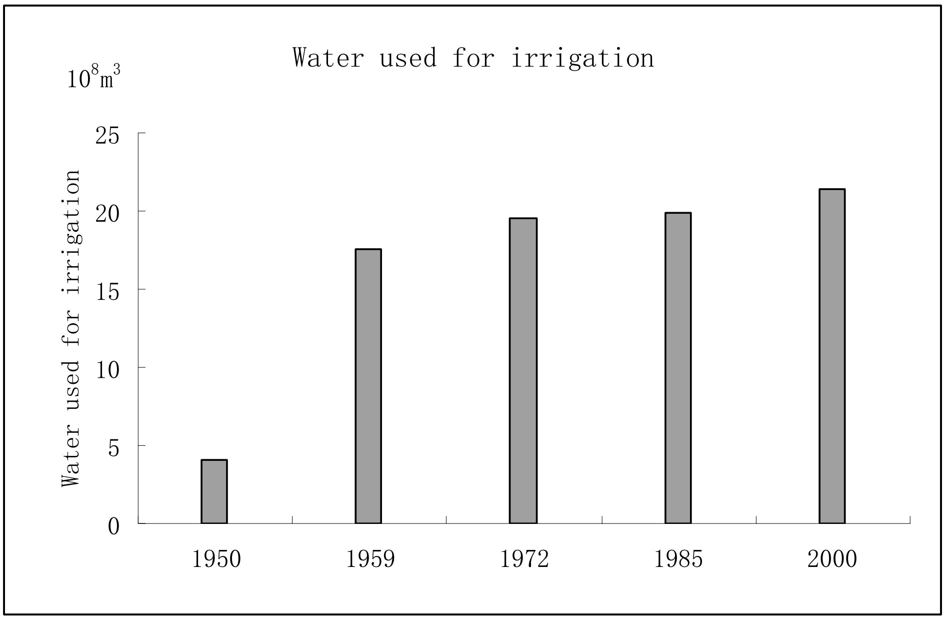


Fig. 19: Water used in Aibi Hu region (Tayir and Tawakul, 2001).
Abb. 19: Wassermenge für die Feldbewässerung der Aibi See-Region.
图例 19: 艾比湖地区农田灌溉用水量.

Table 11: Surface area change of Aibi Lake (Tayir and Tawakul, 2001).
Tab. 11: Flächenveränderung des Aibi-See.
图例 11: 艾比湖水面面积变化情况.

Year	1950	1957	1972	1985	2000
Lake surface area (km^2)	1200	1070	599	560	520

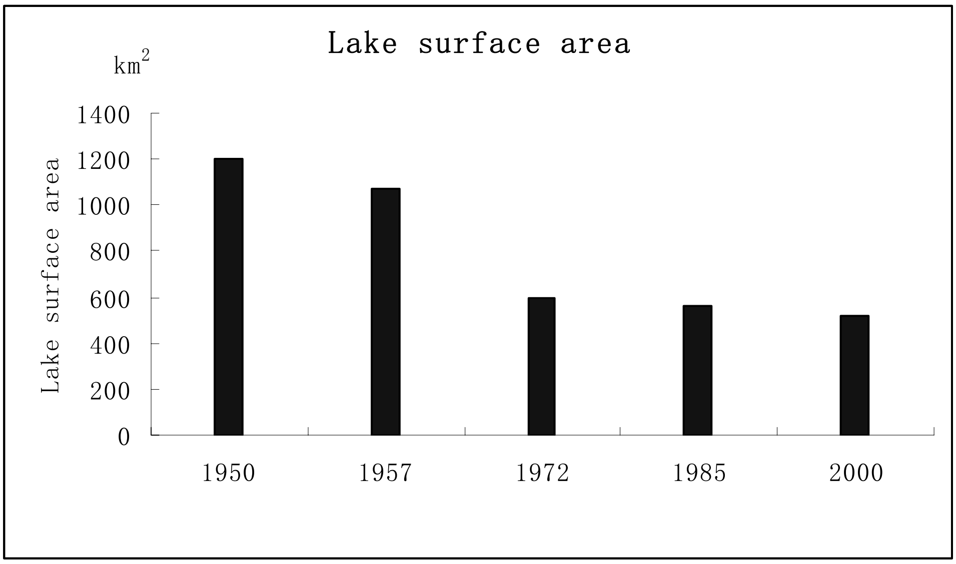


Fig. 20: Surface area change of Aibi Lake (Tayir and Tawakul, 2001).
Abb. 20: Flächenveränderung des Aibi-See.
图例 20: 艾比湖水面面积变化情况.

Fig. 21: Perishing forest in Aibi Hu region (photo by author, 2005).
Abb.21: Sterbender Wald in der Aibi See-Region.
图例 21: 艾比湖地区干枯的胡杨林

Fig. 22: Wasteland in Aibi Hu region (photo by author, 2006).
Abb.22: Wüstenbildung in der Aibi See-Region.
图例 22: 艾比湖地区荒废的土地.

As a result, the lake surface area decreased very quickly from 1950 to1972, from 1200 km^2 to 599 km^2. During 1972 to 1985, although there was a big increase in human population, the farmland did not increase a lot and the lake surface remained almost the

same until today (Fig. 20, Table 11).
Due to the rapid growth of the human population and irrational resource exploitation, many environmental problems have emerged and the degradation became serious. The conflict between supply and requirement of water resources is becoming crucial day after day, especially the discrepancy between the upstream and the downstream distribution of the rivers.
This happened at the expense of forests and grasslands, which are now seriously destroyed. The ecosystem became worse and worse during this time.

2.1.10 Conservation strategy

For the protection of the degraded ecosystem in this region, in June 2000, the government of the autonomous province of Xinjiang confirmed the Aibi Hu region as a nature reserve. After two years of preparation, the management unit of ‘Xinjiang Aibi National Wetland Nature Reserve’ began to work on the field. At present, there are 25 officers and 152 workers operating in the reserve.
Since 2002, some conservation work have been conducted by the administration of Aibi Hu National Nature Reserve. 10 ranger stations were established for forest prevention in this region. They have built two observation towers for forest fire prevention. They also constructed two bridges and 60 km field tracks in the reserve area for the conservation work of the reserve.

Fig. 23: Xinjiang Aibi National Wetland Nature Reserve, main entrance (photo by author, 2005).
Abb.23: Nationalpark Aibi-See (Xinjiang), Haupteingang.
图例 23:新疆艾比湖湿地自然保护区.

To protect the reserve against wind erosion, 234.4 hectars of trees were planted in the western area outside of the borders of the reserve. The forestry administration of the local government was taking care of these trees.
In order to reduce human impact in this area, the government decided to close farmland of about 1000 km^2 along the southern and western border of the reserve. They think those fields should be returned to forest or grassland. They also decided to emigrate 143 families (678 persons) to other places from this area in the following two years.

Since 2001, the administration of the reserve organized several groups of scientists (mainly from Xinjiang Normal University and Xinjiang University) to investigate the vegetations and the hydrological situation in this area and this work is still in continuation.

According to information from the administration of the reserve, there are still many unsolved problems. In the following years, they plan to achieve the following goals:

1. The lake surface should be increased and kept at about 800 km^2. For this purpose, 267.2×10^6 m^3 additional water should be provided to the lake. The problem how to reach this aim is still on study.
2. As the forest area decreased in the past decades (2.1.1.6), they want to find an effective way to increase the forest area and also the species diversity. (The administration of the reserve was hoping that some scientific guidelines for the forest development in this region could be given after this study).
3. A re-establishment of the shelter vegetation in order to restore its protective function in this region is imperative. It was suggested that 1000 km^2 of vegetation in this area should be re-established. The administration of the reserve hopes that some research work should be organized and the scientific guidelines for this could be given by different groups of scientists.
4. This area is faced with the growing challenge in recent years for salvaging diminishing endangered wild animals, it included *Testudo horsfieldi* (Horsfield's Tortoise), *Gazella subgutturosa* (Persian Gazelle), *Gypaeus barbatus* (Bearded Vulture), *Ciconia nigra* (Black Stork), *Cygnus Cygnus* (Whooper Swan) and *Grus grus Lifor's* Crane (灰鹤) etc. It is very important to protect these wild animals in this region. The administration of the reserve thought that it is essential to search for methods for animal conservation.
5. The basic establishment and equipment should be improved for the conservation work in the reserve. It includes 11 ranger stations with a total area of 940 m^2 (10 have been finished) and 4 observation towers (2 have been finished). They also want build 4 docks, 20 km fence, dig 20 wells and plant forest shelter belt of about 400 km^2. In long term, they also want to construct a research building of about 1500 m^2 in the reserve.
6. The administration of the reserve found that it is difficult to emigrate the people to other places from this area. They want the government to make a special policy and give financial support for these families.
7. As the whole area of the Aibi reserve is 2,670.85 km^2, the administration of the reserve felt that there are shortage of human power for the conservation work. At this moment, there are 25 officers and 152 workers working in the reserve. They think the officers should be increased to 50, the workers should also be increased.
8. There was an idea that a project should be put into practice to transport the water from Yili river (the other side of Tianshan Mountain) to Aibi Hu region, this project is still in discussion.

The strategy on how to protect the area is currently in progress, the management institute of Aibi Hu National Wetland Nature Reserve also wants to get some suggestions from this study.

2.1.11 Establishment of permanent research plots

The research plots were established in the south-eastern part of the Aibi Hu National Nature Reserve, where the dominant species *P. euphratica* is growing. Location of the first seven plots (A 101, A 111, A 121, A 131, A 141, A 151 and A 102, Fig. 24; Appendix 11, Fig. A-6) were selected along the old river band of Aqikesu River which was dried up at present. These seven plots were selected for the transect of tree growth analysis of *P. euphratica*. Outside of the transect, one additional plot (A 112) was added for the monitoring of the growth situation of *P. euphratica* between forest and desert.
The geographical position of the plots was estimated with eTrex Legend GPS equipment. The measurement was repeated with a Trimble 5700 GPS system in September 2006 (2.2.1).

Each plot was selected with an area of 1 ha (100*100 m). Plot sides were measured to the nearest 0.1 m.
Apart from the eight plots of *P. euphratica*, a special plot (A 201) was adjusted to the complete area on which Aibi Hu Birch is growing. On this plot, all trees were numbered and stand description was made.

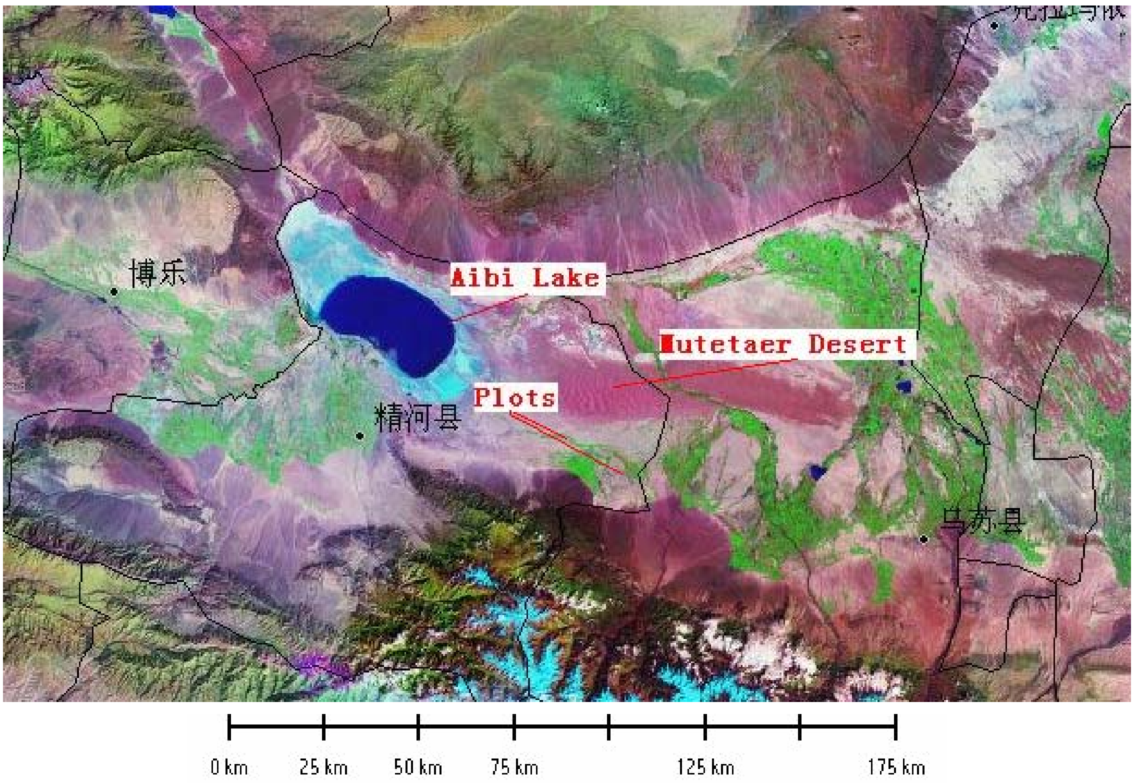


Fig. 24: Location of the research area in Aibi Hu region (source: Aibi Hu National Nature Reserve, P.R. China).
Abb. 24: Lage der Untersuchungsflächen in der Aibi See-Region.
图例 24: 样地在艾比湖地区的位置.

2.2 Data collection

2.2.1 Soil analysis

In the study area, 19 soil samples were collected on the selected plots. Texture and nutrient contents of the soils was analyzed in the laboratory in the College of Life and Environmental Science, Xinjiang Normal University, Xinjiang, P.R. China.
In addition, density (g cm^{-3}), organic matter (%), total N (%) and available phosphor (mg kg^{-1}) were measured.

Table 12: Geographic coordinates where the soil samples were taken.
XJCN*: Soil samples analyzed in Xinjiang Normal University. BGM**: Soil samples analyzed by Berliner Gasanlagen Messtechnik (BEGATEC).
Tab. 12: Geografische Koordinaten der Bodenproben-Entnahmestellen.
图表 12: 艾比湖研究区域土壤样品采集点地理位置.

Soil Sample 样品编号	Latitude 纬度	Longitude 经度	Altitude 海拔高度[m]	Date 采样日期
No.12-01XJCN*	N43°36′45.78″	E83°39′0.36″	318	09/06
No.12-02 XJCN	N44°36′40.5″	E83°33′43.98″	295	09/06
No.12-03 XJCN	N44°36′41.28″	E83°35′48.95″	299	09/06
No.12-04 XJCN	N44°34′54.96″	E83°43′6.06″	337	09/06
No.12-05 XJCN	N44°36′38.16″	E83°33′44.88″	295	09/06
No.12-06 XJCN	N44°36′42.3″	E83°33′46.98″	296	09/06
No.12-07 XJCN	N44°36′51.84″	E83°37′40.86″	316	09/06
No.12-08 XJCN	N44°37′4.68″	E83°33′49.86″	283	09/06
No.12-09 XJCN	N44°36′8.34″	E83°40′41.28″	317	09/06
No.21-01BGM**	N44°34′8.1″	E83°44′27.18″	245	06/06
No.21-02 BGM	N44°34′20.28″	E83°44′30.54″	246	06/06
No.21-03 BGM	N44°37′4.8″	E83°33′51.06″	289	06/06
No.21-04 BGM	N44°36′1.56″	E83°43′53.28″	269	06/06
No.22-05 BGM	N44°36′42.5″	E83°38′59.4″	284	09/06
No.22-06 BGM	N44°36′44.1″	E83°39′1.5″	284	09/06
No.21-07 BGM	N44°34′20.28″	E83°44′30.54″	346	06/06
No.21-08 BGM	N44°37′48″	E83°33′51.06″	289	06/06
No.21-09 BGM	N44°36′1.56″	E83°43′53.28″	369	06/06
No.22-10 BGM	N44°36′42.5″	E83°38′59.4″	284	06/06

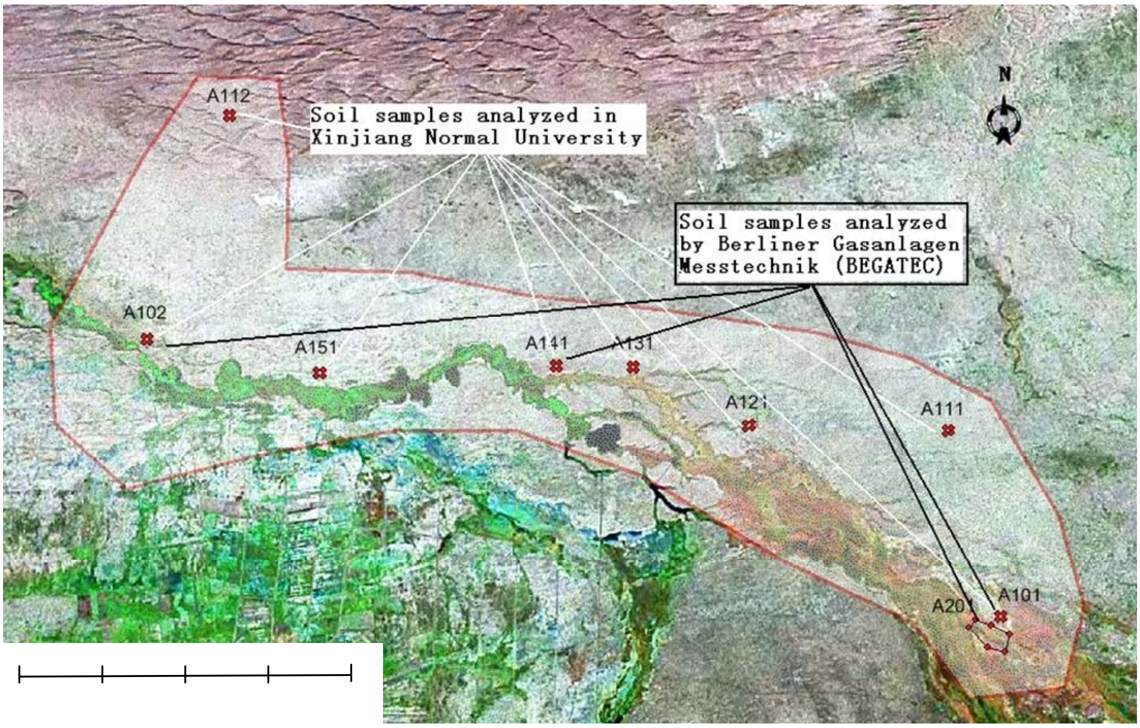


Fig. 25: Locations where the soil samples were taken.

Abb. 25: Lageplan der Bodenproben-Entnahmestellen.

图例 25: 土壤样本采集点位置.

On plots A 101, A 111, A 102 and A 201 soil samples were taken from the layer and 10 cm below surface. Samples were transported to Technical University of Berlin and they were analyzed by Berliner Gasanlagen Messtechnik (BEGATEC).

The following characteristics were analyzed:

Nitrate (DIN EN ISO 10304-1, mg kg^{-1}), phosphate (DIN EN ISO 10304-1, $mgkg^{-1}$), ammonium (DIN 38406-E5, mg kg^{-1}) and chloride (DIN EN ISO 10304-1, mg kg^{-1}) were analyzed photometrically; the pH-value (DIN 38404-C5) of the soil samples were measured with a pH-electrode in water; the percentage of total organic carbon (TOC, DIN EN 1484, %) was analyzed with an infrared analyzer; sulfate (DIN EN ISO 11885, %), sodium (DIN EN ISO 11885, %), potassium (DIN EN ISO 11885, %) and calcium (DIN EN ISO 11885, %) were analyzed with inductively coupled plasma spectrometry (Appendix 4 Table A4-1).

After the data analysis in 2006, it was found that a detailed analysis was needed for this study. In May 2007, soil samples were taken again from the surface layer, 10 cm below and 60 cm below the surface on all the eight *P. euphratica* plots and density (g cm^{-3}), pH-value, salt content (ppt), total organic matter (%) and conductivity (ms cm^{-1}) were measured (Appendix 4 Table A4-2).

2.2.2 Microclimate

In order to get the microclimate data in the study site, two automatic weather stations (DAVIS VANTAGE PRO) were set up at the beginning of the growing season 2006.

The first station was set up on the plot A 201 where the Aibi Hu Birch is growing, the second station was set up near the plot A 102.

Table 13: Geographic coordinates of the weather stations in the study area.
Tab. 13: Geografische Koordinaten der Mikroklima-Stationen.
图表 13: 艾比湖研究区域的自动气象站地理位置.

Weather Station 站点编号	Location 站点位置	Latitude 纬度	Longitude 经度	Altitude 海拔高度	Start Date 建站日期
No. 1: HSL	A 201	N44°34′9.7″	E83°44′30.6″	355m	11/05/06
No. 2: DDQ	A 102	N44°37′1.4″	E83°33′53″	280m	24/05/06

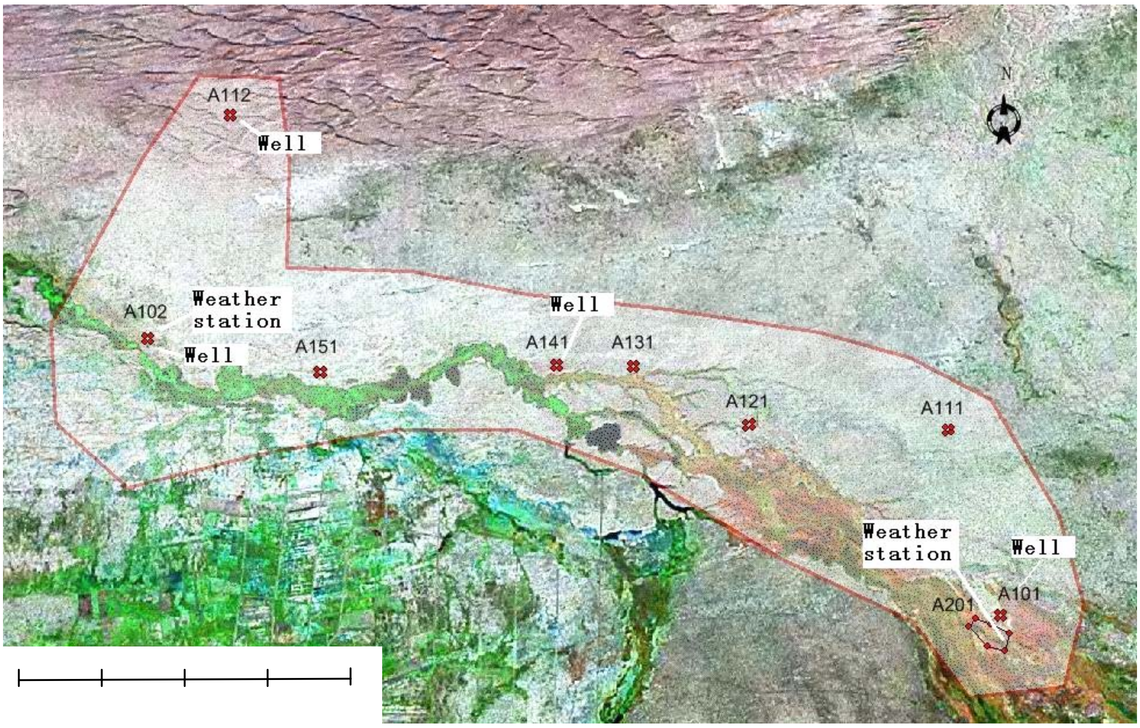


Fig. 26: Geographic coordinates of the weather stations and the wells to measure the ground water level.
Abb. 26: Lage der Mikroklima-Stationen und der Grundwasser-Pegelbrunnen.
图例 26: 气象站及用于观测地下水位的水井地理位置.

The following climate information was collected automatically by the equipments once an hour during the growing season 2006: Temperature, humidity, wind speed, wind direction, heat index, rain fall, rain rate, solar energy and solar radiation.
Microclimate data was analyzed with the Weatherlink Software (Weatherlink for Vantage Pro) provided by the Institute of Desert Meteorology, CMA, Urumqi, Xinjiang, P.R. China.
The microclimate data are used to get the average value of temperature and precipitation and it was also used to contribute to the final evaluations.
This work was done together with co-workers from the Institute of Desert Meteorology, CMA, Urumqi, Xinjiang, P.R. China.

Fig. 27: An automatic weather station was set up near plot A 102 (Dong Da Qiao Station; photo by author, 2006).
Abb.27: Automatische Mikroklima-Station in der Nähe der Untersuchungsfläche A 102.
图例 27: 建在 A 102 样的地自动气象站.

2.2.3 Ground water level

In order to find out the influence of ground water level on tree growth in the study area, this parameter was measured in the selected plots.
On plot A 102, the existing well in the Dong Da Qiao Station of the Nature Reserve was used to measure the ground water level. On the plots A 101 and A 141, two wells were dug for this purpose. One was established in May 2006 and the other in August 2006.
Ground water level was measured every two weeks in the growing season 2006. In May 2007, for the measurement of the ground water near to the desert, another well was dug on plot A 112. Ground water level was measured every two weeks together with the other three wells during the growth season 2007. In this measurement, the accuracy was < 0.01 m.

Table 14: Geographical coordinates of the wells for measuring the ground water level.
Tab. 14: Geografische Koordinaten der Brunnen für die Messung des Grundwasserstandes.
图表 14: 用于观测地下水位的水井地理位置.

Well 编号	Location 站点位置	Latitude 纬度	Longitude 经度	Altitude 海拔高度[m]
No. 1	A 101	N44°34′9.7″	E83°44′30.6″	346
No. 2	A 102	N44°36′1.4″	E83°33′53″	289
No. 3	A 141	N44°36′42.6″	E83°38′57.9″	312
No.4	A 112	N44°39′0.5″	E83°35′0.1″	288

Fig. 28: The new well used for measuring the ground water level (plot A 141; photo by author, 2006).
Abb.28: Neuer Brunnen für die Messung des Grundwasserstandes (plot A 141).
图例 28: 位于 A 141 样地的用于观测地下水位的水井.

2.2.4 Criteria of the plots

On the selected eight *P. euphratica* plots and one Aibi Hu Birch plot (A 201), the following data were collected (modified procedure of Kleinschmit et al., 2005):

Geographical position: XY-coordinates of the corner-posts of the plots were estimated with GPS systems. This work was done in May 2006 using an eTrex Legend GPS equipment with an accuracy of <1 m. The measurement was repeated in September 2006 with a Trimble 5700 GPS with an accuracy of <0.1 m. Corner points of each plot were marked with cement posts embedded in the soil.

Altitude (a.s.l): The altitude of the plots were estimated and recorded to the nearest 5 metres above sea level with an eTrex Legend GPS equipment.

Slope: The angle of slope was measured with a clinometer and it was recorded to one degree. For the plots on which the slope is irregular, the limits of slope angle was recorded.

Surface form: The surface form classified and recorded as slightly or strongly convex or concave level, and as even or irregular.

Topography: The topography of the plots was recorded as P (plateau), S (slope), D (depression, drought river bed), V (valley, meadow) and H (hill, dune).

Stand description: This parameter was recorded as: Open stand (10, canopy is not closed, clear distance between the crowns of neighbour trees); Clustered (20, trees are mainly clustered in groups up to five trees, within the clusters the canopy is closed); Bands of trees (30, trees are mainly clustered to linear bands, within the clusters the canopy is closed); Clustered (40, in groups >5, trees are mainly clustered in groups of more than five trees, within the clusters the canopy is closed); Closed stand (50, the trees form more or less a closed canopy).

Density: Crown coverage was classified as: 1 Distance between crowns >= two times crown width; 2 Distance between crowns < two times crown width, but > crown width; 3 Distance between crowns < crown width; 4 Crowns are partly connected; 5 Closed canopy with small gaps.
Saplings of major tree species: Living saplings (< 3.5 cm) of the major tree species was counted.
Numbered and dated photos of each plot were taken and recorded (Appendix 12 Fig. 8: QuickBird images of the eight *Populus euphratica* permanent research plots).

2.2.5 Tree parameters

On the selected *P. euphratica* plots, all trees were numbered and X-Y-coordinates of each tree were determined. Tree height and diameters at the breast height (DBH) were measured in May and September 2006. The same measurement were repeated in May and September 2007.
During the first measurement campaign in May 2006, the following tree parameters were collected:
Tree number: Each tree was numbered and printed with a permanent mark.
XY-coordinates: XY-coordinates of each tree was estimated with an eTrex Legend GPS equipment with an accuracy of < 1 m in the first measurement campaign in May 2006. In September 2006, this measurement was checked with a Trimble 5700 GPS equipment with an accuracy of < 0.1 m on selected trees.
Height: Heights of all the individuals with the diameter (DBH) larger than 3.5 cm were measured with a classical clinometer having an accuracy of < 0.1 m in May 2006. The measurement was taken from the opposite sides of each individual. This measurement was repeated again with a laser dendrometer (MDL, Laser Ace 300) in September 2006. In May and September 2007, the measurement was repeated with a classical clinometer. The accuracy of the measurement was checked by repeating one measurement three times in May 2007. As the crown forms of this species in this region were very irregular, sometimes it was difficult to measure the height very correctly. Although the instrument has the accuracy of < 0.1 m, in the measurement on *P. euphratica* the accuracy was < 0.5 m (4.1). In the measurement on Aibi Hu Birch, the accuracy was < 0.2 m.
Diameter (Diameter at Breast Height, DBH): All trees with the diameter (DBH) larger than 3.5 cm on the transect plots were marked with a permanent marker at the breast height (1.3 m). Diameters (DBH) were measured with girth bands with the accuracy of 0.01 cm in May and September 2006. The measurement was repeated again in May and September 2007. The accuracy of the measurement was checked by repeating one measurement three times in May 2007. Although the girth bands we used have an accuracy of 0.01 cm, because of the rough bark of the trunk, it was very easy to have an error of 1 cm. In the measurement, an accuracy of < 1 cm was found (4.1). In the measurement of Aibi Hu Birch, an accuracy of < 0.5 cm was reached.
On plot A 101 and A 102, 10 individuals of *P. euphratica* stems were selected according to the diameter and the respective height distribution. Diameters (DBH) were measured with girth bands every two weeks during the growing season 2006. In May 2007, the

areas where those 20 individuals are growing were surrounded by fences and they were girdled with permanent girth bands at 1.3 m above ground. Reading of the girth bands were taken every two weeks during the growing season 2007. The accuracy of this measurement was < 0.01 cm.
Special protocols for bending trees, trees with multi-stems, trees with swelling at 1.3 m, forked trees and trees on slopes are written in Appendix 6: Protocol for forest and tree data acquisition.
Crown width: Crown width was measured two times with an accuracy of 0.1 m in May and September 2006. The position of the stem was recorded.
Stem form: Stem forms were classified as 10: Trees with single trunk; 20: Forked trees; 21: Forked trees with one or more dead trunks; 22: Forked trees with all trunks being dead.
Crown form: Crown forms were classified as 1: No secondary crown; 2: Shoot growth starts to form a secondary crown; 3: Secondary crown dominates; 4 Primary crown is dead.
Leaf loss: Leaf loss was estimated according to the percentage of a full leaved tree. It was classified as <10 %, <20 % ... <80 % or > 80 %.
Crown damage: Crown damage was classified as 10: Regular leaf or branch loss in the whole crown; 11: Leaf or branch loss mainly in the inner crown, outer crown is apparently more vital; 12: Leaf or branch loss mainly in the outer crown, inner crown is apparently more vital; 13: Irregular loss of leaves or branches; 14: Leaf or branch loss mainly in the upper crown; 21: Upper crown is dead; 22: Main branches are dead; 31: Apparently no vitality; 32: Parts of a dead tree are visible.
Stem lean: Stem lean was classified as 1: straight (0 - 13°), 2: medium to heavy lean (13 - 45°) and 3: extreme lean (> 45°).
A detailed protocol for data acquisition is shown in Appendix 15: Protocol for forest and tree data acquisition.
In May 2006, on plot A 201 where the endemic birch Aibi Hu Birch is growing, all trees were numbered and X-Y-coordinates of each individual was determined with an eTrex Legend GPS equipment having an accuracy of < 1 m.
Heights of all the individuals were measured with a classical clinometer having an accuracy of 0.1 m. The measurement was taken from the opposite sides of each individual. The accuracy of the measurement was checked with a laser dendrometer (MDL, Laser Ace 300) in September 2006.
The stem diameters of all the individuals were measured at the height of 1.0 m above ground in May 2006. For the measurement of trees with the diameter less than 6 cm, a vernier calliper with an accuracy of < 0.01 mm was used. For the measurement of the trees with the diameter larger than 6 cm, a girdled band with the accuracy of < 0.1 mm was used.
In this plot, 37 individuals (10% of the total number, plot A 201) were selected and wood samples were taken from 14 individuals. Annual ring width was measured in the laboratory of Deutsches Archäologisches Institut (DAI), Zentrale Berlin.

2.2.6 Harvest

In August 2007, three example medium sized trees were harvested in the study site. The trees were selected according to their growth status. Tree No. 1 and No. 3 were chosen to represent the trees which were growing well. Tree No. 3 represented the trees with poor growth performance.

Table 15: Location of the three harvested trees.
Tab. 15: Lage der geernteten Bäume.
图表 15: 标准木地理位置.

Number 编号	Latitude N 纬度	Longitude E 经度	Altitude 海拔高度 [m]
No.1	N44°37′09.26″	E83°33′39.28″	292
No.2	N44°37′10.27″	E83°33′41.44″	293
No.3	N44°37′11.46″	E83°33′43.74″	293

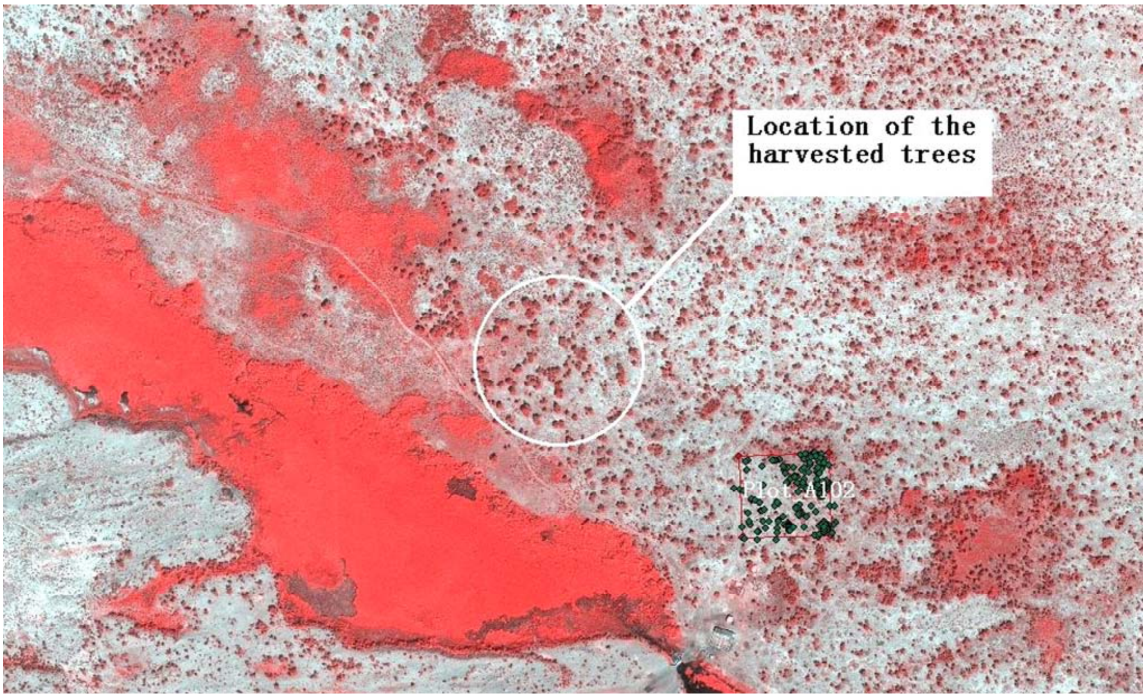


Fig. 29: Location of the three harvested trees.
Abb.29: Lage der geernteten Bäume.
图例 29: 标准木地理位置.

After the measurement of the tree parameters, the selected trees were cut down. Leaves were collected and dried in the open dry air. Leaf areas were measured by a small programme developed for this study (2.2.2.3). The dried leaves were transported to Urumqi and were weighed in the laboratory of the Xinjiang Forestry School in Urumqi.
Wood from the felled trees was separated to stem, living branches and dead branches. They were cut to small parts and were put to the open air to let them dry by nature. Three months later, when the wood became completely dry, they were weighed using a balance

with an accuracy of < 0.01 kg.
Biomass of the three harvested trees was used to correct the coefficient to get the formula that connects the height, DBH and wood volume based on the formula of the silimar species (Pappel, Robusta, result from Degenhardt A., 2001).

2.2.7 Wood samples for tree ring analysis

Wood samples were taken at breast height with conventional corers on A 101, A 102, A 111 and A 131 on *P. euphratica* trees. On each plot, 15 trees were selected and two samples were taken from two different directions on each tree.
In addition, 37 of the endemic birth Aibi Hu Birch (plot A 201) individuals were selected (about 10 percent of the whole living individuals) and one wood sample was taken from each tree at 1.0 m height.

Fig. 30: Wood samples were taken on a selected plot (photo by author, 2005).
Abb.30: Stammholz-Bohrkern-Entnahmestelle.
图例 30:在观测样进行年轮采样.

The cores were fixed in paper roles and were transported to TU-Berlin. There they were pressed in 6 mm micro channels and then sanded with paper up to a grain of 400. The measurements were performed at a work-station of the dendrochronological laboratory of the German Archaeological Institute in Berlin (Deutsches Archäologisches Institut, DAI). Annual ring width of each sample was measured and ages of the trees were determined by counting the growth rings under a stereo-microscope (magnification 80x to 500x, Zeiss, Germany).

2.3 Data analysis

2.3.1 Statistical analysis

Microsoft Excel was used for the statistical analysis of the data collected for this study.
In statistical calculations, heights and diameters of the individuals were subdivided into classes (3.5). In the displaying of height and DBH distribution, Box-and-Whisker plots were used. This method provides the median and 50% of the height and DBH in boxes. On both side of the boxes the range of the lower and the upper 25% of the data values are shown (Roger M. et al., 2003).
To describe the difference between stem numbers of the stands on the different plots, same height and diameter class width and same x-axis and y-axis scaling were used in the figures (Appendix 3: Table A3-1 and Table A3-2).
In the analysis of the relations between tree parameters, the linear regressions were calculated and tested first. If the relation could not be represented by a straight line, other nonlinear models were applied.
The results were graphed by means of the programmes provided by Microsoft Visio and Excel. Mean values and standard errors of the data analysis were given. All analyses were performed with MS Windows.

2.3.2 Tree ring analysis

The analysis of the tree rings of *P. euphratica* is generally difficult because of abrupt growth changes and narrow rings. The accuracy of the measurements was first checked by visual assessment. For the further evaluation the digital image software was used.
Mean curves of each tree were used by averaging the two samples from the different directions. Some not well fitting samples were corrected by comparing them with others. After the correction, the curves of the samples fitted very well together.
Age structures were estimated by the limited numbers of samples from plot A 101, A 111 and A 102. Class widths of 50 years were used on the x-axis for age distribution (Fig. 53). On plot A 131, only 3 individuals were still alive, age structure was not estimated.
The data from the same plot were pooled and an average curve for each plot was obtained. It was used to estimate the growth trends on each plot (3.6).

2.3.3 Other analysis

During the harvest, leaf areas were measured by a small programme developed for this study (Luan J., 2007, personal communication). When the leaves were collected, approximately 10% from each tree were chosen at random. They were separated into groups of 15 or 20 pieces according to their size. Each group was scanned immediately after they were collected when they were still wet and the leaf area was not changed. The total area of each group was calculated by a programme developed by the computer department in Xinjiang Normal University.

The average leaf areas of each tree was calculated using the group area with the following formula:

$$ALA = \text{Group area} / \text{number of leaves.}$$

ALA: Average leaf area.

The average leaf weights were calculated using the group weight with the following formula:

$$ALW = \text{Group weight} / \text{number of leaves.}$$

ALW: Average leaf weight.

The average leaf weight was used to calculate the total number of the leaves on a tree:

$$\text{Total number} = \text{Total weight} / ALW.$$

The total leaf area of each tree was calculated using the total numbers and the average leaf areas:

$$\text{Total leaf area} = ALA * \text{total number.}$$

The accuracy of this method was calculated by the measurement of the area of plotting paper (1 * 1 mm). After repeating it three times, the accuracy was calculated. With this method, an accuracy of $< 0.01\ cm^2$ was received.

3 Results

3.1 Soil

The analysis indicated that all the soils in this region showed some degree of salinization. Appendix 4: Table A4-1and Table A4-2 shows the result of the analysis in 2006. Table A4-1 shows the soil quality of some selected points in the Aibi Hu region (provided by Jin et al. 2006); Table A4-2 shows the soil quality of some selected points in the study site (provided by Xinjiang Normal University, PR China).

In Table A16-1, one can find that the sulfate content differed from 16.7% (Plot A 102) to 5.3% (Plot A 141). It also showed that the total organic carbon in the soil varied significantly. In plot A 201-the Aibi Hu Birch plot- which was the former riverbed, the total organic carbon content of the upper soil layer was 18.4%. However, in plot A141, where most of the trees were dead, the amount was only 0.2%.

In July 2007, a detailed analysis was done on all the eight *P. euphratica* plots. Table 15 shows the result of the soil analysis. In this table, one can find that on the plot near to the desert (plot A 112), the salt content was less in the surface (0.5%) than at 10 cm (0.7 %) and 60 cm (1.3%) beneath. On the other 7 plots, the salt content in the surface was much higher than in 60 cm depth. On plot A 131, the salt content of the surface layer amounted to 20.4% whereas at 60 cm depth it was only 0.6%. The salt content in the surface soil on the other plots ranged from 8.4% (plot A 101) to 17.4% (plot A 151).

In the Northeast, about 2 km from plot A 102, there were salt crusts with a depth of 5 cm on the surface.

The result of the soil analysis showed that on all the eight plots, pH values ranged from 8.3 to 9.1 (Table 16-2).

3.2 Climate

Using the microclimate data from the two weather stations on plot A 201 (HSL) and neighbouring plot A 102 (DDQ), monthly and two weeks average values of temperature and monthly precipitation were obtained. The microclimate data were compared with the climate data from Jinghe weather station measured at the same time in 2006.

3.2.1 Temperature

Hua Shu Lin (HSL) station (A 201)

The microclimate data from the weather station on plot A 201 (HSL station) showed that the monthly mean temperature in the season 2006 ranged from 8.4 ^{o}C to 26.2 ^{o}C; the highest temperature was 40.1 ^{o}C (HSL Station, July 31st, 2006, A 201).

Table 16: Soil quality of some selected points in the study site (Analyzed by Berliner Gasanlagen Messtechnik); TOC: total organic carbon.
Tab.16-1: Bodenqualität an einigen ausgewählten Entnahmestellen der Untersuchungsflächen (BEGATEC,Berlin).
图表 16-1: 研究区域土壤样本分析数据 (柏林 BEGATEC 实验室分析结果).

Number 编号	Depth 采样深度	Nitrate 硝酸盐 mg kg^{-1}	Phosphate 磷含量 mg kg^{-1}	Ammonium 氨基盐 mg kg^{-1}	Chloride 氯化物 mg kg^{-1}	pH-value pH-值	TOC 有机质含量 %	Coordinates 坐标	
								纬度 Latitude N	经度 Longitude E
No.21-01BGM* A201	10 cm	943	25.4	8.5	119	8.4	18.4	N44°34′8.1″	E83°44′27.18″
No.21-02BGM A101	10 cm	326	19.3	2.4	3550	8.9	1.4	N44°34′20.28″	E83°44′30.54″
No.21-03BGM A102	10 cm	133	3.4	1.6	388	8.6	0.4	N44°37′4.8″	E83°33′51.06″
No.21-04 BGM A111	10 cm	30	10.2	1.6	1094	8.8	0.3	N44°36′1.56″	E83°43′53.28″
No.22-05 BGM A141	10 cm	1.3	16.6	1.5	23000	8.7	0.4	N44°36′42.5″	E83°38′59.4″
No.22-06 BGM A141	1.3 m	0.2	16.7	6.3	78	8.9	0.2	N44°36′44.1″	E83°39′1.5″

Number 编号	Depth 采样深度	Sulfate 硫酸盐 %	Sodium 钠含量 %	Potassium 钾含量 %	Calcium 钙含量 %	Carbonate 碳酸盐 %	Chloride 氯化物 %	Coordinates 坐标	
								纬度 Latitude N	经度 Longitude E
No.21- 07 BGM A101	Surface	9.8	4.3	0.25	5.4	0.3		N44°34′20.28″	E83°44′30.54″
No.21-08 BGM A102	Surface	16.70	12.10	0.20	3.40	0.30		N44°37′4.8″	E83°33′51.06″
No.21-09 BGM A111	Surface	11.4	3.9	0.24	4.9	<0.1		N44°36′1.56″	E83°43′53.28″
No.22-10 BGM A141	Surface	5.3	2.3				3.8	N44°36′42.5″	E83°38′59.4″

Table 16-2: Soil quality of the selected points in the study site (July, 2007); TOC: total organic carbon.
Tab. 16-2: Bodenqualität an einigen ausgewählten Entnahmestellen der Untersuchungsflächen (July, 2007).
图表 16-2:样地土壤测试结果(2007,07).

Number 编号	Depth 采样深度 cm	Density 密度 g cm^{-3}	pH-value pH-值	Salt Content 盐度 ppt	TOC 有机质含量%	Conductivity 电导率 ms cm^{-1}	Coordinates 坐标	
							纬度 Latitude N	经度 Longitude E
No.13-01XJCN A 101	Surface	1.29	8.78	8.4	3.6	17.5	N44°34′20.1″	E83°43′30.5″
	10	3.04	8.77	5.3	1.9	9.9		
	60	2.89	8.89	1.3	0.4	2.6		
No.13-02XJCN A 111	Surface	3.05	9.03	16.2	2.5	31.9	N44°36′1.3″	E83°43′55.1″
	10	2.90	8.88	4.0	1.1	7.6		
	60	2.93	8.66	3.6	0.3	6.9		
No.13-03XJCN A 121	Surface	3.01	8.89	16.8	1.9	33.2	N44°36′7.2″	E83°41′22.2″
	10	2.96	8.84	5.5	2.2	10.2		
	60	2.86	8.79	2.3	0.7	4.5		
No.13-04XJCN A 131	Surface	3.27	8.58	20.4	0.9	38.9	N44°36′41.0″	E83°39′59.0″
	10	2.83	8.72	5.6	0.5	10.4		
	60	2.78	8.75	0.6	0.3	13.2		
No.13-05XJCN A 141	Surface	2.94	8.76	11.9	0.7	24.1	N44°36′44.2″	E83°39′1.4″
	10	2.85	8.73	3.7	0.5	7.0		
	60	2.83	8.76	0.1	0.3	2.6		
No.13-06XJCN A 151	Surface	3.13	9.11	17.4	1.0	33.2	N44°36′44.0″	E83°36′0.7″
	10	2.97	8.84	4.1	0.9	7.8		
	60	2.85	8.72	2.8	0.4	5.5		
No.13-07XJCN A 102	Surface	3.07	8.97	14.9	1.4	29.0	N44°37′5.1″	E83°33′50.3″
	10	2.96	8.89	14.4	1.3	27.7		
	60	2.94	8.81	4.8	0.8	9.1		
No.13-08XJCN A 112	Surface	2.85	8.38	0.5	0.2	10.7	N44°39′7.3″	E83°34′59.9″
	10	2.85	8.72	0.7	0.3	15.5		
	60	2.89	8.67	1.3	0.2	2.6		

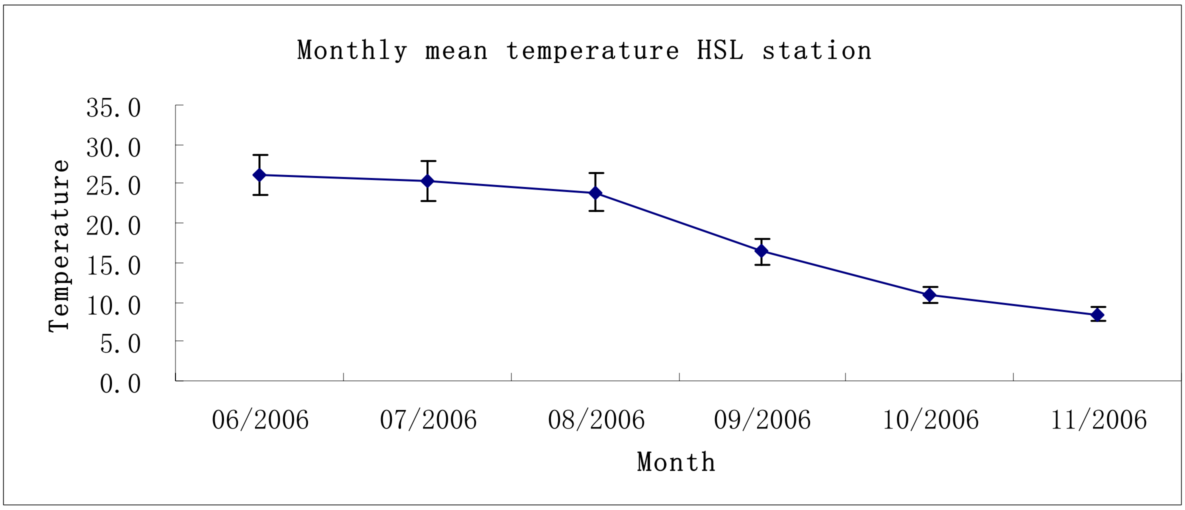


Fig. 31: Monthly mean temperature at Hua Shu Lin（HSL, A 201）station in the season 2006.
Abb. 31: Monatsmittel der Temperatur auf der Monitoringfläche A 201 in der Vegetationsperiode 2006.
图例 31: 建于桦树林气象站观测到的 2006 年生长期气温月平均值变化情况.

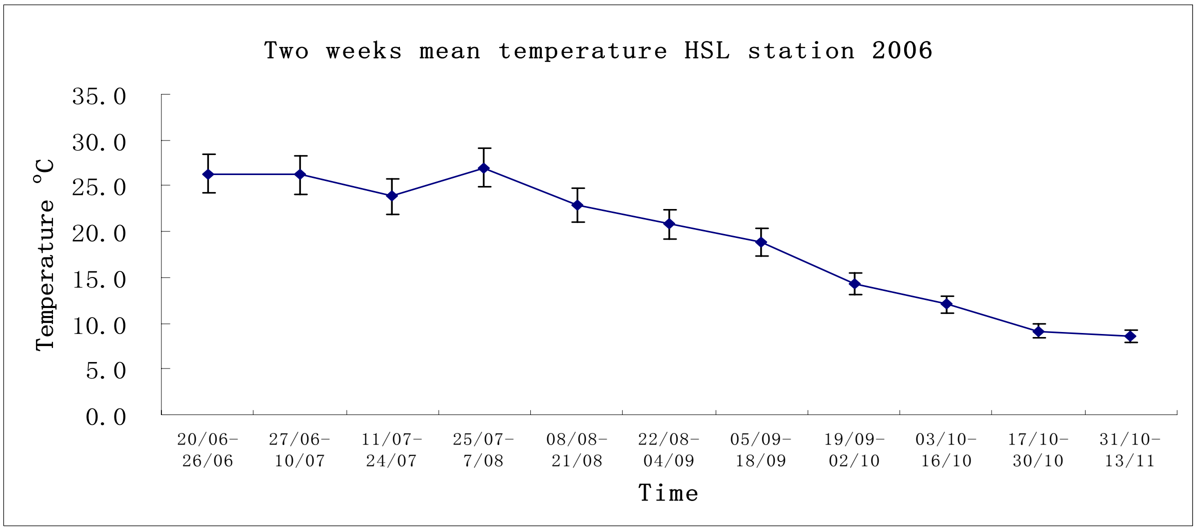


Fig. 32: Two weeks mean temperature at Hua Shu Lin（HSL, A 201）station in the growing season 2006.
Abb. 32: Zwei-Wochen-Mittelwerte der Temperatur auf der Monitoringfläche A 201.
图例 32: 建于桦树林气象站观测到的 2006 年生长期气温每两周平均值变化情况.

Dong Da Qiao (DDQ) station (A 102)

The microclimate data from the Dong Da Qiao station near plot A 102 (DDQ station) showed that the monthly mean temperature in the season 2006 ranged from 8.2 ^{o}C to 26.9 ^{o}C; the maximum temperature was 40.3 ^{o}C (DDQ Station, July 31st, 2006).

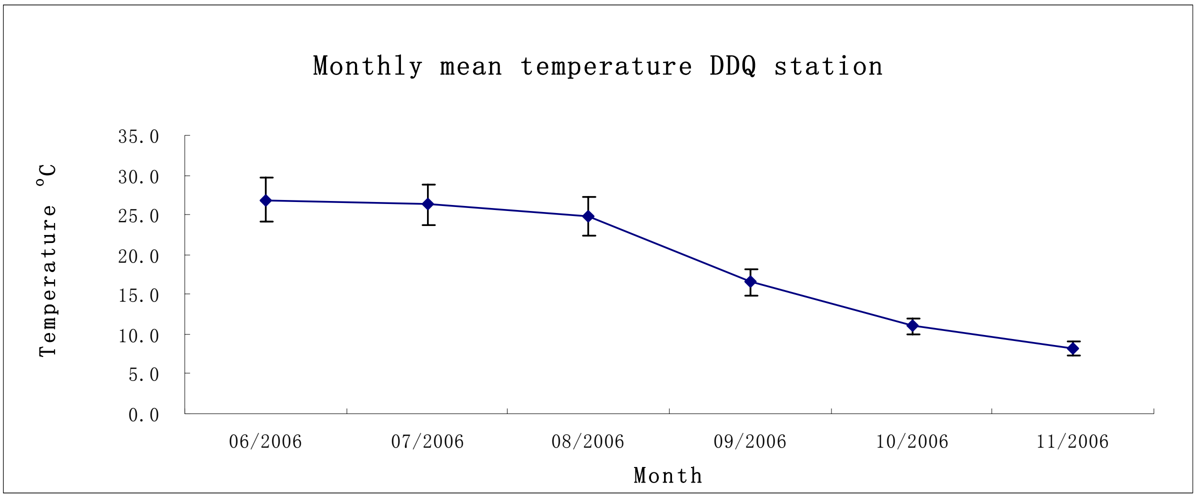


Fig. 33: Monthly mean temperature near A 102 (Dong Da Qiao, DDQ）station in the growing season 2006.

Abb. 33: Monatsmittelwerte der Temperatur nahe der Monitoringfläche A 102 in der Vegetationsperiode 2006.

图例 33: 建于东大桥气象站观测到的 2006 年生长期气温月平均值变化情况.

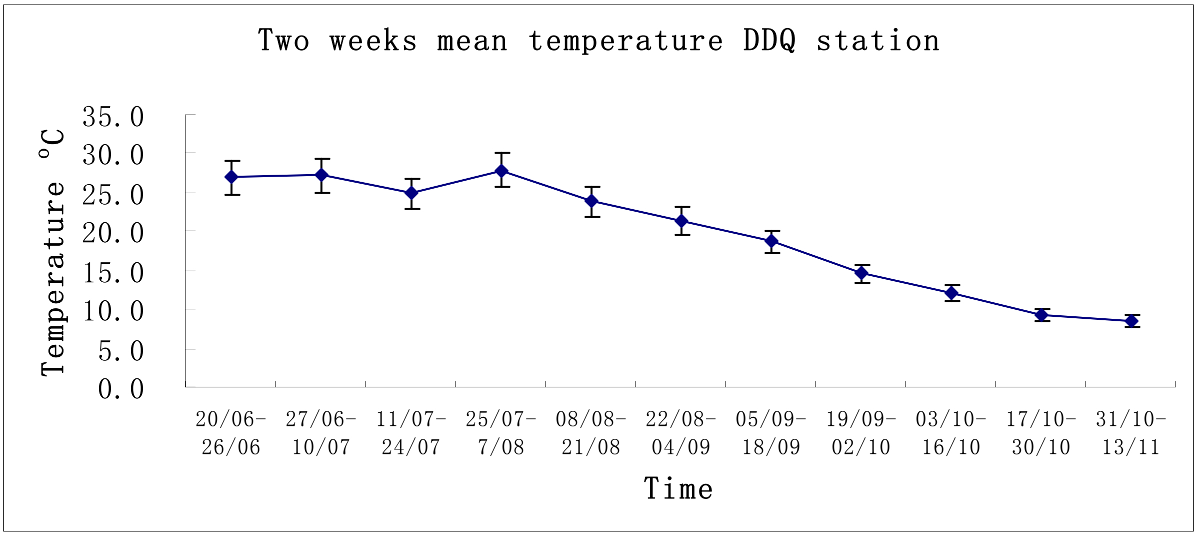


Fig. 34: Two weeks mean temperature at Dong Da Qiao（A 102, DDQ）station in the growing season 2006.

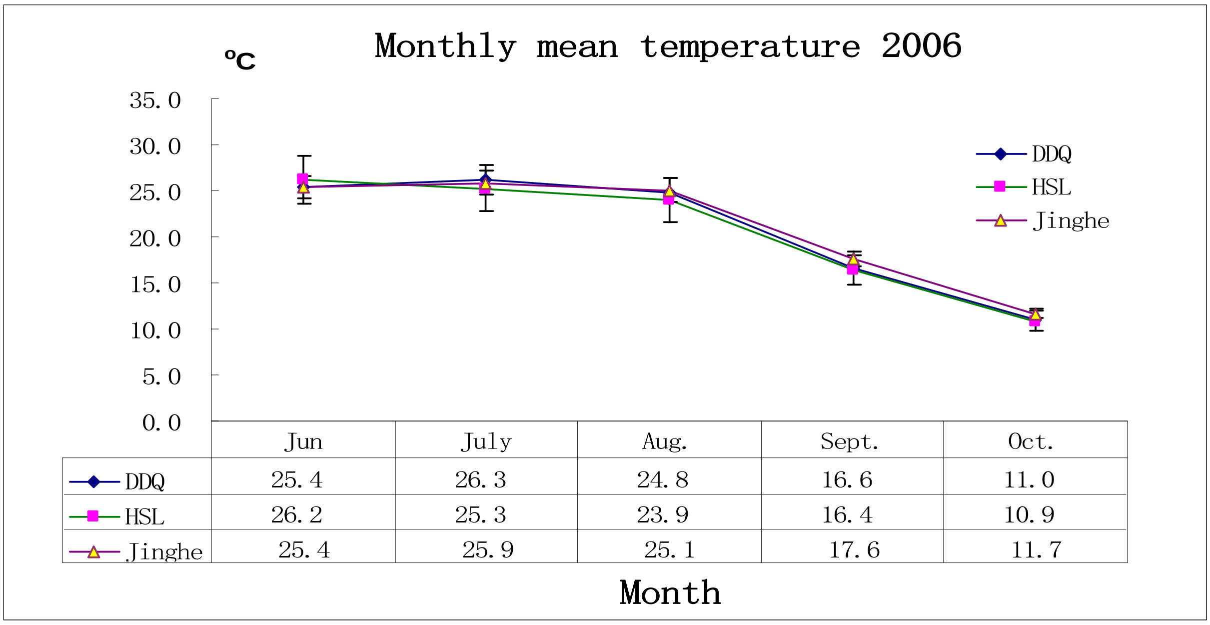
Abb.34: Zwei-Wochen-Mittelwerte der Temperatur nahe der Monitoringfläche A 102 in der Vegetationsperiode 2006.

图例 34: 建于东大桥气象站观测到的 2006 年生长期气温每两周平均值变化情况.

Comparison of monthly mean temperatures

The monthly average temperature of the study site (HSL and DDQ station) was compared with the data from Jinghe weather station. In Fig. 35 one can find that the average temperature in the study site was almost the same as at Jinghe weather station.

The analysis showed that the monthly mean temperature of the microclimate station in the study site during the season 2006 was not obviously different from the monthly mean temperatures in the last 45 (1961 - 2006) years. This indicated that the mean temperature has not changed notably during the last 45 years.



	Jun	July	Aug.	Sept.	Oct.
DDQ	25. 4	26. 3	24. 8	16. 6	11. 0
HSL	26. 2	25. 3	23. 9	16. 4	10. 9
Jinghe	25. 4	25. 9	25. 1	17. 6	11. 7

Fig. 35: Monthly mean temperature at the two weather stations in the study area and the data from Jinghe weather station in the growing season 2006.

Abb. 35: Monatsmittel der Temperatur auf der Monitoringfläche A 201, A 102 und an der Jinghe Station in der Vegetationsperiode 2006.

图例 35: 建于观测样地的两个气象站观测到的 2006 年生长期气温月平均值变化情况与精河气象站数据比较.

3.2.2 Precipitation

Monthly precipitation in the study area (DDQ station, A 102) was compared with the data from Jinghe weather station. In Fig. 36, one can find that there was no obvious difference.

The monthly mean precipitation from the microclimate station in the study site (DDQ station, A 102) during the growing season 2006 was not obviously different from the monthly mean precipitation in the last 45 (1961 - 2006) years. This indicated that the mean precipitation has not changed notably during the last 45 years.

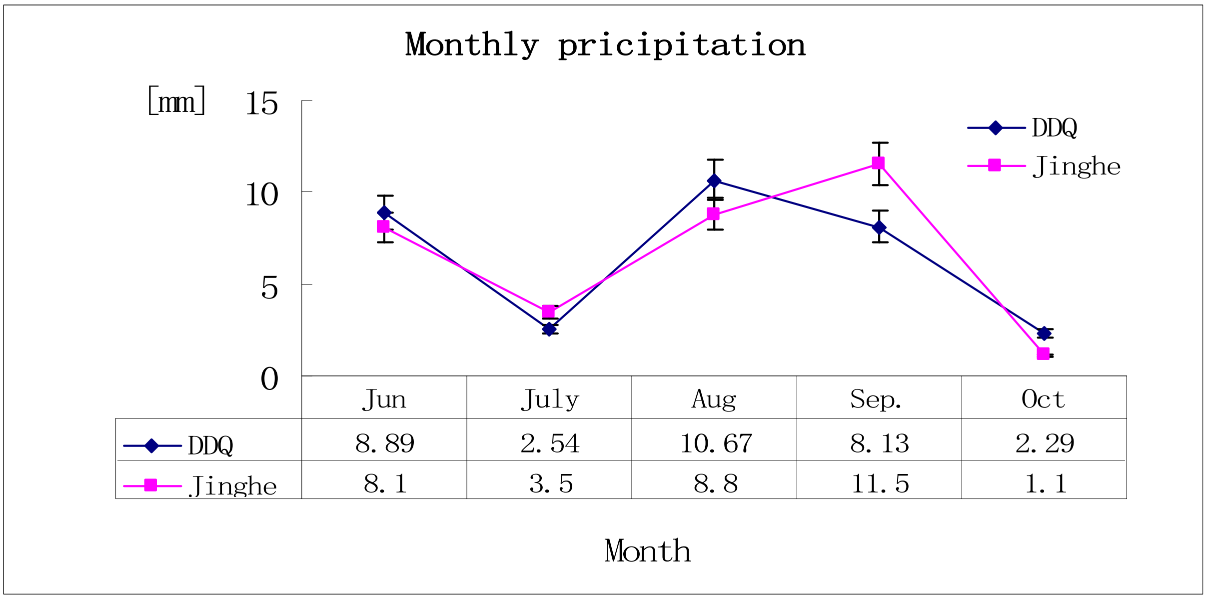


Fig. 36: Comparison of the monthly rainfall at DDQ station (A 102) and at Jinghe weather station in the growing season 2006.

Abb. 36: Monatlichen Niederschlag an den DDQ Mikroklima-Station (A 102) und der Jinghe-Station in der Vegetationsperiode 2006.

图例 36: 观测样 DDQ 气象站观测到的 2006 年生长期降雨量与精河气象站同期数据比较.

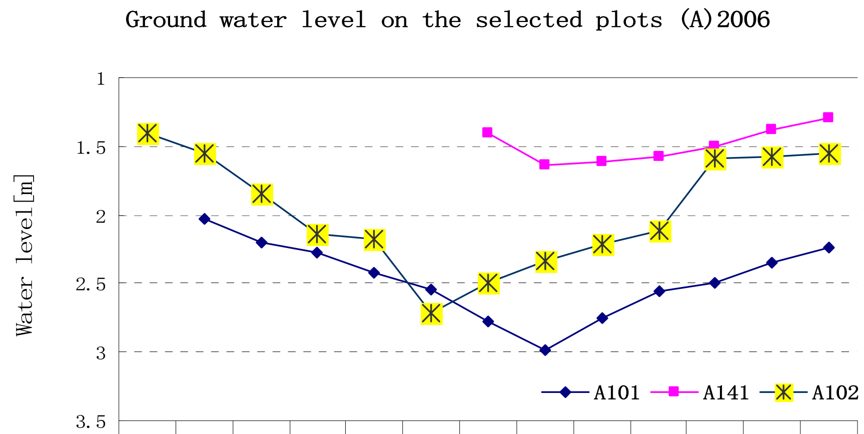
3.3 Ground water level

The data of the every two weeks ground water level measurement in the growing season 2006 and 2007 showed that on all the selected plots, the ground water level was higher than 3 m (Fig. 37).

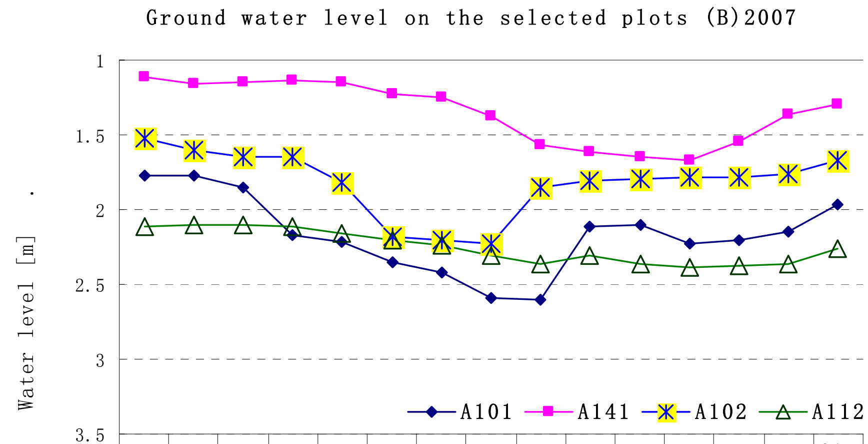
In the season 2006, the water level varied between 2.03 m and 2.98 m on plot A 101. On plot A 141, it was between 1.29 m and 1.64 m. On plot A 102, the water level was between 1.4 m and 2.71 m. The data also showed that the lowest water level occured in the hottest phase of the season in July and August.

The data of 2007 showed that there was no obvious change of the groundwater level compared to 2006. On plot A 101, the water level was between 1.77 m and 2.59 m. On plot A 141, it fluctuated between 1.11 m and 1.67 m. On plot A 102, the water level was between 1.52 m and 2.23 m. On plot A 112, which is near to the desert, the water level varied between 2.10 m and 2.39 m. There was not obvious difference during the whole season on this plot.

As in 2006, the data also showed that the lowest water level occured in the hottest phase of the season in July and August in 2007. The measurement showed that the summer depression occured comparatively later on plot A 141 than on the other plots (Fig. 37).



	9-May	30-May	13-Jun	27-Jun	11-Jul	25-Jul	8-Aug	22-Aug	5-Sep	19-Sep	Oct. 03	Oct. 17	Oct. 31
A101		2.03	2.2	2.28	2.42	2.55	2.78	2.98	2.75	2.56	2.49	2.35	2.24
A141							1.4	1.64	1.61	1.57	1.5	1.38	1.29
A102	1.4	1.55	1.85	2.14	2.18	2.71	2.5	2.34	2.21	2.11	1.59	1.57	1.55



	25-Apr	9-May	23-May	30-May	13-Jun	27-Jun	11-Jul	25-Jul	8-Aug	22-Aug	5-Sep	19-Sep	3-Oct	17-Oct	31-Oct.
A101	1.77	1.77	1.85	2.17	2.22	2.35	2.42	2.59	2.6	2.11	2.1	2.23	2.2	2.15	1.97
A141	1.11	1.16	1.15	1.14	1.15	1.23	1.25	1.38	1.57	1.61	1.65	1.67	1.55	1.36	1.29
A102	1.52	1.6	1.65	1.65	1.82	2.18	2.2	2.23	1.85	1.81	1.79	1.78	1.78	1.76	1.67
A112	2.11	2.1	2.1	2.11	2.16	2.2	2.24	2.31	2.36	2.31	2.36	2.39	2.38	2.36	2.26

Fig. 37 (A) (B): Ground water level on the selected plots in 2006 (A: May 9th, 2006 - Oct. 31st, 2006; B: May 9th, 2007 - Oct.31st, 2007).

Abb. 37 (A) (B): Grundwasserstand an den ausgewählten Untersuchungsflächen, 2006 und 2007.

图例 37 (A) (B): 2006 年 2007 年监测区样地地下水位变化情况.

3.4 Criteria of the plots

On the eight selected *P. euphratica* plots, the number of living trees differed considerably. The highest number of stems occurred on plot A 102 with 185 living individuals. The lowest number was found on plot A 131 and A 141, where a huge percentage of trees had died. On A 131, only three living stems were found. On A 141, the number of living stems was four in 2006. In 2007, one was dead. There were three living stems left (Fig. 38).

Table 17 shows the basic information about these eight permanent plots. In this table, one can find that the slope angles of all the plots were smaller than 5^o. The surface forms of all the plots along the old river bank (A 101-A 102) were slightly concave. On plot A 112 which was close to the desert, the surface form was irregular because of the sand movement by wind forming dunes.

Vegetation species on the plots were very simple, apart from *P. euphratica* and very few arid woody plants like *Tamarix spec.,* it was difficult to find other arboreous plants. This area was in a process of desertification.

Appendix 12 shows the QuickBird images of the eight permanent *Populus euphratica* research plots.

Table 17: Basic information about the permanent research plots.

Tab. 17: Allgemeine Angaben zu den Monitoringflächen.

图表 17: 监测样地基本数据.

Number 编号	Plot 样地	Altitude 海拔高度[m]	Slope 坡度	Surface form 地表结构	Major tree species 树种	Area 面积	Number of trees 立木株数	Number of dead trees 死亡株数
1	A 101	346	< 5°	Level	*Populus euphratica*	1 ha	**33**	**0**
2	A 111	369	< 5°	Slightly concave	*Populus euphratica*	1 ha	**54**	**4**
3	A 121	326	< 5°	Slightly convex	*Populus euphratica*	1 ha	**19**	**1**
4	A 131	320	< 5°	Slightly convex	*Populus euphratica*	1 ha	**3**	**0**
5	A 141	312	< 5°	Slightly convex	*Populus euphratica*	1 ha	**4**	**1**
6	A 151	299	< 5°	Level	*Populus euphratica*	1 ha	**102**	**1**
7	A 102	289	< 5°	Slightly concave	*Populus euphratica*	1 ha	**185**	**1**
8	A 112	288	< 5°	Irregular	*Populus euphratica*	1 ha	**33**	**0**
9	A 201	345	< 5°	Strongly convex	Aibi Hu Birch	19ha	**328+133**	**133**

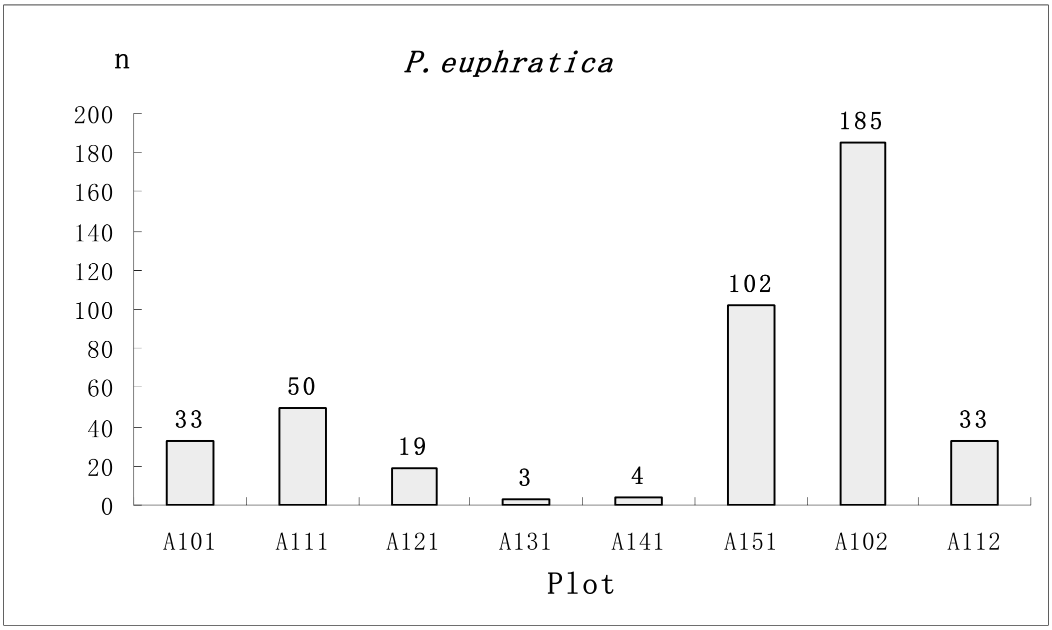


Fig. 38: Number of stems of *Populus euphratica* on the permanent research plots (each 1 ha).
Abb. 38: Stammanzahl von *Populus euphratica* auf den Monitoringflächen.
图例 38: 监测样地中胡杨数目分布情况.

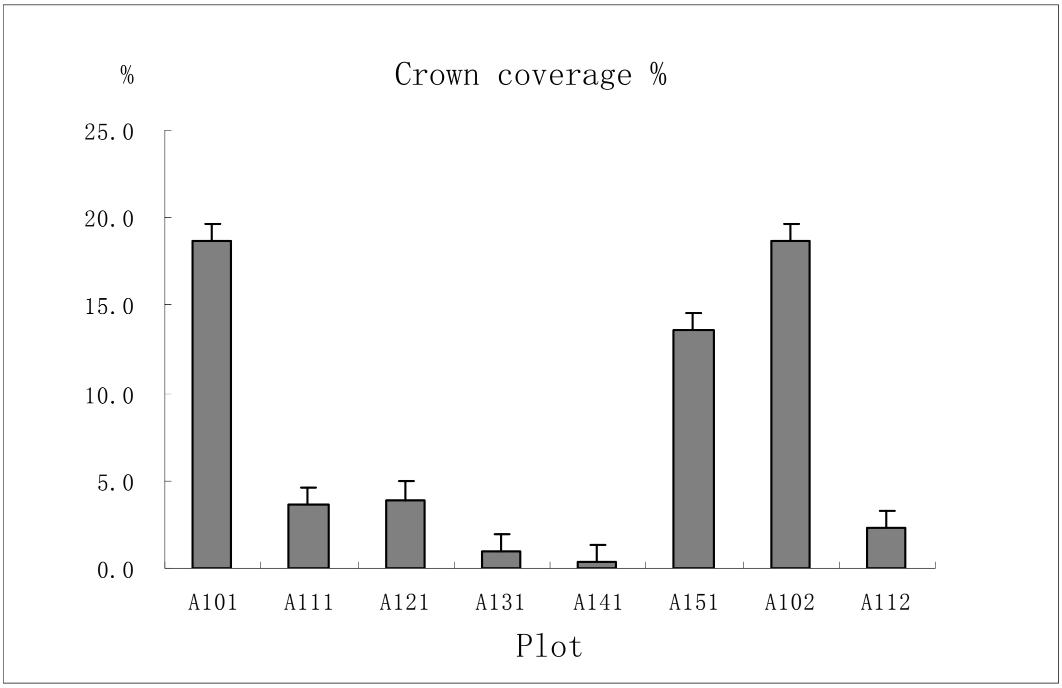


Fig. 39: Crown coverage of *P. euphratica* on the permanent research plots, May 2006.
Abb. 39: Beschirmungsgrad von *P. euphratica* auf den Monitoringflächen.
图例 39: 监测样地中胡杨树冠覆盖率.

3.5 Tree parameters

Height

Means and variances of heights on the plots were analyzed. The data of all the 425 living stems showed that the highest was found on A 151 with a height of 11 m (tree No. 49). The lowest was found on plot A 102 with a height of 1.1 m (tree No. 124). The measurement showed that even the lowest tree on plot A 101 (4.2 m) was higher than the tallest on plot A 112. On average, the height of the trees decreased along the transect from A 101 to A 112. Height distribution was presented with Box and Whisker plots (Fig.43; Appendix 3: Table A 3-1).

Height distributions were also analyzed by subdividing the data into 1 m classes from 2 to 11 m for each *P. euphratica* plot. This classification showed that the number of trees in the class with the highest trees differed considerably from plot to plot (Fig. 40). On plot A 101, the highest trees occurred at 8-9 m, whilst on A 112 the maximum height class was found between 3 and 4 m (Fig. 40).

In Fig. 40, one can also find that at the beginning of the transect, the average height on A 101 (8.37 m) was much higher compared to the end of the transect on plot A 112 (3.45 m). It also showed that on all the plots, the distribution of the heights was not regular. But on average, plot A 111, A 102, A 121 and A 151 height were close to normal distribution; On plot 101, compared to a normal distribution, there were relatively more higher trees; On plot A 112, there were relatively more lower trees; on plot A 131 and A 141, where only three trees were still living, a statistical analysis was not ingenious.

Diameter at breast height (DBH)

The maximum DBH of all the still living 425 individuals of this study was detected on A 111, with DBH of 85.2 cm (tree No. 52), the minimum was recorded with 2.7 cm on A 102 (tree No. 91). The measurements showed that the minimum DBH on A 101 (23.7 cm) was even bigger than the maximum on plot A 112. On average, the DBH of the trees decreased along the transect from A 101 to A 112. On A 101, the average DBH was 46.8 cm, on A 112, it was 14.7 cm (Fig.41; Appendix 3: Table A3-2).

DBH distributions were analyzed by subdividing the data into classes with a width of 10 cm, ranging from 10 to 80 cm. The data showed that the maximum of stem numbers differed considerably between the classes. On plot A 101, the peak value occurred between 40 and 50 cm, whilest on A 112 this value was found between 10 and 20 cm.

In Fig. 42 and Fig. 43, one can find that on plot A 101, DBH of the trees were much more regularly distributed compared to the other plots; it was very close to the normal distribution; On plot A 111, A 151, A 102 and A 112, compared to the normal distribution, there were more trees with a small DBH; on plot A 121, the distribution was less regular, it was not normally distributed, there were two peak values, one was in 20-30 cm class and the other was in 60-70 class, there was no tree in the 40-50 cm class; on plot A 131 and A 141, where only three trees were still living, a statistic analysis was not ingenious.

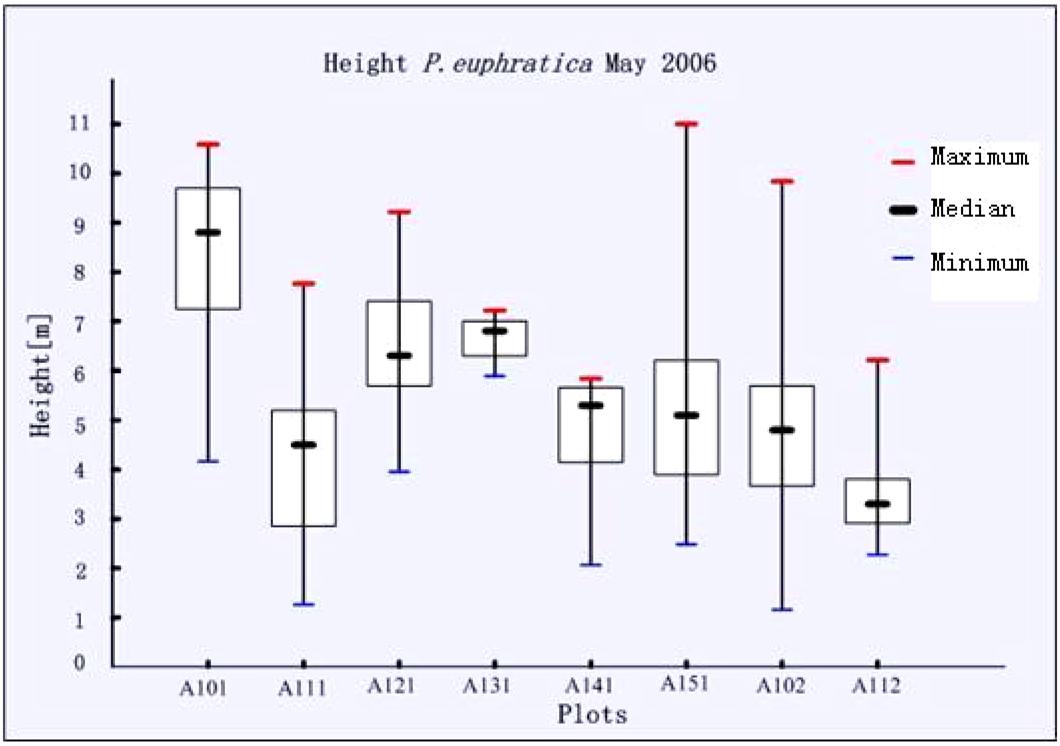


Fig. 40: Height of *P. euphratica* on the permanent research plots: Box and Whisker plots, 2006.
Abb. 40: Höhe von *P. euphratica* auf den Monitoringflächen.
图例 40: 监测样地中胡杨高度分布情况.

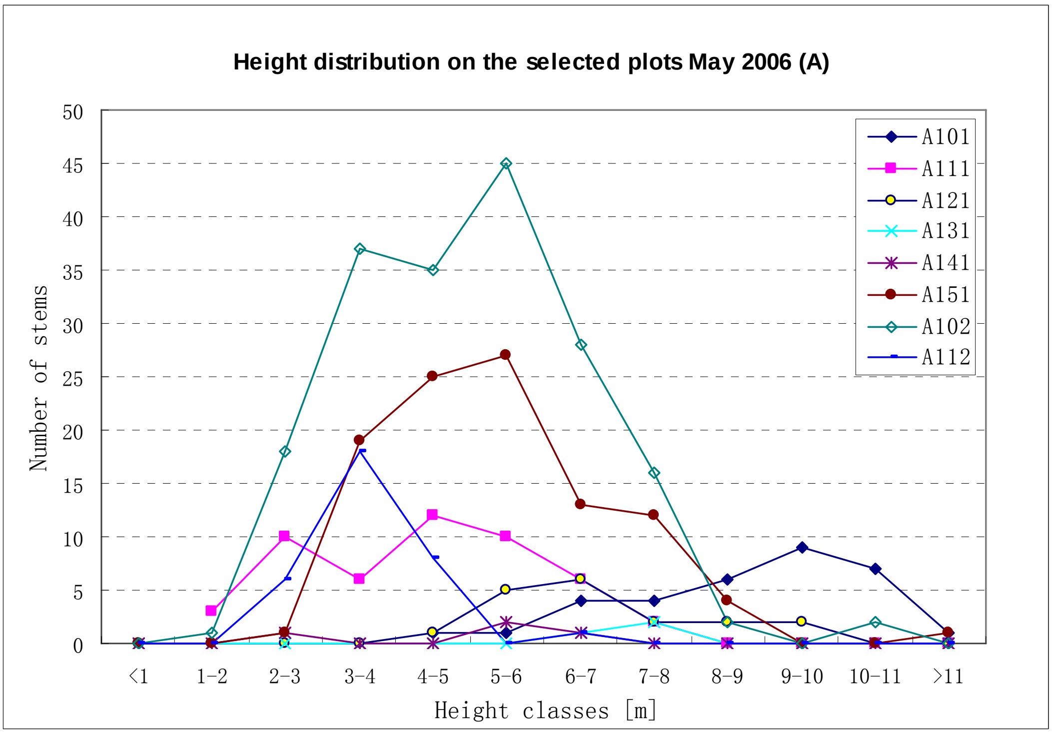


Fig. 41 : Height distribution of *P. euphratica* on the permanent research plots, 2006.
Abb. 41 : Baumhöhen-Klassen von *P. euphratica* auf den Monitoringflächen.
图例 41 : 监测样地中胡杨高度分布情况.

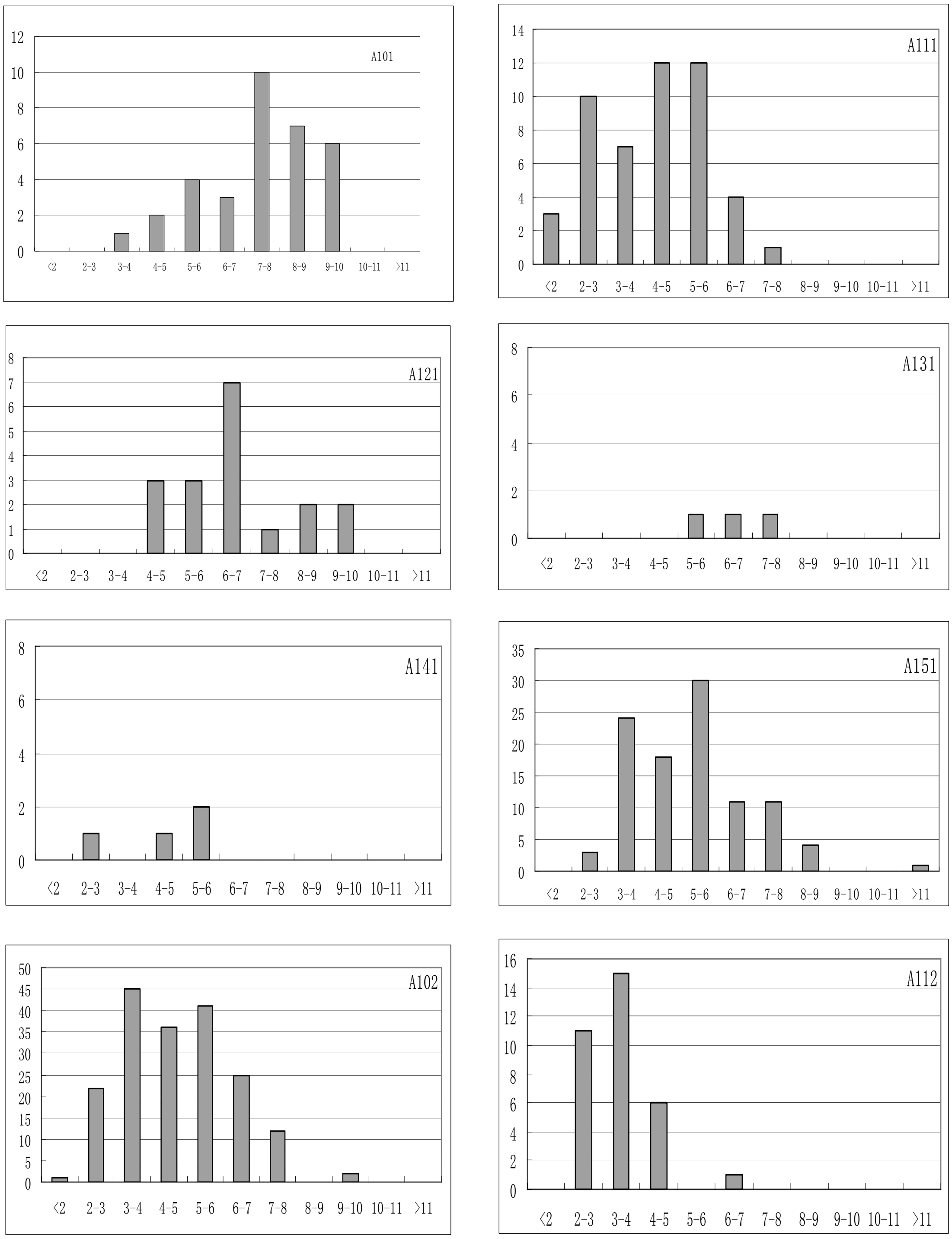


Fig. 42: Height distribution of *P. euphratica* on each research plot in May 2006: X-axis: height classes [m], Y-axis: number of stems (different scales on Y-axis).

Abb. 42: Baumhöhen-Klassen von *P. euphratica* auf jeder einzelnen Monitoringfläche.

图例 42: 胡杨高度在不同监测样地中的分布情况.

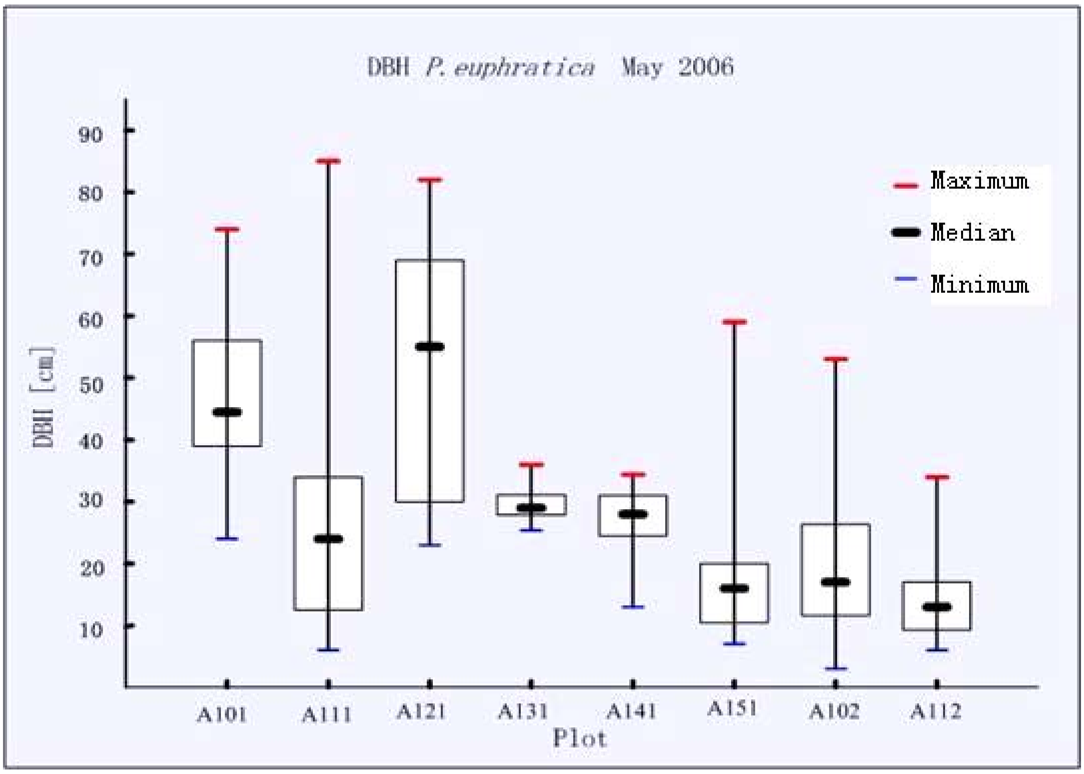


Fig. 43: DBH distribution of *P. euphratica* on the research plots, Box and Whisker plots, 2006.
Abb. 43: BHD von *P. euphratica* auf den Monitoringflächen.
图例 43：监测样地中胡杨胸经分布情况.

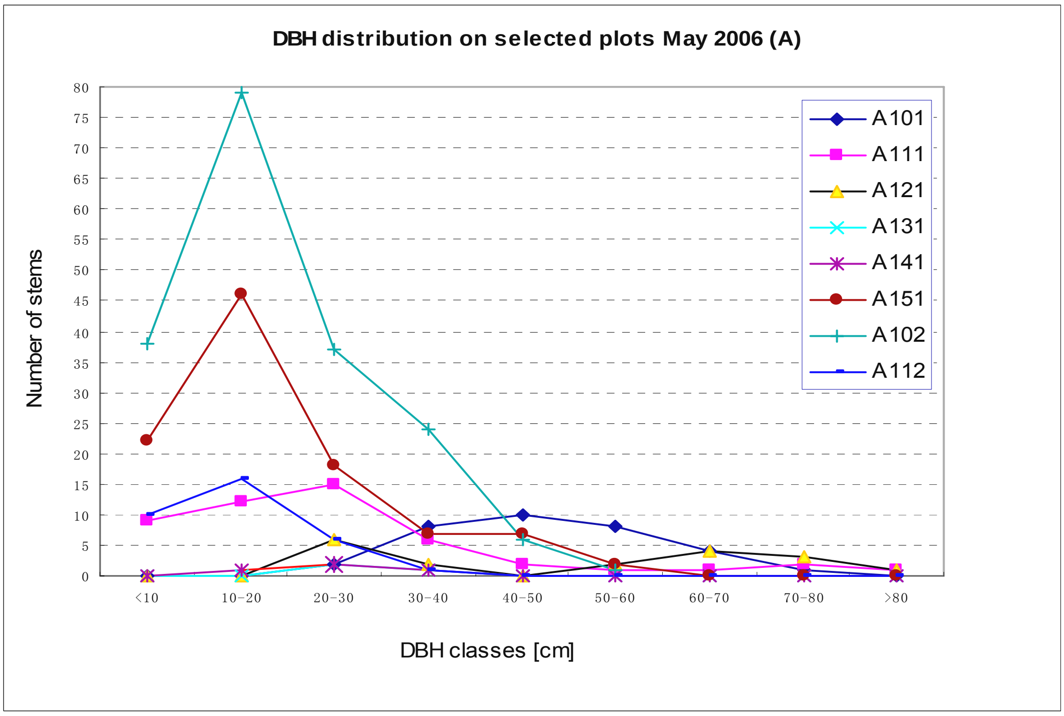


Fig. 44: DBH distribution of *P. euphratica* on the permanent research plots, 2006.
Abb. 44: BHD-Klassen von *P. euphratica* auf den Monitoringflächen.
图例 44：监测样地中胡杨胸经分布情况.

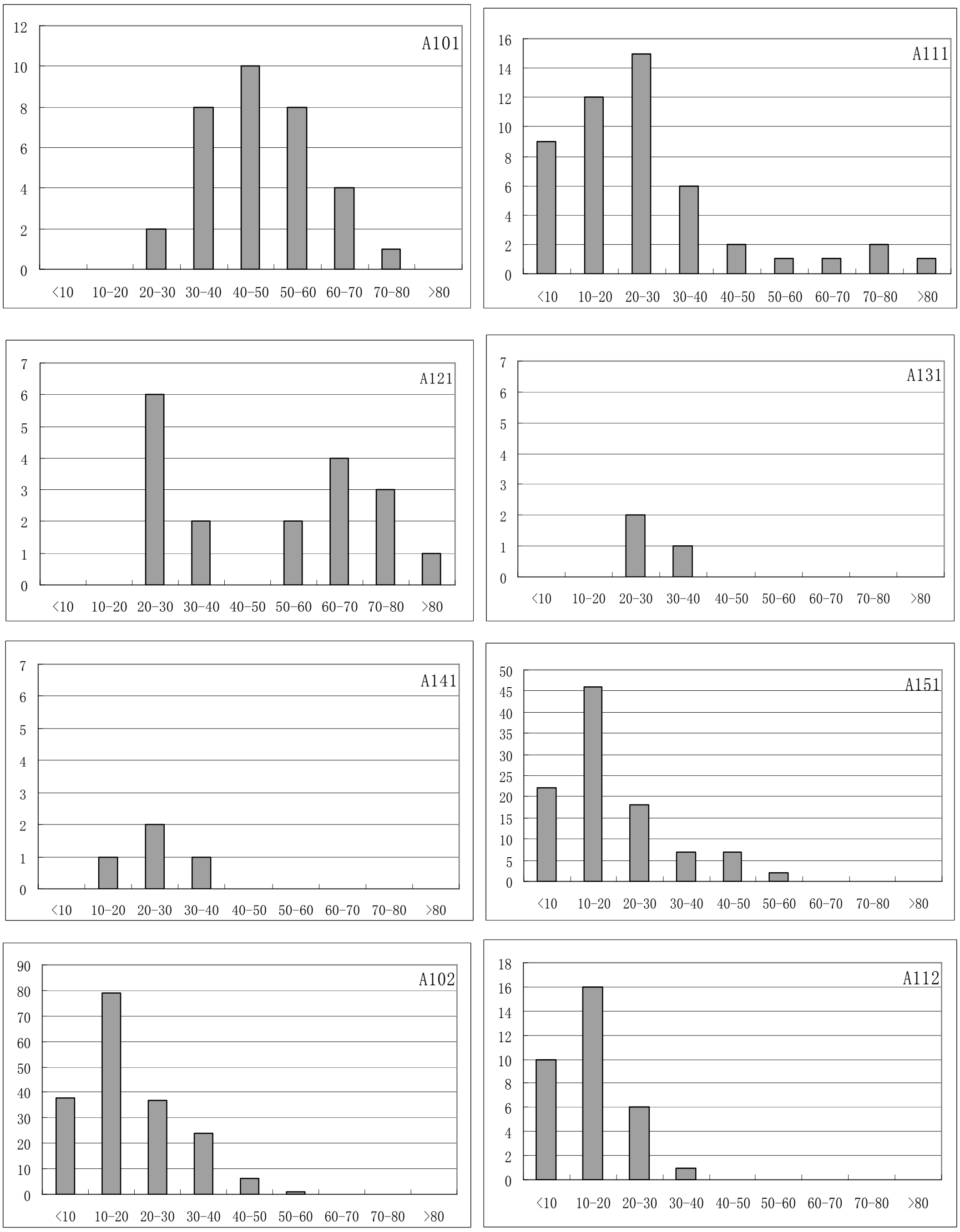


Fig. 45: DBH distribution of *P. euphratica* on each research plot in May 2006: X-axis: DBH classes [cm], Y-axis: Number of stems (different scales on Y-axis).

Abb. 45: BHD-Klassen von *P. euphratica* auf jeder einzelnen Monitoringfläche.

图例 45: 胡杨胸经在不同监测样地中的分布情况.

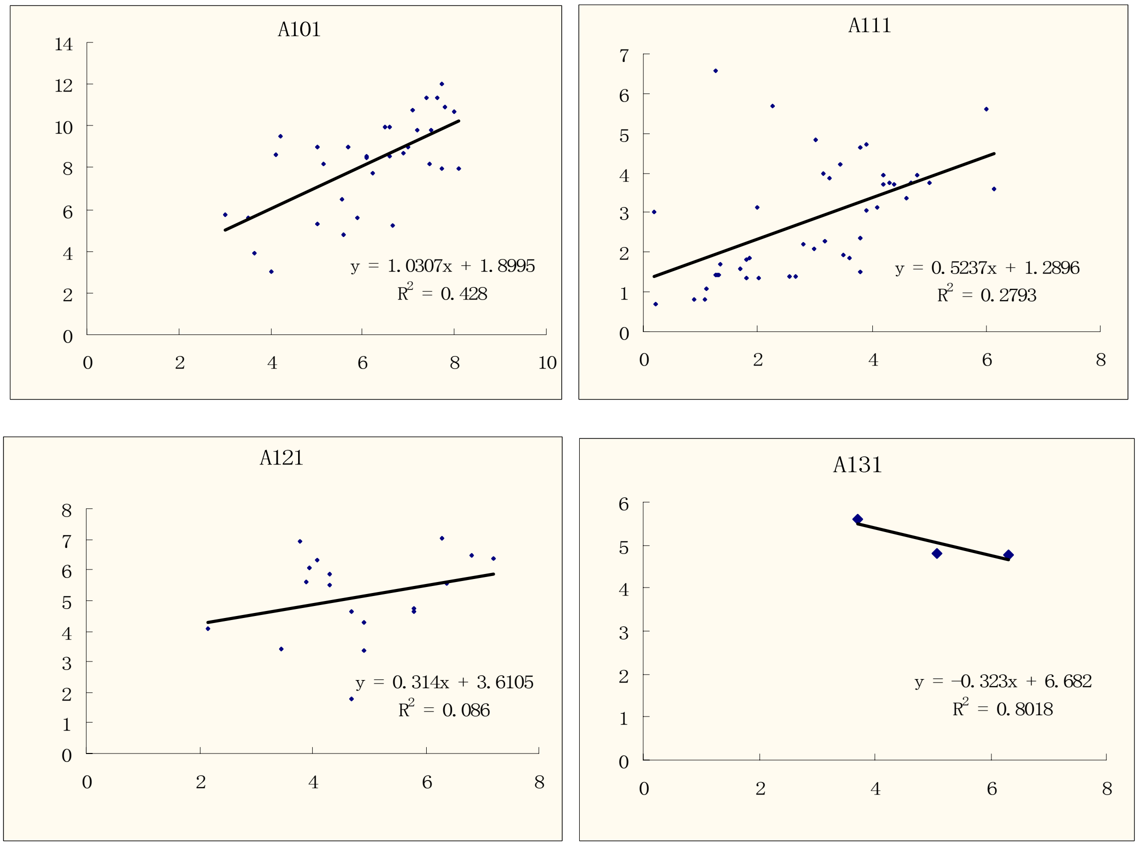
Crown

The crown width of *P. euphratica* was very irregular on all plots. There was no close relation between crown width and tree height or DBH. For example, the tree with the maximum DBH (85.2 cm, A 111, number 52) had a S-N crown width of 3.4 m and W-E 4.1 m, the maximum value of crown S-N width was 12.7 m (A 101, tree No. 1) and W-E width was 11.64 m (A 101, tree No. 16). Even on the same tree, crown width was irregular in different directions. One example is tree No. 56 on plot A 102, the width from South to North was 3.1 m, whilst from West to East 8 m was recorded.

Crown form was analyzed by means of comparing the crown width with the crown height. As the crown widths differed in different directions, average width of S-N and W-E was used in this study.

In Fig. 46 one can find that crown height was not closely correlated with the crown width. On plot A 102, the picture is very unclear although this plot had the highest number of living stems (185).

Regression analysis showed that the relation was weak but, on the average, crown height increased according to the crown width following a linear regression in tendency. On plot A 131 where most of the trees had died, regression analysis was not efficient.



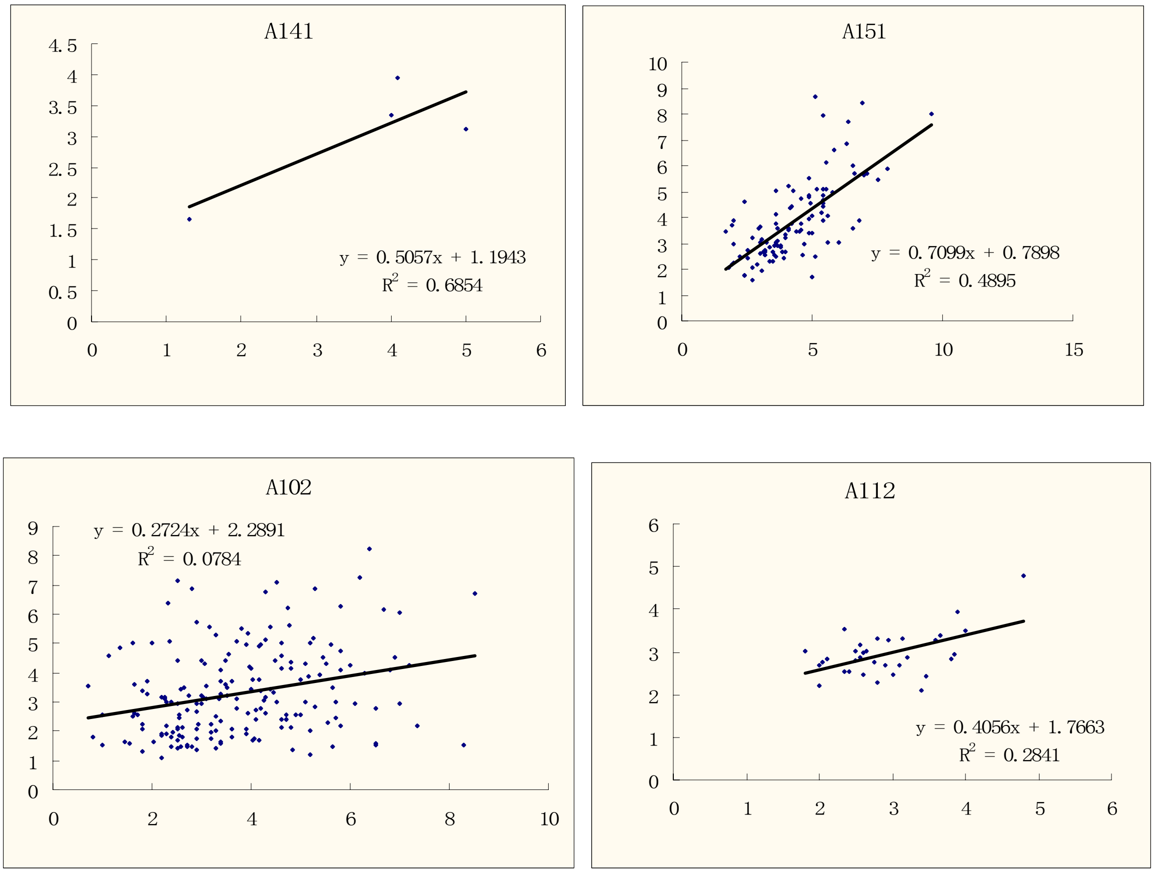


Fig. 46: Allometric relation between crown height and crown width in *P. euphratica* on each research plot, X-axis: crown width [m], Y-axis: crown height [m], May 2006 (different scales on Y-axis).

Abb. 46: Allometrische Beziehung zwischen Kronenlänge und Kronenbreite von *P. euphratica* auf jeder Monitoringfläche.

图例 46: 胡杨立木冠宽与冠高在不同监测样地中的关系.

Using all the data from the plots with the tree numbers $n \geq 19$, the mean allometric relation between crown height and crown width of *P. euphratica* was obtained for the study area. In Fig.47, one can find that on the average, crown height increased according to the crown width following a linear regression in tendency ($y = 0.74x + 0.89$, $R^2 = 0.36$).

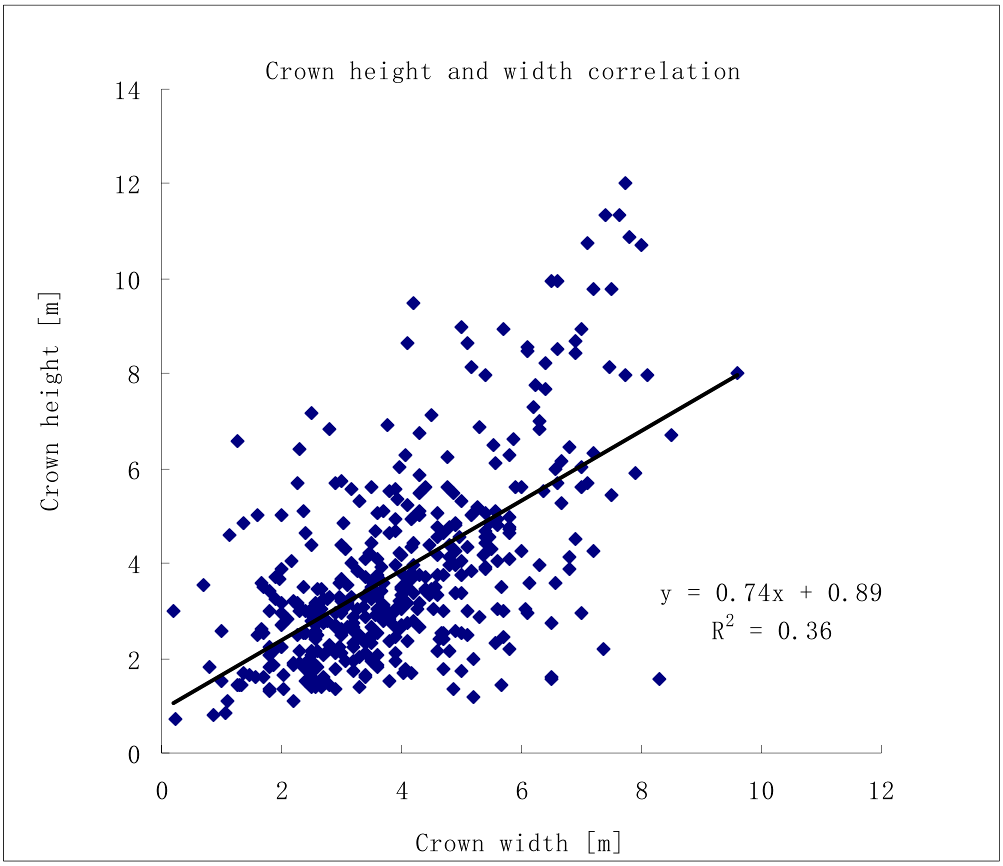


Fig. 47: Allometric relation between crown height and crown width in *P. euphratica*, X-axis: crown width [m], Y-axis: crown height [m], May 2006 (n = 419); all plots.

Abb. 47: Allometrische Beziehung zwischen Kronenlänge und Kronenbreite von *P. euphratica;* alle Flächen.

图例 47: 胡杨立木冠宽与冠高的关系.

Correlation between height and stem diameter

The data showed that the tree height and DBH were not closely correlated. Allometric relation between height and DBH could not be described by linear regressions. In Fig. 48, one can find that the relation was very unclear. This can also be illustrated by the tree with the maximum DBH of 85.2 cm on plot A 111 (tree No. 52). It was only 5.2 m high, i.e. much lower than the highest tree in this study which was 11 m high (A 151, tree No. 49, with a DBH of 39.2 cm).

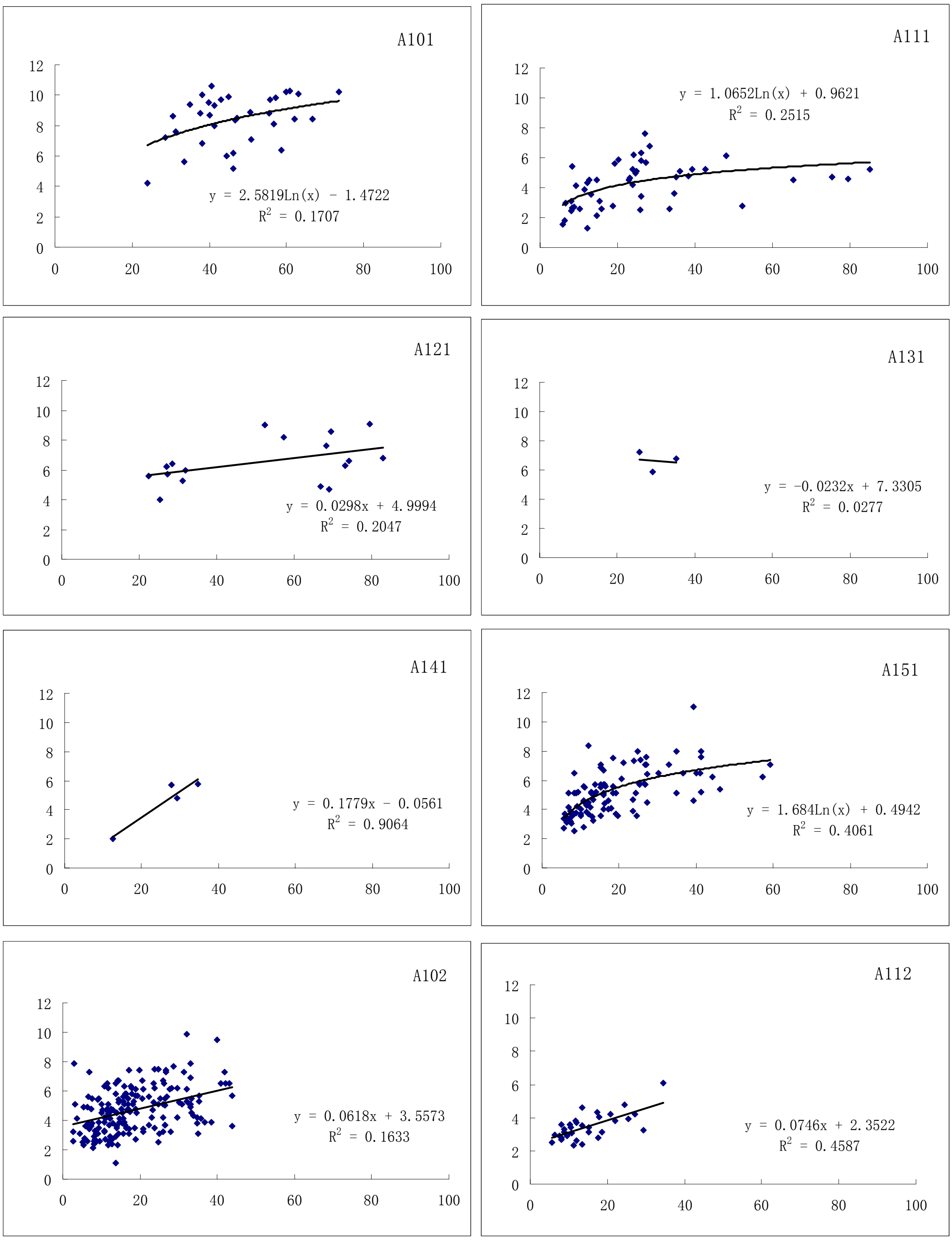


Fig. 48: Allometric relation between DBH and height in *P. euphratica* on each research plot, X-axis: DBH [cm], Y-axis: height [m].

Abb. 48: Allometrische Beziehung zwischen BHD und Baumhöhe von *P. euphratica* auf jeder Monitoringfläche (Schlankheitsgrad).

图例 48: 胡杨胸经与树高在不同监测样地中的异速生长关系.

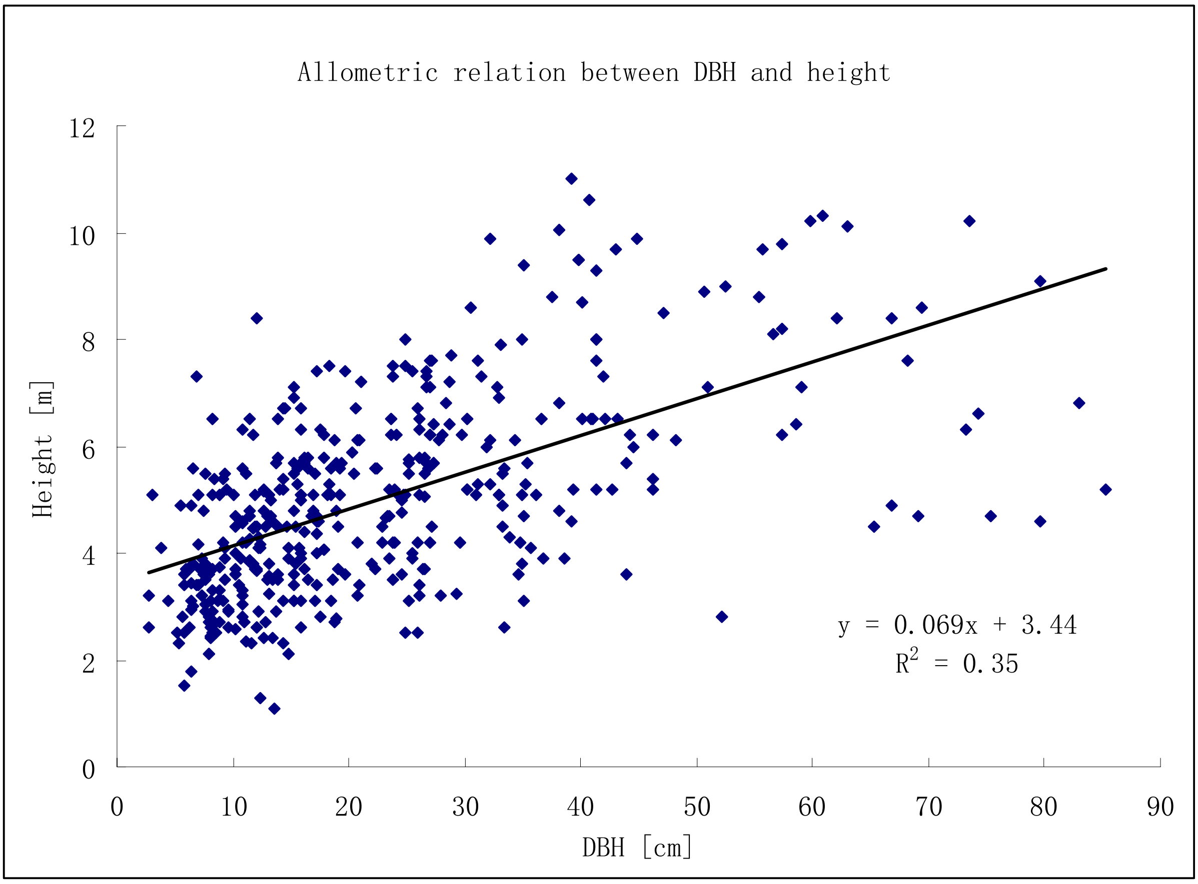


Fig. 49: Allometric relation between DBH and height in *P. euphratica*, X-axis: DBH [cm], Y-axis: height [m] (n = 419); all plots.

Abb. 49: Allometrische Beziehung zwischen BHD und Baumhöhe von *P. euphratica*; alle Flächen.

图例 49: 胡杨胸经与树高的异速生长关系.

Using all the data from the plots with the tree numbers n ≥ 19, the general trend of the allometric relation between DBH and height in *P. euphratica* in the study area was obtained. Fig. 49 shows that, on average, they were following a linear regression in tendency (y = 0.069x + 3.44, R^2= 0.35). In case of using an approximation by a logarithmic regression, R^2 was smaller.

In order to have an overview of the difference of the height - DBH ratio on different plots, average height and DBH was used to get the mean quotient of height and DBH on each plot. In Fig.50 one can find that, on the average, height - DBH ratio increased along the transect in tendency (y = 0.019x + 0.15, R^2: 0.47).

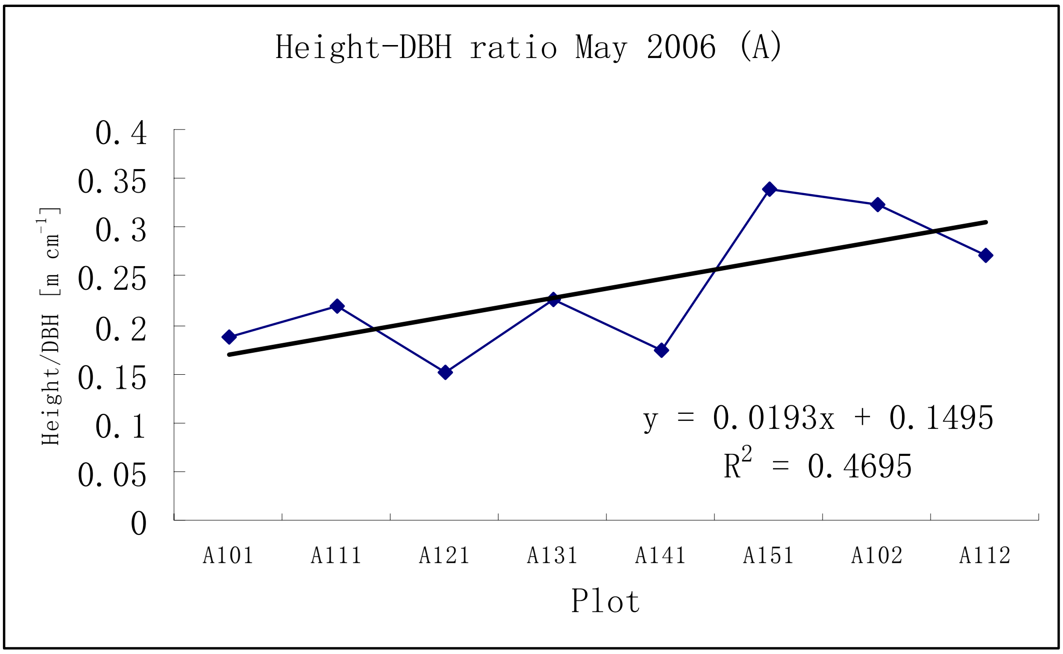
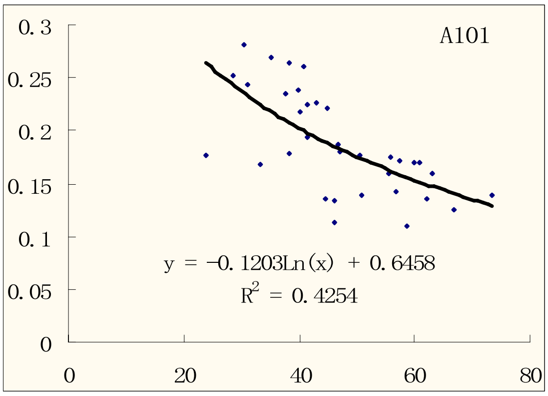
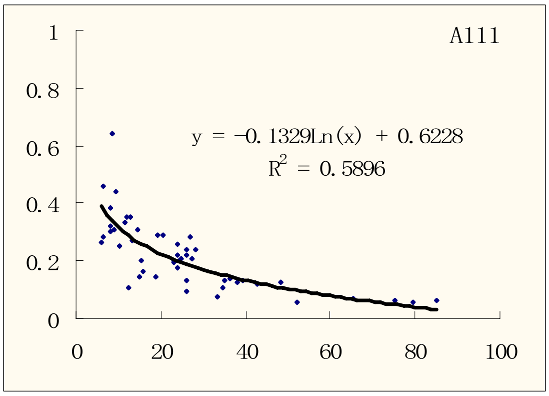


Fig. 50: Height -DBH ratio of *P. euphratica* on the permanent research plots.
Abb. 50: Höhen / Stammdurchmesser-Verhältnis von *P. euphratica* auf den Monitoringflächen.
图例 50:不同监测样地中的胡杨形状比.

Relation between DBH and Height-DBH ratio

Height- DBH ratio was calculated using the tree data from the first measurement (May 2006). The quotient of height and DBH on each plot showed that the relation between DBH and height-DBH ratio was not closely correlated. In Fig. 51, one can find that, on average, the height - DBH ratio decreased whilst the DBH increased. On plot A 141 where most of the trees had died, the relation of DBH and height-DBH ratio was irregular. It differed completely from the other plots.





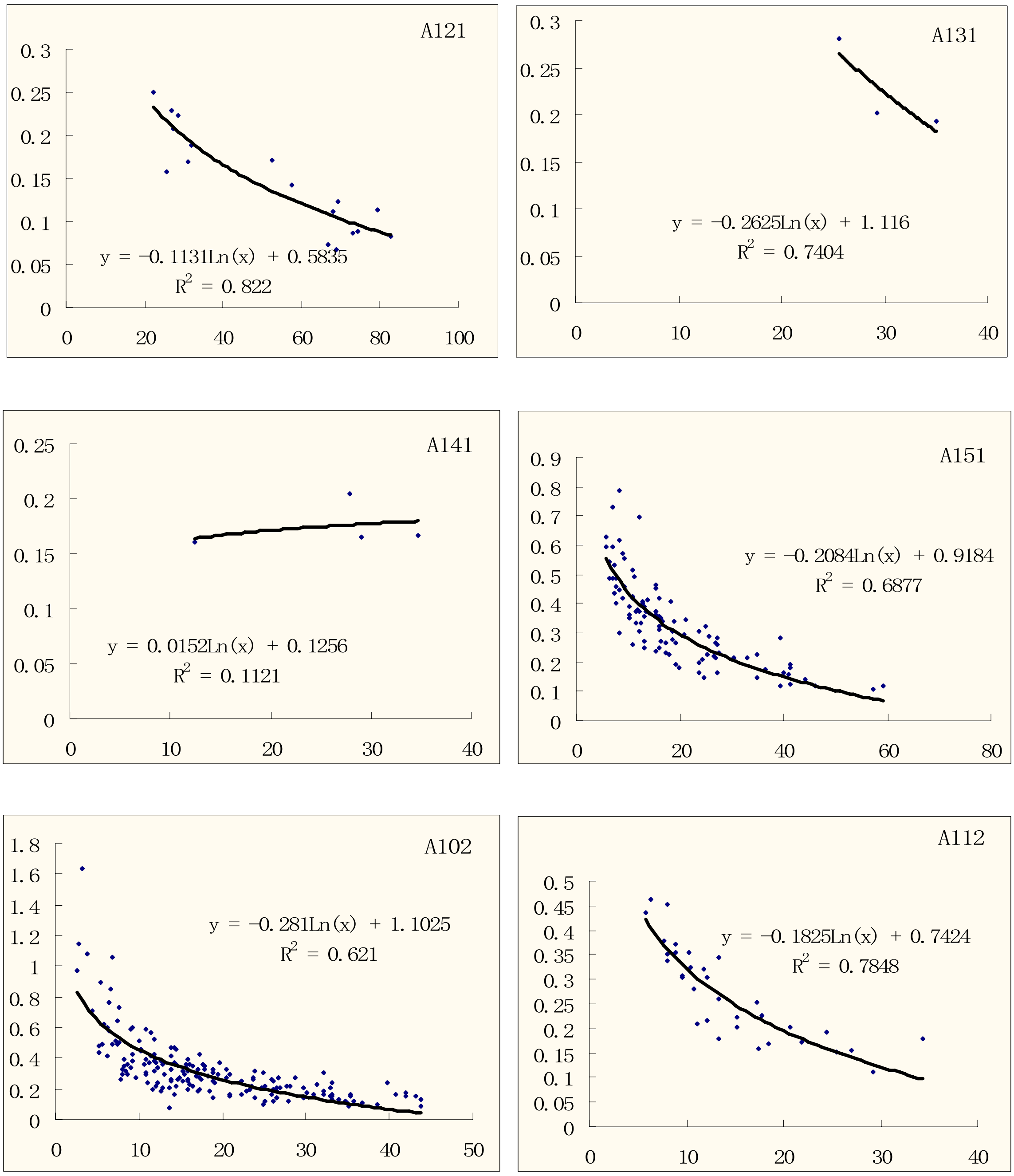


Fig. 51: Relation between DBH and height -DBH ratio in *P. euphratica* on each research plot, X-axis: DBH [cm], Y-axis: height-DBH ratio [m cm^{-1}] (different scales on Y-axis).

Abb. 51: Beziehung zwischen BHD und Höhen / Stammdurchmesser-Verhältnis von *P. euphratica* auf jeder Monitoringfläche.

图例 51:不同监测样地中的胡杨形状比与胸经的对应关系.

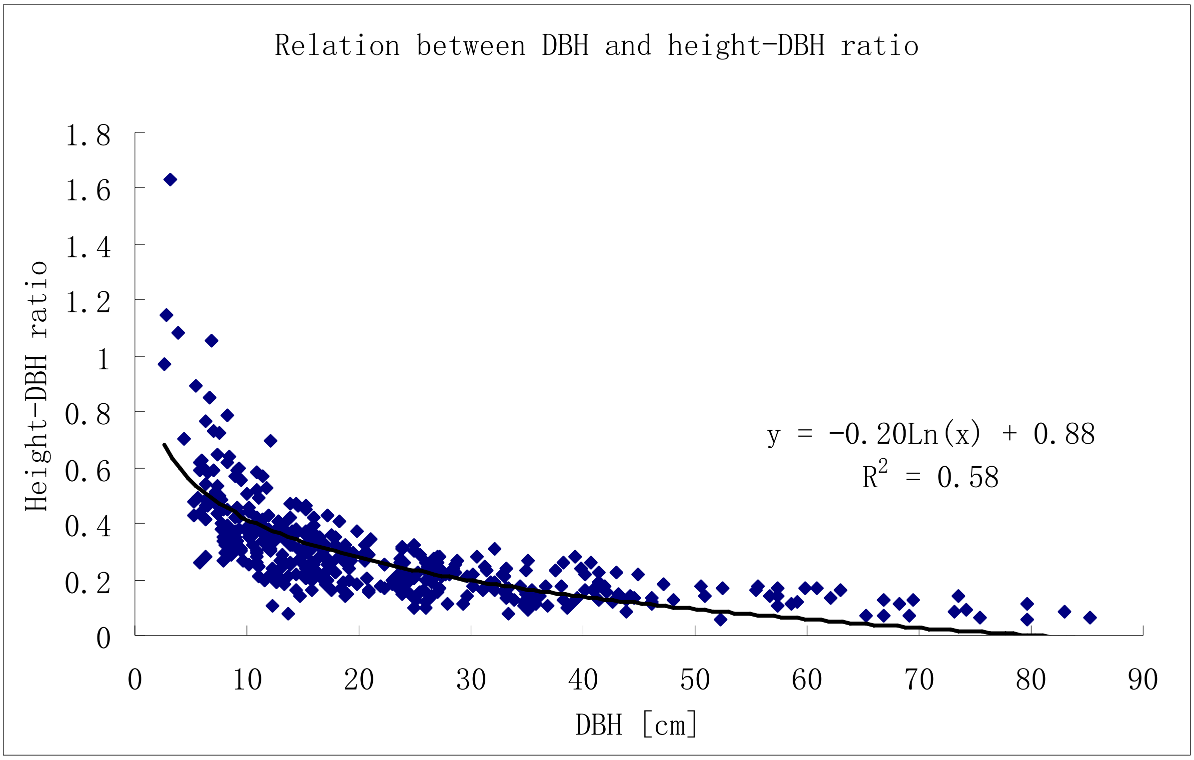


Fig. 52: Relation between DBH and height -DBH ratio in *P. euphratica*, X-axis: DBH [cm], Y-axis: height-DBH ratio [m cm^{-1}]; all plots.
Abb. 52: Beziehung zwischen BHD und Höhen / Stammdurchmesser-Verhältnis von *P. euphratica*; alle Flächen..
图例 52:胡杨形状比与胸经的对应关系.

In order to have an average relationship between DBH and height - DBH ratio in *P. euphratica* in the study area, all data were pooled togther using the plots with the tree numbers n ≥ 19. The result showed that on average, DBH and height - DBH ratio can be described by a logarithmic regression (y = -0.20 Ln(x) + 0.88, R^2 = 0.58, Fig. 52).

3.6 Biomass

The data of the three harvested trees showed that there were lots of dead branches on all the three trees. In No. 1, there were 25.5% dead branches. The percentage was 24.8% in tree No. 3. In the tree No. 2, which represented the bad growth situation, it was 64.8%. Tab.18 shows the mass of the wooden parts of the three selected trees.
Table 19 shows the calculated result of the leaves on the three harvested trees. In this table, one can find that the average leaf area ranged from 8.34 cm^2 (tree No.3) to 11.34 cm^2 (tree No.1). The specific leaf area differed between 5.78 m^2 kg^{-1} (tree No.1) and 6.94 m^2 kg^{-1} (tree No. 3). The total leaf area of the trees showed the bad growth situation (15.11 m^2, tree

No. 2) was much smaller compared to the trees of the same size with better growth conditions (47.85 m^2, tree No. 1).

Table 18: Wooden parts of the three harvested trees.
Tab. 18: Holzanteile der drei geernteten Bäume.
图表 18: 在所选树木上木体部分生物量统计.

Tree No. 编号	Height 高度[m]	DBH 胸径[cm]	Stem weight 树干 [kg]	Living branch 活枝 [kg]	Dead branch 死枝 [kg]	Total mass 总质量 [kg]	Total wood voulme 总材积 [m^3]
T 1	7.4	24.31	80.2	41.7	14.3	136.2	0.298
T 2	5.45	21.34	25.8	12.6	23.2	61.6	0.135
T 3	6.15	25.74	70.4	48.3	15.9	134.6	0.294

Table 19: Leaf data of the three harvested trees.
Tab. 19: Blatt-Parameter der drei geernteten Bäume.
图表 19: 在所选树木上的树叶统计数据.

Tree No. 编号	Number of leaves 总叶数	Total area 总面积 [m^2]	Average leaf area 平均叶面积 [cm^2]	Total weight 总质量 [kg]	Average leaf weight 平均质量 [g]	Specific leaf area 比叶面积 [m^2kg^{-1}]
T 1	42194	47.85	11.34	8.27	0.19	5.78
T 2	16683	15.11	9.06	2.28	0.14	6.63
T 3	47166	39.34	8.34	5.66	0.12	6.94

The total wood volume of the two healthy harvested trees (T1 and T3, Table 18) were used in a first approach to determining the coefficients of the formula that connects the height, DBH and stem biomass based on the result from Degenhardt (2001), (Pappel-Robusta, $V = e^{-10.358675 + 1.78209*\ln(D) + 1.23812*\ln(H)}$).

$$V = e^{-9.7216 + 1.9638*\ln(D) + 1.1542*\ln(H)}.$$

V: Total wood volume; D: Diameter at 1.3 m (DBH); H: Height of the tree.

3.7 Tree ring analysis

Counting of tree rings of all the wood samples taken at random from the study site showed that the oldest tree was 203 years old (tree No. 32, plot A 101), the youngest was 18 years old (tree No. 20, plot A 102).

On plot A 101, the age was distributed between 21 and 203 years; on plot A 111, it was between 21 to 186; on plot A 102, it was between 18 to 168 years. On plot A 131, the only 3 living trees were between 73 (tree No.1, plot A 131) and 82 years old (tree No. 3, plot A 131).

Fig. 53 shows the approximated age structure on plot A 101, A 102 and A 111 from the 53 wood samples. This figure showes that on plot A 101, the trees were older than on the other two plots. The average age was about 140 years there.

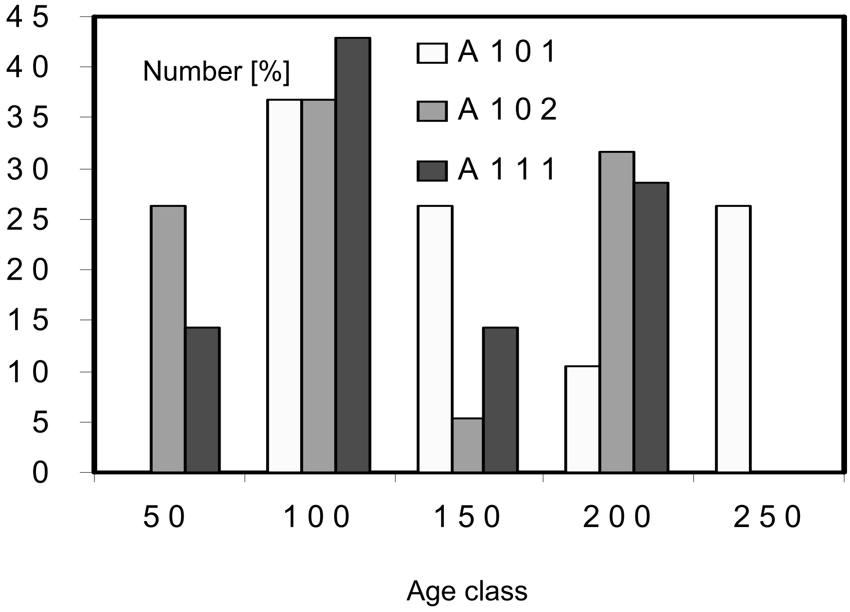


Fig. 53: Approximated age structure of P. euphratica on the three selected plots.

Abb. 53: Ungefähre Altersstruktur von *P. euphratica* auf den Monitoringflächen.

图例 53：胡杨在部分样地中的树龄结构.

In Fig. 54, one can have an overview of the average age on the selected plots. It showed that on the four selected plots, there were no significant differences between the average age. The average age ranged from 90 to 140 years.

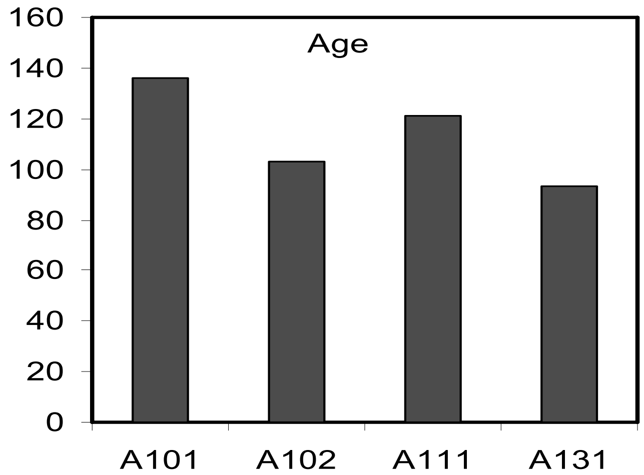


Fig. 54: Average age of *P. euphratica* on the selected plots.

Abb. 54: Durchschnittsalter von *P. euphratica* auf den Monitoringflächen.

图例 54：胡杨在部分样地中的平均树龄.

The measurement of the tree rings of the samples showed that, although the curve lasts 200 years in the past, the sample size is below the number of recommended sample size for further analyses before the year 1910. The average curves of the measurement showed that the years 1944, 1961 and 1993 were pointer years indicating negative influences on tree growth (Fig.55).
The results also showed that the annual increment during the last ten years was smaller in all plots than the annual increment of the last 50 years.
Detailed analysis showed that although the average age of the trees on plot A101 was the highest, the increment of the tree ring width in this plot was more vigorous than on the others.

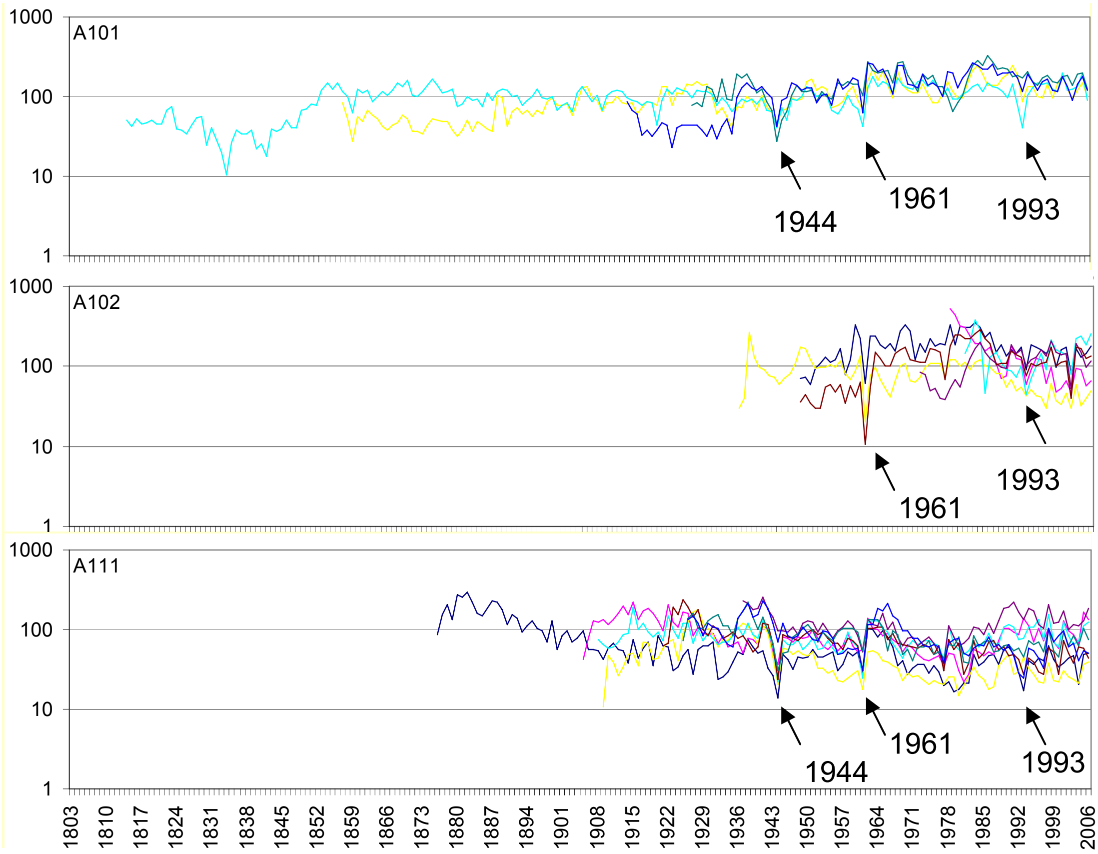


Fig. 55: Dendrochronology of selected *P. euphratcia* trees along the former river Aqikesu with pointer years indicating negative influences on tree growth.
Abb. 55: Dendrochronologie ausgewälter *P. euphratcia* Stämme entlang des ehemaligen Bettes des Aqikesu mit Weiserjahren, die negative Einflüsse auf das Baumwachstum anzeigen.
图例 55: 对部分样地所选择的胡杨年轮分析显示对树木生长的影响.

3.8 Growth of *P. euphratica* over two years

Height measurement over two years

Heights of all the *P. euphratica* individuals on the eight permanent plots were measured four times in May 2006, September 2006, May 2007 and September 2007. Fig. 56 shows the average height growth on each plot.

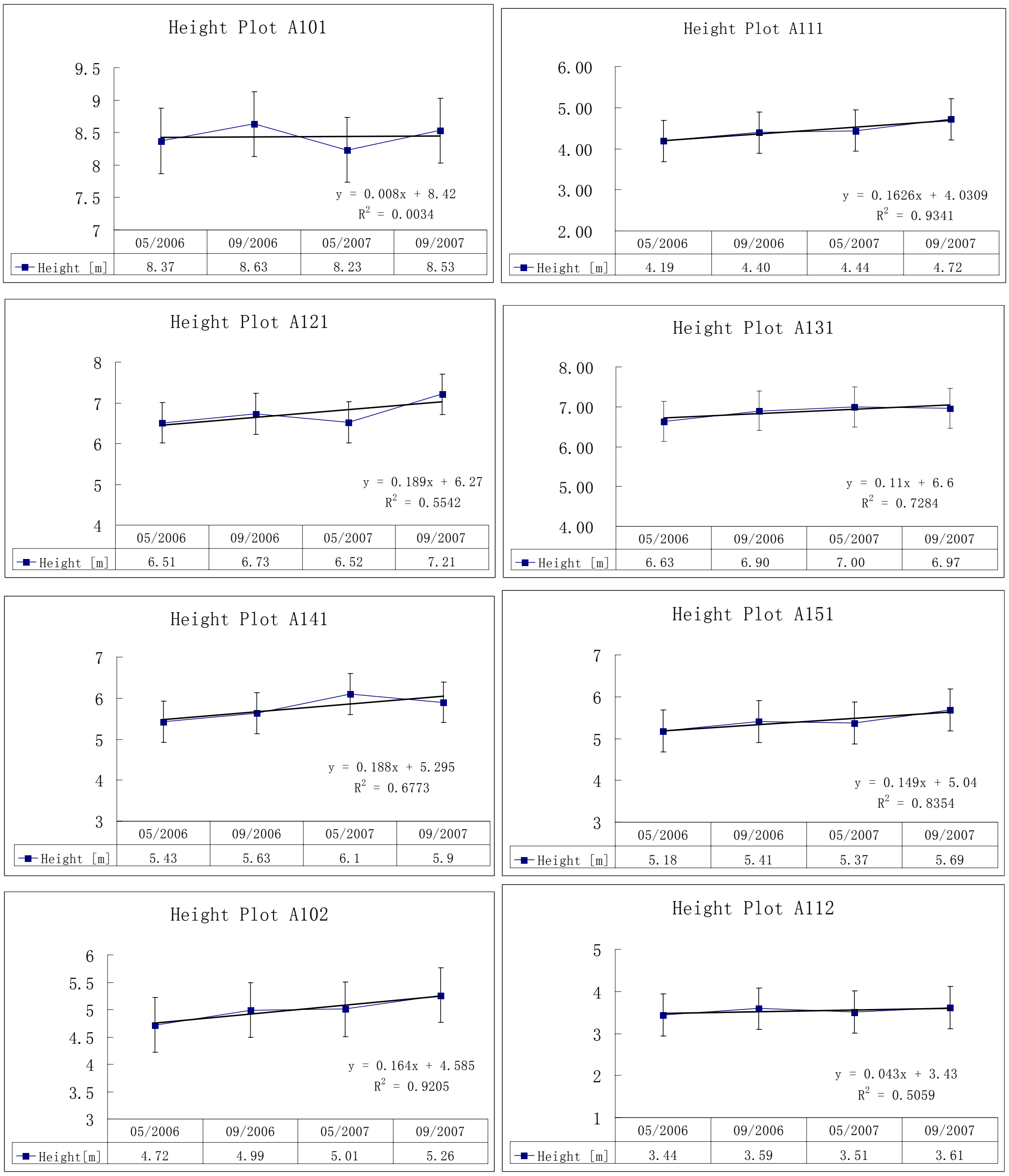


Fig. 56: Height growth of *P. euphratica* on the permanent research plots (X-axis: date, Y-axis: tree height [m], May 2006-Sept. 2007); different scales on Y-axis.

Abb. 56: Höhenwachstum von *P. euphratica* auf den Monitoringflächen (Mai 2006 - Sept. 2007).

图例 56: 监测样地中胡杨高度生长情况(2006.05 - 2007.09).

In Fig. 56, one can find that, on average, the maximum height in 2007 was recorded on plot A 101 (8.53 m, 09/2007) and the minimum height on plot A 112 (3.61 m, 09/2007). The average height increased on each plot differently.

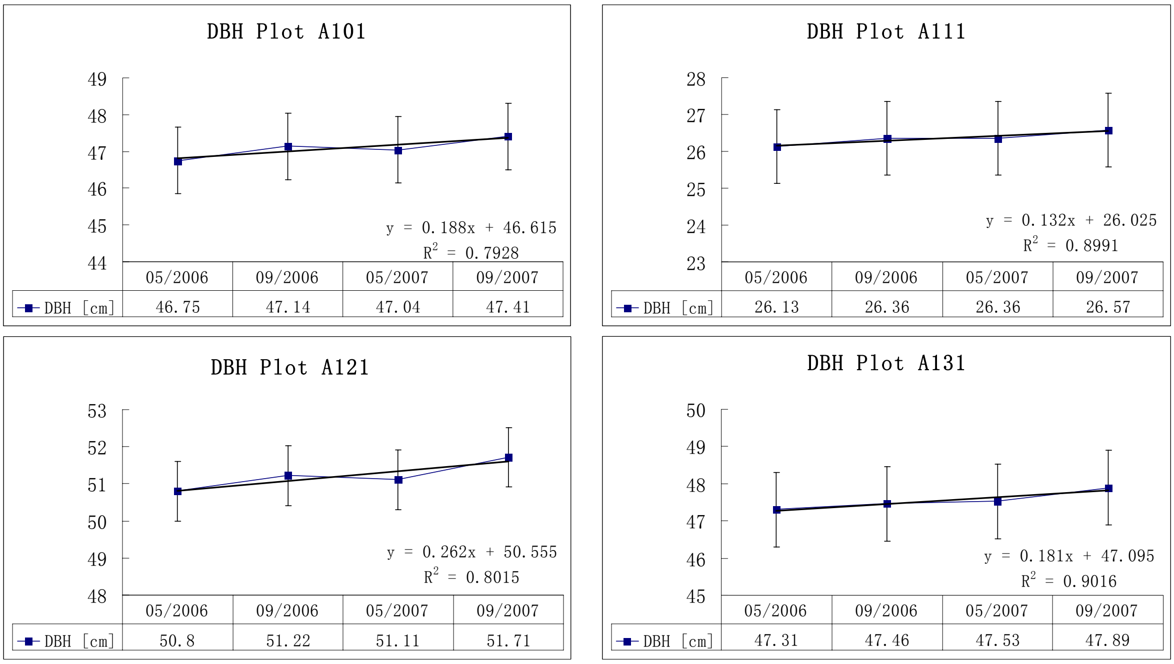
Table 20: Height growth of *P. euphratica* on the permanent research plots.
Tab. 20: Höhenwachstum von *P. euphratica* auf den Monitoringflächen.
图表 20: 监测样地中胡杨高度生长情况.

Plot No. 编号	Absolute growth rate per year 年绝对生长量 [m]	Regression 回归关系式
A 101	0.08	$y = 0.008x + 8.42$, $R^2 = 0.0034$
A 111	0.27	$y = 0.16x + 4.03$, $R^2 = 0.93$
A 121	0.25	$y = 0.19x + 6.27$, $R^2 = 0.55$
A 131	0.16	$y = 0.11x + 6.60$, $R^2 = 0.73$
A 141	0.24	$y = 0.19x + 5.29$, $R^2 = 0.68$
A 151	0.26	$y = 0.15x + 5.04$, $R^2 = 0.84$
A 102	0.27	$y = 0.16x + 4.58$, $R^2 = 0.92$
A 112	0.09	$y = 0.04x + 3.43$, $R^2 = 0.51$

To sum up, on plot A 101 and plot A 112, the height increment tendency was very weak. On the other plots, the average height of *P.euphratica* had a tendency to increase (R^2: 0.55 - 0.93, Table 20), the absolute growth rate ranged from 0.08 m to 0.27 m per year.

DBH measurement over two years

The measurement of diameter at breast height (DBH) during the two research years showed that the DBH increment was more significant than the height increment on the same plot.



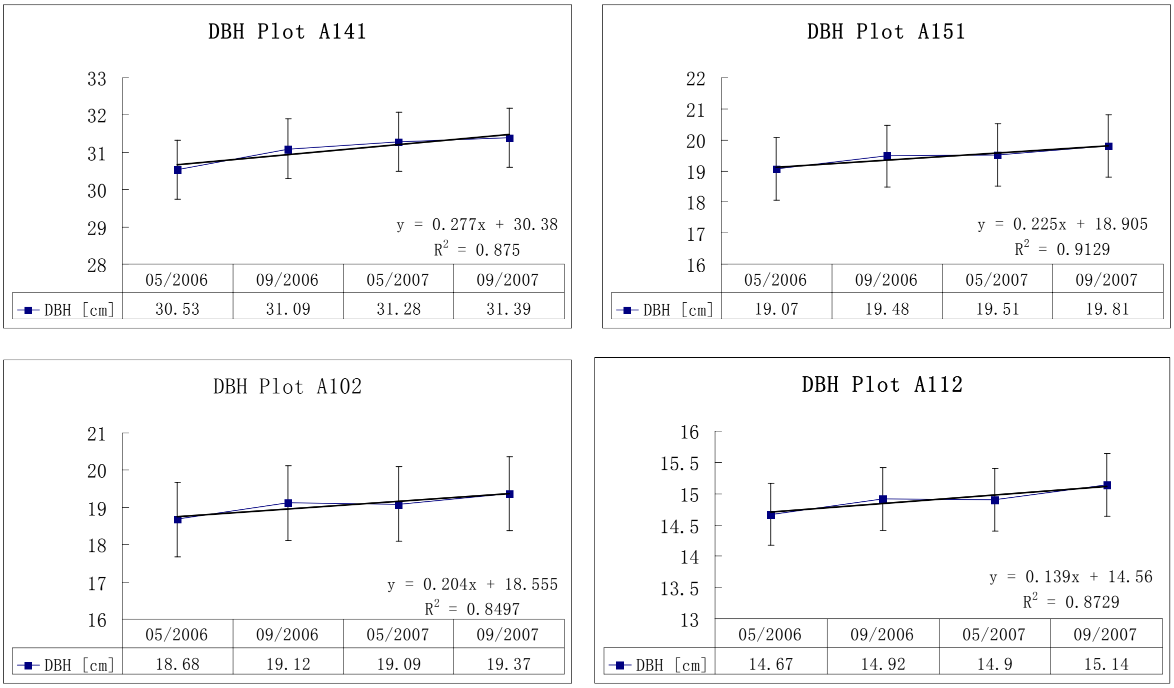


Fig. 57: DBH growth of *P. euphratica* on the permanent research plots (X-axis: date, Y-axis: DBH [cm], May 2006 - Sept. 2007); different scales on Y-axis.
Abb. 57: BHD von *P. euphratica* auf den Monitoringflächen (Mai 2006 - Sept. 2007).
图例 57: 监测样地中胡杨胸经生长情况(2006.05-2007.09).

Fig. 57 shows the average DBH of the four measurements during 2006 and 2007 on each plot. In this figure, one can find that, on average, the maximum DBH in 2007 (47.4 cm) was reached on plot A 101 (09/2007); the minimum DBH was 15.3 cm on A 112 (09/2007).

Table 21: DBH growth of *P. euphratica* on the permanent research plots.
Tab. 21: BHD von *P. euphratica* auf den Monitoringflächen.
图表 21: 监测样地中胡杨胸经生长情况.

Plot No. 编号	Absolute growth rate per year 年绝对生长量 [cm]	Regression 回归关系式
A 101	0.33	$y = 0.19x + 46.62$, $R^2 = 0.79$
A 111	0.22	$y = 0.13x + 26.03$, $R^2 = 0.90$
A 121	0.45	$y = 0.26x + 50.56$, $R^2 = 0.80$
A 131	0.29	$y = 0.18x + 47.10$, $R^2 = 0.90$
A 141	0.43	$y = 0.28x + 30.38$, $R^2 = 0.88$
A 151	0.37	$y = 0.23x + 18.91$, $R^2 = 0.91$
A 102	0.34	$y = 0.20x + 18.56$, $R^2 = 0.85$
A 112	0.24	$y = 0.14x + 14.56$, $R^2 = 0.87$

To sum up, on all the eight plots, the average DBH of *P.euphratica* increased clearly in tendency (R^2: 0.79 - 0.91), the average absolute growth rate ranged from 0.22 to 0.45 cm per year (Table 21).

The result of the every two weeks measurement during 2006 and 2007 (Appendix 5 Table A-5) with the permanent girth bands showed that the trees grew from May to August each year. The average absolute growth rate of those selected trees was (24.36-23.60)/2 = 0.38 cm per year.

3.9 Aibi Hu Birch

Height

On plot A 201 where the endemic birth Aibi Hu Birch is growing, height of all the 328 living individuals were measured and height distribution was analyzed by subdividing the data into 1 m classes from 1.5 to 6.5 m. On this plot, the highest tree was 6.7 m high (tree No. 249) and the lowest 1.7 m (tree No. 327). The classification showed that the maximum of stems occurred in class 2.5 - 3 m. The height classes were approximately following a Poisson distribution (Fig. 58).

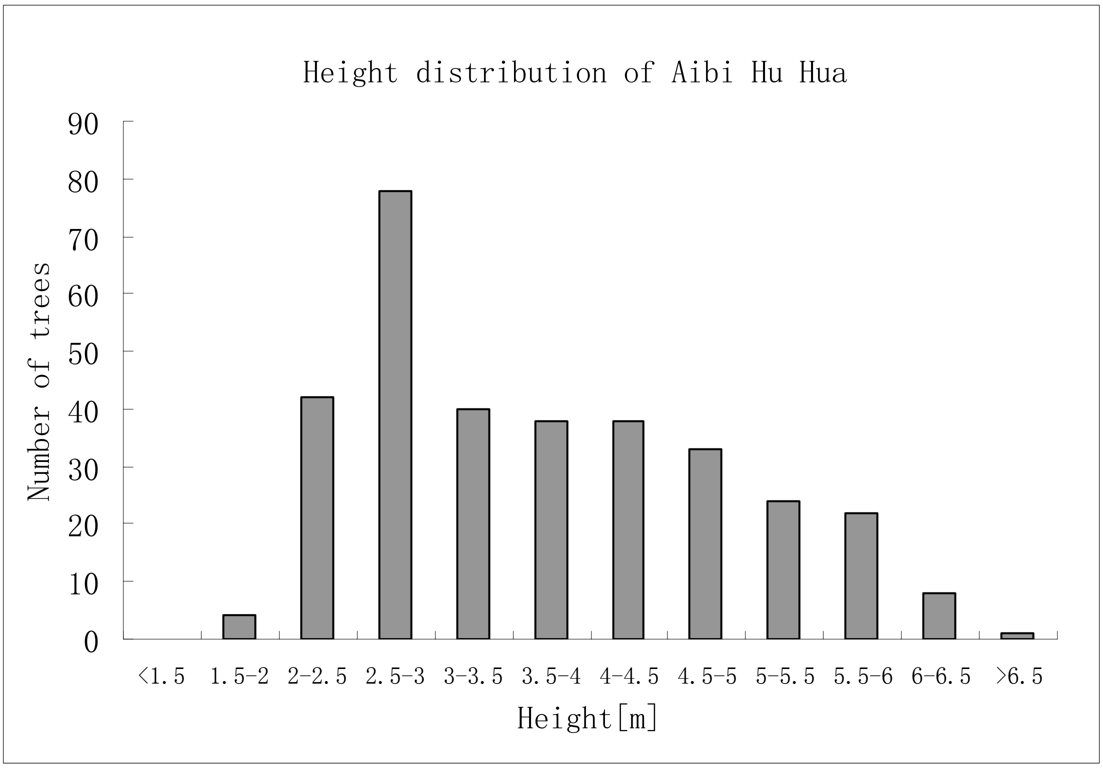


Fig. 58: Height distribution of Aibi Hu Birch on plot A 201.

Abb. 58: Baumhöhen-Klassen der Aibi Hu-Birke auf der Monitoringfläche A 201.

图例 58: A 201 样地中艾比湖桦高度分布情况.

Diameter at one meter height

Because the height of all the individuals of Aibi Hu Birch ranged from 1.7 to 6.7 m, different from the normal procedure (DBH: 1.3 m above ground), the diameter of this species was measured at one meter above ground. The maximum diameter of all the 328 individuals was 21.0 cm (tree No. 290), the minimum was at 2.4 cm (tree No. 34).

Diameter distribution was analyzed by subdividing the data into classes with widths of 2

cm each, ranging from 2 to 20 cm. The data showed that the maximum of stem numbers occured between 4 cm and 6 cm (Fig. 59).
Fig. 59 shows that the diameter distribution was approximately following Poisson distribution in general.

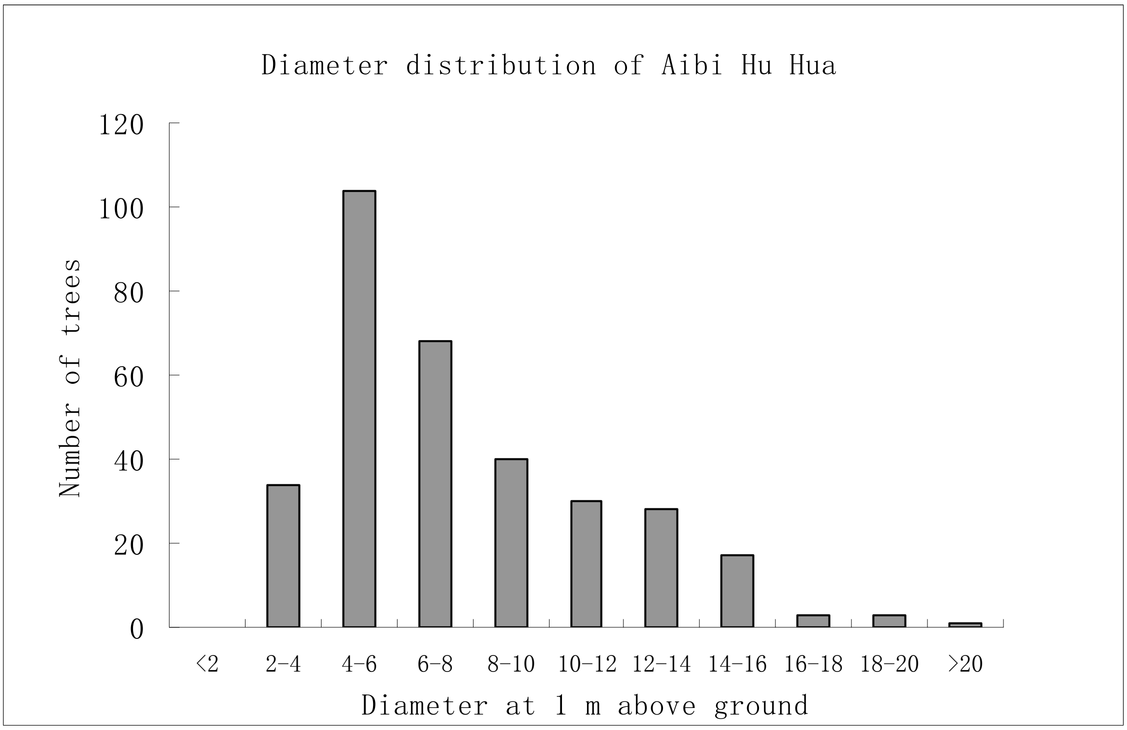


Fig. 59 : Stem diameter distribution (at 1 m above ground) of Aibi Hu Birch on plot A 201, 2006.
Abb. 59: Diameter-Klassen (1 m über Grund) der Aibi Hu-Birke auf der Monitoringfläche A 201.
图例 59: A 201 样地中艾比湖桦树经分布情况.

Crown

Crown width of Aibi Hu Birch was measured from East to West and South to North for each individual. The data showed that this species has a very regular crown width formation. There were no big differences between the diameter E-W and S-N for each individual (Fig. 60). Detailed analysis showed that the average width of E-W was little bigger than S-N. The relation can be described by a linear regression: Y (S-N) = 0.83X (E-W) + 0.09, $R^2 = 0.76$.
Crown form of Aibi Hu Birch was analyzed by means of comparing the crown width with the crown height. Average width of S-N and E-W was used from the selected 10% individuals as crown width in this case. In Fig. 61 one can find that crown height was closely correlated with the crown width. Crown height increased according to the crown width following a linear regression: Y (crown height) = 0.79x (crown width) + 0.21, $R^2 = 0.75$.

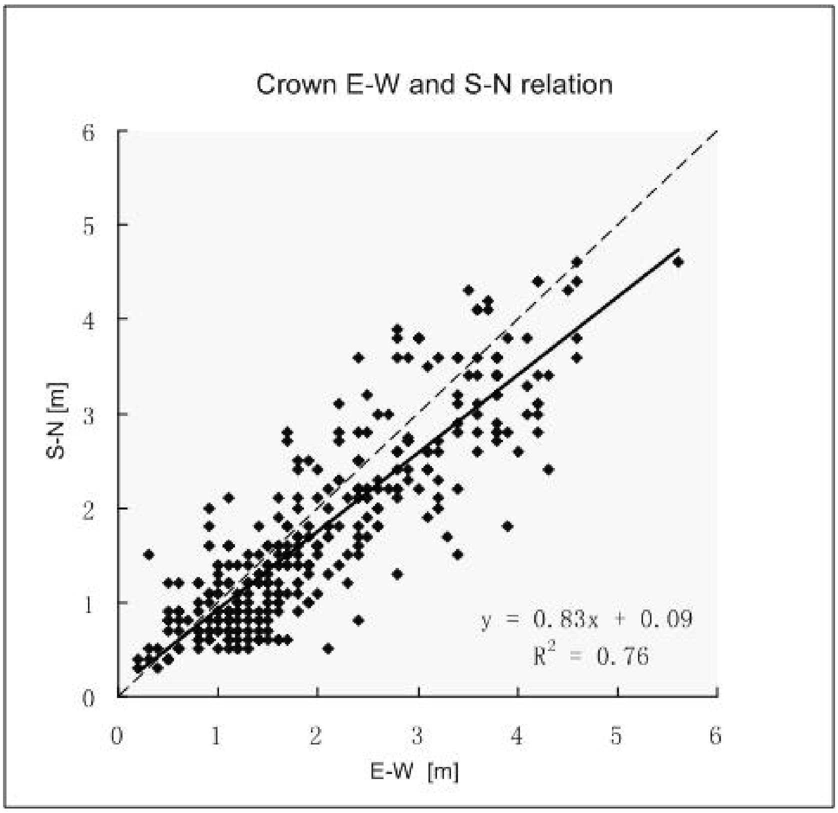


Fig. 60: Crown width E-W/S-N relation of Aibi Hu Birch on plot A 201, 2006 (dotted line: E-W/S-N=1).
Abb. 60: Kronenausdehnung (O-W und S-N) der Aibi Hu-Birke auf der Monitoringfläche A 201.
图例 60: A 201 样地中艾比湖桦冠宽分布情况.

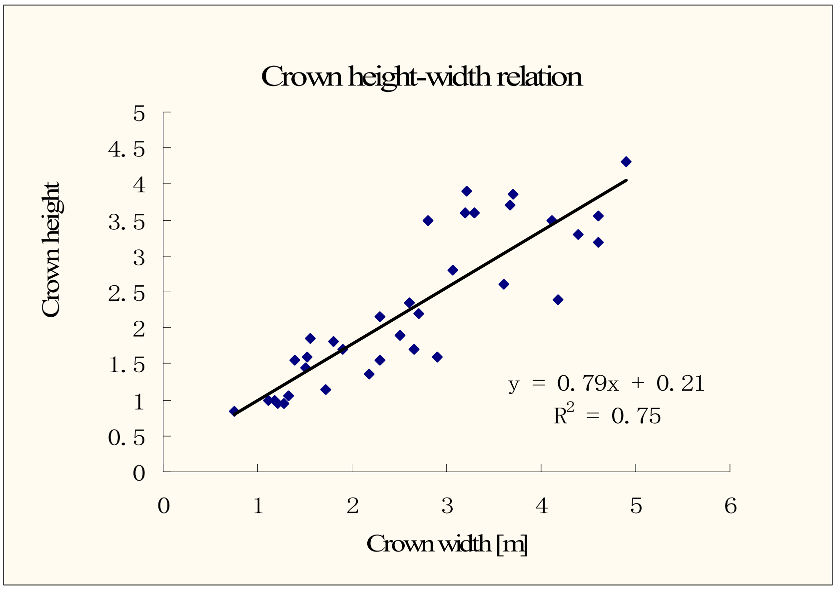


Fig. 61: Allometric relation between crown height and crown width in Aibi Hu Birch on plot A 201, X-axis: crown width [m], Y-axis: crown height [m], May 2006 (n = 36 selected individuals).
Abb. 61: Allometrische Beziehung zwischen Kronenlänge und Kronenbreite der Aibi Hu-Birke auf der Monitoringfläche A 201.
图例 61: A 201 样地中艾比湖桦冠宽与冠高的关系.

Correlation between height and stem diameter

The data showed that tree height and diameter were closely correlated. Allometric relation between height and diameter can be described by a logarithmic regression (y = 2.06 Ln(x) - 0.28, R^2= 0.70, Fig. 62).

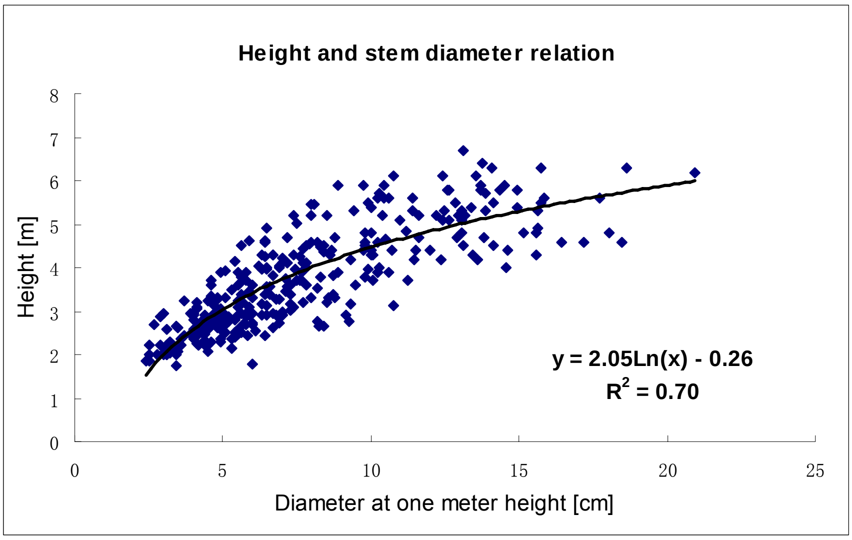


Fig. 62: Allometric relation between diameter and height in Aibi Hu Birch on plot A 201, X-axis: diameter at one meter above ground [cm], Y-axis: height [m], 2006.

Abb. 62: Allometrische Beziehung zwischen BHD und Höhe der Aibi Hu-Birke auf Fläche A 201 (Schlankheitsgrad).

图例 62: 艾比湖桦树经与树高在 A 201 监测样地中的异速生长关系.

Age structure of selected stems

Counting of tree ring of the 14 samples showed that the miximum age was 38 years. Fig. 63 shows the age structure of the selected stems.

In Fig.63 one can find that all of the individuals of the small population of Aibi Hu Birch were young trees. The data of the samples showed that the youngest was 18 years old (s1, dead tree) whilst the oldest was 38 years old (tree No. 166, plot A 201).

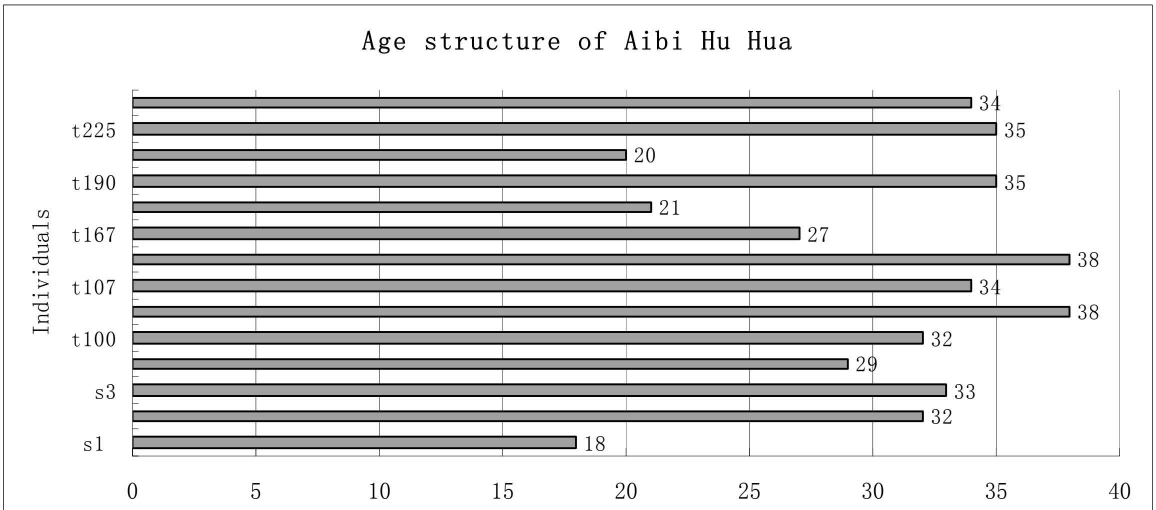
Growth over two years

Growth of the endemic birch Aibi Hu Birch over two years was calculated using the measurement at the beginning of the growth season 2006 and the end of growth season 2007.

Absolute growth rate of height was obtained using the average value of the 328 living individuals of the measurement in May 2006 and September 2007. The growth rate was: (3.91-3.69)/2 = 0.11 m per year (Fig.64).

During these two years, 3 trees died (No. 4, No.12 and No. 13).

Absolute growth rate of diameter at one meter height was obtained using the average value of the 328 living individuals of the two measurements. The absolute growth rate was: (8.31-6.63)/2 = 0.34 cm per year (Fig. 65).



	s1	s2	s3	s4	t100	t105	t107	t166	t167	t175	t190	t210	t225	t244
Age	18	32	33	29	32	38	34	38	27	21	35	20	35	34

Fig. 63: Age structure of Aibi Hu Birch on plot A 201 (n=14; s1-s4: dead trees; t100-t244: living stems).
Abb. 63: Die Altersstruktur der Aibi Hu-Birke auf Fläche A 201.
图例 63: A 201 样地中的艾比湖桦树龄结构.

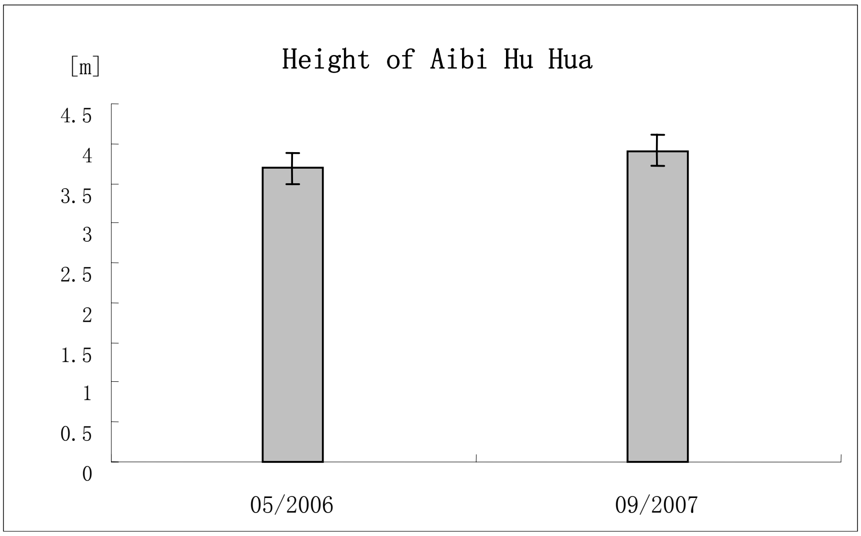


Fig. 64: Height of Aibi Hu Birch on the permanent research plot A 201 (May 2006 and Sept. 2007).
Abb. 64: Höhe der Aibi Hu-Birke auf der Monitoringfläche A 201 (Mai 2006 und Sept. 2007).
图例 64: A 201 监测样地中艾比湖桦高度生长情况(2006.05 与 2007.09).

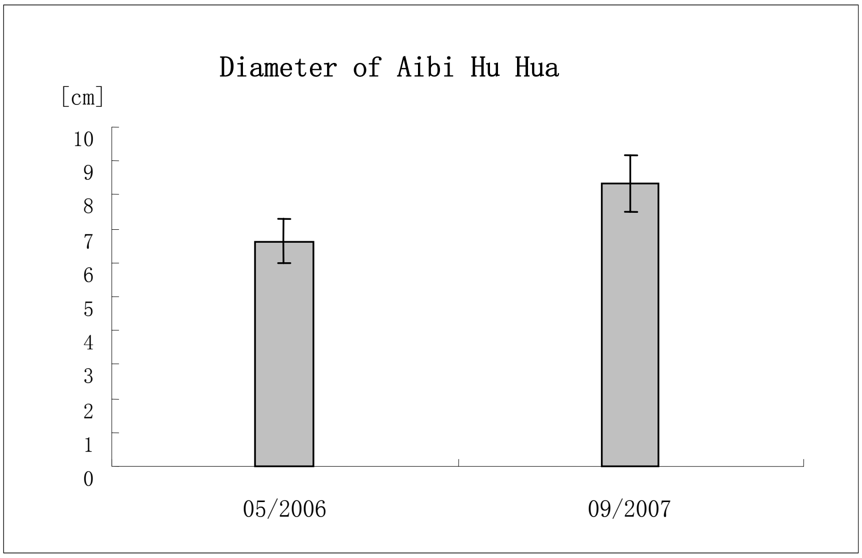


Fig. 65: Diameter (1 m height) of Aibi Hu Birch on the permanent research plot A 201 (May 2006 and Sept. 2007).

Abb. 65: Stammdurchmesser (1 m über Grund) der Aibi Hu-Birke auf der Monitoringfläche A 201 (Mai 2006 und Sept. 2007).

图例 65: 监测样地中艾比湖桦 1 米高处直径生长情况(2006.05 与 2007.09).

4 Discussion and Conclusions

4.1 Data quality

Repeated measurements (n=3) of *P. euphratica* trees showed that the accuracy of tree height was 0.2 - 0.5 m. This was not precise enough for the determination of the annual growth rate of an individual. But on a whole view, one could obtain an average growth rate for a whole plot in total. This is appropriate for forest description on the base of statistical analysis.

During the measurement, it was found that the value of DBH from the same tree could vary between 1 to 2 cm because of the rough bark on the trunk. Repeated measurement showed that the standard error was <1 cm. This was not accurate enough for determining the annual increment rate which was less than 1 cm. Compared to this, the values from the permanent girth bands on the selected trees (n=10) had an accuracy of <0.01 cm, this was accurate enough to indicate the annual growth rate for the selected individuals.

The accuracy of < 0.2 m (2.2.1.5) in the measurement of the height of Aibi Hu Birch was also used for the statistical analysis to get the average annual growth rate of the whole plot. This was not accurate enough to indicate the annual growth for each individual seperately.

Repeated measurements (n=3) of the diameter of Aibi Hu Birch (at 1 m height, 2.2.1.5) showed that an accuracy of < 0.5 cm could be revealed. This was not accurate enough for determining the annual increment rate of an individual which was less than 1 cm (average 0.34 cm, 3.9). However, it can be used to obtain an average annual growth for the whole plot by means of statistical analysis.

Underground water level was measured with a meter band with an accuracy of 0.01 m. This value was precise enough for the purpose of this study. Because the ground water level was fluctuating between 1 to 3 m.

Soil analysis was conducted several times in different laboratories both in China and in Germany (2.2.1.1). It was difficult to quantify the error because there were no parallel measurements and ring analyses. Comparison of the different data showed that the accuracy, which the laboratories provided, was acceptable.

The number of individuals of *P. euphratica* (n=425) was big enough for describing the growth performance in general; the data from the living stems of Aibi Hu Birch (n=328) was also big enough for describing its growth performance in general.

It can be assumed that considering all the possible variables, with the exception of tree vitality, that the results are accurate and consistent enough for the purpose of plot comparisons and that they can be used to obtain the average description of forest development over a period of two years.

4.2 Conclusions from the measurements on trees

4.2.1 *Populus euphratica*

Criteria of the plots

The distribution of *P. euphratica* in the study site was different from the Tarim region. In the Tarim region, there were many clustered *P. euphratica* trees (Li X. et al., 2003). In our study site, only on plot A 102, there were some young trees clustered. On all the other seven plots, canopies of individuals were not connected. There were no clustered trees with more than five individuals. The crown coverage of the plots was 0.3% (A 141) to 18.7% (A 101 and A 102, Fig. 39).

It was found that the number of living stems on some plots (A 111, A 121, A 141, A 151 and A 102) were on the way to decrease within two years during this study. In 2007, 8 of the 433 trees (1.9%) were dead (table 17).

Propagation in this region was different compared with *P. euphratica* forests in the Tarim region of Xinjiang (Chen Y.J, Li Y.N. and Li W.D., 2005) and other similar places (Kang X.Y., 1997). In this study, no regrowth of *P. euphratica* was found in 2006. In 2007, some root suckers were found on plot A 101 after the plot was fenced for one year.

Height

According to Zhang H.F. and Li X. (2006), the normal height distribution of a middle age *P. euphratica* forest in the similar semi-arid area, e.g. Tarim region, was 8 - 20 m. In this study, the measurement of all the 425 living stems showed that all the trees was ranged from 1.1 to 11 m (3.5 Tree parameters). It indicated that the average height in the study site was much lower than in healthy forests.

The height distribution of living stems in a healthy forest should be regular and following the normal distribution (Gaussian distribution). But in this study site, on all the plots, the distribution of the heights was irregular (3.5, Fig.41).

DBH

Compared to the healthy *P. euphratica* forest (Wang S., 1996; Zhang H.F. and Li X. 2006), the DBH distribution was very irregular. Only on plot A 101, the DBH distribution was close to normal distribution. On all the other seven plots, it was not normally distributed (3.5, Fig.44). In other words, *P. euphratica* trees on most of the plots were not growing as well as in the regions where *P. euphratica* forests are growing well.

Crown

The measurement showed that there was no close relation between crown form and tree height and DBH (Fig. 46). Crown height was not closely correlated with the crown width. It indicated that the *P. euphratica* trees were in a poor growth situation.

Correlation between height and stem diameter

The data showed that the correlation between height and stem diameter was very weak (3.5, Fig. 49). On average, there was a tendency to increase the height - DBH ratio along the transect (Fig. 50, R^2: 0.47). But it was a very slight one. It indicated that the formation of the trees were not regular.

Biomass

The formula that connects the height, DBH in order to calculate stem biomass was based on a very low number (n=3). It was not accurate enough for the actual use (Meng C.H. et al., 1990). It must be improved in the future study for the purpose of calculate the biomass production (4.9). The suggested number should up to 30 for actual use.

Tree ring analysis

Compared to the age structure of the *P. euphratica* forest in the Tarim region in Xinjiang (Wang S., 1996; Westermann, 2005), the age structure showed that the forest in this area had less young trees (3.7 tree ring analysis) i.e. there was a lack of regrowth in this area for a sustainable development of forests.

The event of the negative influences in 1944, 1961 and 1993 cannot be clearly interpreted yet. According the climate data from Jinghe weather station (2.1.1.3, Fig. 6, Fig. 8), annual precipitation or temperature change seemed not to have an obvious effect on it (4.5). This is open to future studies.

Growth of *P. euphratica* over two years

In the similar semi-arid area, like the Tarim region in Xinjiang, the annual height increment was 0.25 – 0.30 m (Wang S., 1996). In this study, the data of two years measurement showed that the annual height increment was 0.08 – 0.27 m (3.8, Fig. 56) i.e. the height increment was slower than the average absolute growth rate of a healthy *P. euphratica* forest.

The data from measurements over two years showed that the absolute DBH growth rate was 0.22 – 0.45 cm per year (3.8, Fig. 57). This was much smaller compared to the average growth rate which amounted to 0.56 – 0.85 cm per year in the Tarim region (Wang S. et al., 1996).

The data of the DBH measurements from the permanent girth bands showed that the season for stem diameter growth lasted from May to August each year (Appendix 5, Table A-5); this was same as in the Tarim region (Wang S. et al., 1996).

To sum up, in the study site, growth of *P. euphratica* over two years from 2006 to 2007 was slower compared to the similar Tugai forest in the Tarim region. The trees in the forest in this region were not normally distributed and they were in a status of poor growth. There was a lack of regrowth and the forest had a tendency to deteriorate.

4.2.2 Aibi Hu Birch

Measurements of the tree parameters of the endemic Aibi Hu Birch showed that height and diameter (1 m height) distribution (3.9, Fig. 58 and 59) were not normally distributed. Compared to a normal distribution (Liao C.X. et al., 2007), there were too many young trees and therefore, a Poisson distribution fitted the data better.

Age structure of the selected stems (3.9, Fig. 58, n=14) also showed that it was a very

young forest with no trees elder than 40 years.
The correlation between height and stem diameter was approximately regular (3.9, Fig. 62). Also the measurements of the crown forms showed that this species had a very regular crown formation (3.9, Fig. 60, Fig. 61). It indicated that Aibi Hu Birch trees were still growing well.
The measurement of the growth over two years (3.9) showed that the average absolute rate of diameter growth was 0.34 cm per year. It was smaller compared to other birch species from Xinjiang which was between 0.5 to 1 cm per year (Yang W.L., 2000). The absolute height growth rate was 0.11 m per year. It was also very small compared to the similar species which was between 0.4 to 1 m per year (Yang W.L., 2000).
To sum up, the endemic birch Aibi Hu Birch was growing normally but the absolute growth rate was smaller compared to the other indigenous birch species, e.g. *Betula halophila* Ching ex P.C.Li. It tends towards a dwarfish growth. As there were only 328 of the total 461 individuals (71.1%) still living and this species was not found in any other places, it is very important to take special care for its survival.

4.3 Soil influence

Total salt content in the soil is one of the most important factors that affect the survival of *P. euphratica* trees in semi-arid areas (Sun X., 1993). According to the results of the studies by Chen B.H. (1992) and Chen S.L. et al., (2001), *P. euphratica* trees can not grow well if the salt content reaches 2-3%, if the salt content is higher than 3%, it will die gradually.
In this study, it was found that the salt content in the soil on most of the plots exceeded this limit value in the upper soil layers. It was also higher than the similar places e.g. the lower reaches of the Tarim River (Zhang Y.S. et al., 2004).
In appendix 4, one can find the soil quality of some selected points in Aibi Hu region (provided by Jin H.L. et al., 2006). After two year of studying, it can be assumed that the real reason for the death of *P. euphratica* was the soil salinization. It should not be the shortage of water as was concluded in many articles (Li W.H. et al., 2002; Ma J.Y., Li X.Q., 2005). In 2006, the data from the analysis of the soil samples did not show the salt content in details and it was not clear enough to support this hypothesis.
In May 2007, a detailed analysis was done on all the eight *P. euphratica* plots. The result showed that on most of the plots, the salt contents were too high for the growth of *P. euphratica* trees (3.2, Table 15). Apart from A 112, on all the other seven plots, salt contents were higher than the critical load of 3%. On plot A 131, the salt content in the surface soil even came to 20.4%. The comparison of the soil analysis on the plots showed that on plot A 131 and A 141 (surface salt content 11.9%) where most of the trees had died, the salinity in the soil was higher than on the other plots. One can assume, therefore, that the salinity in the soil and groundwater was more decisive than the lack of water supply from groundwater. It can be concluded that the shortage of water was not the real reason for the death of *P. euphratica* in this area. The high salinity was responsible for the dying of the *P. euphratica* in the study site.
On plot A 112 which is near to the desert, sand movement made the surface soil unstable, the salt content was lower compared to the other plots. Salt content (0.5%, surface; 1.3%,

60 cm underground) had not reached the limit value. Soil salinization had no significant influence on the growth of *P. euphratica* trees on this plot.
Apart from the salinity of the soil, pH value is another important impact factor on *P. euphratica* trees growth (Wang C., 1989; Wang S. et al., 1996). According to Chen B.H. (1992), *P. euphratica* trees can grow well even if the pH value comes to 9.3. The result from Wang S. et al. (1996), indicated that *P. euphratica* trees can grow well if the pH value comes to 9.6 in the soil. On all the eight plots, the pH values ranged from 8.4 (plot A 112) to 9.1 (plot A 151). Thus indicating that in this area, it had not come to the limit value. This result also supports the hypothesis that *P. euphratica* trees can grow well even if the pH value comes to 9.1.
On plot A 201, where the endemic Aibi Hu Birch was growing, because it was the former river bed, the total organic carbon (TOC) was much higher than on the other plots. On this plot it amounted to 18.4% which was much more than as was in other plots (Table A4-3). Opposite to TOC, on plot A 201, pH value was measured 8.4 which was the lowest on all the plots. According to the publication (Mei X.D. et al., 2006), the suitable pH value for the similar birch (*Betula halophila*) in Xinjiang was 5.0-7.5. Also the pH value on plot A 201 came to 8.4. Therefore it can be assumed that the high pH value could also have some negative influence on the growth of Aibi Hu Birch.

4.4 Impact of climate

P. euphratica trees can grow well at the locations with a wide variety of temperatures. Dry continental climate is suitable for its growth (Deng S.W., 1983; Philipp, 2006). The climatic conditions in Aibi Hu region are typical of the continental dry climate (Qian Y.B. et al., 2004).
The analysis of the regional climate parameters over the past 50 years in this study showed that since 1961, the temperature had a tendency to increase but very slightly (2.1.1.3, Fig. 6); it remained fairly stable compared with other parts in Xinjiang (Wang S.D. and Wang J., 2003; Su H.C. and Han P., 2003).
The precipitation showed a tendency to increase but not very much (2.1.1.3, Fig. 8). The average increment in precipitation was 39.16 mm within 45 years (1961-2006) and it will not have a lot of positive effects on tree growth.
There was an visible evidence that the effects of desertification in this area was spreading (Yang Y.L. et al., 1996). But the deterioration of the environment was not dependent on the amount of precipitation (Yang L.P., 1981; Feng Q., 1998). It was linked directly to the increasing withdrawals of water supplies and the excessive water usage due to agricultural irrigation and land reclamation especially for cotton fields. In other words, the results of this study indicate that the slight trend to climate change had no obvious effect on tree growth in Aibi Hu region.

4.5 Impact of hydrological change

Hydrological situation has a significant influence on *P. euphratica* tree growth (Wang G.X., 2000; Xu H.L. et al., 2003; Fu A.H., 2004). With 90.9 mm of annual precipitation in this region, *P. euphratica* trees can only grow if they have access to groundwater, lakes or rivers (Thomas F. et al., 2006). In the study site, most of the available water for *P. euphratica* trees came from underground.

Due to the human activities in the last fifty years, the utilization of water resources has experienced many changes (2.1.1.9, Table 10). This huge change had a significant influence on the water distribution situation from the upper reaches to the lower reaches of the rivers (Tang Q.C. et al., 1992, 1995). By now, the hydrological condition is completely different compared to fifty years ago (Song Y.D. et al., 1991; Li X.L., 1997).

Groundwater level is one of the important eco-environmental factors affecting *P. euphratica* tree growth in the semi-arid area (Xu H.L. et al., 2004). The soil water content and salt content which influenced tree growth in arid areas are closely correlated to the depth of the ground water level (Fu A.H., 2004). When the ground water level is higher than 2 m, evaporation and capillary flow can force the minerals, dissolved in the ground water, to move upwards and accumulate in the top soil. This lead to soil salinization which influenced tree growth (Wang R.H. et al., 2002). In extreme cases, it can cause the death of the tree (Xu H.L. et al., 2002). In the study site, e.g. on plot A 131, the salt content in the surface soil was 20.4%; there were only three trees still living, most of the trees had died.

On the other hand, if ground water level is lower than 5-10 meter, the capillary flow can not reach the root system of the tree. This leads a lack of water available to the tree root (Chen Y.N. et al., 2003, 2004).

The measurement of groundwater level in 2006 and 2007 showed that on all the plots, the ground water level was higher than 3 m (3.3 Ground water level). On plot A 141 where most of the trees were dead, the ground water level was higher than 2 m during the whole growing season 2006 and 2007 (1.29 -1.64 m, 3.3 Ground water level). This level was much higher than the maximum limit of water level for *P. euphratica* which is 5 - 10 m (Xu H.L., 2004) or 7-23 m (Gries D. et al., 2003). In other words, the water level was not too low for *P. euphratica* growth. Water was still available for *P. euphratica* trees.

In the study area, the former Aqikesu River was partly dried up. As a result, because of the high evaporation rates and low precipitation, the ground water close to the surface tended to evaporate intensively, leaving a salt concentration that could not be washed away. Thus was responsible for the dying of the *P.euphratica* in the study site (4.2).

My results indicated that ground water level is one of the critical ecological factors that control *P. euphratica* growth. The former researches in the Tarim River region also showed its impact on this species (Zhang F.J. et al., 2005). To prevent soil salinization in this area, we have to keep the ground water level lower than 2 m in order to reduce the salt content near the soil surface (this was done formerly by the flowing of the water in the old Aqikesu River). Contrarily, if the water level is too low to supply the root systems, the moisture necessary for the adequate plant growth in this area cannot be guaranteed to prevent desertification. This could inhibit plant growth and increases the effects of wind erosion and sand drift (Nikolaev V.V. and Baimyradov D., 1987).

Therefore, it is very important to keep the ground water level between maximum water supply for tree growth (including other plants) and the minimum harmful effects of soil salinization and achieve the best results for desertification control in this region i.e. the *P. euphratica* restoration efforts in this region needs a successful management of ground

water level.
Two ways to solve the problem are suggested. The best way is to revert the water flowing of the old Aqikesu River. If not possible, one should find a way to keep the ground water level depth between 2 and 4 m in this area. Anyway, the salinity has to be reduced for the forest development.

4.6 Influence of growing human population

Growing oasis population need a lot of water for irrigation, it can destroy the ecological balance in the semi-arid area and thus cause the change of the landscape in the surrounding areas (Li X.C. 1998; Li X.M. and Zhang X.M, 2002).
In the study area, as a result of the sharp increment of oasis population in this region (2.1.1.9, Table 8), the farmland area increased very quickly, about 10 times within 50 years (2.1.1.9, Table 9). It caused the total water use for irrigation increased 5 times from 1950 to 2000 (2.1.1.9, Table 10). The direct effect on the study site was the dry up of the Aqikesu River.
The irrational utilization of water resources resulted in directly further acceleration of the recent desertification process in the region (Yang C.D. 1990; Jin H.L. et al., 2006). Over the last five decades, about 2415.6 km^2 arable land was turned into unproductive soil in the surrounding area of Aqikesu River (Yang Y.L. et al., 1996).
Another impact of human activities on the forest of this region was over-grazing. According to the information from Aibi Hu National Nature Reserve, there were about 45,000 domestic animals in the reserve (Gao X., 2007, personal communication). These animals destroyed almost all the young trees and it made the forest regrowth impossible.
The ecosystems and their sustaining ecological balance are extremely sensitive in this region (Qiao C.M., 1996; Chen Q., Chen Z.J. and Zhang X.G., 2005). Once destroyed, it would be very difficult to restore it. In the process of developing water and land resource utilization, it is necessary to consider the requirements of ecological sustainability as well as the reasonable scale and the limits of exploitation (Zhou X., 1993; Li X.L., 2001). The investigation in this study showed that the unreasonable use of water resources and over-grazing was still continued in the prevalent disregard of the natural vegetation areas, i.e. new farmland was opened 20 km away from the study site in the upper reach of Aqikesu River in 2006 (mainly cotton fields). Therefore, it is very important to control the water use and reduce the number of the domestic animals.
The conclusion is that in the last fifty years, the human population in the up reaches increased too quickly. It has to be controlled in order to meet the challenge of restoring the natural hydrological balance maintaining the ecosystems and to provide sustainable development of this region.

4.7 Nature reservation strategy

1. As was explained in the text, that the soil salinization in the lower reaches in the study site was the primary reason for the death of *P. euphratica*. Therefore, the most important mode of activity is to reduce the salt content in the soil. In searching a better

resolution of this problem, effectual method on the sustainable management, especially on how to get enough surface water in this region should be studied.

2. The best way for the survival of *P. euphratica* in this region is to recuperate the flowing of water in the old Aqikesu River. The amount of water used for the farmland in the upper reaches has to be reduced. In order to do this, the area of the total farmland in the upper reaches, especially the cotton fields, have to be reduced. The limited area should be studied as soon as possible and for the existing farmland, a set of optimum mechanisms for managing water resources have to be developed. Advanced technology for optimum irrigation is needed and investments for installation of water saving facilities are essential.
3. During this study, it was found that the undue collection of firewood and blind gathering of medicinal herbs were one of the important reasons for the desertification in this region. This has to be stopped immediately.
4. Over-grazing made regrowth in this area impossible: During this study, a fence was built around plot A 101 in 2006, after one year, in 2007, many root suckers and young shoots from underground horizontal shoots were found. In contrast to this, on all the other plots which were open to the domestic animals, no young trees were found. This indicated that, without the influence of the domestic animals, it is possible to get root suckers and regrowth by nature in this area. According to the Aibi Hu National Nature Reserve, there were about 45,000 domestic animals in the reserve. These huge amounts of animals eat almost all the young *P. euphratica* trees which made growth in this area impossible. The amount has to be reduced to a reasonable number. The number has to be defined for camels, horses, cows, sheeps and goats separately because of their different grazing preference and behavior (reasonable numbers of each species should be studied in future research).
5. The reduction of forest since 1950 in this region caused the protective function as a shield against wind and sand erosion and desertification has become greatly impaired (Yang Y.L. et al., 1996). The establishment of sandbreaks and wood stands in the connected region is necessary to prevent the desertification.
6. For the forest development in this region, apart from the protection of the living stems, it is imperative to find a way on raising seedlings in this area. According to the situation in this aera, it would be very difficult to get enough fresh water for seedlings in large scales by nature process. Artificial seedling cultivation should be adopted. The best way is make the use of the strong sprouting capacity of root-suckers, in doing this, methods and effects of root-sucker regeneration in this region should put into practice as soon as possible.

5 Problems for future work

As growth analysis of forest needs a long period of observation, this study of two years was not long enough. The study should go on after this thesis. The monitoring are supposed to be continued and the eight *P. euphratica* plots and the Aibi Hu Birch plot will serve as long-term plots for investigating the growth performance of forests in this region.
In the future, the following problems should be studied:

1) Effective ways of salinity reduction should be studied in the future. A possible answer might be the same way of floodplain management as people did along the Tarim River (Yang G. & Guo Y., 2004; Hoppe et al., 2006).
2) Transpiration and photosynthesis have to be measured in response to a possible climate change (temperature and CO_2 concentration increase); Water-use efficiency of *P. euphratica* in this region should be studied.
3) To investigate the impact of regrowth and find a suitable method for raising seedlings is very important in the future study. In this study, only one fence was successfully used to compare with the open plots. In the future study, more fences (50%) should be used. The possibility of using the technology from the successful examples in the similar places (Sun H.X. et al., 2000; Gao R.H. et al., 2005) should also be studied.
4) The formula which connects the height, DBH and stem biomass (3.6) was the result of only three harvested trees. To get a better formula for describing growth and wood production of *P. euphratica*, it should be improved. In doing this, more trees should be harvested in the future study. The first step could choose 5 additional trees and than use the 8 trees to determine the coefficients to get a better formula. If it would be necessary to increase the number again, further individuals should be harvested. The suggested number is up to 30.
5) According the tree ring analysis in this study, within the last 70 years, in 1944, 1961 and 1993, there must have been events which had negative influences on tree growth (3.7). The reason for this should be studied. More work should be done by tree ring analysis to assess the interactions between environment and tree growth.
6) As there were about 45,000 domestic animals in the reserve, their number should be reduced, their functional role and reasonable number have to be studied. A possible method could be to have an experiment with different numbers of goats, sheep, cows, horses and camels grazing on selected plots to quantify the impact factor.
7) Data of field measurement should be combined with the satellite images to monitor the health state of tree stands on large scales in this region i.e. by inquiry on the ground and by remote sensing.
8) There are still something unclear about the small population of Aibi Hu Birch, the Aibi Hu Birch plot (A 201) should be used for a long-term monitoring of the growth of this species. The DNA of this birch should be compared with the other birch species of Xinjiang in a completely separate abundant study.
9) Other woody plant species (e.g. *Tamarix spec.*) should be investigated on the plots in respect to their growth response to water shortage and salinization.
10) Effects of oxygen shortage on root and root sucker growth of *P. euphratica* should be studied under defined environmental conditions (greenhouse, laboratory etc.) and be compared with results from measurements in the field.

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References

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Appendix

1 Table A-1: Temperature data of the study area in 45 years (Jinghe station, 1961 - 2006).

2 Table A-2: Monthly mean precipitation of the study area in 45 years (Jinghe station, 1961 - 2006).

3 Table A3-1: Height of *P. euphratica* on the permanent research plots; Table A3-2: DBH distribution of *P. euphratica* on the permanent research plots.

4 Table A4-1: Soil quality of some selected points in Aibi Hu region (provided by Jin H.L. et al., 2006); Table A4-2: Soil quality of some selected points in the study site (provided by Xinjiang Normal University, P.R. China).

5 Table A-5: Every two weeks measurement of DBH on plot A 102 during the growth seasons in 2006 and 2007.

6 Fig. A-1: Topographical map of Xinjiang, P.R. China (modified from a TU.Berlin map).

7 Fig. A-2: Relief map of Aibi Hu region (provided by Aibi Hu National Nature Reserve, Xinjiang, P.R. China).

8 Fig. A-3: Hydrographical map of Aibi Hu region.

9 Fig. A-4: Vegetation map of Aibi Hu region (Aibi Hu National Nature Reserve).

10 Fig. A-5: Distribution of the research plots in the study area on overview satellite picture (Source: Aibi Hu National Nature Reserve, Xinjiang, P.R. China).

11 Fig. A-6: Location of the research plots on the QuickBird image.

12 Fig. A-7: QuickBird images of the eight *Populus euphratica* permanent research plots.

13 Fig. A-8: QuickBird image of the endemic birch (Aibi Hu Birch) research plot.

14 Protocol for forest and tree data acquisition (Source: Prof. Dr. Birgit Kleinschmit, TU Berlin, modified).

(More details about the study area and data are available by contact to Mr. Ruide YU, yuruide@yahoo.com.cn).

Appendix 1

Table A-1: Temperature data of study area in 45 years (Jinghe station, 1961-2006; Source: Institute of Desert Meteorology, P.R. China).

Tab.A-1 : Klimadaten des Untersuchungsgebietes (Jinghe Station, 1961-2006), Temperatur.

图表 A-1: 研究区域气温月平均值数据 (精河气象站, 1961-2006).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1961	-15.9	-10.8	3.2	15.1	20.0	21.6	24.9	22.7	17.4	5.8	-0.4	-9.1
1962	-18.5	-12.4	3.9	11.9	21.1	23.7	26.2	24.7	18.8	9.3	-1.9	-11.1
1963	-12.4	-4.2	6.6	8.5	19.1	24.0	25.1	23.2	16.1	9.7	2.1	-8.1
1964	-16.7	-19.1	-0.1	10.7	18.6	23.2	24.4	23.7	17.2	6.4	-0.2	-10.0
1965	-13.6	-11.3	1.6	13.2	20.4	23.3	27.2	24.1	18.0	8.9	-0.2	-14.1
1966	-15.2	-9.1	2.9	10.1	16.6	24.5	25.4	24.9	20.4	7.7	-3.5	-13.7
1967	-20.0	-14.7	1.2	13.1	21.7	23.9	24.5	22.0	16.0	10.1	-4.4	-13.3
1968	-13.5	-12.5	3.1	9.0	21.3	23.8	25.2	23.2	14.5	8.3	-2.4	-10.7
1969	-20.8	-19.5	-2.3	11.2	18.0	23.1	25.1	21.9	16.2	8.7	-0.9	-10.3
1970	-15.6	-8.1	-1.0	11.7	17.8	22.7	24.3	23.3	17.6	7.7	-2.5	-13.5
1971	-16.3	-11.8	-3.5	11.2	18.2	24.1	24.4	23.5	17.9	9.4	1.1	-5.5
1972	-15.7	-18.3	-0.7	11.8	20.3	22.8	22.9	22.6	15.4	7.1	0.5	-8.3
1973	-11.6	-9.0	1.5	13.2	17.1	23.3	25.5	23.7	17.1	6.7	0.8	-8.7
1974	-15.3	-16.5	0.1	14.3	21.3	24.0	27.0	23.5	16.7	6.9	0.1	-19.7
1975	-13.7	-10.3	3.7	12.0	16.5	22.8	25.9	23.7	18.4	8.4	-4.9	-16.0
1976	-15.6	-9.0	-1.7	10.8	20.8	23.7	24.9	23.9	17.1	7.6	-6.3	-14.9
1977	-19.2	-15.5	-1.5	12.2	19.7	26.7	24.5	24.2	18.9	9.3	2.1	-9.1
1978	-19.8	-14.8	1.8	14.1	18.8	24.3	26.6	22.1	19.3	7.6	0.3	-6.3
1979	-14.6	-8.7	-0.9	8.7	16.9	22.8	25.5	24.2	17.6	10.7	-5.1	-9.0
1980	-16.7	-10.7	-2.6	11.8	20.5	22.8	26.1	24.2	18.1	10.0	3.0	-9.1
1981	-16.9	-13.5	3.0	13.1	19.5	24.8	25.6	24.2	17.9	7.2	-1.9	-12.1
1982	-10.2	-6.3	1.5	13.4	20.5	24.5	25.6	23.7	17.8	10.5	-0.4	-11.7
1983	-11.6	-6.1	4.9	13.0	17.8	23.1	25.5	25.0	16.8	9.5	1.0	-7.2
1984	-16.2	-13.7	1.9	9.2	19.5	23.5	24.7	24.8	17.3	7.9	-0.3	-20.3
1985	-17.2	-9.8	-3.9	12.3	17.9	23.3	26.1	23.5	17.0	7.8	-1.6	-10.9
1986	-17.0	-14.1	0.7	10.8	19.7	22.6	26.1	22.9	18.3	7.6	-2.2	-12.8
1987	-13.5	-7.8	-2.2	11.3	19.4	21.2	26.8	24.9	17.5	5.5	-4.3	-9.1
1988	-13.3	-18.0	-3.7	11.7	16.6	24.0	24.8	23.1	19.1	8.2	1.2	-5.6
1989	-15.2	-14.0	-1.0	10.2	19.6	23.2	25.3	23.3	17.1	9.7	-1.1	-0.6
1990	-10.6	-9.5	2.4	11.8	19.6	25.5	24.8	23.0	18.3	8.9	-0.5	-7.2
1991	-13.8	-12.8	-0.5	13.5	20.4	24.4	25.8	23.1	18.5	10.5	-1.3	-8.2
1992	-14.4	-10.2	1.2	13.9	18.3	23.3	25.2	21.4	14.0	6.8	-2.8	-7.7
1993	-16.3	-5.3	2.1	11.1	16.5	23.8	24.5	22.0	16.2	8.0	-4.9	-16.0
1994	-16.9	-12.5	-2.1	10.7	19.5	24.4	25.3	23.4	15.4	7.6	4.6	-8.4
1995	-18.3	-9.5	1.2	13.8	18.8	24.5	25.4	23.6	18.5	8.8	0.1	-10.9
1996	-16.3	-12.3	0.2	9.9	19.5	24.6	26.4	22.7	17.9	8.5	-1.1	-10.3

1997	-11.5	-10.0	5.4	17.6	21.8	24.9	26.1	23.6	18.9	11.8	-4.2	-12.7
1998	-17.2	-6.3	-0.1	10.5	18.1	26.4	26.0	25.8	17.8	9.1	0.2	-9.0
1999	-15.1	-7.1	-1.6	12.6	20.9	23.6	26.6	24.6	17.8	11.1	-0.5	-8.4
2000	-15.8	-8.8	2.0	15.4	21.4	25.2	26.2	25.0	18.6	5.1	-2.4	-8.9
2001	-12.5	-9.3	4.3	11.0	22.4	25.5	24.8	25.0	17.3	9.0	2.7	-15.0
2002	-12.6	-9	0.6	9.4	19.4	25.3	23.7	23.9	19.1	9.8	-1.3	-11.9
2003	-15.4	-7.7	2.3	13.9	20.8	24.5	25.9	23.8	18.2	8	0.2	-8
2004	-18.8	-17.8	2.2	13.8	20.2	25.9	27.2	23	19.9	9.8	1.7	-13.2
2005	-18.3	-5.2	2.9	14.3	19.9	25.4	25.9	25.1	17.6	11.7	3.1	-8.6
2006	-15.4	-11.1	0.9	12.0	19.4	24.0	25.5	23.7	17.6	8.6	-0.8	-10.6
Average	-12.6	-9	0.6	9.4	19.4	25.3	23.7	23.9	19.1	9.8	-1.3	-11.9

Appendix 2

Table A-2: Monthly mean precipitation of the study area in 45 years (Jinghe station, 1961-2006; Source: Institute of Desert Meteorology, P.R. China).

Tab. A-2: Monatsmittel der Niederschläge (Jinghe Station, 1961-2006) .

图表 A-2 : 艾比地区降水量数据(精河气象站, 1961-2006).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1961	4	0	2.4	14.2	12.7	4.4	16.9	24.8	6.7	0.7	0.5	3.2
1962	7	2.5	3.2	5.2	19	6.8	2	1.2	11.7	0.9	7.3	1.8
1963	0	1.3	8.7	7.9	8	18	5.7	12.7	0.9	5.8	0	7.3
1964	3.2	1	29.2	26.7	11.2	7.3	23.1	7.3	1.3	3.2	0.6	3.2
1965	3	0	2.4	7.9	13.3	1.9	9.6	17.1	0.3	4.7	5.4	6.9
1966	2.7	1.3	20.5	7.3	17.5	29.9	7.4	14.9	0.7	0.3	0.5	3.3
1967	6.5	2.8	1.6	5	4.5	15.1	10.3	5.3	3.4	4.6	1.3	1.6
1968	1.4	0.2	2.2	9	9.8	3	9.6	4.4	0.5	0	0.7	4
1969	1	0.8	22.2	6.4	35.4	13.5	23.5	4.2	11.6	16.6	0.5	6.6
1970	1.8	0.2	15.2	17.9	10.9	23.9	14.8	17.9	6.3	0.8	4	3.3
1971	0	6.1	6.2	23.5	6.1	1.3	3.2	14.3	4.2	0.1	4.9	14.5
1972	2.3	0.6	3.2	7.4	9.3	27.6	4.5	12.7	9	2.8	8.2	1.3
1973	4	6.6	1.3	23.7	16.7	13.2	6.9	11.2	15	0.1	1.8	1.2
1974	5.4	2.5	1.8	12.3	13.4	14.6	3.7	5.9	3.5	7.3	10	0.7
1975	0.6	2.3	1.6	2.2	0.9	9.8	12.4	7.5	2.7	9.4	0.2	4.6
1976	1.1	2.5	1.2	7.9	16.2	3.8	3.5	0.7	11.7	31.9	1.5	1
1977	6.2	2.3	1.6	0.6	10.2	4.2	18	2.8	7	14.4	2.3	11.8
1978	1	1.1	27.2	1.5	21.6	11.4	27.3	0.6	2.2	5.8	1.4	0.7
1979	9	3.8	3.9	14.4	0.8	18.2	4.3	1.8	14.7	6.2	3.5	1.5
1980	7.4	7.8	13.9	16.8	17.6	5.6	11.1	12.8	6.7	3.8	0	9
1981	4.2	2	13.1	15.5	4.9	14.5	21.6	13.2	16.8	3.5	3.3	0.8
1982	1.5	0.1	0.9	0	13.8	34.5	12.6	10.1	11.4	9.6	7.2	1.6
1983	5.7	1.3	0.2	1	29.9	14.1	13.8	51.1	24.9	3.9	5.4	5.1
1984	4	1.1	2.1	15.7	11.6	17.4	9.5	0	10.2	8	2.2	3.6
1985	2	10.9	6.1	5.1	19.2	21.5	2.8	1.8	1.4	0.7	9.4	10.2
1986	3.6	2	6.9	10.7	17.3	26.4	5.2	5.6	2.5	7.6	10.9	16.2
1987	2.2	5	21.8	14.2	12.3	33.2	7.1	2.7	48.5	5.5	2.9	8.5
1988	5.4	14.3	1.8	0.4	44.8	19.9	20.5	4.4	10.8	6.4	0.8	10.5
1989	5.5	5.3	0.8	0.3	3.2	1.6	8.3	6.4	19.4	13.9	1.9	11.3
1990	3.8	2.9	6.2	30.8	23.3	3.2	8	6.6	1.1	3.5	3.6	5.5
1991	4.8	1.4	1.1	4.9	0	14.6	12.5	13.3	1.1	1.1	1.8	13.1
1992	5.8	8	1	17.6	20.6	17.9	7.6	20.8	2.9	2.8	0.4	8
1993	3.2	5.5	9.4	1.5	38.8	7.3	16.5	11.5	10.2	17.2	12.3	15.7
1994	4.9	6.4	1.4	18.3	16.3	0.9	11.1	29.1	1.2	1.6	15.9	22.9
1995	2.2	4.8	10	0	12.7	5.9	20.2	6.9	2.6	4.5	2.4	2.4
1996	2.4	2.9	7	3.5	32.7	7.5	7.5	18.9	5.3	3.5	7.7	4.1

1997	5.4	1.6	2.6	11	2.9	7	16.4	4.7	3.8	1.2	1	3.2
1998	9.1	4.2	0.4	30	12.8	5	16.9	18.5	4.4	7.7	0.4	11.2
1999	2.9	4.2	0.5	7.7	28.8	21	10.4	11.9	12.5	10.2	7	5
2000	5.6	2.1	0.3	0.3	7.1	9	20.6	22.2	7.6	17.7	3.7	5
2001	5.2	2.8	1.5	17.1	5	26.4	44.2	11.6	18.8	23.4	0.8	7.6
2002	5.2	14.4	6.1	25.6	17.1	21.9	15.6	2	10.4	19.5	0	4.8
2003	3.2	8.3	3	12.7	28.4	22	21.1	5.2	18.2	0.8	9	5.9
2004	2.5	9.7	1.3	8.3	17.4	18.4	27	3.9	17.2	3.8	1.6	10.8
2005	3.3	2.6	20.8	3.9	19.7	6.7	9.2	14.6	12.1	0.7	0.8	3.5
2006	2.8	8.9	7.4	15.8	10.9	8.1	3.5	8.8	11.5	1.1	16	5.5
Average	3.8	3.9	6.6	10.6	15.4	13.5	12.8	10.6	8.8	6.5	4.0	6.3

Appendix 3

Table A3-1: Height of *P. euphratica* on the permanent research plots.
Tab. A3-1: Höhe von *P. euphratica* auf den Monitoringflächen.
图表 A3-1: 监测样地中胡杨立木高度分布情况.

Plots	Max	Lower 25% median	Median	Upper 25% median	Min
A101	10.6	9.7	8.7	7.2	4.2
A111	7.6	5.2	4.5	2.8	1.3
A121	9.1	7.4	6.2	5.6	4.0
A131	7.2	7.0	6.8	6.3	5.9
A141	5.8	5.7	5.2	4.1	2.0
A151	11.0	6.1	5.1	3.9	2.5
A102	9.9	5.7	4.7	3.6	1.1
A112	6.1	3.8	3.3	2.9	2.3

Table A3-2: DBH distribution of *P. euphratica* on the permanent research plots.
Tab. A3-2: BHD von *P. euphratica* auf den Monitoringflächen.
图表 A3-2: 监测样地中胡杨立木胸经分布情况.

Plots	Max	Lower 25% median	Median	Upper 25% median	Min
A101	73.53	56.66	44.88	38.19	23.87
A111	85.24	33.39	23.95	12.30	5.80
A121	82.91	69.34	54.97	27.69	22.35
A131	35.10	32.17	29.24	27.44	25.65
A141	34.67	30.51	28.46	23.98	12.50
A151	59.11	25.12	15.60	10.82	5.73
A102	53.87	26.02	16.15	11.05	2.67
A112	34.38	17.83	12.09	9.55	5.73

Appendix 4

Table A4-1: Soil quality of some selected locations in the Aibi Hu region (provided by Jin et al. 2006).

Tab A4-1: Bodenqualität an einigen ausgewählten Entnahmestellen in der Aibi Hu-Region .

图表 A4-1: 艾比湖地区土壤测试结果.

Number 编号	Depth 采样深度 cm	Density 密度 $g\ cm^{-3}$	Organic matter 有机质含量%	Total N 总氮含量%	Available phosphorus 速效磷含量 $mg\ kg^{-1}$	Vegetation type 植被类型	Coverage 盖度%	Coordinates 坐标	
								纬度 Latitude N	经度 Longitude E
No.11-01XJCN	40	1.47	2.8	0.2	0.5	Reed 芦苇湿地	> 75	44°38′6.59″	83°15′0.94″
No.11-02XJCN	60	1.31	0.8	>0.1	2.6	*Populus euphratica* 疏林地（胡杨）	< 10	44°39′39.2″	83°19′19.7″
No.11-03XJCN	60	1.17	4.8	0.3	83.2	*Populus euphratica* 阔叶林地（胡杨）	> 75	44°40′27.1″	83°22′36.1″
No.11-04XJCN	60	1.15	3.2	0.2	51.3	Shrub 灌木林地	> 80	44°42′ 17″	83°21′0.2″
No.11-05XJCN	40	1.45	1.3	>0.1	7.2	Shrub 沙生灌丛	< 30	44°40′59.1″	83°18′45.5″
No.11-06XJCN	40	1.41	0.3	>0.1	4.6	Bare soil 裸地（沙质湖岸）	0	44°50′13.8″	82°49′26.9″
No.11-07XJCN	60	1.51	0.9	>0.1	6.0	Reed 矮旱生芦苇	< 5	44°50′13.8″	83°21′9.63″
No.11-08XJCN	60	1.35	1.0	>0.1	6.0	Shrub 沙生灌丛	20	44°56′6.65″	82°49′2.69″
No.11-09XJCN	60	1.25	6.2	0.3	54.4	*Populus euphratica* 阔叶林地（胡杨）	> 50	44°41′	83°18′5.61″
No.11-10XJCN	45	1.10	17.2	0.9	6.9	Aibi Hu Hua 阔叶林地(艾比湖桦）	75	44°36′4.94″	83°37′8.29″
No.11-11XJCN	45	1.12	6.0	0.3	28.1	Grassland 草甸	80	44°34′11″	83°44′40.9″

Table A4-2: Soil quality of some selected locations in the study site (provided by Xinjiang Normal University, PR China).

Tab A4-2: Bodenqualität an einigen ausgewählten Entnahmestellen der Untersuchungsflächen in der Aibi Hu-Region.

图表 A4-2: 研究区域土壤样本测试结果(新疆师范大学).

Number 编号	Depth 采样深度 cm	pH-value pH-值	Organic matter 有机质含量%	Total N 氮含量%	Available phosphorus 速效磷含量 mg kg^{-1}	Conductivity 电导率 ms cm^{-1}	Salt content 盐度 ppt	Coordinates 坐标 纬度 Latitude N	Coordinates 坐标 经度 Longitude E
No.12-01XJCN	0-10	9.5	0.5	8.4	29.1	2.3		44°36′45.78″	83°39′0.36″
	10-30	9.9	0.3	7	31.3	0.8			
	30-60	9.5	0.3	18.2	190.5	0.2			
	>60	8.8	0.4	18.2	17.6	0.3			
No.12-02XJCN	0-30	8.9	1.3	14	13.5	7.6		44°36′40.5″	83°33′43.98″
	30-60	8.6	0.4	2.8	9.4	4.7			
	>60	8.5	0.3	9.8	3.3	3.8			
No.12-03XJCN	0-10	8.6	0.9	25.2	40.4	5.0		44°36′41.28″	83°35′48.96″
	10-40	8.8	0.3	16.8	14.6	3.7			
	40-60	8.7	0.4	14	24.5	4.9			
	>60	8.9	0.5	32.2	11.9	3.8			
No.12-04XJCN	Well bottom					0.2	>0.1	44°34′54.96″	83°43′6.06″
No.12-05XJCN	Well bottom					1.1	0.5	44°36′38.16″	83°33′44.88″
No.12-06XJCN	0-10					58.6	30	44°36′42.3″	83°33′46.98″
	10-60					5.5	2.8		
No.12-07XJCN	0-20					0.8	0.4	44°36′51.84″	83°37′40.86″
	20-60					0.3	0.1		
No.12-08XJCN	0-10					9.0	4.6	44°37′4.68″	83°33′49.86″
	10-60					3.6	1.8		
No.12-09XJCN	0-10					0.7	0.3	44°36′8.34″	83°40′41.28″
	10-30					1.8	0.9		
	30-60					0.4	0.1		

Appendix 5

Table A-5: Every two weeks measurement of DBH on plot A102 during the growth season in 2006 and 2007.

Tab A-5: 14-tägige Messung des BHD auf der Monitoringfläche A 102 in den Vegetationsperioden 2006 und 2007.

图表 A-5: 2006 和 2007 年 A102 样地胸经测量数据.

2006												
Tree No.	30/05	13/06	27/06	11/07	25/07	08/08	22/08	05/09	19/09	03/10	17/10	31/10
11	22.74	22.81	22.99	23.14	23.27	23.27	23.27	23.28	23.32	23.30	23.30	23.01
14	24.19	24.33	24.46	24.55	24.57	24.59	24.57	24.62	24.65	24.58	24.58	24.58
17	20.01	20.33	20.35	20.46	20.56	20.56	20.57	20.95	20.95	20.62	20.54	20.55
19	21.11	21.34	21.45	21.56	21.56	21.59	21.57	21.66	21.73	21.72	21.67	21.66
24	33.72	33.87	34.06	34.09	34.09	34.09	34.17	34.15	34.21	34.20	34.16	34.18
47	24.88	24.96	25.13	25.27	25.33	25.30	25.27	25.28	25.33	25.32	25.32	25.33
53	22.63	22.72	22.83	22.96	22.99	22.96	22.95	23.05	23.06	23.01	23.00	23.02
103	18.71	18.82	19.03	19.07	19.15	19.12	19.14	19.10	19.14	19.12	19.09	19.09
110	18.93	19.05	19.22	19.27	19.39	19.36	19.35	19.33	19.39	19.36	19.36	19.36
130	29.07	29.21	29.37	29.48	29.59	29.60	29.61	29.61	29.64	29.63	29.62	29.63

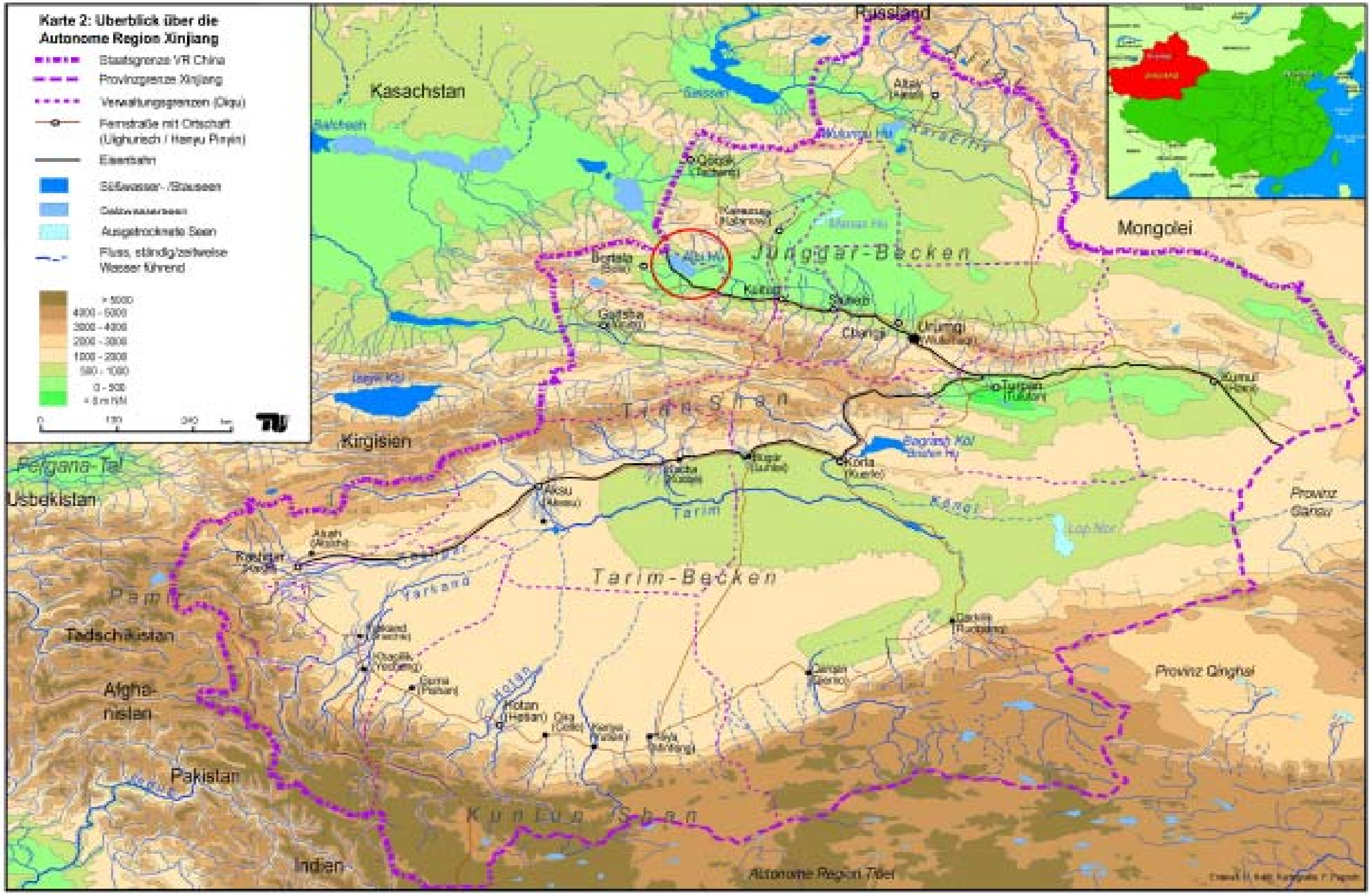
2007														
Tree No.	10/04	25/04	09/05	30/05	13/06	27/06	11/07	25/07	08/08	22/08	05/09	19/09	03/10	17/10
11	23.33	23.33	23.33	23.34	23.39	23.46	23.54	23.55	23.56	23.56	23.57	23.56	23.57	23.57
14	24.64	24.64	24.64	24.65	24.68	24.72	24.74	24.75	24.76	24.76	24.77	24.77	24.78	24.78
17	20.50	20.53	20.58	20.66	20.74	20.85	20.87	20.87	20.81	20.81	20.81	20.81	20.81	20.81
19	21.64	21.65	21.69	21.80	21.93	22.02	27.04	22.13	22.13	22.13	22.13	22.12	22.13	22.13
24	34.16	34.12	34.13	34.17	34.25	34.31	34.35	34.36	34.37	34.37	34.38	34.38	34.46	34.51
47	25.35	25.35	25.35	25.37	25.40	25.46	25.50	25.52	25.53	25.54	25.54	25.54	25.55	25.55
53	22.98	23.04	23.04	23.09	23.14	23.23	23.24	23.26	23.26	23.26	23.26	23.26	23.26	23.26
103	19.08	19.09	19.09	19.24	19.32	19.33	19.33	19.41	19.41	19.40	19.40	19.40	19.40	19.40
110	19.39	19.38	19.41	19.59	19.65	19.74	19.76	19.78	19.78	19.79	19.80	19.85	19.85	19.85
130	29.67	29.67	29.67	29.67	29.69	29.72	29.73	29.74	29.75	29.75	29.76	29.75	29.76	29.76

Appendix 6

Fig. A-1:Topographical map of Xinjiang, P.R. China (modified from a TU-Berlin map).

Abb.A-1:Topographische Karte von Sinkiang (Xinjiang).

图例 A-1:中国新疆地形图 (资料来源:柏林工业大学).

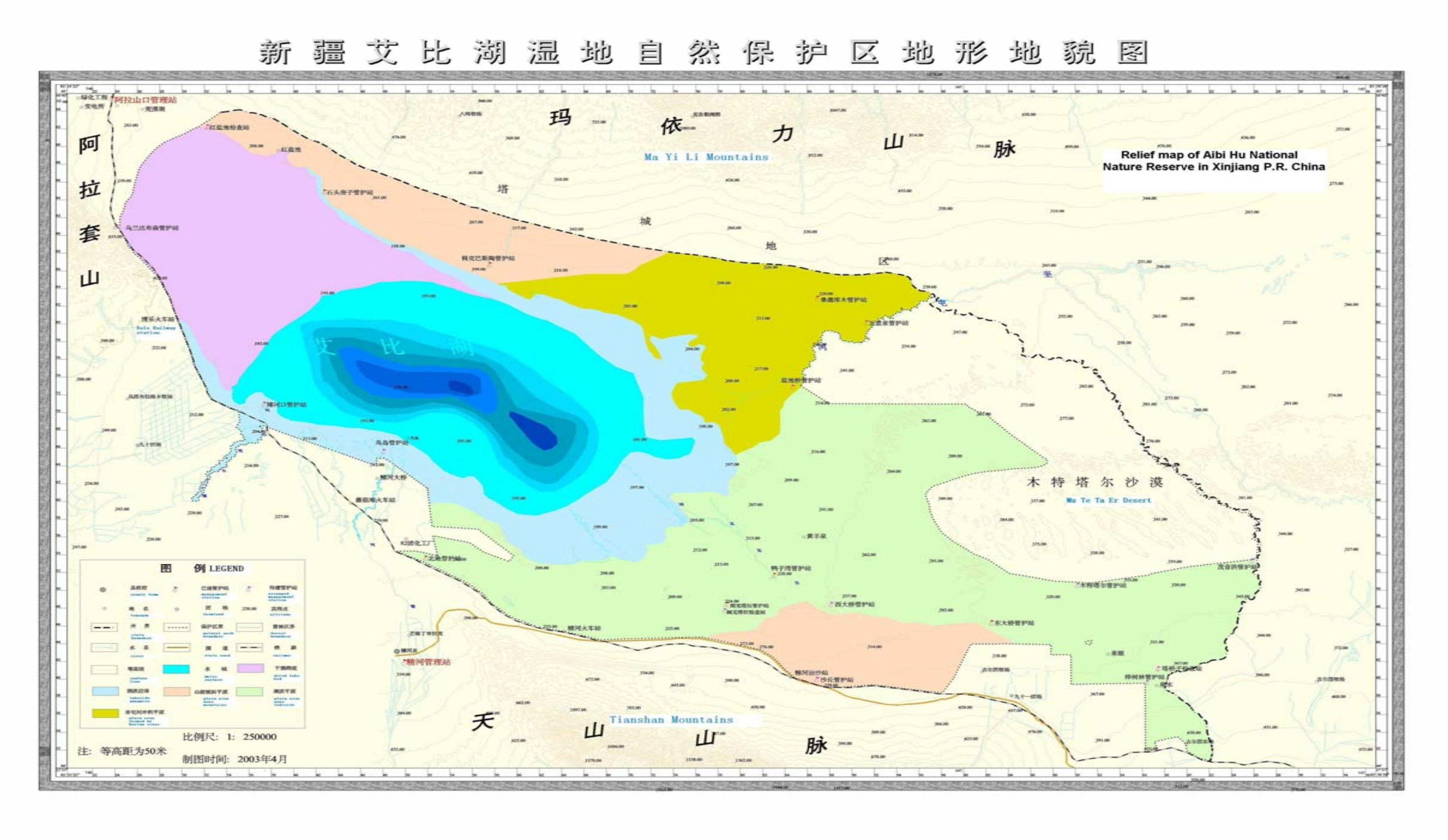


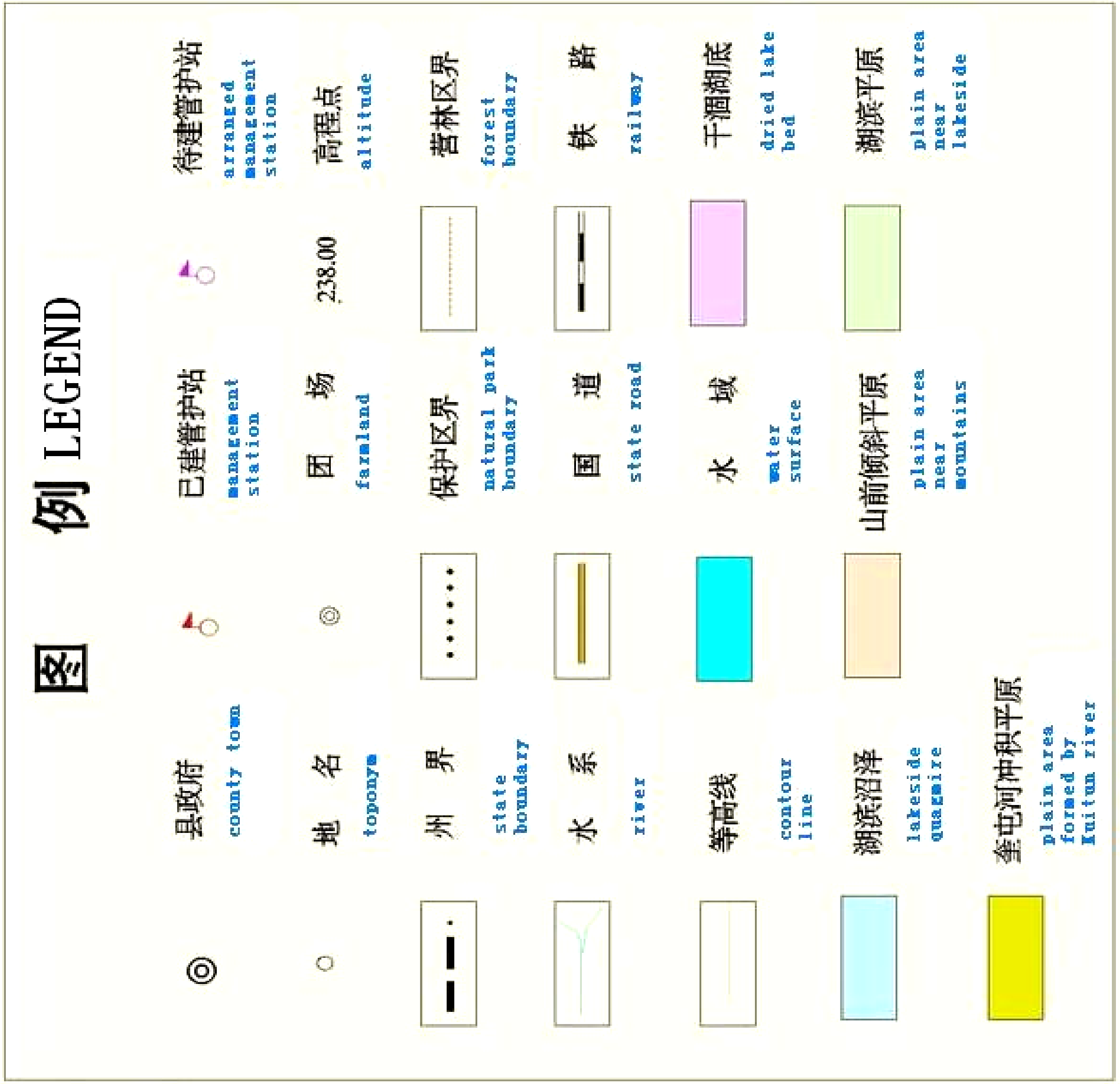
Appendix 7

Fig. A-2: Relief map of the Aibi Hu region (provided by Aibi Hu National Nature Reserve, P.R. China, 2004); legend on next page.

Abb.A-2: Reliefkarte des Untersuchungsgebietes Aibi Hu - Nationalpark.

图例 A-2: 研究区域地貌图(中国新疆艾比湖保护区提供).



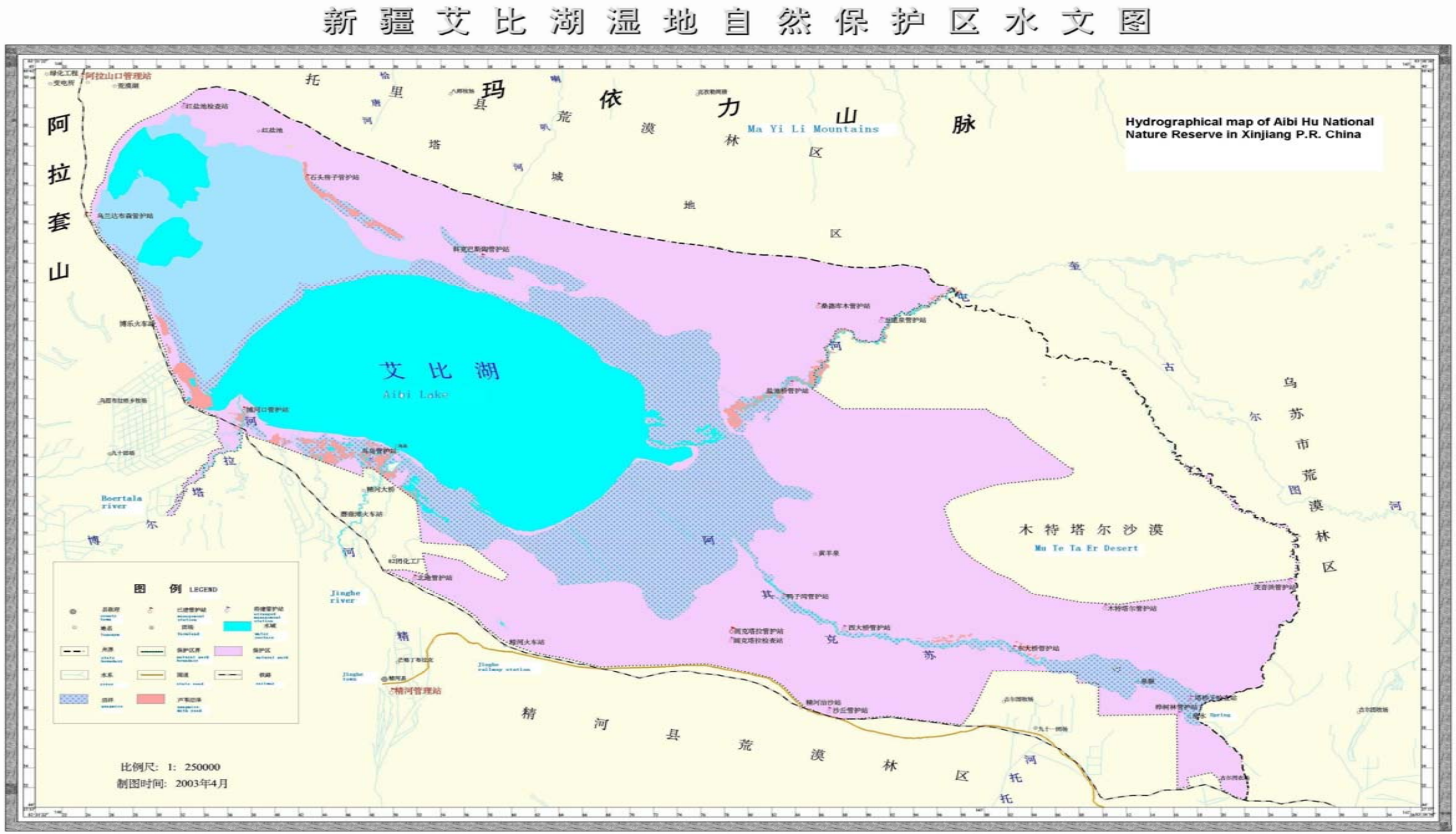

图例 LEGEND
县政府 county town
已建管护站 management station
待建管护站 arranged management station
地名 toponym
团场 farmland
238.00
高程点 altitude
州界 state boundary
保护区界 natural park boundary
营林区界 forest boundary
水系 river
国道 state road
铁路 railway
等高线 contour line
水域 water surface
干涸湖底 dried lake bed
湖滨沼泽 lakeside quagmire
山前倾斜平原 plain area near mountains
湖滨平原 plain area near lakeside
奎屯河冲积平原 plain area formed by Kuitun river

Appendix 8

Fig. A-3: Hydrographical map of the Aibi Hu region (provided by Aibi Hu National Nature Reserve, P.R. China, 2004); legend on next page.

Abb.A-3: Hydrographische Karte des Aibi Hu - Nationalpark.

图例 A-3: 研究区域水文图(中国新疆艾比湖保护区提供).




图例 LEGEND
县政府 county town
已建管护站 management station
待建管护站 arranged management station
地名 toponym
团场 farmland
水域 water surface
州界 state boundary
保护区界 natural park boundary
保护区 natural park
水系 river
国道 state road
铁路 railway
沼泽 quagmire
芦苇沼泽 quagmire with reed

Appendix 9

Fig. A-4: Vegetation map of the Aibi Hu region (provided by Aibi Hu National Nature Reserve, P.R. China, 2004); legend on next page.

Abb. A-4: Vegetationkarte der Aibi Hu-Region.

图例A-4: 艾比湖地区植被分布图.

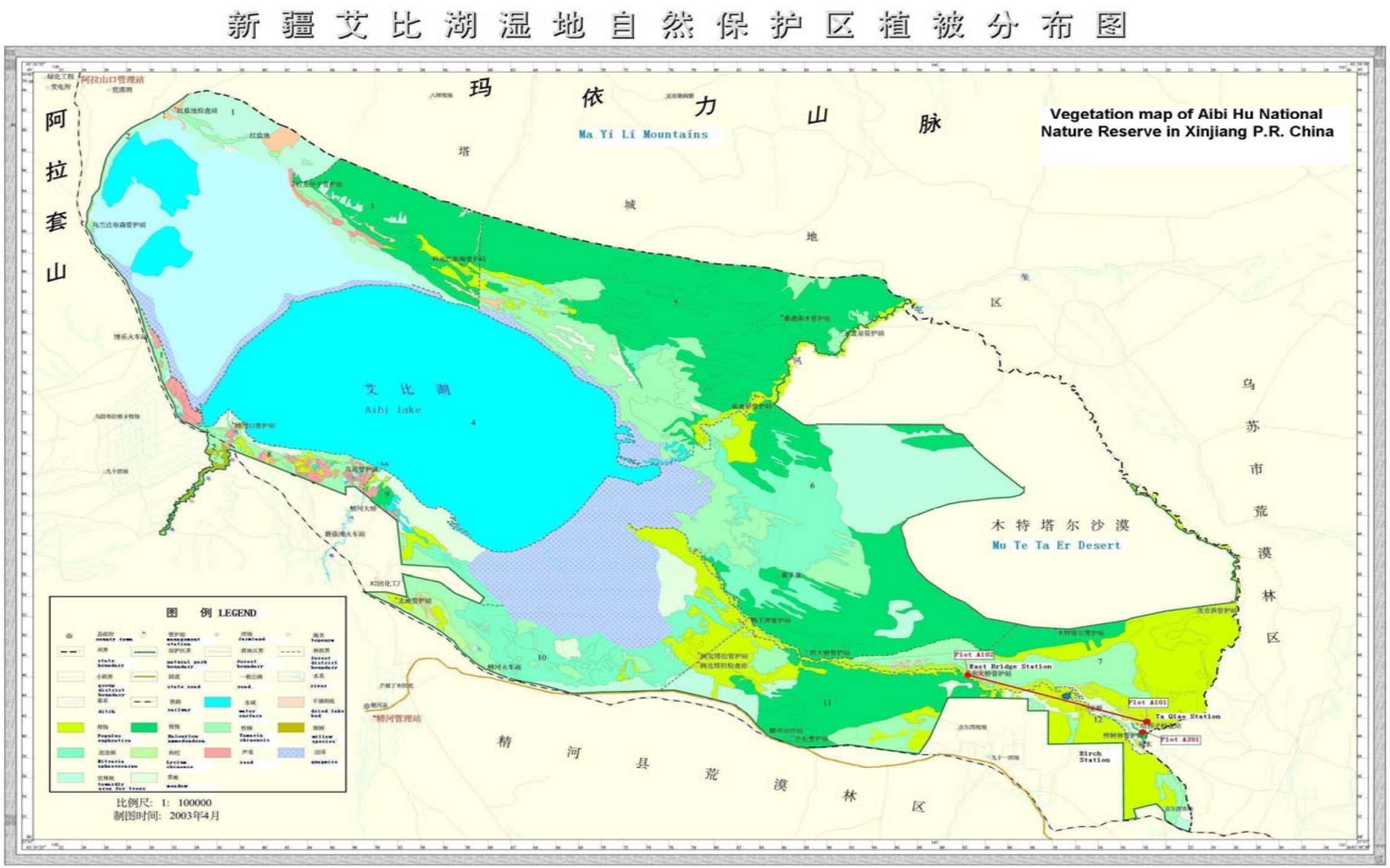


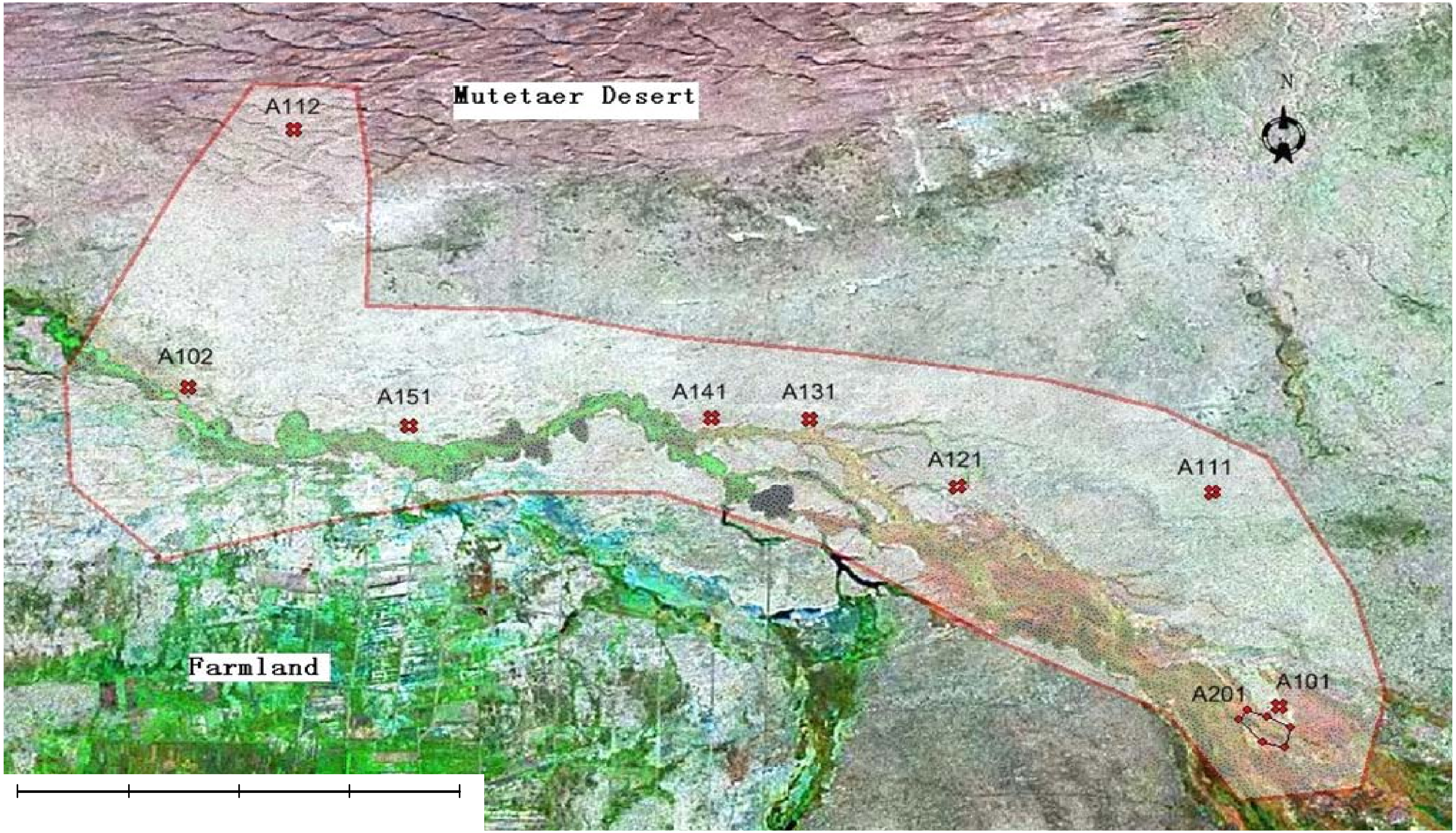

图 例 LEGEND
县政府
county town
管护站
management station
团场
farmland
地名
toponym
州界
state boundary
保护区界
natural park boundary
营林区界
forest boundary
林班界
forest district boundary
小班界
group district boundary
国道
state road
一般公路
road
水系
river
渠系
ditch
铁路
railway
水域
water surface
干涸湖底
dried lake bed
胡杨
Populus euphratica
梭梭
Haloxylon ammodendron
怪柳
Tamarix chinensis
柳树
willow species
泡泡刺
Nitraria sphaerocarpa
枸杞
Lycium chinense
芦苇
reed
沼泽
quagmire
宜林地
towardly area for trees
草地
meadow

Appendix 10

Fig. A-5: Distribution of the research plots in the study area on overview satellite picture (Source: Aibi Hu National Nature Reserve, P.R. China, 2004).

Abb.A-5: Verteilung der Untersuchungsflächen auf dem NASA Satellitenbild.

图例 A-5: 观测样地在研究区域的分布.

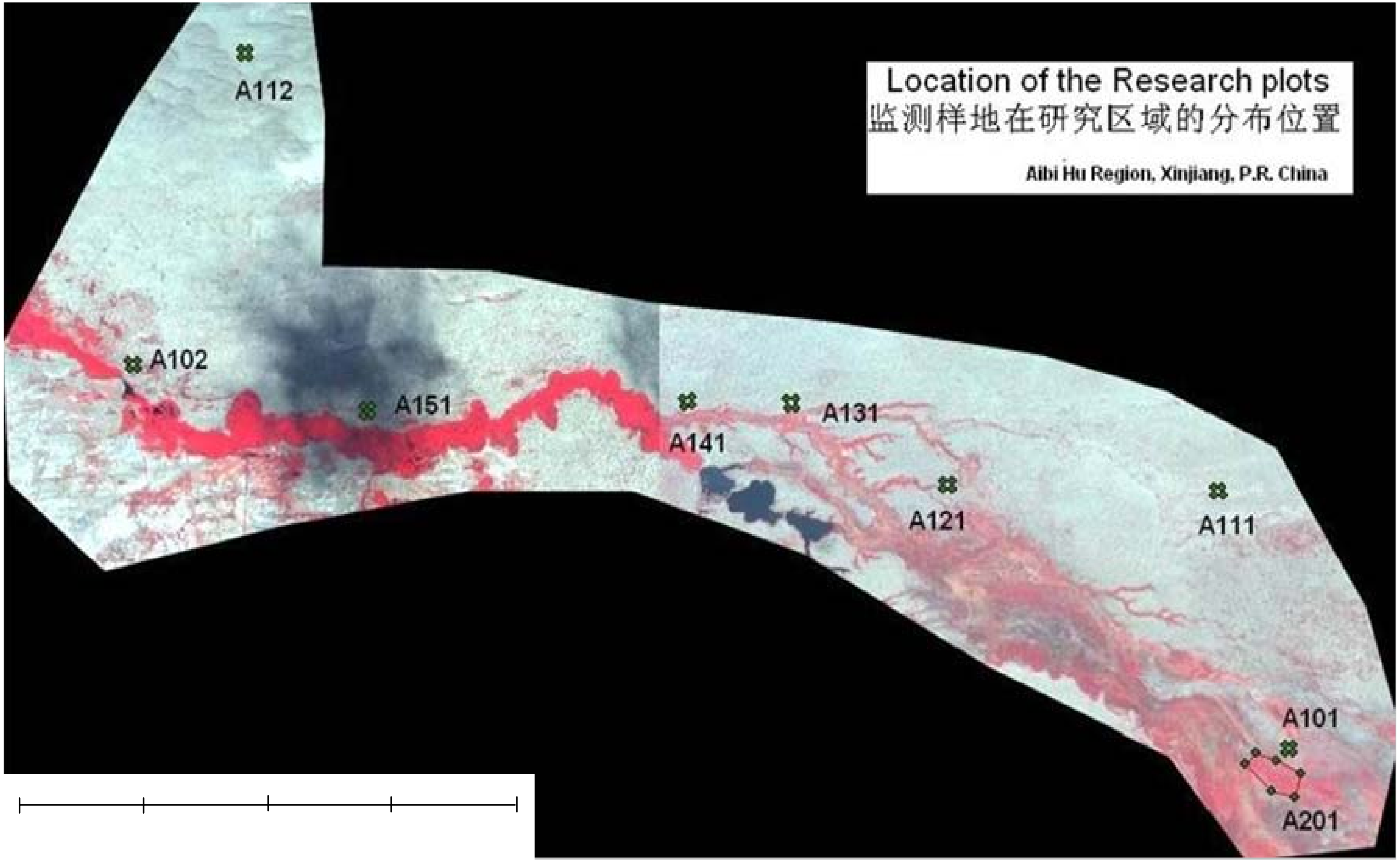


Appendix 11

Fig. A-6: Location of the research plots on the QuickBird image (modified from the QuickBird satellite image from U.S, August 2006).

Abb. A-6: Lage der Untersuchungsflächen auf dem QuickBird Satelliten-Bild.

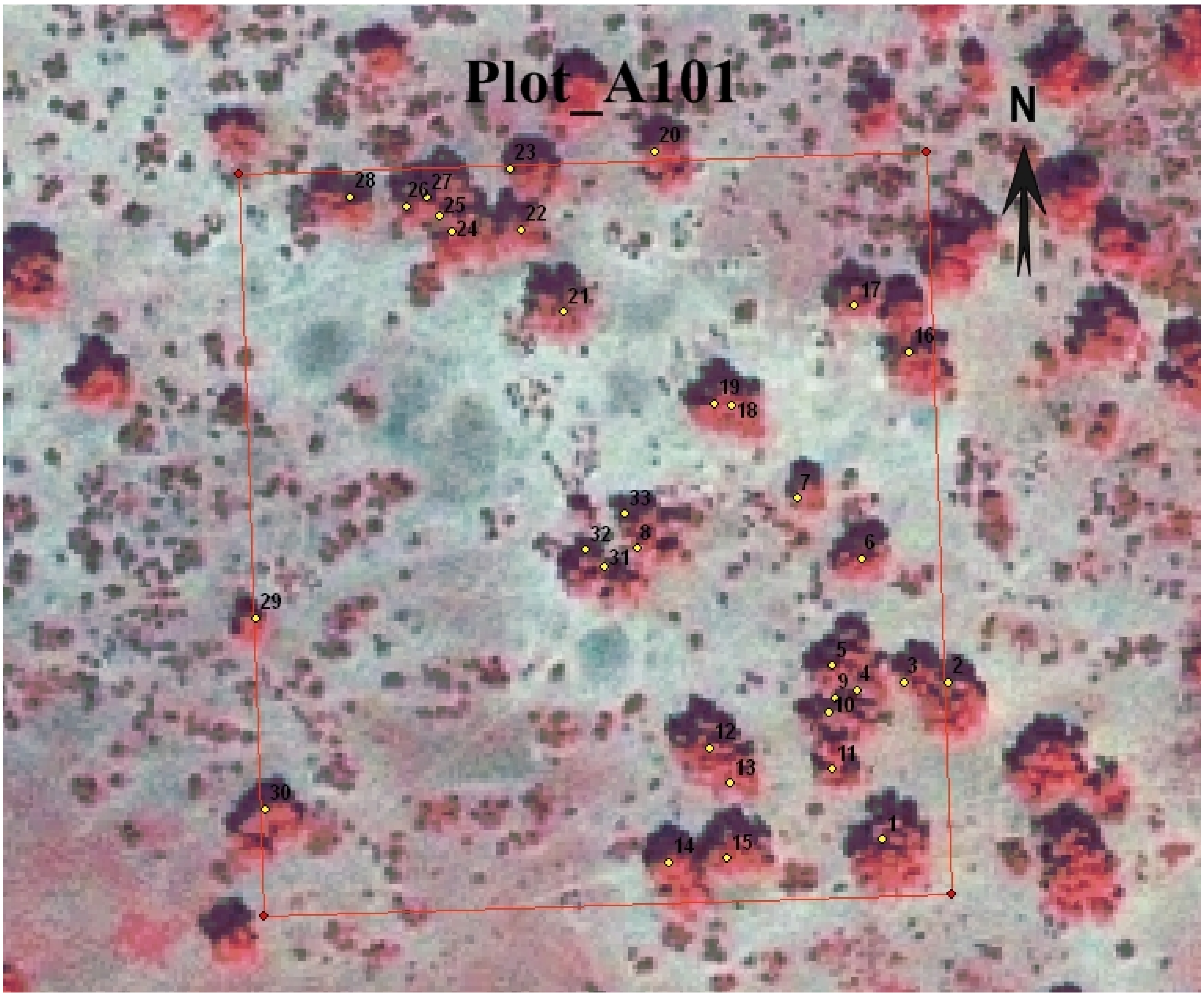
图例 A-6: 监测样地在 QuickBird 影像图中的位置.



Appendix 12
QuickBird images of the eight *Populus euphratica* permanent research plots.

Appendix 12- 1

Fig. A7-1: QuickBird image of the permanent research plot A101, stem numbers 33, 1 ha, (modified from the QuickBird satellite image from U.S, August 2006).
Abb. A7-1: QuickBird Satelliten - Bild der Monitoringfläche A101.
图例 A7-1: A101 监测样地 QuickBird 卫星影像图.

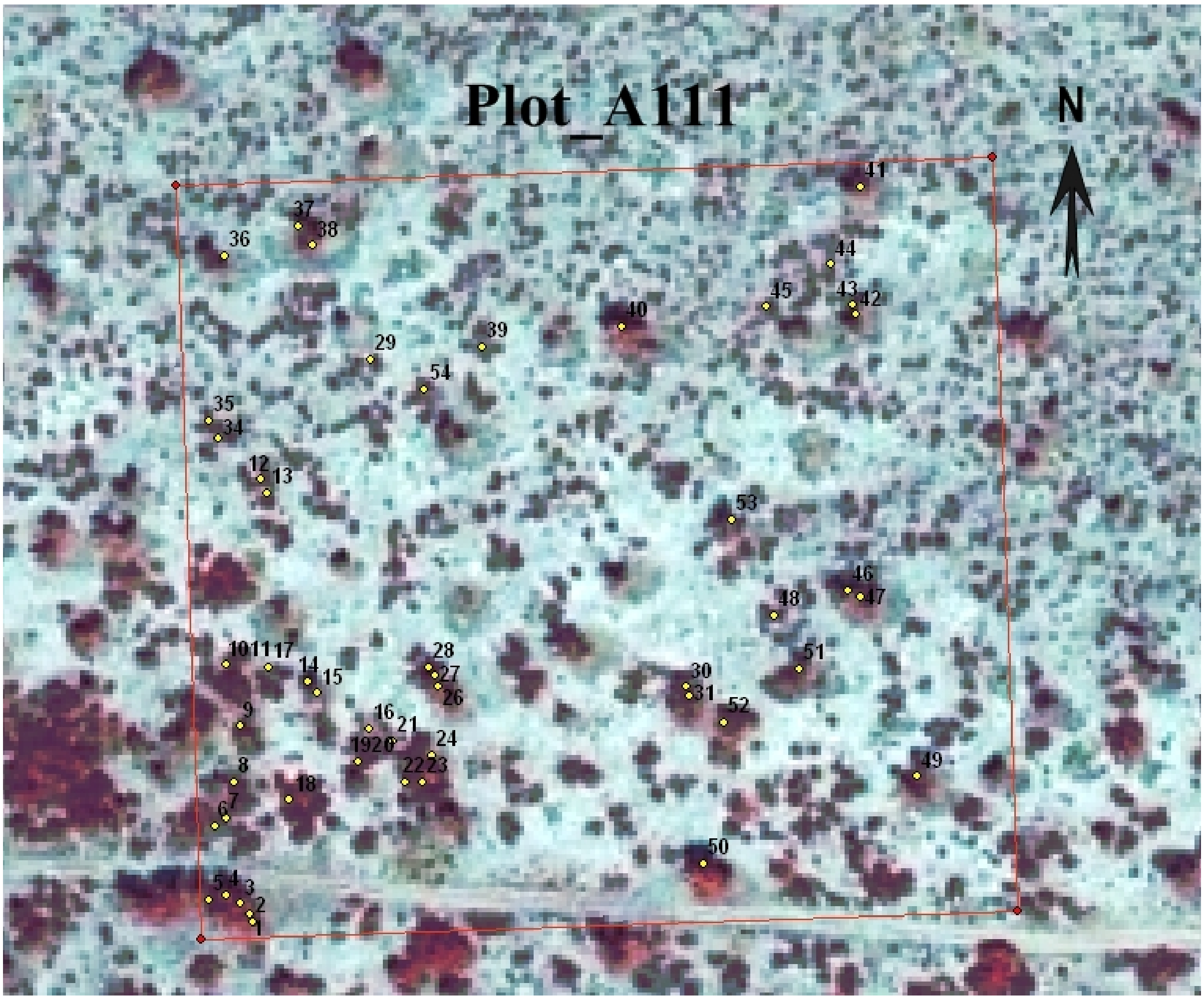


X-Y-coordinates of corner points:

A	N 44°34′18.99″	E 83°44′31.49″
B	N 44°34′18.99″	E 83°44′27.09″
C	N 44°34′22.40″	E 83°44′31.49″
D	N 44°34′22.40″	E 83°44′27.09″

Appendix 12- 2

Fig. A7-2 QuickBird image of the permanent research plot A111, stem numbers 50, 1 ha, (modified from the QuickBird satellite image from U.S, August 2006).
Abb. A7-2: QuickBird Satelliten - Bild der Monitoringfläche A111.
图例 A7-2: A111 监测样地 QuickBird 卫星影像图.

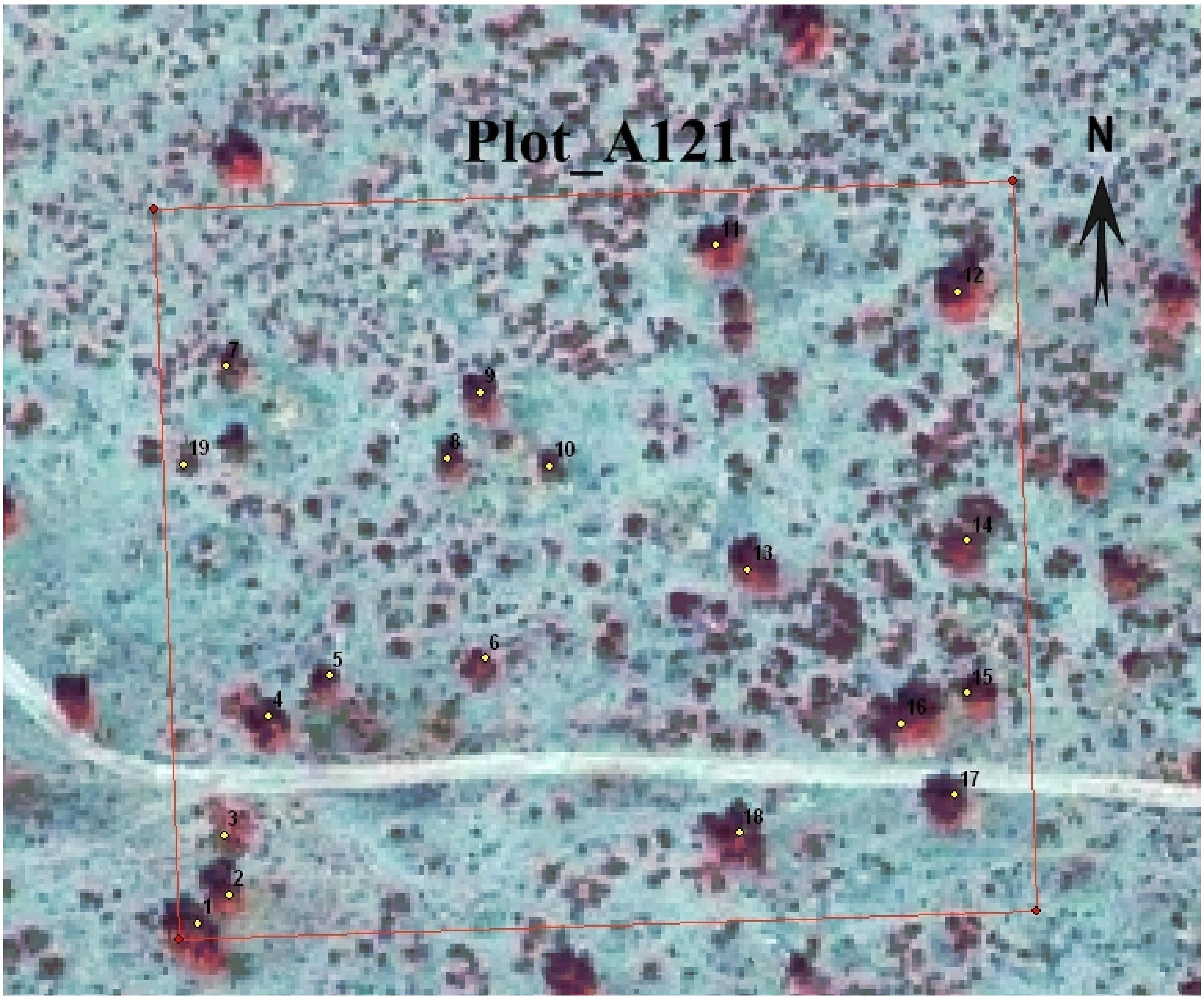


X-Y-coordinates of corner points:

A	N 44°36′0.90″	E 83°43′52.20″
B	N 44°36′0.90″	E 83°43′56.89″
C	N 44°36′3.99″	E 83°43′52.20″
D	N 44°36′3.99″	E 83°43′56.89″

Appendix 12- 3

Fig. A7-3: QuickBird image of the permanent research plot A121, stem numbers 19, 1 ha, (modified from the QuickBird satellite image from U.S, August 2006).
Abb. A7-3: QuickBird Satelliten - Bild der Monitoringfläche A121.
图例 A7-3: A121 监测样地 QuickBird 卫星影像图.

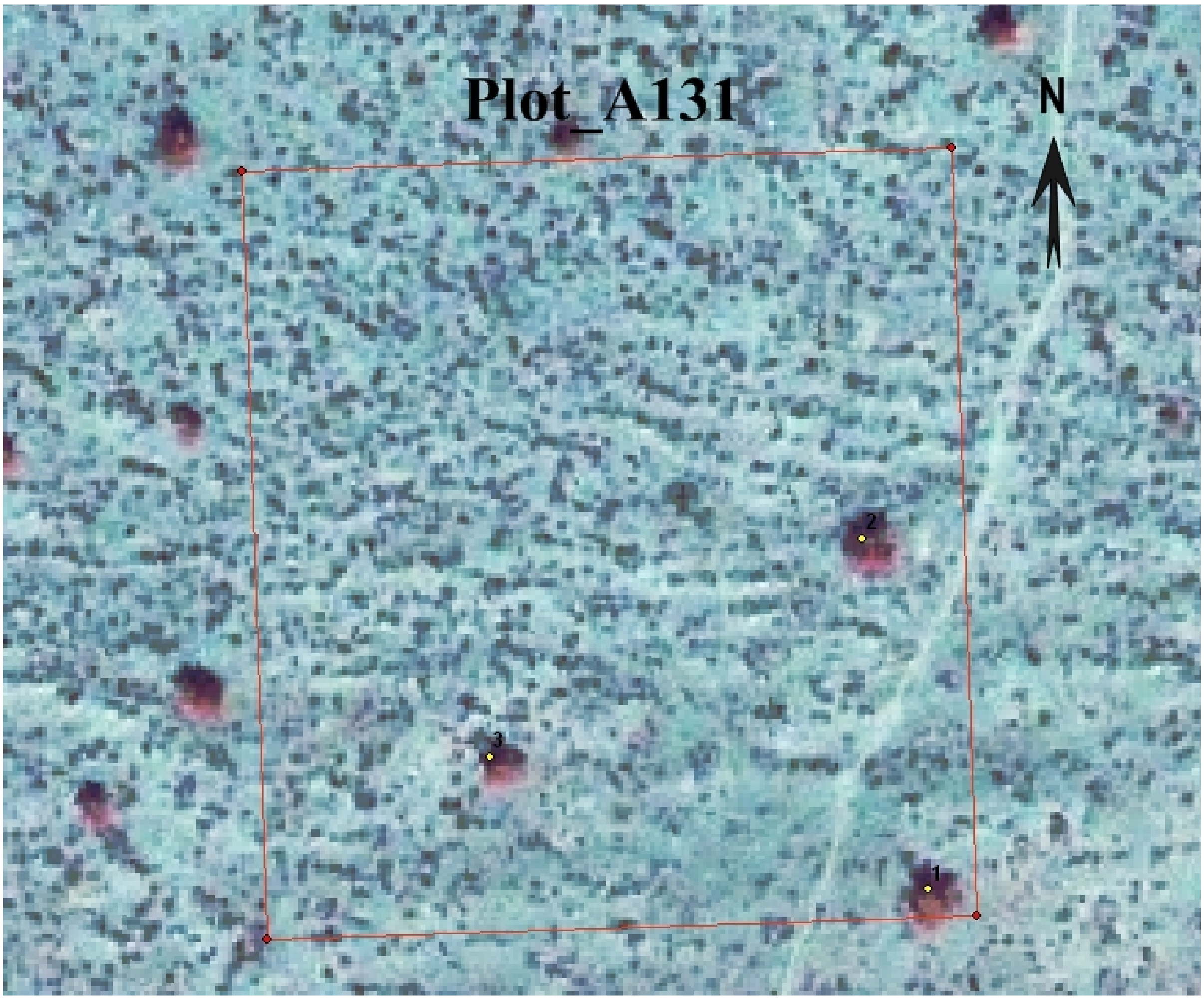


X-Y-coordinates of corner points:

A	N 44°36′6.99″	E 83°41′21.40″
B	N 44°36′6.99″	E 83°41′26.49″
C	N 44°36′10.1″	E 83°41′21.40″
D	N 44°36′10.1″	E 83°41′26.49″

Appendix 12- 4

Fig. A7-4: QuickBird image of the permanent research plot A131, stem numbers 3, 1 ha, (modified from the QuickBird satellite image from U.S, August 2006).
Abb. A7-4: QuickBird Satelliten - Bild der Monitoringfläche A131.
图例 A7-4: A131 监测样地 QuickBird 卫星影像图.

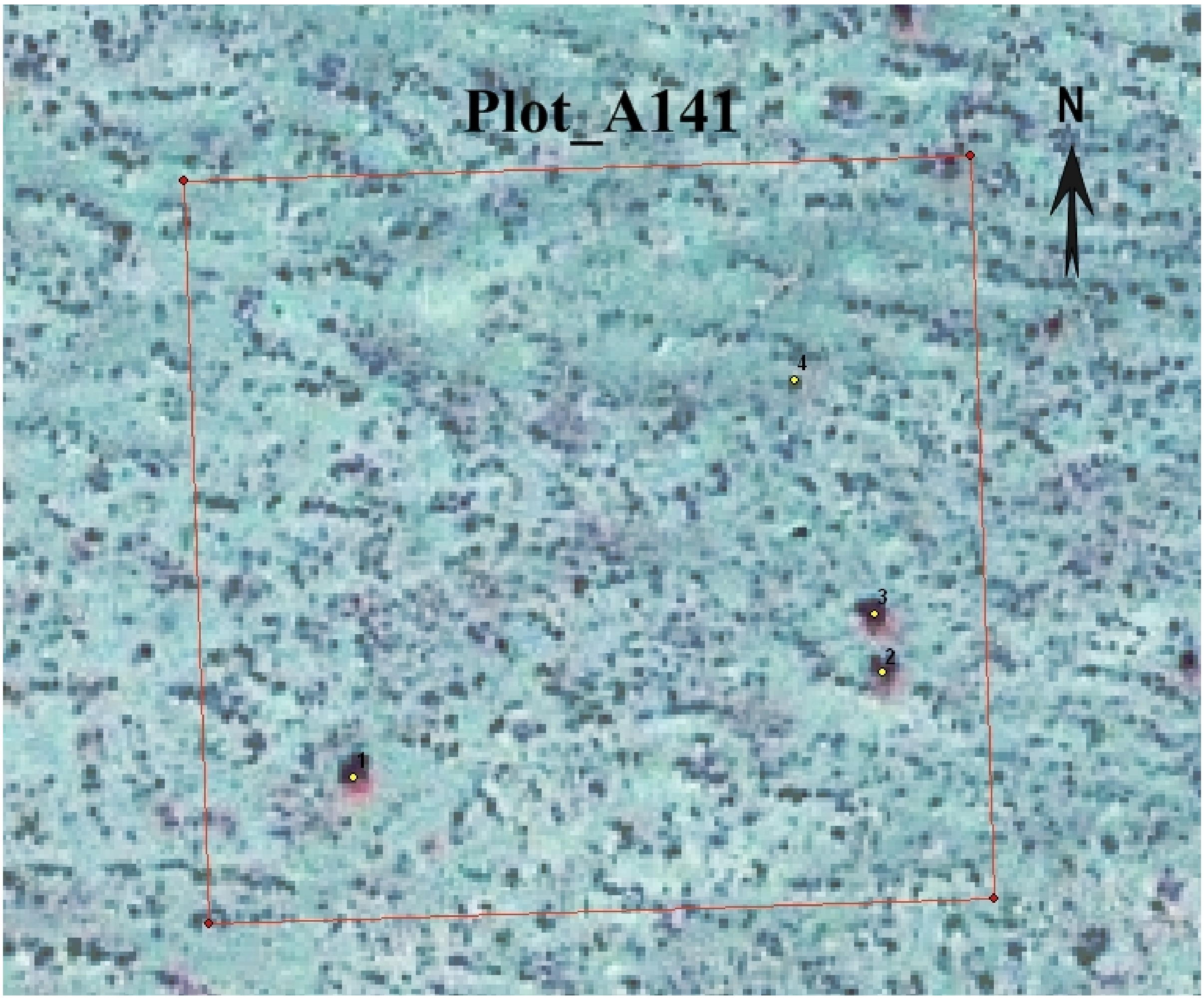


X-Y-coordinates of corner points:

A	N 44°36′40.49″	E 83°40′0.19″
B	N 44°36′40.49″	E 83°39′55.79″
C	N 44°36′43.89″	E 83°40′0.19″
D	N 44°36′43.89″	E 83°39′55.79″

Appendix 12- 5

Fig. A7-5 QuickBird image of the permanent research plot A141, stem numbers 4, 1 ha, (modified from the QuickBird satellite image from U.S, August 2006).
Abb. A7-5: QuickBird Satelliten - Bild der Monitoringfläche A141.
图例 A7-5: A141 监测样地 QuickBird 卫星影像图.

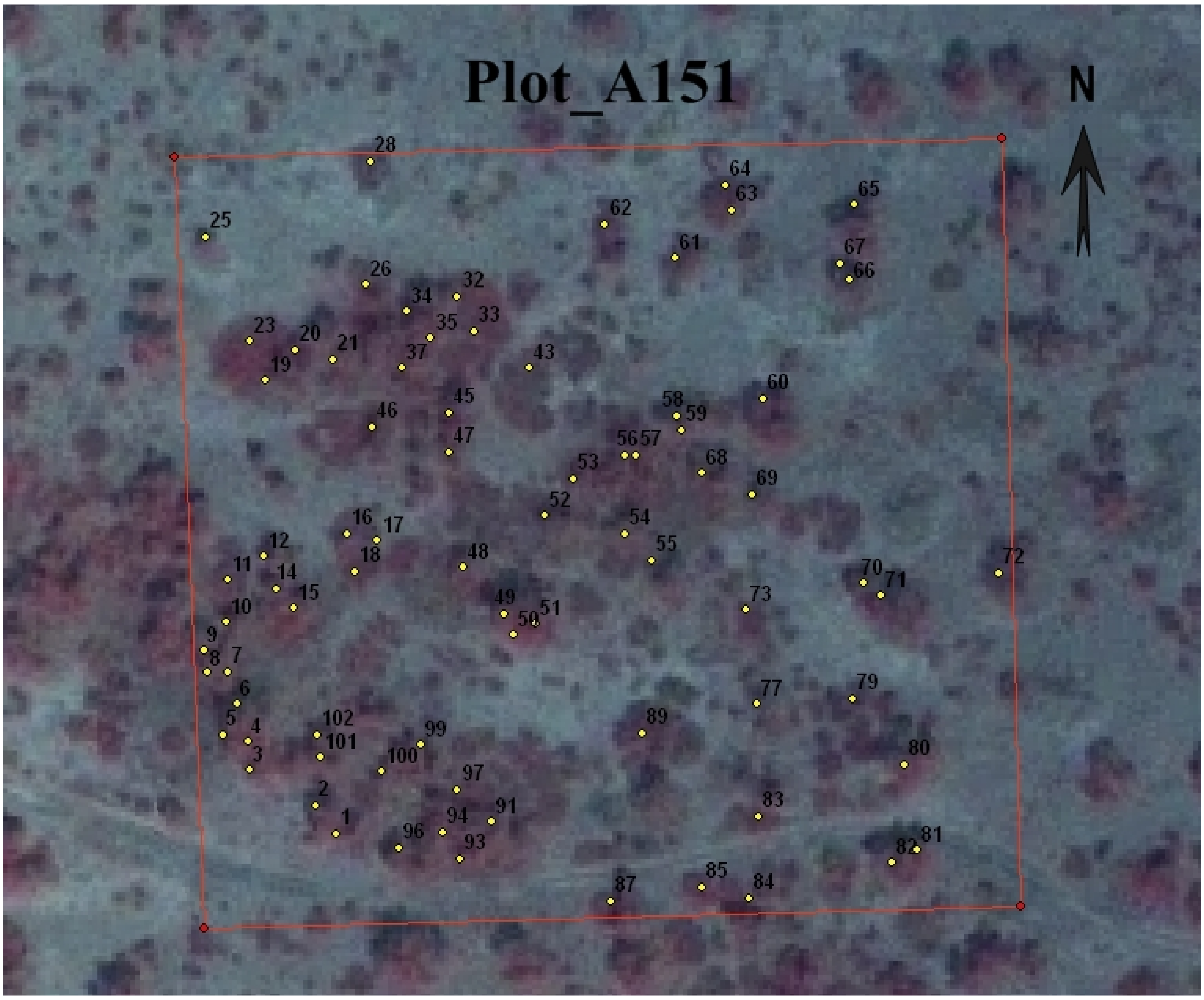


X-Y-coordinates of corner points:

A	N 44°36′42.59″	E 83°38′57.9″
B	N 44°36′42.59″	E 83°39′2.49″
C	N 44°36′45.69″	E 83°38′57.9″
D	N 44°36′45.69″	E 83°39′2.49″

Appendix 12- 6

Fig. A7-6: QuickBird image of the permanent research plot A151, stem numbers 102, 1 ha, (modified from the QuickBird satellite image from U.S, August 2006).
Abb.A7-6: QuickBird Satelliten - Bild der Monitoringfläche A151.
图例 A7-6: A151 监测样地 QuickBird 卫星影像图.

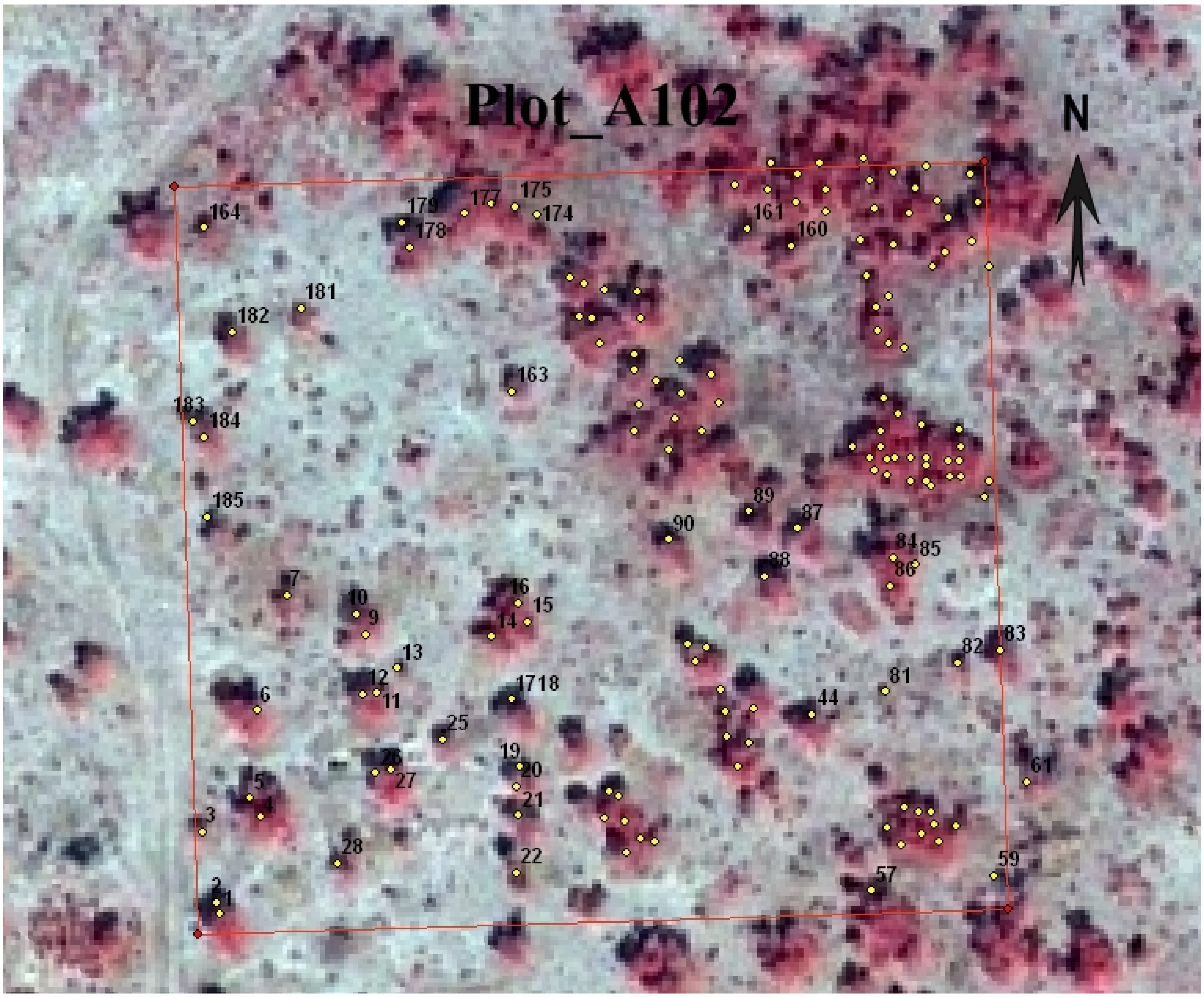


X-Y-coordinates of corner points:

A	N 44°36′42.99″	E 83°35′58.89″
B	N 44°36′42.99″	E 83°36′3.70″
C	N 44°36′46.19″	E 83°35′58.89″
D	N 44°36′46.19″	E 83°36′3.70″

Appendix 12- 7

Fig. A7-7: QuickBird image of the permanent research plot A102, stem numbers 185, 1 ha, (modified from the QuickBird satellite image from U.S, August 2006).
Abb. A7-7: QuickBird Satelliten - Bild der Monitoringfläche A102.
图例 A7-7: A102 监测样地 QuickBird 卫星影像图.

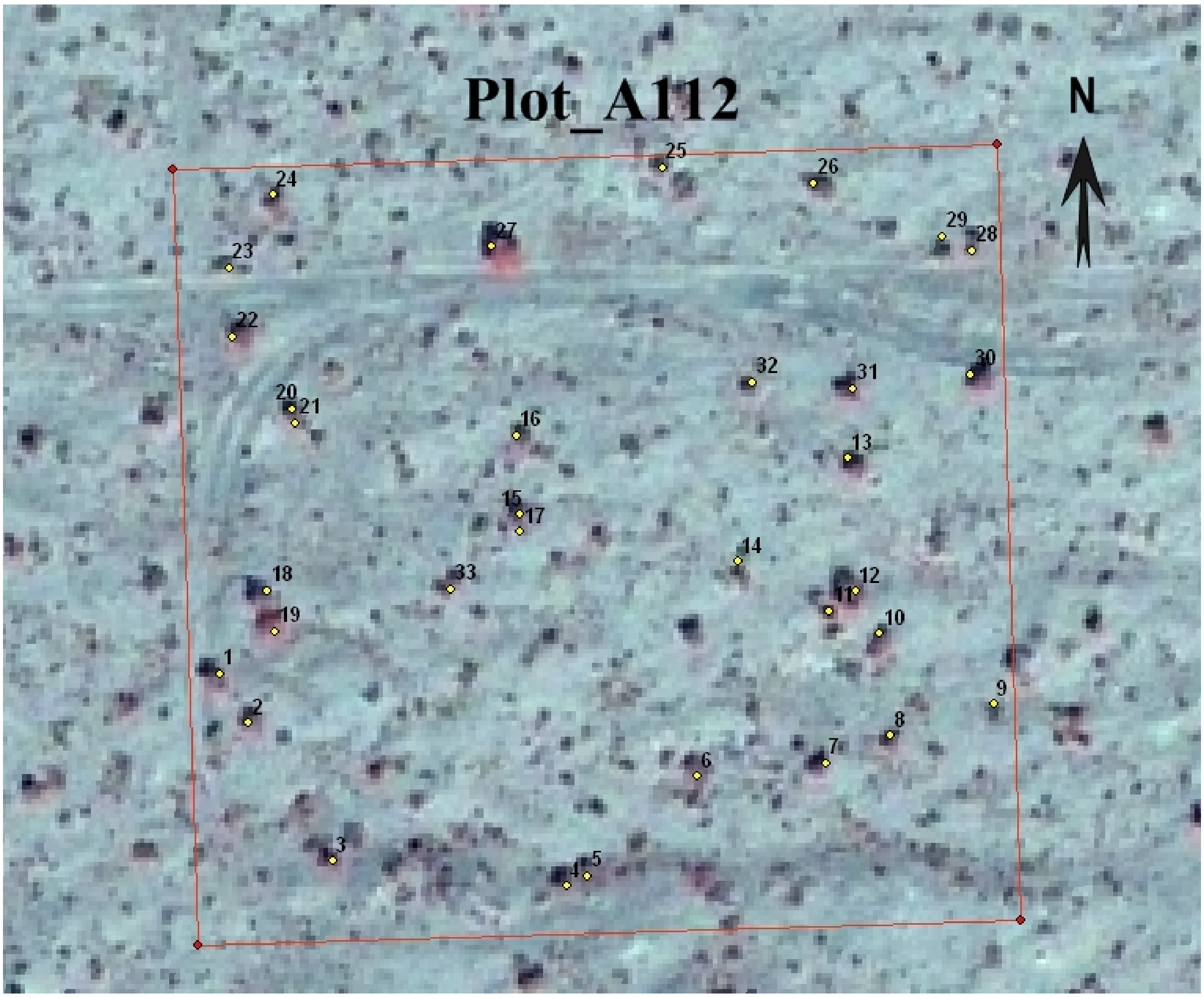


X-Y-coordinates of corner points:

A	N 44°37′4.19″	E 83°33′49.20″
B	N 44°37′4.19″	E 83°33′53.89″
C	N 44°37′7.29″	E 83°33′49.20″
D	N 44°37′7.29″	E 83°33′53.89″

Appendix 12- 8

Fig. A7-8: QuickBird image of the permanent research plot A112, stem numbers 33, 1 ha, (modified from the QuickBird satellite image from U.S, August 2006).
Abb. A7-8: QuickBird Satelliten - Bild der Monitoringfläche A112.
图例 A7-8: A112 监测样地 QuickBird 卫星影像图.



X-Y-coordinates of corner points:

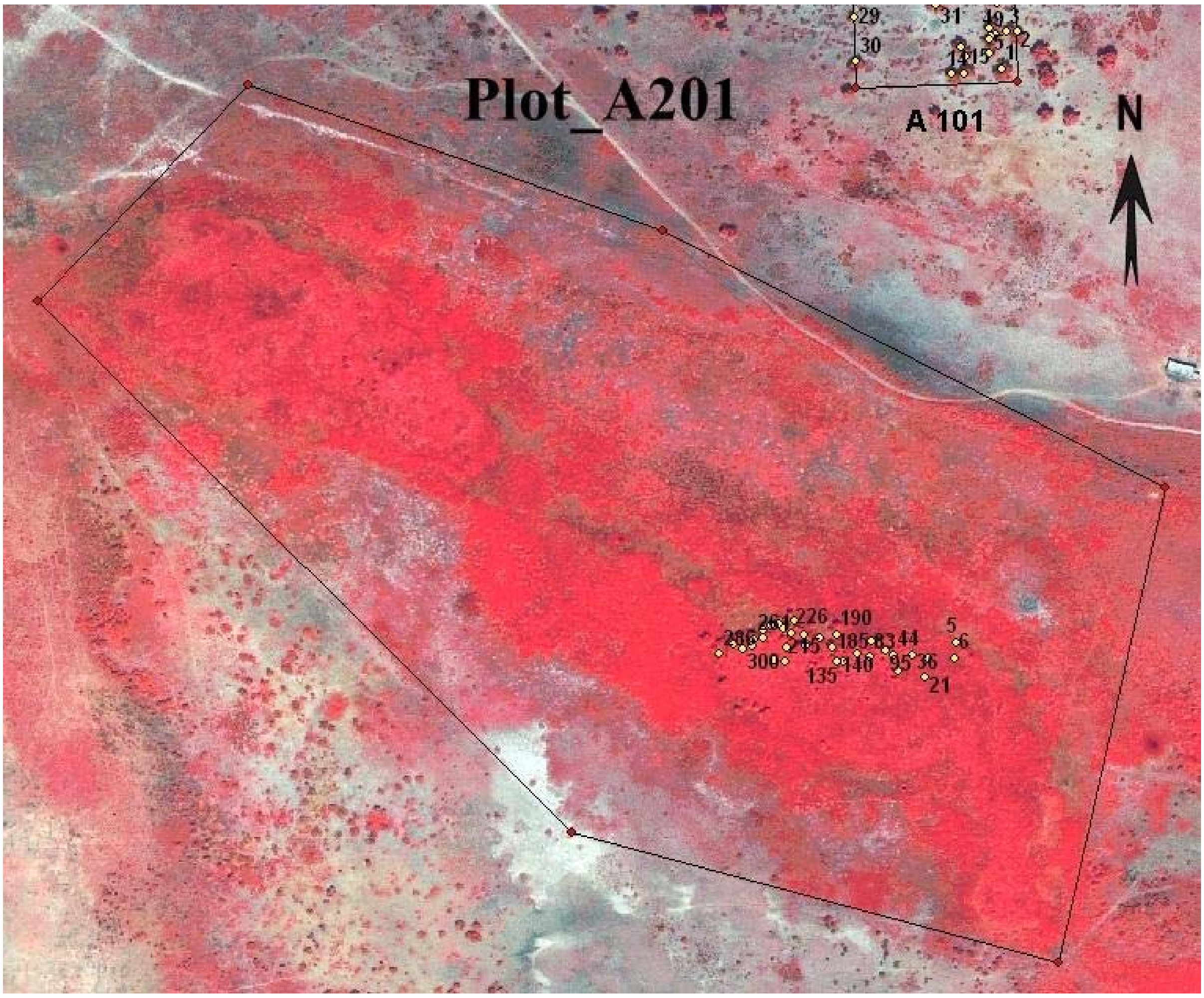
A	N 44°39′4.2″	E 83°34′57.1″
B	N 44°39′4.2″	E 83°35′1.7″
C	N 44°39′7.3″	E 83°34′57.1″
D	N 44°39′7.3″	E 83°35′1.7″

Appendix 13

Fig A-8: QuickBird image of the endemic birch (Aibi Hu Hua，A201) research plot(modified from the QuickBird satellite image from U.S, August 2006).

Abb. A-8: QuickBird Satelliten - Bild der Monitoringfläche A201.

图例 A-8: A201 监测样地 QuickBird 卫星影像图.



X-Y-coordinates of corner points:

A	N 44°34′17.03″	E 83°44′12.91″
B	N 44°34′6.96″	E 83°44′12.91″
C	N 44°34′6.96″	E 83°44′53.37″
D	N 44°34′17.03″	E 83°44′53.37″

Appendix 14

Protocol for forest and tree data acquisition.

Source: Prof. Dr. Birgit Kleinschmit, TU Berlin, Institut für Landschaftsarchitektur und Umweltplanung /Fachgebiet Geoinformationsverarbeitung in der Landschaftsplanung, modified.

Sample protocol

Plot data

- Date
- Plot number PLOT
- Geographical position GP

The geographical position of several prominent points in the plot or near the plot has to be estimated with a GPS system with an accuracy <1m.

- Altitude (asl) ALT

They should be recorded to the nearest 5 metres above sea level.

- Aspect / Exposition ASP

In compass degrees.

- Slope SLOPE

The angle of slope should be measured with a clinometer or hypsometer or other suitable instrument and recorded to the nearest degree. If the slope is irregular, note the limits of slope angle.

- Surface form SURF

Record it as slightly or strongly convex or concave, or level, and as even or irregular.

- Major soil group SOIL

This is to be obtained by reference to FAO soils maps. Where a local soil survey has been carried out, details are to be provided, including reference to any published source.

- Topography TOP

P	Plateau
S	Slope
D	Depression, drougth river bed
V	Valley, mead
H	Hill, dune

- o XY-coordinates of the corner-posts X/Y_POSTx GP_REFERENCE

XY-coordinates have to be measured with an accuracy of 0.1 meters. The reference point of the XY-coordinates has to be marked permanently (e.g. with an iron post thriven into the ground). Further the geographical position of the posts and the reference point (GP_REFERENCE) has to be estimated.

- o Stand description T_POS

Stand description T_POS	*Tree distribution within the stand*
Open stand **10**	Canopy is not closed, clear distance between the crownes of neighbour trees
Clustered in groups up to 5 **20**	Trees are mainly clustered in groups up to five trees, within the clusters the canopy is closed
Bands of trees **30**	Trees are mainly clustered to linear bands, within the clusters the canopy is closed
Clustered in groups >5 **40**	Trees are mainly clustered in groups more than five trees, within the clusters the canopy is closed
Closed stand **50**	The trees form more or less a closed canopy

- o Density DENS

Crown coverage DENS	*Crown coverage* *If the trees are clustered two values have to be assigned:* *(a) inside group (without brackets: „x“),* *(b) outside group (with brackets: „(x)“)*
1	Distance between crowns >= two times crown width
2	Distance between crowns < two times crown width, but >

	crown width
3	Distance between crowns < crown width
4	Crowns are partly connected
5	Closed canopy with small gaps

- Saplings of major tree species SAP

Saplings ***SAP***	*On 1m² living saplings (<3.5cm) of the major tree species have to be counted. It has to be repeated at least 10 times within one plot*
Plot n° ; sample n°	Number of saplings
Populus euphratica	
Tamarisken	
Haloxylon	

An extra sheet (saplings) should be used

Tree data

Each tree has to be numbered with permanent colour and has to be marked at breast height for the DBH measurement.

- Date
- Tree number NUMBER.
- Tree species
- XY-coordinates

XY-coordinates have to be measured with an accuracy of 0.1 meters.

- DBH all trees > 3.5cm DBH

The DBH has to be measured with accuracy of 0.1 centimetres at permanently marked points using a standard Mensuration girthing tape and regarding appendix 1

- Height all trees > 3.5cm DBH

The height has to be measured two times from opposite directions. The rules for an accurate tree height measurement have to be followed (appendix 2)

- Crown width CW: four times with an accuracy of 0.1 meters. The position of the stem has to be recorded, so that the crown radius can be estimated in 8 directions

Direction	Crown width	Distance of stem from
S-N		S
SW-NO		SW
W-O		W
NW-SO		NW

- Crown spring CP

Each measurement of crown spring has to be done in the same way as tree height measurements.

1. *Upper crown height*, UCP, the height from ground of the the point at which the crown is complete in all directions.
2. *Lower crown height*, LCP, the height from ground of the lowest branch (not whorl) on the tree with live foliage, in other words, the lowest living branch.

- Stem form SF

Stem form	
Single trunk **10**	Tree with single trunk
Forked tree **20**	Forked tree
- one or more dead trunks **21**	one or more trunks are dead, at least one living trunk
- all trunks are dead **22**	all trunks are dead

- crown form CF

Crown form CF	
1	No secondary crown
2	Shoot growth starts to form a secondary crown
3	Secondary crown dominates
4	primary crown is dead

- Leaf loss LOS

Leaf loss ***(P_/ S_) LOS***	*Estimate, Percentage of a full leaved tree. (For the estimate dead branches are also regarded):* *<10 %, <20 %,..., <80 %, > 80 % independent estimates for primary (P) and secondary (S) crown are nessassary*

- Crown damage TYP

Crown damage ***(P_/ S_)TYP***	*independent estimates for primary (P) and secondary (S) crown are necessary* *up to three values can be assigned for each tree / crown*
regular **10**	Regular leaf / branch loss in the whole crown
Inner crown **11**	Leaf / branch loss mainly in the inner crown, outer crown is apparently more vital (window-effect)
Outer crown **12**	Leaf / branch loss mainly in the outer crown, inner crown is apparently more vital
Irregular **13**	Irregular loss of leaves/ branches
Upper crown **14**	Leaf /branch loss mainly in the upper crown
Dead upper crown **21**	Upper crown is dead
Dead main branches **22**	Main branches are dead
Standing dead **31**	Apparently no vitality
Stock **32**	Parts of a dead tree are visible

- Stem lean INCL

Stem lean	***INCL***	*Rough estimate of the stem lean*
0 - 13°	**1**	straight
13 - 45°	**2**	Medium to heavy lean
> 45°	**3**	Extreme lean

- Shooting SHOOT

Shooting	***SHOOT***	*Stem with shoot (and epicormic branches which still do not form a secondary crown but have the potential to do it.*
without	„ „	Stem without shoots(and epicormic branches)
Some young shoots	**11**	Some, fresh young shoots which are <u>not branched</u>
Many young shoots	**12**	Many, fresh young shoots which are <u>not branched</u>
Some older shoots	**21**	Some, older shoots which are already <u>branched</u>
Many older shoots	**22**	Many, older shoots which are already <u>branched</u>

- Ground vegetation VEG

Ground vegetation VEG	*Ground vegetation in percentage below the crown*
0	Without or with dead plants
1000 (+ %)	grasses
2000 (+ %)	Herbs
3000 (+ %)	Reed
4000 (+ %)	Tamarix
5000 (+ %)	Poplar saplings

- Fructification FRUCT

Fructification	***FRUCT***	
Without	0	No fruit
less	**1**	Less fruit

medium **2**	Medium fruit
high **3**	Many fruit

- Insect pests INSEC

Insect pests INSEC	*Has to be noted if apparent*

- Green colour intensity GREEN

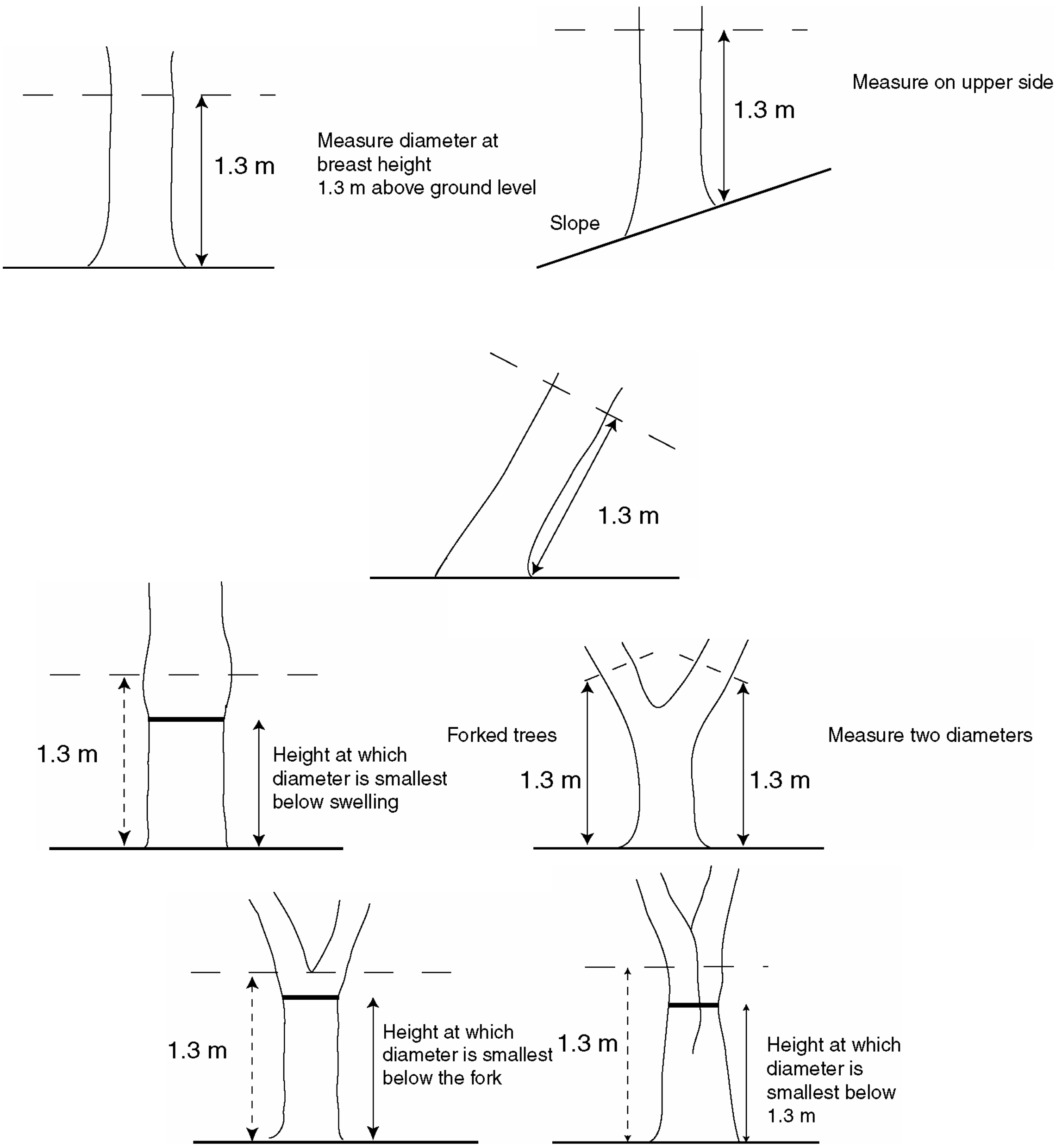
Green colour intensity CH	*Rough estimate of the green colour intensity of the crowm. The estimation has to be done from distance*
1	Light green
2	Dark green
0	yellowed

- Leaf area index LAI

Has to be measured with an appropriate instrument.

Appendix 14-1

Protocols for measuring the diameters of leaning trees, forked trees and those with swellings at 1.3 m (Anonymous, 2002).

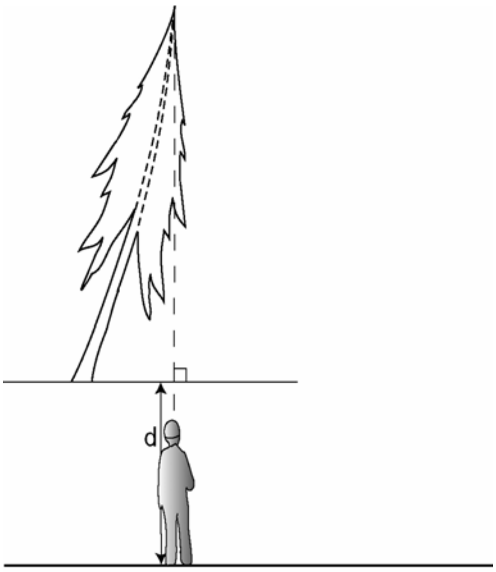


Appendix 14-2
Protocols for measuring the tree height

1. Two height measurements should be taken from opposite sides of the tree. The total height is the arithmetic mean of these two readings.

2. The distance to the tree should exceed tree height for a correct bearing of the tip.

Leaning trees should be measured in exactly the same way as above, except the two measurements must be taken at 90º to the direction of the lean.



Stand at right-angle to direction of lean